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Foreword

The OECD Review of Austria's Innovation Policy is part of a series of OECD country reviews of innovation policy (http://www.oecd.org/sti/inno/oecd-reviews-of-innovation-policy.htm). It was requested by the authorities of Austria, represented by the Federal Ministry of Education, Science and Research (BMBWF) and the Federal Ministry for Transport, Innovation and Technology (BMVIT). The review was jointly supported by the ministers in charge, Prof. Heinz Faßmann (BMBWF) and Nobert Hofer (BMVIT). The review was carried out by the OECD Directorate for Science, Technology and Innovation under the auspices of the Committee for Scientific and Technological Policy (CSTP).

The purpose of this review is to obtain a comprehensive understanding of the key elements, relationships and dynamics that drive Austria's innovation system and the opportunities to enhance the system through government policy. More specifically, the review:

- provides an independent and comparative assessment of the overall performance of the Austrian innovation system
- recommends where improvements can be made in the system
- formulates recommendations on how government policies can contribute to such improvements, drawing on the experience of OECD and non-OECD countries and other evidence on innovation processes, systems and policies.

The review is relevant to a wide range of stakeholders in Austria, including government officials, entrepreneurs and researchers, as well as the general public. It aims to provide a comprehensive presentation of the Austrian innovation system and policy to a global audience through the OECD communication channels.

A draft version of the "Overall assessment and recommendations", containing key issues and recommendations, was presented for peer review at the Meeting of the Working Party for Technology and Innovation and Policy (TIP) of the CSTP in June 2018. Margherita Russo (Università degli Studi di Modena e Reggio Emilia, Italy) and Kai Husso (Ministry of Employment and the Economy, Finland), both national delegates to the TIP, acted as peer reviewers.

The review was led by Gernot Hutschenreiter, Head, Country Innovation Policy Reviews Unit (Science and Technology Policy Division [STP], Directorate for Science, Technology and Innovation [DSTI], OECD). The review report was drafted by Alistair Nolan and Johannes Weber (both STP, DSTI, OECD), with inputs from Julia Melkers (consultant to the OECD and Associate Professor, School of Public Policy, Georgia Institute of Technology, United States), Espen Solberg (consultant to the OECD and Head of Research, Nordic Institute for Studies in Education, Research and Innovation, NIFU, Norway), and Stephen Roper (consultant to the OECD and Director, Enterprise Research Centre, and Professor of Enterprise, Warwick Business School, United Kingdom) under the supervision of and with written contributions from Gernot Hutschenreiter. The review benefited greatly from the contributions of Christian Rammer (Centre for European Economic Research, ZEW, Germany).

The review draws on a series of interviews with a wide range of major stakeholders in the Austrian innovation system during a fact-finding mission to Austria in October 2017. The review likewise draws on the results of stakeholder discussions at the Europatagung 2017 held during the fact-finding mission in Vienna. A background report helped prepare for the OECD visit. A first discussion of the planned review took place at the Europatagung 2016.

The background report was commissioned by the BMVIT and the then existing Federal Ministry of Science, Research and Economic Affairs (BMWFW) and prepared by a team from the Austrian Institute of Technology (AIT), Joanneum Research (JR), the Austrian Institute of Economic Research (WIFO) and the Vienna Science and Technology Fund (WWTF).* The background report contains a broad range of information that has been used in the review. This review also benefited from comments and additional information provided by stakeholders in Austria, including during a stakeholder workshop held in June 2018 in Vienna.

The authors owe much to the support and co-operation of Austrian government officials, in particular Christian Naczinsky (Ministry of Education, Science and Research and Austrian delegate to the Committee for Scientific and Technological Policy) and Rupert Pichler (Ministry of Transport, Innovation and Technology), with support from Sarah Gradl (Ministry of Education, Science and Research) and Gerald Thiel (Ministry of Transport, Innovation and Technology). Many of the stakeholders the OECD met during the fact-finding mission and at the stakeholder discussions provided valuable information and data and were instrumental in the preparation of this report.

Special thanks go to Prof. Helga Nowotny, former President of the European Research Council (ERC) and Chair of the ERA Council Forum Austria, for hosting the Europatagung, and for her interest in the review.

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Acronyms and abbreviations

ACR	Austrian Cooperative Research
AI	Artificial intelligence
AIT	Austrian Institute of Technology
aws	Austria Business Service
BERD	Business enterprise expenditure on research and development
BMWD	Ministry of Digital and Economic Affairs
BMBWF	Ministry of Education, Science and Research
BMVIT	Ministry for Transport, Innovation and Technology
CDG	Christian Doppler Research Association
COMET	Competence centres for excellent technologies
EIF	European Investment Fund
EIS	Enterprise Investment Scheme
ERA	European Research Area
ERDF	European Regional Development Fund
FFG	Austrian Research Promotion Agency
FWF	Austrian Science Fund
GDP	Gross domestic product
GERD	Gross domestic expenditure on R&D
GOVERD	Government sector expenditure on R&D
HEI	Higher education institution
HERD	Higher education expenditure on R&D
HPC	High-performance computing
HTL	Higher technical and vocational school
ICT	Information and communication technology
IMBA	Institute of Molecular Biotechnology
IST	Institute of Science and Technology Austria
JR	Josef Ressel centre
KLIEN	Austrian Climate and Energy Fund

LBG	Ludwig Boltzmann Gesellschaft
LBI	Ludwig Boltzmann institute
M2M	Machine-to-machine
MEP	Manufacturing Extension Partnership
MNE	Multinational enterprise
NFTE	National Foundation for Research, Technology and Development
OeAW	Austrian Academy of Sciences
OI	Open innovation
PPPI	Public Procurement Promoting Innovation
PCT	Patent Cooperation Treaty
PRI	Public research institute
R&D	Research and development
RFTE	Austrian Science Board
RTI	Research, technology and innovation
RTO	Research and technology organisation
SEIS	Seed Enterprise Investment Scheme
SFB	Special research programme
SME	Small and medium-sized enterprise
STEM	Science, technology, engineering and math
STI	Science, technology and innovation
TTO	Technology transfer office
UAS	Universities of applied sciences
VBC	Vienna Biocentre
VC	Venture capital

Executive summary

From inputs to impacts

Austria's innovation system has developed rapidly over the past two decades. From 1998 to 2016, Austria showed the second highest increase in R&D intensity of all OECD countries, exceeded only by Korea. The rapid growth of R&D inputs was matched by a similar increase in human resources for STI. Increased resources have helped to expand STI activities and opportunities for learning, but outputs and outcomes have not always met expectations. To become a leader in innovation, Austria faces the challenge of transforming its sizeable investment in STI into more decisive economic and social impacts.

Building an internationally excellent research system

Austria has an advanced research system with a number of international strengths, such as in quantum physics and life sciences. The foundation of the Institute of Science and Technology Austria was a landmark institutional innovation. But the research system faces some important challenges, some of them related to the public universities. Reforms to improve career prospects for researchers have been initiated, but need to become more visible to help retain and attract outstanding researchers. Expanding the new tenure track model across the entire university system will help to better position the system internationally. A new system of university funding is being implemented, bringing more transparency and better relating funding to indicators. Developing suitable incentives for excellent research, e.g. by applying output indicators for research, will be important, and carefully designed performance agreements should help to stimulate outstanding research. An excellence initiative is currently under discussion, and could be an important step to increase the share of competitive funding of basic research (in particular through FWF), which would likewise raise the scientific impact of the Austrian research system. Policy initiatives to strengthen the research system will require continuous impact monitoring.

Broadening and upgrading the industrial R&D base and accelerating Industry 4.0 uptake

Austria has a strong export-oriented manufacturing sector. Business innovation in Austria is characterised by high levels of R&D across all industries, including in manufacturing sectors that have low R&D intensities globally. A number of Austrian firms are global technology leaders in their respective niches, and subsidiaries of multinational enterprises find Austria an attractive location for research-intensive activities. Upgrading industrial R&D, accelerating Industry 4.0 and facilitating structural change will require greater support for innovative high-growth firms. And expanding R&D capabilities in key areas of Industry 4.0 and the fields of artificial intelligence, big-data analytics and their applications in production, could help to strengthen Austria's industrial base.

Building a world class human resource base

Austria's higher education sector has expanded substantially over the past two decades, leading to continuous increases in the supply of a tertiary-educated labour force. The supply of qualified researchers and technology graduates has broadly kept up with the demand from firms. For Austria to become leader in innovation, it will be paramount to continue broadening and deepening its human resource base. This requires attention to the entire range of skills formation, from vocational education to postgraduate studies.

Tackling barriers to the advancement of female researchers, but also expanding doctoral schools with structured PhD training across the university system, and increasing funding for doctoral students, will help to improve the human resource base for science and innovation and elevate the quality and reputation of doctoral education. Finally, sufficient financial resources will be needed to roll out the new system of university funding and maintain the high quality of education at Universities of Applied Sciences as the sector's planned expansion occurs, while also improving its capacities to perform top-level applied research.

Increasing the contribution of science to innovation

Austria has well developed links between industry and science, and the co-operation between industry, universities and public research institutes is well-supported through a number of programmes and policy measures. However, to better link basic research with industrial innovation across disciplinary borders, it will be necessary to put a stronger focus on globally-leading and radical innovation in strategic fields, such as those bearing on global challenges. Building Austria's capacities to use research and innovation to address societal challenges should also involve industry. The national debate relating to the EU's Horizon Europe programme and "missions" is an excellent opportunity that should also lead to stronger co-operation across funding agencies supporting basic and applied research. Innovation in business would likewise benefit from raising the capacity for outstanding research in Austria's Research and Technology Organisations, in part by better profiling these institutions.

Adapting the policy mix and strengthening policy governance

Adapting Austria's mix of STI instruments to emerging needs, and strengthening the governance of policy, are critical to increase the efficiency of the STI system and effectively address emerging needs. More regular evaluations are needed of portfolios of major public support instruments, applying international best practice as concerns methodology and data access. A single Council for Science, Research and Innovation, anchored at the highest political level, could strengthen co-ordination and forward-looking decision making, while advancing a whole-of-government approach and addressing innovation-relevant issues beyond R&D and technology. To meet the objective of becoming an innovation leader, Austria's policy mix will need an increase in the share of competitive funding for excellent research and possibly more targeted support for ambitious and globally relevant innovation. Developing the governance and operational frameworks of major funding agencies (FFG and *aws*), by strengthening their autonomy, while reinforcing the strategic steering capacities in the relevant ministries, should lead to efficiency gains.

Chapter 1.
Overall assessment and recommendations

This chapter presents an overall assessment of Austria's innovation system and policy, reflecting the key findings of the review. It identifies strengths and weaknesses with respect to research and innovation policy and performance, and develops concrete policy recommendations for improving Austria's performance in science, technology and innovation.

Achievements and challenges

Rapid increase in science, technology and innovation (STI) resources

Austria has achieved a great deal in recent decades. As a result of strong long-term economic performance, the country's gross domestic product (GDP) per capita is the eighth highest among OECD countries and fourth in the EU28, slightly ahead of Germany, Sweden and Denmark. Levels of poverty and income inequality are both below the OECD average. Despite successful long-term social and economic development, Austria underwent strain during the global financial crisis and its aftermath, with slowing productivity growth and unemployment rising well above levels long considered normal in Austria. Macroeconomic performance has since rebounded, with economic growth above the rates in neighbouring Germany and the Euro area as a whole. Current projections foresee a slowdown of GDP growth, in line with global trends.

Austria's system of science, technology and innovation (STI) has recorded significant successes in recent decades. Investment in research and development (R&D) increased remarkably since the end of the 1990s, when Austria's R&D intensity (aggregate R&D expenditure as a percentage of GDP) was below the OECD average and significantly lower than in other small, open economies (to which Austria prefers comparison). The European Union target of an R&D intensity of 3% was met in 2014. In 2016, R&D intensity stood at 3.09%, the sixth highest among OECD countries and the second highest in the EU28. R&D intensity is forecast by Statistics Austria to reach 3.19% in 2018. These impressive advances notwithstanding, Austria is unlikely to achieve the very ambitious national R&D intensity target of 3.76% by 2020, as set in the federal government's Research Technology and Innovation (RTI) Strategy 2011-20. From 1998 to 2016, Austria showed the second highest increase in R&D intensity of all OECD countries, exceeded only by Korea. The rapid expansion of R&D inputs was matched by a similar increase in human resources for STI. The scientific output of universities also grew rapidly. Austrian science, for example in the field of quantum communication and information, has world renown. Vienna is a major biotech hub in Europe, as is Linz in mechatronics and Graz in automotive and production technologies. Austria is also home to a number of firms which are world leaders in certain technological fields and niche markets.

Austria performs well in Europe in the field of Smart Grids, leading some major EU projects in public transport in Europe. And Austria has been a net resource recipient in the Horizon 2020 and the preceding 7th Framework Programme. Austria has attracted significant internationally mobile R&D investment, and is also successful as an exporter of manufactures, as diagnosed in several OECD Economic Surveys of Austria. Austrian firms, including small and medium-sized enterprises (SMEs), show a high propensity to co-operate with other firms and with universities and other research organisations. Vienna is the largest student city in the German-speaking world, with some 200 000 students. More broadly, Vienna consistently ranks among the top three cities in the world on quality-of-life indices. And Austria possesses globally recognised cultural attractions and esteemed educational institutions in music and the arts.

Furthermore, significant policy expertise and support exists for STI. Government funding of business R&D in Austria is significantly above the OECD average, as a share of GDP, and is notably higher than in almost all comparator countries. Austrian policymakers have helped create centres of research excellence, including through the "greenfield" founding of the Institute for Science and Technology (IST) Austria which was recently included in the Nature 2018 Index of the Top 30 (universities) under 30 (years old). The establishment is in progress of a large public-private research centre for microelectronics (Silicon Austria Labs). Up to EUR 280 million are budgeted for a period of five years, at the end of which around 400 researchers in the fields of electronics-based systems and microelectronics are expected to be employed at Silicon Austria Labs. Policy makers recognise the transformational importance of digitalisation, and through many channels act to accelerate its diffusion. There has been considerable experimentation over decades with varied institutional models to support innovation, and evaluation of innovation policy instruments is a widespread practice.

From inputs to impacts

While many successes have been recorded, Austria's economy, society and STI system face significant challenges, especially if the country aspires to be a global leader in innovation. The rapid increase in resources for STI has helped to expand STI activity and opportunities for learning. But a change in innovation policy strategy is now required. Austria will need to move towards a system which is less focused on expanding inputs and pays more attention to the evidence-based achievement of specified impact, i.e. on the efficiency and effectiveness of its investment in STI. In this context, the review´s recommendations regarding additional funding should mainly be seen as recommending a shift towards more effective, impact-oriented funding and should not necessarily be interpreted as a call for a general funding increase. However, this does not preclude increases in certain areas nor increases in spending for R&D and innovation over time, in line with the Austrian federal government's R&D intensity target (currently 3.76% over the long term) if considered beneficial. For Austria to become an innovation leader, innovation policy will need to:

- Increase the efficiency of investment in R&D and better transform high levels of R&D investment into productivity growth, high-impact innovations and global market access;
- Better steer the entire innovation system towards excellence;[1]
- Ensure a sufficient supply of human resources for innovation in a context of disruptive technological change and evolving skills demand.

Opportunities exist to improve the efficiency of the Austrian STI system, while maintaining or even improving equity. Opportunities also exist to develop a number of virtuous circles in the system. For example, improving universities' production of excellent research, and their commercialisation capacities, could help to grow the currently weak venture capital sector (because venture capital activity typically follows growth in investable projects), and also help attract and retain human capital.

In aiming for leadership in innovation, Austrian innovation policy will have to address several strategic tasks, which include:

Building an internationally excellent research system

- *Strengthening excellent research in universities.* The potential and excellence of Austria's research community has been impeded – among other factors – by a lack of competitive funding of basic research relative to many leading innovators (e.g. the Netherlands, Sweden and Switzerland). Austria's leading universities lag behind their counterparts in funding per student. This has limited the country's ability to sufficiently equip its public universities with suitable infrastructure and human resources, particularly PhDs involved in basic research. The shortfall in competitive funding for basic research could also hinder Austria's long-run ability to specialise to a greater extent than today in more science-based industries. But to narrow the gap to the international frontier will require not only a higher share of competitive funding, but also further improvements to the governance and strategic capabilities of universities and other research organisations.

- *Improving the international visibility and attractiveness to senior researchers of Austrian higher education institutions (HEIs)*. Compared to leading innovators, Austria's universities lag in major international rankings, undermining their ability to attract talented domestic and foreign students and researchers. Austria has experienced shortcomings in the recruitment of high-profile academics, the provision of internationally competitive career prospects and is in need of a governance and funding system that can better respond to changing demands and raise quality in teaching and research. A number of initiatives have recently been taken in the area of career development and recruitment in HEIs (e.g. the new tenure track model, opportunity hiring, etc.). An Austrian research excellence initiative should strengthen competitive funding for basic research and address pertinent issues such as the retention of established researchers in the country.
- *Improving the steering of universities towards strategic goals*. In the past, the performance agreements with HEIs have failed to effectively steer Austrian HEIs towards high quality. They have tended to represent a rather blurred mix of activities and target outcomes, and have over-emphasised activities at the expense of a clear focus on key desired outcomes and outputs. The performance agreements for the period 2019-21 apply the new capacity-oriented, student-based university funding model. This is a step forward in transparency and steering. The new model can be expected to improve basic conditions for teaching and research, such as the ratio of professors to students. However, its impact on research excellence may be less than expected, as research funding is not linked to any indicator of research output.

Broadening and upgrading the industrial R&D base and accelerating Industry 4.0 uptake

- *Paying more attention to issues related to data generation, access and use.* A broader vision of innovation will be needed beyond that driven by R&D. Data as an innovation input, innovation in services and in business models, business scale-up, and more rapid diffusion of technology, are among the themes which should be treated with greater emphasis, at least with respect to business sector innovation. Issues related to data generation, access and use are a recurring part of this report, because data will play a key role in Austria's innovation future, in new business models and in the development and evaluation of public policy (which could become more effective and efficient). Austria has large untapped potential in this regard.
- *Enabling the development and expansion of more technology and research-intensive sectors of production*, while continuing to facilitate the upgrading of technological capabilities in existing sectors. Austria's main areas of specialisation are in traditional sectors. More technologically and research-intensive sectors such as information and communication technology (ICT) and pharmaceuticals are less represented. There is concern that current specialisation patterns could limit growth opportunities. Structural change needs to occur in a context of rapid digitalisation and "Industry 4.0".

Building a world class human resource base

- *Creating the human resource base for innovation leadership*. Over the past two decades Austria has made continued gains in the supply of science and technology graduates and trained researchers. Austria has strengths in higher technical and vocational schools and has built up a successful sector of universities of applied sciences (UAS). However, Austria still lags with regard to the share of female researchers. In addition, flexibility between tertiary and vocational education is limited, as is inter-disciplinarity in higher education programmes. Doctoral education often has little structure and is poorly funded. Participation in work-based education and training is rather low, as are higher education completion rates. Innovation and entrepreneurship education is primarily limited to business administration curricula, but interdisciplinary and extra-curricular courses are increasingly offered within Higher Education institutional entrepreneurship strategies.

Increasing the contribution of science to innovation

- *Evolving the already well developed links between industry and science*: Interaction between businesses, universities and public research institutes (PRIs) is well established in Austria and supported through a variety of policy measures, including funding for collaborative R&D projects, temporary labs, and joint research infrastructures, as well as funding for research and technology organisations (RTOs). While the existing networks and programmes effectively contribute to industry-science links, they often focus on established innovation paths. A key challenge will be to develop new institutional arrangements that provide powerful incentives for path-breaking innovation that links application-oriented basic research with industrial innovation across disciplinary boundaries. More generally. Austria could benefit from taking a more strategic approach to developing the RTO sector and other transfer-oriented institutions.

Adapting the policy mix and strengthening policy governance

- *Continuously adapting the policy mix to ongoing changes.* Austria's policy mix for business R&D and innovation has altered substantially in recent years, with the emphasis increasingly placed on more generic support for R&D through a tax incentive (the Research Premium). About three quarters of additional public R&D funding to enterprises between 2006 and 2015 (excluding the co-operative sector) can be attributed to this instrument. Due to design features of the Research Premium, and the increase in the tax exemption rate to 14% in 2018, this shift is likely to continue. While tax incentives are well-suited to incentivising more R&D across all industries and types of firms, at low administrative cost, direct support is often better suited to providing targeted incentives for R&D and innovation in critical fields that policymakers consider might be experiencing underinvestment. In many countries such fields have included new markets (such as personalised medicine, or autonomous vehicles), societal challenges (such as the aging population, and low-carbon growth), and transitions such as in advanced manufacturing and digitalisation. Accordingly, a balanced policy mix is needed that takes full advantage of the relative strengths of both direct and tax-based public support instruments for business R&D. Most OECD countries operate such a mix.

While some strategic efforts are underway, for instance in the area of Industry 4.0, more needs to be done to catch up with innovation leaders.

- *Establishing clearer priorities in the innovation system overall and effecting more concerted action among Ministries (and agencies)*. An opportunity exists to better articulate Austria's many public STI policies with societal challenges. Strengthening R&D and innovation for societal challenges (and "missions") is one way to achieve higher impact from STI investments by producing more spillovers from individual research and innovation activities and by better transforming research results into economic activity and social practice.
- *Better steering the entire innovation system towards international excellence and high levels of impact.* A new RTI Strategy 2020+ can play a key role by providing the framework for a major shift in research and innovation policy – as reflected in the policy priorities described above – and for catalysing new forms of more effective governance, which will themselves be required for the realisation of the new RTI Strategy.

To join the leading countries in research and innovation, Austria needs a long-term perspective, continued reform efforts and sustained investment that is likely to require adaptation in the mix of policy instruments. In addition, a broader policy approach is required that goes beyond an increase of R&D intensity. Under such an approach, Table 1.1 summarises the main policy challenges and the associated priority actions.

Table 1.1. Main challenges and priority actions

Main policy challenges	Priority actions
Building an internationally excellent research system	• Continue rolling out and monitoring the new system of university funding and the performance agreements in terms of their impact on stimulating outstanding research. Use the results to strengthen the required incentives (e.g. by applying output indicators for research). • Implement an initiative for research excellence, strengthening the competitive component of basic research funding by increasing the budget of FWF, both for FWF's traditional activities and for innovations in its portfolio (e.g. co-operation with FFG on societal challenges, funding of established researchers, etc.). • Adopt and monitor the new tenure track model across the entire university system, increasing permanent faculty positions and supporting early-career researchers.
Broadening and upgrading the industrial R&D base and accelerating Industry 4.0 uptake	• Strengthen support for innovative high-growth firms and new firms with growth-based business models ("scale-ups") to broaden and deepen the domestic business R&D base and facilitate structural change. • Shift public support to business R&D that explores new technological solutions, combines technologies in novel ways, or takes up new scientific discoveries. • Expand R&D capabilities in key areas of Industry 4.0 and strategically important fields of AI, big-data analytics and their applications in production, and give visible priority to accelerating diffusion of Industry 4.0 technologies.
Building a world class human resource base	• Continue tackling inequities and barriers to the advancement of female researchers to make full use of the human resources.

	• Increase flexibility and modularity in tertiary and vocational education and training, among other things by continuing and accelerating the expansion of the Universities of Applied Sciences sector. • Expand modern doctoral schools with structured PhD training and improve funding for PhDs.
Increasing the contribution of science to innovation	• Reinforce linkages between industry and science in ways that put a stronger focus on globally leading innovation and radical innovation in strategic fields, while actively involving industry. • Strengthen Austria's capabilities to use and issues-driven collaborative programmes to support research and innovation for new markets, tackling societal challenges (such as aging population, low-carbon growth and security), missions and transitions (such as digitalisation). This requires combinations of basic and applied research. • Further capitalise on the existing network of RTOs by raising their capacity for outstanding research through profiling, improved performance measurement supported by a common core of comparable indicators, with a view to move towards a more strategic and performance-based governance and funding.
Adapting the policy mix and strengthening policy governance	• Create a single Council for Science, Research and Innovation either as a strong advisory council, or as a council engaging in policy co-ordination and forward-looking decision making, and which would have to be anchored at the highest political level. The latter option would be preferable if Austria wishes to make science, technology and innovation a pillar of long-term development. • Steer the policy mix towards emerging needs, more competitive funding for excellent research and ambitious innovation. • Develop the governance and operational framework of major funding agencies, notably FFG and *aws*, by strengthening their operational autonomy while building strategic steering capacities in the Ministries in charge. Use such a framework to enable better management of the programme portfolios handled by the agencies. • Initiate more regular state-of-the-art evaluations of portfolios of public support instruments (including the Research Premium, FFG and other programmes) and their interlinkages, applying international best practices in providing data access, without compromising the confidentiality of sensitive data.

Summarising the analysis in this report, Table A.1 in Annex 1 presents the results of a SWOT analysis of the Austrian innovation system.

Research and innovation in the business sector

On a number of measures, achievements in innovation in the Austrian business sector are impressive. Austrian firms have significantly increased R&D spending in recent years: from 2004 to 2015 total R&D performed in the business sector (BERD) increased at an annual rate of 7%. And R&D intensity has increased across all sectors of business. In most industries, Austrian firms have a higher R&D intensity than does the OECD overall, including in many low-tech and medium-tech sectors. Austria also has a number of firms which lead globally in technological niches.

Among comparator countries – most of which are the home base of large multinational enterprises (MNEs) – Austria ranks last in terms of triadic patent intensity (patents per EUR business R&D) and just ahead of Belgium for patent intensity for applications at the European Patent Office (EPO) and the Patent Co-operation Treaty (PCT). However, growth of patent applications is faster than for the OECD overall and faster than in most comparator countries. This may partly reflect the increase in R&D competencies vested in some Austrian subsidiaries of foreign-owned MNEs. This phenomenon could merit a separate study.

At around 19%, Austria has a relatively high share of manufacturing in GDP, much higher than in the United Kingdom (10%) or the Netherlands (12%), and more similar to the shares in its neighbours Switzerland (18%) and Germany (23%). Developments in manufacturing are thus of particular importance for Austria and are also, as a consequence, a major theme in Austrian innovation policy. Issues of Industry 4.0 are considered particularly important today, and are therefore a focus in the recommendations set out below.

Industry 4.0

The generic term "Industry 4.0", or the fourth industrial revolution, refers to the use in industrial production of recent, and often interconnected, digital technologies that enable new and more efficient processes, and which in some cases yield new goods and services. The associated technologies are many, from developments in machine learning and data science which permit increasingly autonomous and intelligent systems, to new control devices that enable second-generation industrial robotics.

Strengthening universities in the strategically important fields of artificial intelligence (AI), big-data analytics and their applications in production

Public funding for Industry 4.0 comes from a mix of programmes. BMVIT's Production of the Future programme is an important initiative, although most Industry 4.0-relevant funding comes from the "basic programme" of the FFG. Industry 4.0-related centres are also being set up as part of the COMET programme. In academia, in part because of Austria's small size, in some subject areas only a few professors have international renown (even though excellent academics work in such fields as industrial engineering, informatics, mechatronics and bio-technology). There exists a widespread view among Austrian experts that government support for Industry 4.0 is often too fragmented, lacks critical mass and budgets, and operates over time horizons which are too short.

Benefit could be had by greater concentration of research support on subjects in which leading professors are working, or on a few fields which will matter for production in the long-run. For a variety of reasons, it is proposed that policy seek a major strengthening of universities in the fields of artificial intelligence (AI) and big-data analytics, including complex systems, with a focus on applications in production. Developing lasting strengths in AI and big-data, and their links to production, offers particular benefits. AI has the potential to raise productivity in industry and in services. Doing so will also help Austria maintain industrial capacity in the face of increasing global competition in manufacturing, including from emerging and former transition economies. AI is also a general purpose technology, which means that competencies developed in this area will spill across the entire economy. Developing internationally recognised excellence in using AI in production will likely attract talented students. And AI is unlikely to be superseded by other technological developments: the future will only require better AIs, not something entirely different.

Addressing data supply and use

Today, it is unlikely that Austria, or any other country, could consistently lead in global innovation without a world-class data eco-system. Significant data-related activities and initiatives exist in Austria, from the Digital Roadmap for Austria to the Data Market Austria, and a new Digital Strategy, which is in the making. The potential approaches to better deploying data for research and economic purposes have been set out in detail in a number of studies (such as the BMVIT-sponsored 2014 report "Conquering Data in Austria"). However, various observations suggest that further progress on the data economy is needed. For instance, in both government and business, consultation with practitioners suggests little active roll-out of AI solutions, beyond proof-of-concept, and practitioners indicate an overall lack of awareness of the economic importance of data across Austrian industry, the research community and the public. And in part because of regulation, opportunities for data-centred value creation in both the private and public sectors are often missed.

Ensuring suitable digital infrastructure

Overall broadband coverage in Austria is high: in 2016 around 98% of Austrian firms with less than 10 employees had a broadband connection. However, by a number of measures various broadband deficits affect Austrian firms. Rates of mobile broadband connectivity are lower than in leading economies, and only 10% of firms have fast broadband connectivity of at least 100 Mb/s. This is less than half the shares in Denmark, Finland, Lithuania and Sweden. And in June 2017 the percentage of fibre connections in total broadband subscriptions, at just 1.8%, was one of the lowest in the OECD area. Fibre-optic connectivity has advantages over copper-cable based Internet which are important for Industry 4.0.

Austrian policymakers have allocated significant resources and elaborated detailed plans to address the broadband deficits. Recent OECD Economic Surveys of Austria have called for more public investment in the fibre network (as foreseen in the Broadband Plan 2020) and more active policy to encourage competition among service providers. In April 2018 Austria adopted a 5G Strategy which aims to ensure nationwide coverage of 5G mobile services by the end of 2025.

Another important aspect of digital infrastructure is access to high-performance computing (HPC). Austria's Vienna Scientific Cluster works to facilitate access to HPC for scientists. But responses to the 2017 OECD STI Outlook questionnaire suggest that initiatives to enlarge access to HPC for firms might be lacking. While there is little evidence that access to HPC is a constraint for Austrian firms today, such access, and awareness of HPC's applications in industry, will become more important for Industry 4.0 (and the development of AI) in future.

Accelerating diffusion of Industry 4.0 technologies

Most firms are technology users, rather than technology creators. But, for a variety of reasons, gaps can persist between actual and potential technology use. These gaps are typically greatest between SMEs and larger firms. Research indicates that having a high share of SMEs and micro-firms in the business sector – as Austria has – is likely to hinder technology diffusion. Indeed, the OECD's Science, Technology and Industry Scoreboard 2017 suggests that SMEs in Austria are significantly less innovative than large firms. More generally, the balance of evidence indicates that the diffusion of digital technologies in firms and households in Austria lags behind peer countries (although not in all subsectors of industry).

Many governments seek to accelerate technology diffusion among SMEs by supporting institutions that facilitate the use of knowledge, methods and technical means. This is also the case in Austria, where a diverse set of institutions offer technology-oriented business services, applied R&D services and various knowledge exchange and demand-based mechanisms. The Platform Industry 4.0 was also established by the BMVIT and social partner organisations to provide knowledge on Industry 4.0 to companies, academia, RTOs, and the general public. But no national dedicated intermediary exists providing diagnostics, guidance and mentoring (such as the United States' Manufacturing Extension Partnership programme).

Strengthening trust in cloud computing

In 2016 only 17% of Austrian firms used cloud computing. In the manufacturing sector this rate was around 20%. By comparison, in Finland, the country with the highest incidence of cloud use in manufacturing in the OECD, the rate was 69%. The share of non-financial firms in Austria that use cloud computing for advanced applications is also below the EU28 average. Evidence was not found of the economic impacts to date of Austria's cloud-computing deficits. However, as Industry 4.0 technologies progress, it is probable that machine data and data analytics, and even production monitoring and control systems, will increasingly be situated in the cloud. In considering cloud use, businesses in Austria cite fears over data security and uncertainty in placing data in extra-territorial servers. Such concerns are real. However, provided that users understand the terms of service and security practices of service providers, cloud computing should improve security overall.

Recommendations

- *Expand capabilities in key areas of Industry 4.0, by significantly strengthening universities and PRIs in the strategically important fields of AI, big-data analytics and their applications in production.* The forthcoming recruitment of additional professors at universities can be of great help in this regard. The required strategic allocation of resources could also be channelled through BMVIT's programme of Stiftungsprofessuren (endowed professorships), taking into account the strategic strengths and potential of different universities. Professorships might be linked to emerging initiatives in these fields at COMET centres.
- *More broadly, consider strengthening AI capabilities for production as one part of the forthcoming Austrian Strategy for AI currently being developed.* A growing number of OECD member and non-member countries are currently developing national AI strategies.
- *Strengthen Austria's data eco*-*system*. A number of steps might be considered, including, among other actions:
  - The availability of useful and usable government data could be increased.
  - Austria might replicate the experience from a number of countries, which suggests the value of having a national strategy or plan for open data, which can guide the goals and actions on open data of national and local authorities.

Austria might do this by somewhat enlarging its current Open Innovation Strategy (the open data dimensions of which primarily concern research).
    - Singapore's example might be studied, where a Data Sandbox Programme has been created, offering safe spaces in which rules are loosened (within a limited framework), where companies can build new applications and services, while governance, compliance, regulatory and security issues can be tested.
    - Consideration could be given to integrating studies of data science and the data economy much earlier in the education system.
- *For Industry 4.0, give visible priority to the goal of accelerating diffusion, especially among SMEs.* Web-based information portals can be useful, but are insufficient. More active diagnostics and guidance are more effective (but also more costly). Greater emphasis should be given to the deployment of known methods to new users. A frequent theme in Austria's diffusion institutions is the transfer of leading-edge technologies. However, a large share of companies would benefit most from assistance in choosing and adopting off-the-shelf technologies, rather than advanced technologies. It would be helpful, in focusing on diffusion, to systematically and quantitatively compare the impacts of Austria's diverse diffusion institutions.
- *Seek to increase trust in the cloud and stimulate cloud adoption.* Steps might be taken, for instance, to expand the availability of information tailored to SMEs that need to understand the technical and legal implications of cloud service contracts. This could include providing information on the scope and content of certification schemes relevant for cloud computing customers.
- *Seek to increase the speed of deployment of fibre-optic cable in the broadband network, so as to close the gap that exists with many other OECD countries in due time.*
- Building on lessons learned from programmes with similar goals in other countries, *monitor the adequacy of access to high-performance computing for firms and raise awareness of potential applications in the business sector.*

Ensuring enabling framework conditions for innovation and entrepreneurship

Austria has lower shares of sectors characterised by high innovation or research intensity, compared with leading innovation countries. Austria's main areas of specialisation are rather in traditional sectors. Firms in these sectors have generally successfully upgraded to stay internationally competitive, and tend to have high levels of R&D intensity by international standards. However, a concern is that these specialisation patterns might signal limits to potential growth as fast-growing new areas are underrepresented, or deficiencies in the ability of the innovation system to generate breakthrough innovation, even if there is evidence of still untapped potential in the current pattern of technological specialisation.

Austria needs excellent framework conditions for innovation and entrepreneurship to enable economic diversification and address the longstanding concern that structural change towards more research and technology-intensive sectors has been too slow. Even if Austria's patterns of economic specialisation to date reflect sources of comparative advantage that it can continue to build on, opportunities for new sources of growth and job creation will likely be lost if policy fails to meet the requirements raised by new technologies and business models. Excellent framework conditions will also facilitate continued upgrading of existing economic activities.

Current framework conditions for start-ups in Austria are quite positive overall. Progress is also being made in various fields, for instance through adoption of the 2017 Deregulation Act and the Deregulation Principles Act, and by the reform of bankruptcy law so as to lower the cost of failure for entrepreneurs. But, from an innovation policy perspective, there are several areas in which regulatory frameworks could be strengthened. These include: improving the environment for financing start-ups; and, reducing regulation of professional services and retail trade. Better skills matching in labour markets also benefits the diffusion of leading technologies, and is an area where Austria has room for improvement.

The government programme 2017-22 stresses a commitment to "facilitate start-ups and scale-ups, especially for technology intensive companies". The evidence suggests, however, that the business environment in Austria is significantly more conducive to start-up than scale-up. The proportion of start-ups which anticipate creating 6 or more jobs over five years is below that in most European countries. And across manufacturing and services, the proportion of Austrian firms that achieve medium or high growth – defined as 10% employment growth or more per annum – lags that of most European economies and a range of comparator countries.

A key barrier to boosting the level of high-growth companies in Austria is the shortage of risk capital, including angel funding and formal venture capital. Other factors may also be important, including other aspects of legislation related to bankruptcy and competition policies, as well as managerial capacities. With respect to comparator countries, Austria stands out in terms of its relatively low level of venture capital activity. One recent report puts total VC investment in Austria at around 12% of that in Denmark and 11% of that in Sweden. This relatively low level of VC investment applies both to early stage and more mature ventures. Key to encouraging individual engagement in equity provision for scale-up firms are appropriate tax incentives. Austria is unusual internationally in not currently offering such incentives. Pension funds, which form an important component of VC funding in other countries, are also largely absent from the funding scene in Austria. In other countries (notably the United States, but also in a comparator country like Sweden), reforms to pension fund legislation and structures have been key to the development of VC investments. In Sweden, for example, 55% of VC market funding is today provided by pension funds.

Giving tax incentives to individual investors, along with pension fund reform, may help to promote a flow of funds from within Austria into the supply of equity. A complementary goal is to attract equity funding internationally. This suggests a fund-of-funds approach and a co-investment role for government. A fund-of-funds approach has important substantive and signalling benefits.

Austria also has an increasingly well-developed network of incubators and accelerators. These provide valuable support for nascent and growing firms – as do angel investors – but in each case the primary focus is on the development of the business rather than the development of the capabilities of the leadership team (the AplusB centres have followed such an approach, but with the academic community). Experience from across the OECD suggests the value of a dual approach which develops the capabilities of firms' leadership teams alongside the development of their business.

Recommendations

- *Consider adopting tax incentives for individual and syndicated Angel Investment, e.g. along the lines of the United Kingdom's Seed Enterprise Investment Scheme*

(SEIS) and Enterprise Investment Scheme (EIS) and reflecting documented European best practice.

- *Establish an Austrian Growth Fund to co-ordinate public support for early-stage equity markets.* Other countries both of small (Denmark, Finland, Israel) and medium size (United Kingdom) have significant public engagement in fund-of-funds activities. Central to this should be the expansion of existing fund-of-funds activity. Documentation and legislation may need to have both German and English variants to attract international investment.
- *Promote investment readiness among scale-ups.* To complement developments in the supply of private equity Austria should explore the potential for a systematic programme to support investment readiness among scale-up firms. This should target firms with significant growth potential and build on experience from across the OECD.
- *Develop targeted schemes to support management and leadership development in firms with the potential to scale.* Examples exist of international good practice in this respect, including the Irish Management for Growth Programme, and Italy's Prime programme. Engaging universities as co-ordinating partners would also strengthen university-industry links and provide a mechanism for achieving national coverage with regional delivery.

The contribution of Higher Education Institutions and Public Research Institutes to innovation

Building a world-class human resource base for research and innovation

Broadening and deepening the human resource base

In Austria, HEIs have expanded significantly over the past two decades. Along with reform efforts that include alignment with the Bologna Process, Austria has made continuous gains in the supply of science and technology graduates and trained researchers. The availability of qualified researchers has so far kept up with the growth of R&D expenditure, and the overall level of educational attainment in Austria's labour force has shifted upwards.

For Austria to achieve its objective of becoming an innovation leader, broadening and deepening the human resource base is paramount. Ensuring the necessary supply of human resources for scientific research and innovation requires attention to all types of skill formation, from vocational education and training to expanding enrolment in science and technology disciplines in higher education, including postgraduate studies.

Vocational skills, developed in particular through higher technical and vocational schools (among them Höhere Technische Lehranstalten – HTL)[2] that teach five-year programmes specialising in different fields of technology and business skills, have for long been important and continue to be a pillar for innovation activities, particularly among SMEs. Other vocational schools also play an important role in this regard.

Universities of Applied Sciences (UAS) were established from 1994 on. They are a growing sector in the HEI system. UAS complement universities' science-based education with professional education, with a focus on meeting the demand for tertiary skills in their regions of location. In particular, the UAS are important in meeting demand for high-skilled labour from SMEs. With a science based education, and the generation of knowledge through applied science and learning, the UAS work closely with businesses in conducting application-oriented research. While UAS are engaged in research, their share of total R&D

expenditure in the higher education sector is low (at 3.8% in 2013), especially compared to public universities, although this share is increasing.

With respect to reform efforts to support the upskilling of students and facilitate increased degree attainment, the ERA Council Forum recommends that more vocational higher education should be shifted to the UAS. This implies a potential increase of UAS students, with a consequential increase in funding for the UAS so as to meet an expansion while maintaining capabilities. The BMBWF project "Shaping HEIs for the Future" (*Zukunft Hochschule*) proposes an increase in UAS student numbers from the current 14% of the student population to 30% in the medium term (and 60% over the long run). Such a shift would imply a substantial acceleration of the ongoing expansion of the UAS system. The recent decision to create additional study places at UAS up to 2022/23 is an important step, but further action will be needed. A strengthening of the UAS sector, while retaining the "binary system" of universities and UAS, would be beneficial in its own right, with the added benefit of facilitating the ongoing reform of the public universities and the objective to move higher education towards greater excellence.

Achieving greater gender diversity

The underrepresentation of female researchers in the business sector, PRIs and HEIs, particularly in natural science-related fields, impedes the Austrian innovation system in fully utilising its human resource potential. Among established and young and highly innovative firms, women account for just 26% of those employed in research. In addition, the share of Austrian women with interests in, and expectations for, careers in the sciences is well below the OECD average. Gender disparities in Austria point to missed opportunities to fully benefit from the human capital of women, compared to other countries. In 2017, the overall share of female researchers was 23% all sectors of R&D performance, compared to 36% for the EU28. Evidence shows considerably lower involvement of women than men in authorship, grant-getting, and other aspects of knowledge development. While the ratio of male to female scientific authorship has improved, the gender gap in this regard is more than double the EU average.

Despite having room for improvement in terms of gender diversity in science, Austria ranks above the EU average in the proportion of women leaders of HEIs, and in the proportion of women serving on scientific boards and commissions relevant to innovation. Austria has recently taken important steps to address gender disparities in science and engineering disciplines. The amended University Act 2002, the national ERA roadmap, and steering instruments (such as performance agreements and output-orientated budgeting) address the hiring of a more gender balanced workforce, as well as support for work-life-care balance.

Adjusting the number of graduates and the quality of PhD education to future needs

Austria has substantially increased the number of first-time graduates at the bachelor and master's levels. The number of STEM graduates per 1 000 members of the population aged 20-29 more than doubled between 2000 and 2012, and is surpassed only by Switzerland and Denmark. Despite this increase, STEM graduates, notably in engineering and ICT, are still considered to be in short supply by many in the business sector, especially during economic upturns.

As indicated in the previous section, Austria's research and innovation capacity could be improved by more fully realising the country's human resource potential. The completion rate of Austrian students entering bachelor-level programmes is below the OECD average.

Only 23% of students succeed in completing their course of study within the standard period of study (and just 58% within the three years beyond that period). At the master's level, these shares are 37% and 61% respectively.

The percentage of doctorate holders as a share of the working age population (at 0.9%) is currently somewhat below the OECD average. The turnout of graduates at doctorate level has been stagnating for some time, although their composition is changing and doctorate studies are now better geared to train future researchers. However, the research environment for young researchers may still not be conducive to the highest quality of training. The current high rate of student enrolment in doctoral programmes, combined with a high drop-out rate, constitute a drain on resources and reputation. Austria is now prioritising the resolution of this issue.

Austria acknowledges that developing world class doctoral education is essential and is undertaking efforts at reform, for instance by seeking to increase the number of doctoral graduates in STEM disciplines. There remains considerable scope for improvement, however. Structured PhD programmes that apply strict, standardised and transparent selection processes, practice international recruitment and support the transition to a research career are still the exception in Austria. In 2016, the share of doctoral students enrolled in these programmes was a modest 14%. In addition, just 47% of doctoral students are either employed directly in universities or receive third-party funding. This affects the social sciences and humanities in particular. In response to these shortcomings, improving doctoral education is becoming a priority in Austria.

Expanding life-long learning in the existing labour force

Austria will also need to adapt and strengthen the skills of those already in the labour force. In most countries, initial formal education only provides an inflow to the workforce of around 2-3% of the numbers in work. A major challenge exists in upgrading the skills of the in-work population, because of their large numbers and because their skill levels are on average below those of recent graduates. Data from the OECD's Programme for the International Assessment of Adult Competencies (PIAAC) show relatively low scores on problem solving in technology rich environments among working-age Austrians. As in other OECD countries, effective systems for life-long learning and workplace training are critical, so that the process of skills upgrading matches the speed of technological change. Co-operation between the public and private sectors is critical in this regard.

Recommendations

- *Respond to growing skills demand from the research and business sectors by improving Austria's education system through more flexible vocational and tertiary education and strengthened higher education in fields related to science, technology and creative industries.*
- *Continue and accelerate the expansion of the UAS system, and provide sufficient funding for implementing this expansion without loss of quality.* A strong UAS sector would be beneficial in its own right, and would also facilitate the ongoing reform of public universities.
- *Take further measures to raise the share of women in business sector research, which continues to be low by international standards. Continue support for transforming Austria's PRIs and universities by tackling gender inequities and barriers to the retention and advancement of female researchers.* This should

include targeted funding for doctoral studies and early career research grants for female researchers, among other measures.

- *Ensure the availability of sufficient funding for doctoral students.* Priority should be placed on providing opportunities for doctoral students to meaningfully engage in research activities as part of their training, and to do so in partnership with faculty. More competitive admissions procedures will help to raise the quality of tertiary education and increase completion rates.
- *Ensure the wide adoption of structured PhD programmes through the new system of university funding and support from FWF. Apply strict quality criteria for structured PhD programmes,* including research excellence, interdisciplinary research options, transferable skills training as well as transparent, fair and international recruitment.
- *Strengthen adult learning opportunities to complement formal tertiary education.* Improving the system of life-long learning is essential for updating the skills of the existing labour force in the face of rapid changes in skills demand and for assisting those out of work seeking to re-enter the labour force.
- *Improve the availability of digital and STEM-related skills in the existing labour force by partnering with suitable institutions to facilitate lifelong learning*. The UAS may be particularly well suited to adopt this approach, although implementation should not be limited to the UAS.

Strengthening the contribution of higher education institutions to research and innovation

HEIs in the Austrian innovation system

Austria's HEI landscape currently consists of 22 public universities, 21 UAS, 11 private universities and 14 university colleges for teacher education. Public universities are responsible for teaching about 80% of the Austrian student population. The entire HEI sector – statistically including the Academy of Sciences (OeAW) and IST Austria – performed 23.5% of aggregate R&D in Austria in 2015. The R&D capacities at HEIs are much higher (with about 18 200 full-time equivalent R&D personnel) as compared to the government sector (2 758 full-time equivalent R&D personnel).

For a number of reasons, Austria's universities perform relatively poorly in widely used international rankings. This may reduce their ability to attract top-level domestic and foreign students and researchers (with the exception of certain areas of excellence).[3] Raising the international visibility and attractiveness of Austrian HEIs for senior researchers is hence an important concern. Countries such as Denmark have successfully increased the visibility of their universities through mergers (both of universities and formerly non-university research institutes). While Austria's HEIs include areas of excellence and provide significant capacities for high impact research, there is scope for improvement. Areas for ongoing improvement include: adapting governance and funding to changing demand and to the need to raise levels of quality and excellence in teaching and research, and providing internationally competitive career perspectives.

The new system of university funding

The 2018 Amendment to the University Act 2002 brings considerable changes to the way Austrian universities are funded. The new model will be applied for the first time in the performance agreement period (2019-21). The main objectives of the new model for "capacity-oriented, student-related" university funding are:

- Increasing the quality of teaching and research and "advancement and appreciation of the arts" (for the universities of art), by improving support and supervision ratios (briefly teacher-to-student ratios) and reinforcing research.
- Achieving more transparency through separating funding for the performance areas (pillars) of "teaching", "research / advancement and appreciation of the arts" and "infrastructure/strategic development".
- Increasing the proportion of students actively taking exams.

In the new funding model each university continues to receive a global budget for a three-year performance agreement period. This will be composed of separate funding for the three pillars:

- For the first pillar ("teaching"), the basic indicator is the number of active students, i.e. students in degree programmes who actively take exams[4] (student places). In addition, two "competitive indicators" are used to provide specific incentives in each of the first two pillars. For teaching, the competitive indicators are a) the number of graduations in regular bachelor, masters and diploma programmes, and b) the number of studies "very actively" pursued by students[5] on the other hand.
- For the second pillar ("research / advancement and appreciation of the arts"), the basic indicator is the number of scientific and artistic personnel. For research, the competitive indicators will be a) third-party funding revenues, and b) the number of doctoral students with employment.
- The third pillar ("infrastructure and strategic development") – in addition to payments for buildings, additional clinical cost etc. – comprises strategic funds for new incentives and direct investment in areas that cannot be unambiguously assigned to one of the first two pillars, e.g. the social dimension or digital initiative.

Overall, the new model of university funding is an important step in the right direction as it provides a higher degree of transparency by separating the funding streams for teaching and research and establishes a direct link between performance-agreement indicators and university funding.

With the current specification of the indicators, Austria has chosen a "soft" way of introducing the new funding model. In the area of teaching, the basic indicator is responsible for the allocation of 96% of the respective budget. For the area of research, the basic indicator accounts for 91% of the budget. This is mirrored by a relatively modest share given to the "competitive indicators": 4% for the two competitive indicators for teaching, and 9% for those for research. This specification leaves considerable scope to expand the competitive component of institutional university funding by increasing the weight of the competitive indicators. These might in fact be increased in the future, based on the experience had during the current performance agreement period.

While the use of the indicators mentioned above can be expected to have a positive impact, e.g. on the quality of doctoral education, the teacher-to-student ratio, etc., the current set of indicators might not have significant impact on research excellence. Among the indicators for research, there is currently no output indicator (such as qualified publications, for instance). The indicator of third-party revenue may be correlated with research quality, but this is not necessarily the case. This depends on the type of remunerated research. Moreover, success in earning third-party revenue by winning research grants depends – to some extent – on the budget of the FWF. While the increase in the FWF budget for 2018-21 is a commendable step, its level remains low (e.g. on a per-capita basis) relative to similar funding organisations in comparator countries.

More broadly, the performance agreements 2019-21, combined with the increase of university funding by EUR 1.3 billion, are an important step towards a capacity-oriented student-based system. However, a sustained effort, including in terms of investment, will be necessary to roll out a fully-fledged system of this kind with the desired properties in terms of funding of student places. Furthermore, the current system of admission regulations appears rather complex and should in time be simplified, delegating the selection of students largely to universities.

In order to provide sufficiently powerful incentives to achieve greater research excellence and other goals of the forthcoming RTI Strategy 2020+, it will be necessary to carefully monitor the overall efficacy of the new funding system and to consider adjustments by employing approaches that have been demonstrated to be effective (and which are commonly used) in other countries, such as including output indicators for research funding.

Improving the efficacy of performance agreements

Appropriate funding and adequate steering mechanisms are prerequisites for high-performing, entrepreneurial and innovative universities. An important device in the system of strategic steering of the autonomous Austrian universities and their institutional funding are the performance agreements. These agreements are negotiated on a three-year cycle between BMBWF and each university.

The negotiation of these agreements through several rounds has been an important learning process for both sides in the negotiation. Areas for improvement were identified in previous performance agreements. These included an excessively extensive coverage of the agreements, which was partly related to the absence of a clear distinction between routine activities of universities on the one hand, and strategic priorities and projects of strategic character and importance on the other hand; an ambiguity arising from differences in the understanding of what profiling and profile development means for individual universities; and, a lack of clarity on the consequences of non-achievement of particular projects and goals.

Up to now, the activities covered have often been considered too many and their alignment with institutional profiles, particularly with respect to improving the universities' performance and international competitiveness, weak overall. This reduces the ability of performance agreements to steer the Austrian universities towards higher quality and excellence. Performance agreements have contained a mix of activities and target outcomes, over-emphasising the former at the expense of a clear focus on a limited number of desired outputs and impacts. Most importantly, the performance agreements have lacked reward-based objective setting and clearly articulated consequences when targets are not met.

However, performance agreements can be an efficient means of improving institutional performance of universities and other research institutions. The implementation of the new system of capacity-oriented, student-based model of university financing is an opportunity to strengthen the steering capacity of the performance agreements and make them more effective in practice.

Developing internationally competitive career perspectives for faculty and researchers

Achieving Austria's goal of becoming an innovation leader will require that further attention be given to both the funding of researchers and faculty and the provision of internationally attractive working conditions and career perspectives of research personnel. Barriers to the advancement of faculty careers present a distinct risk of increased departures from the system, and could undermine the ability to attract high-performing faculty. A low numbers of permanent contracts creates a system with poor incentives for productivity and retention. In the absence of reform, the risks to Austria are that the strongest members of faculty leave, and that the ability to attract competitive and star researchers will decline.

The RTI Strategy 2011-20 recognised that there is much to be gained from introducing a fully-fledged tenure track model. Comprehensive implementation of the reform of the new tenure track model is critical for improving Austria's standing as a location for high-quality and excellent research. Accordingly, progress with and the impact of this reform should be monitored continuously, and reviewed in due time (after five years, as is currently foreseen). Moreover, the newly created option for "opportunity hiring" offers universities a simplified procedure to hire a number of international top scientists.

In addition to providing career perspectives for young researchers, a major concern is the attractiveness of university positions to senior scientists, in particular those coming from abroad. In contrast to most other European countries, Austrian universities are free to decide on how much they want to spend on recruiting international "star professors". Constraints to attracting senior scientific personnel are often linked to limitations in internal funding at HEIs which also applies to building the research infrastructure necessary for cutting-edge research. The recent budgetary increase in university funding and the new university funding model applied in the funding period 2019-21 are intended to improve the situation and bring an additional 350 professors to the Austrian university system.

Recommendations

- *Monitor the progress made with the new system of university funding, in particular the overall efficacy of the new funding system in contributing to major goals of the forthcoming RTI Strategy 2020+, e.g. in the area of research excellence. Consider, in due time, adjustments using approaches that have been shown to be useful in other countries, notably the inclusion of output indicators for research.*
- *Adapt and focus the performance agreements on a limited number of strategic objectives with a clear outcome orientation. Reinforce the universities' capabilities for strategic planning.*
- *Carefully monitor the progress and experience with the new tenure track model gathered across universities.* Successful implementation of the new model is of critical importance for Austrian universities' research performance. Early-career researchers, in particular, should gain from the new arrangement.
- *Consider mechanisms to formally reduce faculty teaching obligations using course buy-outs based on, for instance, excellent research performance*. Standard models for this can be observed in leading institutions in the United States and in Europe. These mechanisms enhance faculty productivity as well as competitiveness in faculty hiring processes when used as components of a hiring package

Leading institutions performing basic research: OeAW and IST Austria

Both OeAW and the IST Austria are critical institutions for performing high-level internationally renowned basic research in Austria. The research record of both OeAW and IST in terms of scientific publications, scientific prizes and ERC grants is remarkable. For example, since 2007, OeAW and IST researchers have received 78 ERC grants (41 for OeAW, 37 for IST), compared to 125 for all Austrian universities. The success rate of IST Austria in competitive ERC funding is 44%, making it one of the leading organisations in Europe in this respect, ahead of Oxford University and ETH Zurich.

The OeAW is both a learned society of well-established researchers and a research performing institution. With 1 600 employees and an annual budget of more than EUR 160 million, OeAW is a major institution for basic research. Its institutes cover a wide range of disciplines, from life sciences, physics and mathematics to humanities and social sciences. They are usually closely connected to a university both geographically and through directors holding university professorships. Some institutes are organised as independent legal units (e.g. the new life sciences institutes IMBA, CeMM, GMI) with high professional management standards.

IST Austria was founded in 2009 and brought an institutional innovation to the Austrian research landscape. The IST Austria – which is modelled after Israel's Weizmann Institute – is an internationally oriented research institution offering doctoral and postdoc programmes in the natural sciences and mathematics. The share of international students and researchers is exceptionally high compared to any other research organisation in Austria. Based on a tenure-track system, a research group organisation and an interdisciplinary orientation, IST was able to attract a large number of talented young researchers. With a staff of about 600 and an annual budget of EUR 70 million, IST is smaller than OeAW but expected to grow, from 48 research groups in 2018 to 90 research groups in 2026.

Recommendations

- *Maintain adequate funding for the excellent basic research performed at OeAW while further strengthening dedicated management and governance functions.*
- *Continue commitment and support for the successful evolution of IST Austria.* The IST has clearly been an institutional innovation in the Austrian science system, meeting high expectations in terms of quality of research, doctoral and post-doc education and internationalisation.
- *Nurture increasing linkages between the IST Austria and the surrounding research and innovation ecosystem*, e.g. through developing mutually beneficial co-operation with Austrian universities and research institutes, as well as developing the IST's role as an incubator and strengthening its evolving linkages to the business sector.

Applied research and transfer-oriented institutions

A major role in industry-science co-operation is played by research organisations, institutes and centres, the majority of which (with the exception of LBG) has industry-science collaboration as a main mission. These research organisations, institutes and centres consist of permanent organisations on the one hand and temporary structures on the other:

Permanent organisations

- Research and technology organisations (RTOs) include the Austrian Institute of Technology (AIT), Joanneum Research (JR)[6], the Austrian Co-operative Research association (ACR). They conduct both contract research and directed basic research in fields of relevance to industrial application. They are in varying ways and degrees connected to the university sector, e.g. through joint research projects, appointments of university professors as heads of research units, and joint supervision of PhD students. In addition to JR, the Austrian states (Länder) operate research organisations with a similar profile to RTOs, including Upper Austrian Research, Salzburg Research, Vorarlberg Research, Forschung Burgenland and Carinthian Tech Research. The Silicon Austria Labs are in the process of being established.

The RTO sector – although smaller in size than in some comparator countries – plays a critical role in the Austrian innovation system, notably with regard to industry-science collaboration, but also societal challenges. Due to their organisational diversity, differences in ownership and governance structures, Austria's RTOs are a diverse group of actors. For this reason, strategic co-ordination, and a coherent policy for steering the RTOs, are difficult to achieve. Currently, there is even a lack of common standards and criteria for comparing and assessing the contribution of RTOs to research and innovation in Austria, despite similarities in their most basic mission, which is to translate basic or applied research into economic and social applications and industrial innovation. The fragmentation of the RTO sector comes at a cost. It may result in overlapping and uncoordinated activities, a less than optimal presentation of the sector and its capacities to potential industrial partners (particularly partners from abroad), and a situation where the RTOs' potential for research and education (e.g. for doctoral and postdoctoral studies) is not fully used. While acknowledging the underlying differences, the sector as a whole, and hence the Austrian innovation system, could gain from better co-ordination. At a minimum, and as a first step, a harmonised core reporting system could be put in place. This would be a first step towards an improved steering of the sector as a whole, and could further support the development of a basic funding model (as foreseen in the government programme) and profiling of the RTOs.

Temporary structures

- The COMET programme and its predecessors have contributed substantially to the evolution of industry-science relations in Austria over the past two decades. Currently supporting 22 COMET centres, the programme – which started funding the first centres in 2008 – is the single most important public support instrument for industry-science co-operation. The COMET programme was initially designed to include K1 centres, with a focus on strategic science-industry research agendas; K2 centres, which are larger projects with greater risk and international visibility; and, COMET projects, which develop new science–industry initiatives. In the future, there will be only one type of COMET centre, Centres operate with a duration of 4+4 years, pending a successful mid-term evaluation.
- The Christian Doppler Research Association (CDG) funds a significant number of temporary research laboratories, the CD Laboratories, at universities and PRIs that successfully link science and enterprises in application-oriented basic research, based on an original and flexible governance model. The CDG also funds the

Joseph Ressel Centres at UAS. The CDG-funded research units are embedded in the host research organisations.

- The Ludwig Boltzmann Society (LBG) is a non-university research organisation. The LBG institutes (18 in autumn 2018) are established together with partner organisations and usually operate for seven years, followed by a transition phase to find a permanent organisational structure outside the LBG. They occupy a unique role through their focus on health research and humanities, social and cultural sciences, as well as open innovation and new approaches to science. The LBG also operates a career development centre.

A 2015 impact assessment showed that the COMET programme has been successful in creating new competencies. The programme has proved effective in terms of publication impact, innovation outcomes, qualification of young researchers and the establishment of long-term (international) partnerships and mutual trust. At the same time, the impact assessment identified deficits with regard to basic and higher-risk research. From the observation that COMET centres tend to act as service providers for enterprises, supplying the latter with readily usable R&D results, the assessment concluded that they are not always able to provide new impulses for longer-term innovation strategies.

A recent adjustment, in response to these findings, is the establishment of the new "COMET Module" programme line that funds strategic research projects and is open only to existing K1 centres. As stated in the first call for proposals, "Modules are thematically distinct research units that perform research on the highest level to open up new promising/emerging fields of research that are way beyond the current state of the art. This enables particularly high-risk research. Incremental research is not a goal of COMET Modules." For the time being, the recent adjustment in the COMET programme should be allowed to stand the test of time, being formally assessed at the earliest reasonable opportunity. Challenges for the future also include maintaining openness of the programme for new partners, exploring possibilities to align COMET better with societal challenges and missions, and achieving a compatibility of incentives with an evolving university sector.

In the 2015 impact assessment it is also notable that COMET projects were rated more positively than the COMET centres by some participants. In the context of these developments, as the COMET projects mature, with the possibility of becoming a COMET centre, alternative governance structures could be considered. The development of centres built around a virtual management model of governance would help to maximise flexibility, ensure industry relevance and prevent the accumulation of long-term commitments which make exit more difficult. The lesser need for capital investment in such centres – which would make use of existing research capacities – would also reduce the tendency to focus collaboration on shareholder businesses and open up possibilities for wider engagement.

Recommendations

- *Develop a core monitoring system for RTOs that allows better comparison of their performance* – with their peer organisations in Austria and relevant international RTOs – and enables the strategic governance of the sector, while taking into account the diversity in governance and ownership. Monitoring of activities should be along a pre-defined set of balanced output indicators, including peer-reviewed publications, PhDs trained, patents/licences, innovations, spinoffs, and researcher mobility. It would be desirable to include other transfer-oriented organisations in such an effort.

- *Entrust a federal institution with the responsibility for maximising the collective impact of the RTOs.* This institution, for instance the BMVIT, should take the initiative and develop a monitoring system as described above. In co-operation with regional authorities (Länder), this institution should also take the lead in developing an institutional funding model for the RTOs, and in close co-operation with each organisation, help in defining clear profiles for the RTOs.
- *Assess in due time the impact of the COMET Modules in terms of ambition and the type of research performed.* If this does not meet expectations, more profound change should be considered.
- *Continue with the successful CDG model of funding industry-university co-operation* which combines – in a straightforward and highly flexible manner – basic research with industrial application, providing all partners with powerful incentives to co-operate, and assuring the quality of research performed in the CD Laboratories and JR Centres.
- *Explore ways to adapt the LBG model and avoid frictions by making LBG rules and regulations sufficiently "light" and, from the beginning, compatible with those of the partner universities* which might integrate the respective LBI at the end of the funding period. This implies that LBG rules, contractual arrangements and related practices are well aligned with the legal and organisational practices of the universities.

Support for international STI linkages and co-operation

Austria is well connected with foreign partners in science and innovation, particularly with other EU member countries. Dense international links exist in domestically performed R&D financed from abroad, in international co-authorship of scientific publications, and in the share of public R&D expenditures for transnationally co-ordinated R&D.

International co-operation in science and innovation is essential to address complex inter-related societal, environmental and economic challenges. Engaging in international co-operation in research and innovation helps to access global pools of knowledge, research facilities, and complementary human capital, and contributes to efforts to effectively address regional or global challenges.

Critical for Austria's international collaboration is the participation in the Horizon 2020 programmes, which helps achieve critical mass in research. Accessing funds from these programmes is highly competitive, and Austria's approval rate (2.8% of all approvals in Horizon 2020 after half of the calls have been decided) indicate the high quality and international relevance of the country's scientific research. While successful overall, there have been some problematic issues. Industry participation has been somewhat uneven, and SMEs in particular seem to find it increasingly difficult to participate. High success rates in attracting grants from the excellence-based European Research Council (ERC) are evident.

A recent evaluation of FFG's EIP programme has provided a favourable overall assessment of the support structures and activities. Room for improvement has been identified regarding the provision of more targeted advice and information to various user groups. In addition, the evaluation found that efforts to empower and incentivise Austrian research organisations to develop their own capacities for EU framework programme-related strategies could be strengthened. Improving the links between national support through FFG and EU programmes was also seen to be potentially beneficial. For instance, a system for redirecting highly rated but rejected proposals for EU programmes to relevant national funding instruments could be established, and the research focus between national and EU levels could be better aligned. The governance and co-ordination of ERA policies and support has also been assessed positively. However, there seems to be a need to strengthen the co-ordination of internationalisation and participation in EU programmes at the ministerial level. This has become even more important as the current and upcoming European framework programmes focus on cross-sectoral issues, which will require closer alignment of funding mechanisms and funding bodies at the national level.

Austria's international collaboration is primarily focused on the EU and its member countries, but collaboration beyond Europe remains weak. Initiatives such as the Beyond Europe Strategy can help intensify collaboration with countries outside the European Union. The Beyond Europe programme, which supports Austrian enterprises, research and higher education institutions and other organisations to establish and expand co-operation with partners outside Europe – is small relative to the ambitions of the Beyond Europe Strategy. This is also critical in light of the EU's objective to strengthen third-country collaboration through its next framework programme Horizon Europe.

Recommendations

- *Take a strategic approach to co-operation in European and other international programmes and strengthen co-ordination at ministerial level in this regard.*
- *Consider strengthening, prioritising and co-ordinating national funds for transnational collaboration beyond Europe.* Increased strategic efforts to strengthen collaboration with countries outside Europe can add substantially to the pool of knowledge accessible to Austria.
- *Consider (re)introducing some public co-funding of the costs of participating in EU programmes*, especially for SMEs, to counteract a declining trend in participation.

Re-designing innovation policy

Towards a new RTI Strategy 2020+

The RTI Strategy 2011-20 has been successful in a number of respects

- First, it helped to mobilise and maintain a high level of government support for increasing investment in R&D. Austria succeeded – with the help of the current RTI Strategy – to join the group of countries with the highest R&D intensity. At the same time, on a wide range of STI-related structural and output measures, Austria still lags innovation leaders such as Denmark, the Netherlands, Sweden and Switzerland. Austria's very success in mobilising resources for R&D and innovation has therefore led to questions regarding the cost-effectiveness of STI policy overall.
- Second, the RTI Strategy can be seen as a step towards more communication and co-ordination, as six ministries committed themselves to a set of shared ambitions and priorities in the area of innovation policy. An inter-ministerial "RTI Task Force" was created to support, substantiate and co-ordinate the implementation of the strategy.
- Third, the RTI Strategy contributed to policy continuity.

A number of shortcomings in implementation were addressed in an interim assessment of the RTI Strategy, and in various statements and recommendations of the advisory councils (the RFTE, the Austrian Science Board and the ERA Council Forum).

Based on the record of the current RTI Strategy, and the experience of other OECD countries, Austria's federal government has taken a decision to draw up a new RTI Strategy 2020+ as an instrument of innovation policy governance.

Concentrating on a limited set of strategic goals would help to better communicate the RTI Strategy to all stakeholders and develop a common view among key actors in ministries and agencies on how they can contribute to the RTI Strategy. Concentrating on a few objectives would also help in designing a coherent mix of policy instruments to deliver the strategy. Moreover, the Strategy 2020+ has to integrate other national initiatives with similar goals, such as the forthcoming digital and AI strategies. The experience of the current RTI Strategy as well as international experience indicates that a duration of ten years is too long, at least if no mid-term review is foreseen.

Although already part of the RTI Strategy 2011-20, societal challenges have gained in importance and have become a major pillar of STI policy in many advanced countries and in policy at EU level. Programmes tackling societal challenges require new forms of governance and funding. With a larger focus on mission-oriented funding to address societal challenges in the upcoming Horizon Europe, it will become important to prioritise societal challenges in Austria that are well-aligned with Horizon Europe. This will help create synergies between national and EU funding on these challenges, and help to make better use of resources from the EU.

Strategic discussions are currently underway in Austria on how to make best use of the EU's mission-oriented policy approach, both with regard to finding the best possible alignment with the emerging mission topics at the European level, and in view of defining national missions for Austria. This process could well be a cornerstone of the new RTI Strategy.

Recommendations

- *Focus the new RTI Strategy 2020+ on a few strategic goals related to achieving innovation leadership.* This entails a shift from input targets to a greater focus on the impacts of R&D and other innovation activities and an emphasis on excellence throughout the research and innovation system. It will also be necessary to further strengthen links between science and industry with more ambitious goals, while linking R&D funding more closely to societal challenges and "missions".
- *Align the new RTI Strategy 2020+ with strategic priorities of European RTI policies in Horizon Europe programme and other RTI-related EU funding sources*. The new RTI Strategy should aim at utilising European funding by framing Austrian priorities within broader complementary European thematic areas. Identifying Austria's priority societal challenges will help in this regard.
- *Ensure that the new RTI Strategy 2020+, in particular with the forthcoming initiatives for the digital economy, the Strategy for Artificial Intelligence, the Open Innovation Strategy as well as with national strategies linked to societal challenges* such as the Austrian Climate Strategy, the Austrian Security Strategy, and initiatives in the fields of health and ageing.
- *Link the new RTI Strategy 2020+ with other government initiatives, regional innovation ecosystem profiles, and smart specialisation strategies (RIS3).* The new RTI Strategy should also be linked with initiatives at the state level so as to make best and coherent use of the resources of the federal and state governments.

A greater focus on societal challenges

Societal challenges, such as climate change, population ageing, poverty, social exclusion, and food and energy insecurity, are global concerns. To tackle societal challenges effectively, innovations are needed in a variety of areas and in ways that are systemic and co-ordinated among many actors. A major function of public policy in this context is to guide research through targeted funding and other incentives towards areas where societal needs are greatest and where innovation is most urgent. The RTI Strategy 2011-20 acknowledges the role of R&D and innovation in tackling societal challenges. The new government programme confirms the need to make better use of innovation in the context of grand societal and ecological challenges, and to improve subsequent framework conditions for investing in relevant research.

While thematically open research funding prevails in Austria, a number of programmes addressing societal challenges through R&D exist. An important instrument in this regard is the Austrian Climate and Energy Fund (KLIEN). The KLIEN was – among other things – designed to increase R&D in sustainable energy technologies. Other thematic programmes of relevance to societal challenges are funded through the BMVIT which supports R&D e.g. in the areas of energy and transport, such as the Research, Technology and Innovation Support Programme for Mobility 2012-20. At the European level the strength of Austrian research on societal challenges can be seen in a sound performance in the participation in Horizon 2020.

However, compared to other OECD countries, the "general advancement of knowledge" accounts for a high proportion of government budget allocations to R&D (GBARD) in Austria (70.1%). This is mirrored by a rather small share of allocations directed towards specific socio-economic objectives (which include defence, health, etc.). Total GBARD per capita in Austria is considerably above the EU average. However, total expenditure per capita for specific objectives is often lower in Austria than for the EU, with the exceptions of earth sciences (including climate change), energy, education, and – above all – industrial production and technology. In contrast, the shares of R&D dedicated to health and the environment are comparatively low in Austria.

R&D funding for specific societal challenges is hindered by a lack of effective priority setting. A systematic identification of key challenges for Austrian R&D has gained momentum recently, inspired by the European Commission's proposal for Horizon Europe, where a mission-oriented policy approach to R&D funding plays an important role. This approach will also have to be considered in the new Austrian RTI Strategy.

Effectively addressing societal challenges often requires a multidisciplinary approach and a combination of different types of research and innovation, including combinations of basic and applied research, as well as collaboration between natural and social sciences. It also requires co-operation between research performing and funding organisations, business, government and stakeholders as well as new funding and governance structures.

Recommendations

- *Provide for alignment with thematic fields addressed in Horizon Europe, mobilise research institutions for all four of its pillars and develop national and regional instruments with high complementarity.*
- *Regarding societal challenges, use the EU's new mission-oriented approach to R&D funding to systematically explore and define opportunities for complementary*

national and European thematic priorities. This will help to harness Horizon Europe in ways that further develop Austria's STI capacities.

- *Develop Austria's capacity to effectively address societal challenges through research and innovation.* To achieve this, support long-term collaboration on societal challenges between universities, PRIs, businesses, public administration and other actors. Societal challenges require a combination of basic and applied research.
- *Link with research on societal challenges beyond Europe*. To create synergies with international initiatives and the programmes of other national governments, provide incentives for Austrian actors to participate in international research activities.

An excellence initiative for Austria

To enable excellent research, conducive framework conditions need to be in place. This includes well-endowed universities and research institutes, good working conditions and career perspectives for researchers and a world-class research infrastructure.

Austria has taken a number of efforts to move towards excellence in research. At the institutional level, the foundation of the IST Austria has been a prominent example of funding excellence. Recent initiatives are addressing a number of issues of relevance for research excellence across institutions. Developments that can be expected to contribute to overall research excellence include the increased university funding over the 2019-21 performance agreement period, disbursed under the new university funding model, an increase in the budget for competitive funding of basic research through FWF (albeit less than expected), and recent reforms towards an Austrian tenure-track model. Beyond funding, there have been improvements in doctoral education through initiatives providing incentives for universities to implement structured PhD programmes that are seen to play an important role in raising the quality of research as well as attractiveness for domestic talent and talent from abroad.

The current Austrian RTI Strategy 2011-20 has highlighted the importance of research excellence. While progress has been made towards higher quality and excellence in Austrian science, expectations have not been met across the board. Considering the experience had in a number of countries, both the RFTE and the Austrian Science Board have recently published recommendations in support of an Austrian excellence initiative.

The federal government declared its intention to start an excellence initiative in 2019. The initiative outlined in the government programme emphasises a strengthening of competitive funding for basic research, and increased funding for excellent junior scientists, but also an overall expansion of competitive instruments to stimulate research excellence in universities and PRIs. This initiative could substantially reinforce and complement measures Austria has recently taken to promote research excellence, in particular with regard to strengthening competitive funding of basic research, increasing international visibility and sharpening the profile of Austrian science at the international level.

The comparatively low level of competitive research funding through the FWF, the most important domestic source of competitive funding of basic research, is widely recognised as an impediment to excellent research. An Austrian excellence initiative should addresses this issue. Increasing the budget for the FWF is paramount for strengthening competitive basic research and to financially equip FWF funding programmes to meet high international standards. In this context the reimbursement of overhead costs should be reinstated in FWF funding programmes, as is the case for FFG and European programmes, including Horizon

2020. The excellence initiative would also allow FWF to develop its portfolio of programmes in new directions and enhance cooperation with funding institutions in applied research.

The excellence initiative should build upon existing institutional capacities, strengthen thematic competences (e.g. related to societal challenges and transitions), strengthen co-operation across disciplines and institutions, and thereby reduce the degree of fragmentation of research. The FWF should play a key role in the implementation of a research excellence initiative.

Recommendations

- *Raise the budget of FWF to the level of comparable funding organisation in leading innovating countries. This would allow FWF to step up its traditional funding activities.*
- *Dedicate part of the additional funding for the purpose of a larger-scale funding programme to help retain established researchers in Austria*.
- *Reintroduce the compensation of overhead costs in FWF project funding (analogously to FFG or EU funding).*
- *Use the additional funding to also provide the resources for diversifying FWF's portfolio of funding activities towards* research addressing societal challenges, missions and collaborative research between science and industry.

A larger role for private foundations as a source of research funding

There are currently around 700 foundations in Austria that can be identified as purely philanthropic, representing annual estimated expenditures for public purposes of EUR 25-40 million. The proportion of R&D expenditures attributable to the private non-profit sector is rather low, with a funding volume of around EUR 51 million (0.4% of total R&D expenditure in Austria). And, overall, Austria's philanthropic sector is under-developed compared to countries of similar size such as Denmark, Sweden or the Netherlands, or countries with a similar socio-economic tradition such as Germany.

Due to the lack of a continued tradition of philanthropy in Austria, research institutions have not been in a position to develop expertise in foundation or large donor fundraising. Among existing foundations engaging in science, research or academic education, support largely takes the form of stipends and scholarships. Data availability with regard to the non-profit sector in general and the foundation sector in particular is limited. Available information is based on single studies and research efforts, and comprehensive data are lacking.

A long-term approach and a series of steps are needed to revive larger-scale philanthropic engagement. Policy measures, especially for generating support for research and science, need to address the demand for philanthropic funding, e.g. in universities, and the supply side, namely private philanthropic foundations.

Recommendations

- *Develop long-term commitment and strategies to build a philanthropic landscape in Austria in terms of tax incentives and legal framework conditions modelled on international examples, with the goal of fostering the creation of large endowment foundations and role-models for grant making foundations.* The state could also help provide role models (e.g. creating and endowing foundations that have their own independent governance). A consulting and advisory landscape that provides guidance and instruments for philanthropic action could also be fostered. This could be done, for instance, by developing training and knowledge-transfer initiatives for researchers within academia, for fundraisers outside academia or for donors and foundations directly.

- *Develop measures to support a positive perception of private philanthropy, and demonstrate the impact of private support for actions that meet public purposes.* A helpful step, for example, would be improving science communication to potential philanthropic elites.
- *Seek to increase the institutional variety of organised philanthropic action (e.g. developing and supporting models of donor-advised funds).*
- *Support capacity building for fundraising in research institutions such as universities, universities of applied science or other research institutions.*

Science, technology and innovation governance

New approaches for providing advice and assessing innovation policy

Currently, Austria operates three research and innovation councils providing guidance and strategic advice for science and innovation policy: 1) the *Austrian Council for Research and Technology Development (RFTE)* can be considered the main actor in terms of its remit. Its mandate covers the entire national innovation system, and the RFTE can be consulted by both federal and regional institutions; 2) the *Austrian Science Board*, which has a more narrowly defined mandate and serves as the main advisory body to the Federal Minister in charge of Science and Research, to parliament and to universities on all university-related matters; and, 3) the *Austrian ERA Council Forum*, which is a relatively new high-level expert body advising the Austrian Minister responsible for Science and Research on matters concerning the relationship between the Austrian research and innovation system and European policies.

The new federal government has expressed its intention to merge the three councils into one and strengthen its economic competence. There is no single international best practice as regards this type of council. Rather the choice of available options depends on the specific role the council is assigned in the national innovation system. International comparative studies have identified four types of research and innovation council with regard to their roles: the planning, co-ordination, advisory and platform type of council.

The RFTE has exercised two main functions during its history. While a co-ordination function may have been more prominent in the early years, an advisory function dominated later on. If Austria wants to move the council closer to political decision making and achieve long-term commitment to STI, it may be advisable to anchor the council at the highest political level, as other countries with this kind of ambition have done. In the Austrian case the council's independent secretariat should be placed under the Federal Chancellery. The Federal Chancellor *in person* should chair a minimum of two meetings of the council, with the participation of the other STI-related Ministers and of additional members of government ensured on an ad-hoc basis. It is evident that this arrangement is a deliberate choice that requires personal commitment at the highest level of government, namely the Federal Chancellor and government Ministers. Such an arrangement would signal that Austria values STI as a permanently important area of policy shaping the country's future. This option could take a hybrid form. During the time between the meetings of ministers chaired by the Federal Chancellor with the council, the latter could act as an advisory council performing its usual duties. The alternative option would be an advisory council in the traditional manner, e.g. on the model of the current RFTE, adapted to new tasks and challenges.

Whatever the specific form it might take, such a council should be mandated and equipped to deal with the strategic issues for research, technology and innovation in Austria. The council should support a whole-of-government approach and include, in its work innovation-relevant issues beyond R&D and technology, such as skills, innovation in the public sector, innovation in the health sector, etc. The council should strive to maintain the high level of expertise of the current councils, the international experience and orientation of many of their members, and close interaction with government, while at the same time strengthening their ability to give advice and guidance on non-R&D and non-technological dimensions of innovation policy. More prominence should also be given to innovation as it relates to societal challenges and transitions.

Gathering outstanding personalities in the area of science, industry, new economic activities, finance and innovation stakeholders, the new Council can play a strong role in developing a new vision of the Austrian research and innovation system that focuses on excellence and impact and steering or monitoring the implementation a new RTI Strategy.

Recommendations

- *Establish, in due time, a single Council for Science, Research and Innovation.*
- *Clarify the role of the single Council for Science, Research and Innovation* in the Austrian research and innovation system. In essence, there are at least two feasible options:
  - If the single council's role is primarily in providing independent advice, monitoring and assessment, an adapted version of the RFTE (with some change in scope, for instance regarding societal challenges, and *modus operandi*, for instance using working groups) might be considered.
  - If the single council's role goes significantly beyond advice, to include policy co-ordination, alignment and mobilisation of resources, it will need stronger political anchoring, preferably at the Federal Chancellery. This second option is appropriate if the federal government wishes to make science, technology and innovation a cornerstone of Austria's longer-term policy. This option could also take a hybrid form, with an advisory council meeting periodically, e.g. two times a year in joint sessions with ministers, chaired by the Federal Chancellor while acting as an advisory council in the interim.

Improving horizontal and vertical co-ordination and co-ordination between the federal and state levels

Following recent restructuring, the main governmental STI policy actors at the federal level are the Ministry of Education, Science and Research (BMBWF), the Ministry for Transport, Innovation and Technology (BMVIT) and the Ministry of Digital and Economic Affairs (BMDW). The Federal Chancellery (BKA) and the Ministry of Finance (BMF) also play important roles in terms of their general responsibilities for policy co-ordination and allocation of public budgets. The BMF is also in charge of the Research Premium's administration and evaluation.

Austria's basic institutional set-up involves science and research connected to education in a broad sense, with innovation and technology and cross-sectoral (innovation-related) economic policies residing under separate ministries. This requires effective co-ordination. Co-ordination is further necessitated by the fact that STI policy cuts across numerous policy areas. Moreover, meeting societal challenges calls for a stronger involvement of ministries beyond the traditional core group of STI ministries. The RTI Strategy 2011-20 constituted a step forward as six ministries committed themselves to a set of shared ambitions and priorities for innovation policy. An inter-ministerial RTI Task Force was mandated to "support, substantiate and co-ordinate the implementation of the strategy". A main challenge for Austria's innovation policy is therefore not the lack of horizontal co-ordination mechanisms, but rather the need to make co-ordination more effective and better adapted to new challenges. It seems fair to say that the activities such as those performed in the RTI Task Force have primarily served the need for improved mutual information rather than that of policy co-ordination in a strict sense. Stronger structures and incentives for policy co-ordination may be required.

Implementation of STI policy measures at the federal level is mainly in the hands of three major agencies (FWF, FFG and *aws*). These agencies operate a large number of programmes and funding initiatives. A recent evaluation of FFG and *aws* showed that these two agencies function well overall, but have complex operational models. There are co-ordination problems due to an unclear division of labour between agencies and ministries that results in "under-steering" at the strategic and "over-steering" at the operational level. The evaluation calls for "clear operational and financial autonomy" of the two agencies. This would simplify the operational model, and reduce the large number of ministry-agency communications required for the delivery of programmes. The operational model of FWF is less complex, which reflects its history as a council allocating funds to researcher-initiated projects. In line with its tasks, the FWF has a less diversified programme portfolio than FFG and *aws*.

The division of labour between the three agencies is organised largely along an "innovation stage model", from basic research to applied research, entrepreneurship and business promotion. While this division involves few overlaps and is practical in many ways, it is now widely recognised that the underlying model does not sufficiently reflect important features of contemporary research and innovation. Basic scientific research is often inspired and guided by real-world problems of social relevance (as epitomised by "Pasteur's quadrant") and contributes to their solution along with applied research. Societal challenges require research co-operation across sectoral and disciplinary borders. These interrelations call for closer co-operation and alignment of funding agencies for application-oriented and basic research.[7] In this regard, uncovered ground seems to exist, or potential synergies are underutilised, between the academically-oriented FWF and the more industry-oriented FFG. For instance, large projects addressing health challenges, which combine both applied and basic research, can fall between FFG and FWF. The FWF operates the Clinical Research programme (KLIF) and the FFG the Clinical Studies programme (KLIPHA).

Another important dimension of policy co-ordination relates to the regional dimension. Among others, the nine Länder have major responsibilities in funding the UAS (which are closely linked to the knowledge needs of local industry) as well as RTOs and other research institutes. Furthermore, the emphasis on smart specialisation in EU structural policy has contributed to an increased awareness of the role of regions in innovation policy, and most regions have started to develop strategies for smart specialisation that support a common entrepreneurial vision for regional needs and international opportunities. Since the inception of the federal RTI Strategy 2011-20, all nine Länder have developed their respective regional RTI Strategies, with priorities that align with and complement the thematic priorities in the federal strategy.

Recommendations

- *Strengthen the overall STI governance structures beyond the current design and practices of the RTI Task Force.* The new Council for Science, Research and Innovation could be designed to take on a role in co-ordination.
- *Further develop the governance and operational framework of major research funding agencies, notably FFG and aws by fostering their operational and financial autonomy while reinforcing strategic steering capacity in the Ministries in charge.* Within their political mandates and strategic guidance, agencies should be allowed to develop and manage their portfolio of programmes and instruments. Agencies in Nordic countries could provide examples to study. The new framework should help to reduce the number of programmes.
- *Consider implementing joint calls or alignment of programmes between the major funding agencies, in particular FWF and FFG, as well as aws.* The joint call of FWF and FFG for a quantum research and technology initiative is a promising example in this regard. Inspiration could also be drawn, for instance, from the Research Council of Norway, where a set of common criteria is established for funding projects which combine academic quality and societal relevance.
- *Take due account of innovation policies at the Länder level in the development of the new federal RTI Strategy 2020+, and seek the active involvement of the Länder from the beginning of the process.* Design strategic investment and funding instruments across regional, national and EU level so as to better connect activities with European missions.

Systematic and systemic evaluations of innovation policy

Evaluations and strategic intelligence are critical for planning, designing and implementing STI policies. Since the mid-1990s, supported by the rather unique Platform FTEval, Austria has made much progress in the evaluation of STI policies. Today, a series of national laws and regulations has created a system where a large number of evaluations are carried out on a routine basis. Nevertheless, quantitative impact assessments that seek to identify causal effects are rare. This is mainly due to limited access to and tight restrictions on the use of firm-level and administrative data for evaluation purposes. Austria lags behind international best practice in this regard. This constraint could become even more important over time, as there is reason to assume that the political need for accountability as to the effects of public spending will increase. In the Nordic countries, providing free access to administrative data for research purposes is included in the mandate of Statistical bureaus and implemented according to clear principles and rules for handling data and safeguarding confidentiality. These countries - as well as procedures used in countries such as Ireland and the United Kingdom - are among the most advanced in this regard and could serve as models for improved use of such data in Austria.

Austrian evaluation practice is also mostly focused on individual policy instruments and programmes and, to a lesser degree, on institutions. Broader systemic evaluations are less frequent, although there are some examples, such as the System Evaluation (of the Austrian RTI funding system) carried out in 2009.

Recommendations

- *Improve and simplify access to administrative data for STI policy evaluation purposes.* Consideration should be given to reform of the Austrian Statistics Law to allow researchers and evaluators direct access to anonymised business data for analysis and data matching. A recently launched process of OECD country reviews of access to and management of research data might also help identify ways of improving data access in Austria, without compromising the confidentiality of sensitive data.
- *Expand the currently strong programme-based evaluation culture to include system-wide evaluations (as has been done about a decade ago for the wider STI support system) and strategy processes.* Identifying the potential for - and responsibilities of - Austria in addressing societal challenges should be a natural area of focus. A strategic foresight process should also focus on trends and developments in international markets most likely to affect innovation in Austrian companies (such as, for instance, the implications of increasing vehicle electrification for automotive supply chains). The proposed new Council for Science, Research and Innovation could take a leading role in initiating, supervising and communicating system-wide evaluations and strategy processes.
- *Initiate, on a more regular basis, state-of-the art evaluations of portfolios of support instruments and their interlinkages.* Evaluations of this sort, which are methodologically complex, and data-intensive, could be very useful in informing future decisions on Austria’s overall policy mix for STI.

Annex 1.A.

Table A.1. Strengths, weaknesses, opportunities and threats in the Austrian innovation system

Strengths	Opportunities
• Strong long-term economic performance, with high living standards and quality of life • A strong export-oriented manufacturing sector, upgrading within industries, with world-market leaders and innovators in various niches • Rapid advances in the provision of human resources, creation of the Universities of Applied Science • Rapid increase of research and development (R&D) intensity across most industries and firm size classes, achieving a leading position in the European Union (EU) • A large number of R&D-active firms, including many SMEs, that have significantly expanded their R&D capacity • Increase in research output, with notable institutional innovations (e.g. Institute for Science and Technology Austria) and some international research strengths, such as quantum communication • A multiform sector of research institutes and research and technology organisations (RTOs) that engage in different types of knowledge and technology transfer with businesses • Strong policy commitment to innovation and digitalisation • Successful participation in the EU's 7th Framework Programme, Horizon 2020 and European Research Council grant processes • A developed programme evaluation culture	• Austria's potential to develop and provide necessary human resources, including an increase in the role of women in STI • Excellent (basic) research, the development of new industry-science linkages and competitive (cross-disciplinary) funding (FWF in particular, FFG for applied research) • Excellent and more internationally visible universities through a dedicated excellence initiative • World-class conditions for the creation and scaling-up of innovative firms • A shift in the policy mix towards more targeted initiatives, for instance in developing new markets and tackling societal challenges. This requires changes in governance and funding • A broadened scope of innovation policy beyond R&D input targets to account for outputs and outcomes • Overall policy coherence and co-ordination and better data access to improve policy evaluations • Building a landscape for philanthropic science and innovation funding • Wide implementation of the new tenure track model exploiting the potential of becoming an internationally attractive and competitive career model
Weaknesses	**Threats**
• Specialisation in medium-tech industries and low growth expectations among new enterprises • Weaknesses in the business environment supporting scale-up • Low diffusion of certain digital technologies and deficits in broadband and fibre-based networks • Restrictive data access impeding data-driven innovation and effective policy evaluation and • Underrepresentation of women in research • Comparatively low PhD attainment and a weak system of doctoral education • Lagging performance in the education system (PISA results), high drop-out rates in public universities, shortcomings in adult education (PIACC results) • A university system which is not operating in ways that will continuously attract leading researchers, with performance contracts that fail to strategically steer the university system • Shortage of internationally visible research universities and institutes • Lack of strategic steering and co-ordination of RTOs • Fragmentation and a lack of effective co-ordination in research and innovation policy making and implementation	• Challenges in achieving adequate productivity growth, in a context of rapid population ageing • Failure to diversify into more technology, research and knowledge intensive sectors • Loss of competitiveness vis-à-vis emerging and former transition economies, including in knowledge-based goods and services • Failure to create a conducive ecosystem for innovative entrepreneurship and business scale-up (with low levels of venture capital investment) • Difficulty in attracting and retaining highly-skilled personnel including researchers, with severe international competition for talent • Failure to maintain attractiveness of Austria as a location of R&D investment by multinational firms. • Lack of responsiveness of STI policy and institutions, and broader frameworks, to fast-changing needs, such as the growing primacy of data as an input for innovation • Growing imbalances in the policy mix, crowding out funding in priority areas

Notes

[1] In science, excellence is associated with research that helps to expand the scientific frontier. In the business sector, excellence is associated with exploring entirely new technological solutions (radical innovation), combining technologies in novel ways, and taking up new scientific discoveries. "Excellent" business R&D often results in innovation that: sets new technological or business model standards in an industry that are then followed by others globally; changes the way a market operates; or, makes significant contributions to responding to major societal challenges.

[2] Owing to a change in the ISCED classification, the last two years of higher technical and vocational school now count as part of tertiary education.

[3] This does not imply a low level of internationalisation overall. In 2017, 39% of professors and 31% of doctoral students came from abroad; among newly appointed professors, 53% came from abroad.

[4] Students with at least 16 ECTS credits.

[5] Students with at least 40 ECTS credits.

[6] Joanneum Research is an institute owned by three states (Styria, Carinthia and Burgenland) but operating on a nation-wide (and international) scale.

[7] In some cases, this even led to integration or merger. Examples are the single Research Council of Norway, and the recent creation of UK Research and Innovation as an organisation that brings together the seven research councils, UK Innovate and one new organisation, Research England.

Chapter 2. The Austrian innovation system: Evolution and current challenges

This chapter outlines the evolution and discusses current challenges of the Austrian innovation system. It provides an overview of the expansion and structural change in Austria's expenditure on research and development, and the system's performance in terms of main STI indicators. The chapter further illustrates Austria's performance in international innovation rankings in relation to innovation leaders and reflects on the system's capabilities for international innovation co-operation as well as between industry and science.

The Austrian innovation system: Current challenges

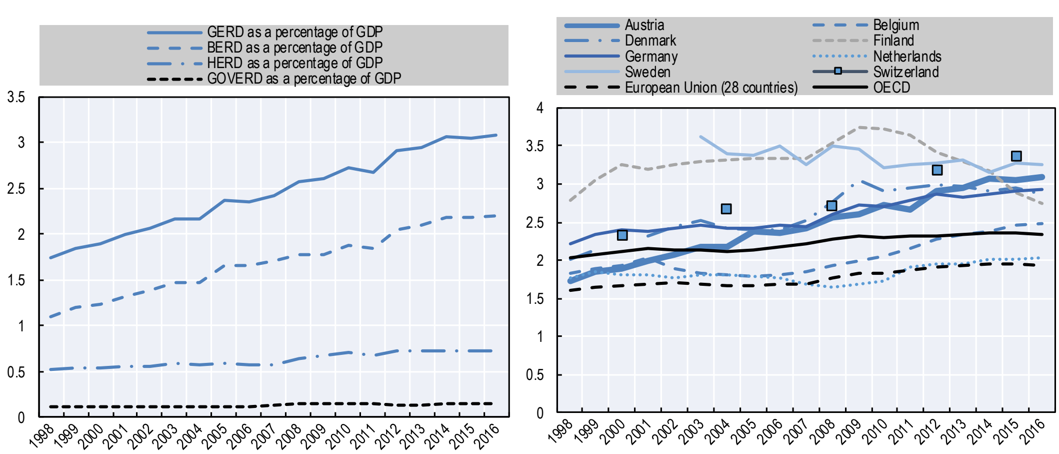
Input and output to R&D and innovation

Towards 3% and beyond

The Austrian innovation system has seen a rapid development over the past two decades. At the end of the 1990s, Austria's research and development (R&D) intensity – total gross domestic expenditure on R&D (GERD) as a percentage of gross domestic product (GDP) – was below the OECD average and significantly lower than in other small, open economies. Since then, R&D expenditure has increased considerably and much faster than in most other OECD countries. The EU's goal of increasing R&D intensity to 3% was met in 2014 (Figure 2.1, left panel). In 2015, R&D intensity was 3.12%. In real terms, between 1998 and 2015, R&D expenditure grew by a compound annual growth rate of 5.2%, compared to 3.0% in the OECD.

All of the main R&D performing sectors contributed to the expansion of R&D expenditure in Austria (Figure 2.1, left panel). The business enterprise sector expenditure on R&D (BERD) as a percentage of GDP increased from 1.10% in 1998 to 2.21% in 2015. The higher education expenditure on R&D (HERD) per GDP increased from 0.52% to 0.76% and the government sector expenditure on R&D (GOVERD) from 0.11% to 0.14%. Between 1998 and 2016 there were only three years with a (slight) decline in R&D intensity (2004, 2006, 2011) and only one year with a decline in the absolute real amount of R&D expenditure (2009).

Figure 2.1. **R&D intensity in Austria by main sector, and in international comparison**



Notes: Value for Denmark for 2000 interpolated; values for Switzerland for 1998-99, 2001-03, 2005-07, 2009-11 and 2013-14 interpolated; values for Sweden for 1998, 2000 and 2002 interpolated. GERD: gross domestic expenditure on R&D; BERD: business enterprise sector expenditure on R&D; HERD: higher education expenditure on R&D; GOVERD: government sector expenditure on R&D.
Source: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en.

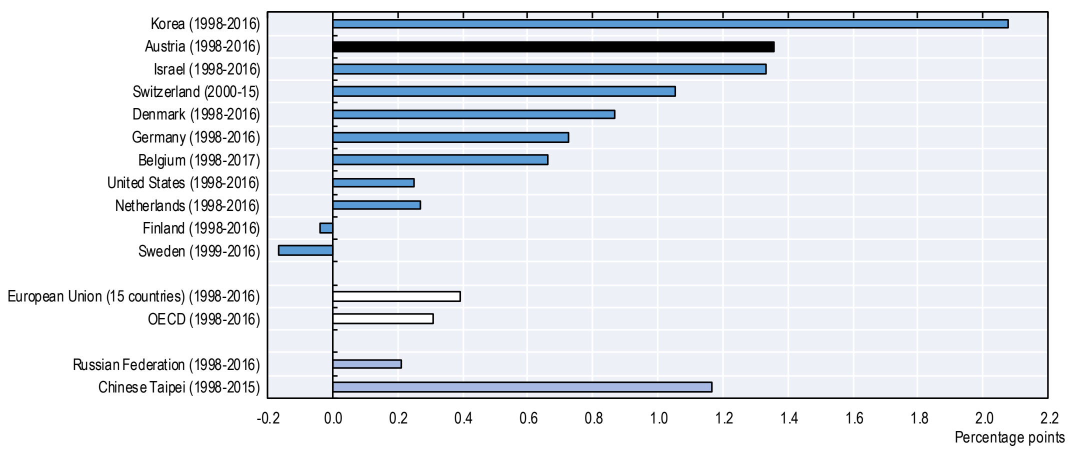
StatLink https://doi.org/10.1787/888933882009

Compared to seven other European countries (Belgium, Denmark, Finland, Germany, the Netherlands, Sweden and Switzerland), Austria's R&D intensity grew at a significantly faster rate, pushing Austria from last to third place within this group of countries by 2015

(Figure 2.1, right panel). While most other countries recorded slow growth or even declining R&D per GDP after 2009, total R&D intensity in Austria continued to increase at the same pace as before. In a global perspective, Austria ranked 6th in terms of R&D intensity in 2015, compared to ranking 20th just 20 years before.

The increase in Austria's R&D intensity between 1998 and 2016, by 1.39 percentage points, was the second largest increase among all OECD countries. Only Korea experienced a more rapid rise. The increase corresponds to that in the economy of Chinese Taipei at the same time, though starting at a much higher initial level (Figure 2.2).

Figure 2.2. **Change in R&D intensity, select countries**



Source: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en.

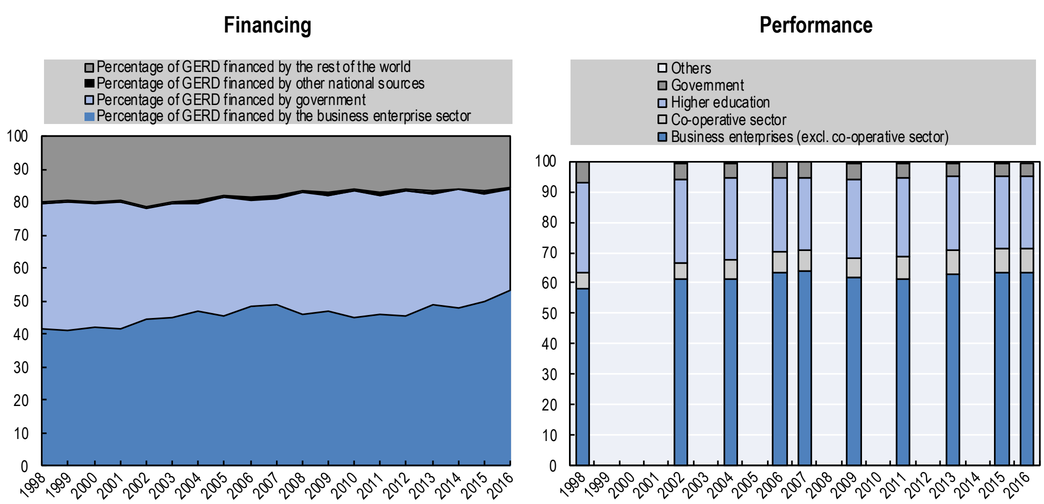
StatLink https://doi.org/10.1787/888933882028

This remarkable escalation of R&D intensity over a rather short period of time, which was itself characterised by a relatively difficult macroeconomic environment, represents a great achievement in Austrian innovation policy. It reflects the federal government's ambition to drive Austria into the group of leading innovation nations, which was formulated as a key goal in the Research and Innovation Strategy (RTI Strategy) in 2011. The increase in R&D expenditure was financed both by the domestic business enterprise sector, the Austrian government and sources from abroad. Domestic business enterprises contributed 53% of the total real increase in R&D expenditure between 1998 and 2015.[1] Their funding for R&D grew at a compound annual real growth rate of 6.1%. The Austrian government (including federal, state and municipal sources) contributed 34% of the expansion of R&D expenditure, corresponding to a real compound annual growth rate of 4.8%. Sources from abroad contributed 12% of the increase in R&D expenditure, which corresponds to a real compound annual growth rate of 3.5%. Funding from abroad includes funding by international and supranational organisations, notably the European Union. The largest part of R&D financing by sources outside Austria comes from multinational enterprises (MNEs) that provide funding for R&D at their Austrian subsidiaries (e.g. Siemens, Infineon, Boehringer, BMW, Novartis).

The different dynamics in R&D financing by source of funding led to an increase in the share of domestic business financing in total financing of R&D in Austria from 41.7% to 48.4% between 1998 and 2016 (Figure 2.3, left panel). The share of domestic government financing in total R&D fell from 37.8% to 35.7%. The share of R&D financing from abroad fell from 20.1% to 15.4%.

The increase in domestic business financing of R&D went hand in hand with an increase of the business enterprise sector's share in total R&D performance. In 1998, 63.6% of total R&D in Austria was performed by businesses (including the co-operative sector). This share rose to 70.8% in 2015 (Figure 2.3, right panel). Within the business enterprise sector, both private businesses and the "co-operative sector" (co-operative research organisations, including the COMET centres) increased their shares of total R&D performed (with private businesses increasing from 58.1% to 63.0%, and the co-operative sector increasing from 5.4% to 7.8%). The share of higher education institutions in total R&D expenditure declined from 29.7% to 24.3% in the same period. The government sector's share fell from 6.4% to 4.4%.

Figure 2.3. **Financing and performance of GERD in Austria by main sector**



Sources: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en; Statistics Austria (2017), R&D statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

StatLink https://doi.org/10.1787/888933882047

Government financing of R&D in Austria was approximately EUR 3.48 billion in 2015. The vast majority of government financing is provided by the federal government (including research council funding and R&D financing by higher education institutions). Other government bodies (state governments, municipalities) account for 10% of total government financing of R&D. Funding by the Austrian government is by far the most important public source of R&D funding. The European Union contributed EUR 0.20 billion to R&D financing in Austria (Table 2.1), which is equivalent to 5.7% of total national government financing.

The largest fraction of government financing of R&D goes to higher education institutions (EUR 2.17 billion in 2015, including the Academy of Sciences), of which EUR 1.51 billion are general university funds. Funding for higher education institutions primarily comes from the federal government, including funding of research projects by the Austrian Science Funds (*Fonds zur Förderung der wissenschaftlichen Forschung*), which was about EUR 0.20 billion in 2015.

Government R&D financing for business enterprises (excluding the co-operative sector) was EUR 0.68 billion in 2015. It accounted for 19.7% of total government financing of R&D and contributed 10.3% to business enterprise R&D expenditure (excluding the co-operative sector) in 2015. The co-operative sector, which consists of contract research organisations such as AIT and Joanneum Research, as well as the competence centres, received 6.0% of total government financing of R&D (EUR 0.21 billion). The single most important funding instrument in this group of R&D performers is the COMET programme. The co-operative sector, which is considered a part of the business enterprise sector in R&D statistics, is a special feature of the Austrian innovation system. It accounts for 8% of total R&D expenditure in Austria and 11% of total BERD.

Table 2.1. **Financing and performance of GERD in Austria, 2015**

Billion EUR

	Performing sector					
Financing sector	Business enterprises	Co-operative sector	Higher education	Government	Private non-profit	**Total**
Business enterprises	4.92	0.13	0.13	0.03	0.01	**5.22**
Government – federal, others	0.66	0.18	2.10	0.19	0.00	**3.13**
Government – states, municipalities	0.02	0.03	0.07	0.23	0.00	**0.35**
Private non-profit	0.00	0.00	0.03	0.00	0.01	**0.05**
European Union	0.04	0.03	0.09	0.02	0.01	**0.20**
Abroad others	1.02	0.45	0.05	0.01	0.02	**1.54**
Total	**6.67**	**0.83**	**2.47**	**0.48**	**0.05**	**10.50**

Source: Statistics Austria (2017a), R&D statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

Government financing of R&D for business enterprises (including the co-operative sector) consists of direct funding through grants for R&D projects (mainly distributed by the Austrian Research Promotion Agency [Forschungsförderungsgesellschaft, FFG]) and to a smaller extent by the Austria Business Service (Austria Wirtschaftsservice, *aws*) and an R&D tax incentive scheme - the research premium ("*Forschungsprämie*"). The cost of the tax incentive scheme was EUR 0.51 billion in 2015. This sum represents more than half of total government financing of business R&D (including the co-operative sector). Total funding by the FFG in 2015 was EUR 0.34 billion in 2015 (based on cash equivalents for loan programmes and including funding to non-businesses), of which EUR 0.20 billion was provided to the business enterprise sector. Funding by the *aws* (based on cash equivalents) for R&D, technology and innovation was EUR 0.11 billion in 2015.[2]

Twelve per cent of government financing of R&D is targeted at government research organisations, including a large number of smaller institutions operated by federal or state governments, municipalities, chambers of commerce and labour, and social security institutions as well as other publicly financed or controlled non-profit organisations. This group is the main receiver of R&D funding by non-federal government levels.

Investment in human resources

The substantial increase in real R&D expenditure in Austria over the past two decades resulted in an almost equal increase in the total number of R&D personnel (measured in full-time equivalents), which more than doubled from 1998 (31 300) to 2016 (73 600). This increase corresponds to a compound annual growth rate of 4.8% (Figure 2.4, left panel).

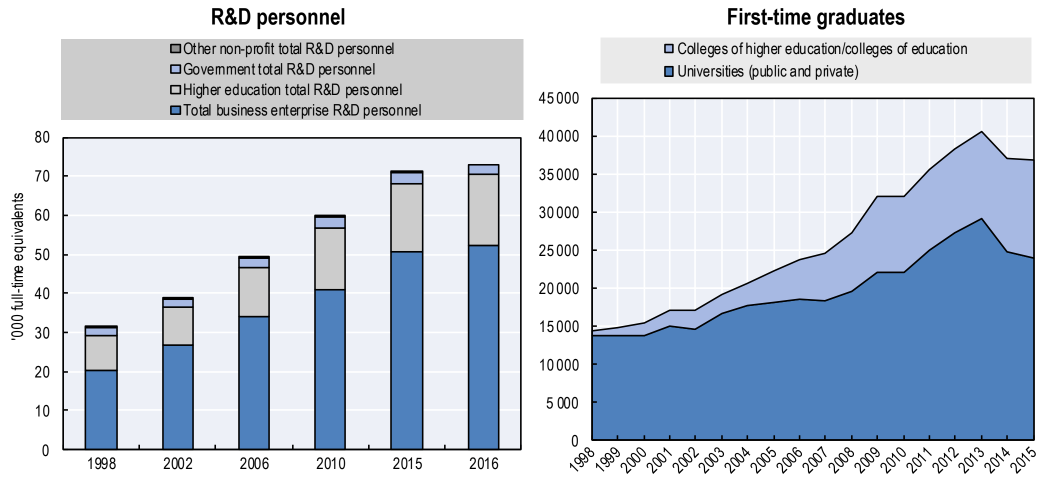
The additional financial resources for R&D have been almost entirely used to expand human resources for R&D. The share of total R&D personnel in total employment grew from 0.85% to 1.62%. The increase in financial resources for R&D did not result in a disproportional increase in wages for R&D workers.

The number of R&D personnel increased faster in the business enterprise sector (5.2%) than in the higher education sector (4.3%) and the government sector (1.4%), reflecting the different growth rates of real R&D expenditure. The expansion of human resources for R&D in the business enterprise sector led to a marked increase in the share of R&D personnel in total industrial employment, rising from 0.72% in 1998 to 1.49% in 2015, putting Austria in sixth place among all OECD economies on this metric. The share of total R&D personnel outside the business enterprise sector in total non-industrial employment grew from 1.34% in 1998 to 2.02% in 2015.

The increase in human resources for R&D in Austria over the past two decades was enabled by a substantial increase in the number of graduates from higher education. At higher education institutions (public and private universities, universities of applied science [*Fachhochschulen*], and colleges of education, excluding short-cycle tertiary education), the number of first-time graduates (bachelor, diploma, direct doctorates) went up from about 14 400 in 1997/98 to about 38 000 in 2014/15 (Figure 2.4, right panel), which is equal to a compound annual growth rate of 6.0% (Statistics Austria, 2017a). The number of foreign graduates increased particularly quickly. Their share in all graduates was 21% in 2014/15 (compared to less than 10% in 1998). The growth in graduate output by higher education institutions was accompanied by a significant increase in government financing of higher education institutions, though at a slower pace than output growth. From 2000 to 2015, government funding for higher education (excluding R&D financing through general university funds) grew in real terms by a compound annual rate of 3.8%. Government funding per graduate (in real terms, excluding graduates from private universities) was EUR 124 000 in 2000 and fell to EUR 96 000 in 2015. Income from tuition fees (only for students exceeding their standard period of study), which were introduced at public universities in 2001, only partly compensates for the drop in funding per graduate.

During the same period of time, the number of doctoral-level graduates[3] showed a much less impressive growth (Figure 2.5, left panel). This number rose from about 2 000 per year in the late 1990s to 2 500 in 2009/10 and fell to about 2 200 in 2014/15. This drop can be linked to an improvement of doctoral training through a change from two-year to three-year doctoral programmes. Accordingly, the huge increase in the number of graduates with tertiary-level attainment had very little impact on the number of graduates with the skills most closely related to research. These weak dynamics as regards new doctorate holders kept Austria below the OECD average for the share of doctorate holders in the working age population. Other countries with an R&D intensity similar to Austria's have significantly higher shares of doctorate holders, including Finland, Germany, Sweden and Switzerland (Figure 2.5, right panel).

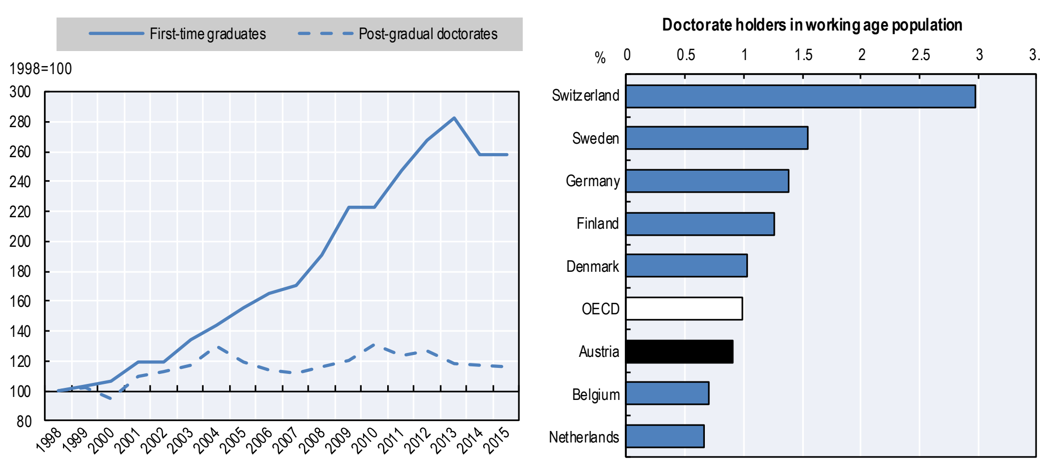
Figure 2.4. **R&D personnel and first-time graduates in Austria**



Sources: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en; Statistics Austria (2018), "Higher education statistics", http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

StatLink https://doi.org/10.1787/888933882066

Figure 2.5. **Post-gradual doctorates in Austria and share of doctorate holders in working age population**

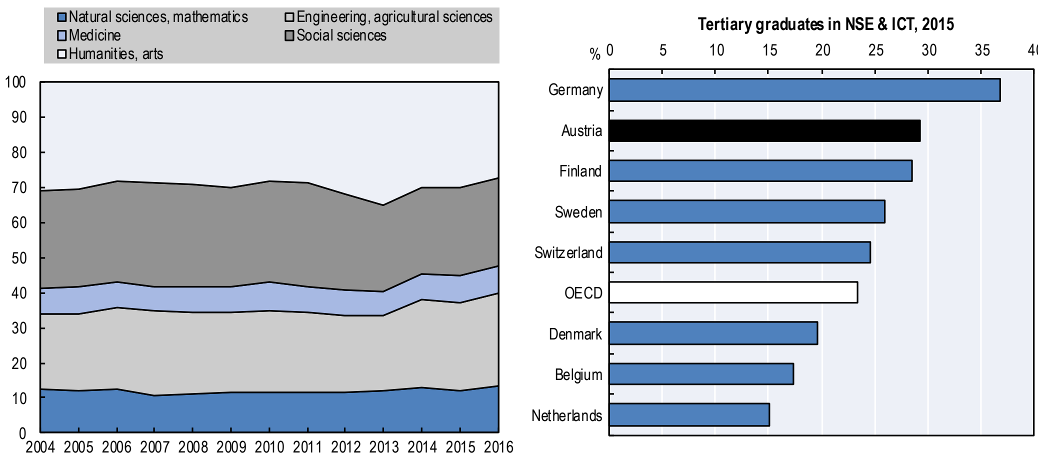


Sources: Statistics Austria (2018), "Higher education statistics", http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml; OECD (2017a), *Education at a Glance 2017: OECD Indicators*, https://doi.org/10.1787/eag-2018-en.

StatLink https://doi.org/10.1787/888933882085

In 2016, 39.9% of all first-time graduates from higher education institutions in Austria (excluding colleges of education) graduated in natural sciences (including mathematics and computer sciences) or engineering (including agricultural sciences) (Figure 2.6, left panel) (OECD, 2017a). This share has gone up significantly in recent years (from 33.4% in 2013). In terms of international comparison, this share is the third highest in the OECD. Among the group of comparator countries in Figure 2.6 (right panel), only Germany shows a higher share (OECD, 2017a).

Figure 2.6. **First-time graduates from higher education in Austria by main field and tertiary graduates in natural sciences, engineering and ICTs (NSE & ICT)**



Source: Statistics Austria based on OECD (2017a), *Education at a Glance 2017: OECD Indicators*, https://doi.org/10.1787/eag-2018-en.

StatLink https://doi.org/10.1787/888933882104

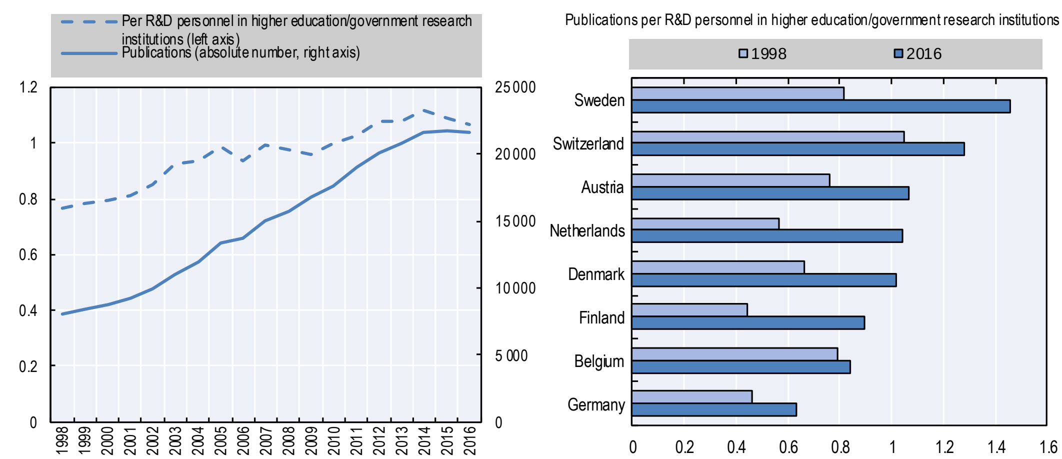
R&D results: Publications, patents and innovations

The increase in financial and human resources for R&D in Austria went hand in hand with an increase in R&D output. For instance, the number of scientific publications by authors affiliated to Austrian institutions grew strongly during the 2000s up to 2014 (Figure 2.7, left panel). For the period 1998-2016, the compound annual growth rate was 5.7%, which significantly exceeds the average annual growth rate in the OECD of 4.0%. Considering all R&D personnel in higher education and government research institutions in Austria, publication intensity – the number of publications per person – rose from 0.76 in 1998 to 1.12 in 2014. This intensity level decreased slightly in the following two years. Within the group of comparator countries, Austria ranked third in 2016 in terms of publications per R&D personnel in higher education and government research institutions, following Sweden and Switzerland (Figure 2.7, right panel).

The number of triadic patents by applicants domiciled in Austria grew from 1998 to 2015 at a compound annual rate of 3.1%. The number of Patent Cooperation Treaty (PCT) patent applications made by applicants from Austria went up by 7.2% annually over the same period. Both growth rates are significantly higher than those for the OECD (0.9% and 5.4%, respectively). When relating the number of patent applications to business enterprise R&D expenditure (measured in 2010 USD PPP), patent intensity fell in terms of triadic patents and slightly increased in terms of PCT patents (Figure 2.8, left panel). With respect to triadic patents, patent intensity in Austria followed the OECD trend, while for PCT patents, Austria fell behind the OECD after 2010. Within the comparison group, Austria ranks last in terms of triadic patent intensity and second from last (ahead of Belgium) for PCT patent intensity (Figure 2.8, right panel).

In terms of sales from product innovations, the Austrian business enterprise sector ranked third among the comparator countries (Figure 2.9, left panel), based on data from the Community Innovation Survey). In 2014, 12.0% of total sales in manufacturing and a range of service sectors were generated by product innovations introduced during 2012 and 2014. Higher shares are reported by Switzerland (19.6%) and Germany (13.3%). A relatively high share of sales from product innovation came from new-to-market innovations (4.8%), which is the second highest share among the comparator countries (the Netherlands being 6.6%). The share of sales from product innovation in the Austrian business sector has not changed much in recent years. In 2010, the figure was 11.9%, falling to 9.9% in 2012 (Figure 2.9, right panel). In most comparator countries, except for Switzerland and the Netherlands, figures on this indicator went down between 2010 and 2014.

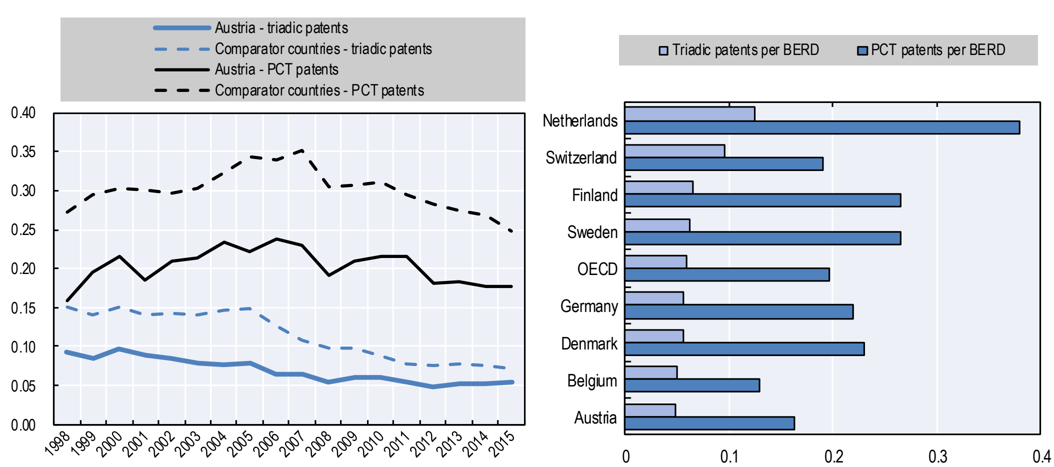
Figure 2.7. **Scientific publications and publications per R&D personnel in higher education and government research institutions**



Sources: SCIMago, https://www.scimagojr.com/countryrank.php; OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en.

StatLink https://doi.org/10.1787/888933882123

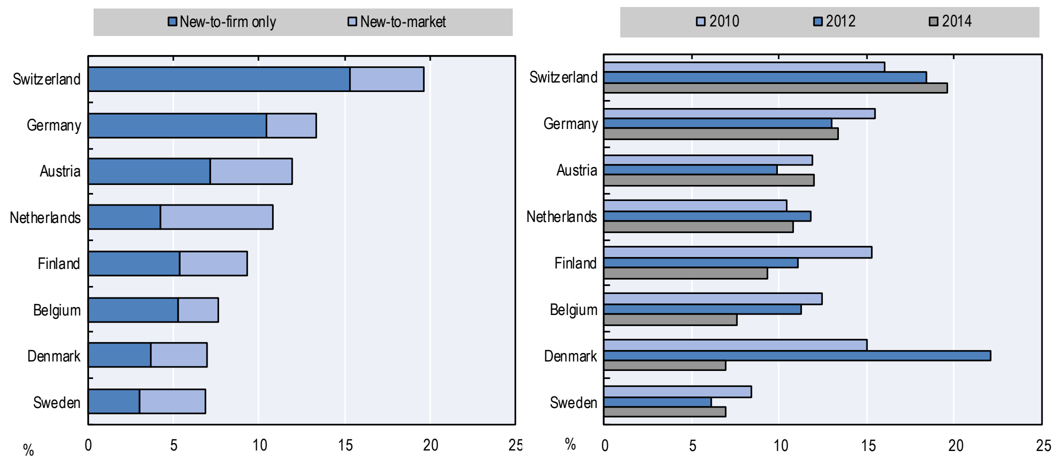
Figure 2.8. **Triadic and PCT patents per BERD**



Note: BERD: business enterprise sector expenditure on R&D. Values for BERD in Austria for 1999-2001 and for 2003 interpolated.
Source: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en.

StatLink https://doi.org/10.1787/888933882142

Figure 2.9. **Sales share of product innovations, 2010-14**



Source: Eurostat, Community Innovation Survey 2010-2014, https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey.

StatLink https://doi.org/10.1787/888933882161

Another indicator of innovation output is the share of firms that introduce at least one innovation during a given three-year period. This indicator primarily reflects the propensity to innovate among smaller firms, since smaller firms represent the bulk of firms in any economy. In 2014, 58.9% of all firms in Austria (with ten or more employees in manufacturing and the service sectors covered by the Community Innovation Survey [CIS]) had introduced at least one innovation during the preceding three-year period. In three comparator countries – Belgium, Germany and Switzerland – this share was higher (Figure 2.10, left panel). In Austrian manufacturing a higher share of firms introduced innovation (62.7%) compared to the service sectors (56.1%) (Figure 2.10, middle and left panels). The majority of innovating firms in Austria introduced both product/process and organisational/marketing innovations. The share of firms introducing only organisational/marketing innovations is rather low in Austria, particularly in the service sector.

System performance and challenges

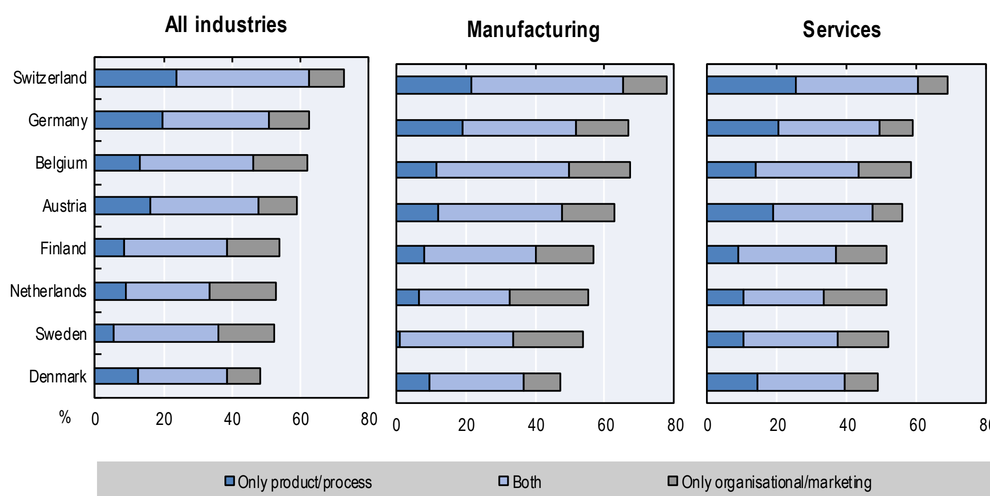
Structural change in the business sector

The rapid expansion of R&D resources in the Austrian innovation system over the past 20 years has primarily taken place in the business enterprise sector. Seventy-six per cent of the total increase in R&D expenditure between 1998 and 2015 in Austria occurred in business enterprises (including the co-operative sector), 20% in higher education institutions and 3% in government research organisations.

Six industries contributed about 70% to the total increase in business enterprise R&D expenditure in Austria between 1998 and 2015, namely: R&D services, manufacture of machinery and equipment, engineering and technical testing services, manufacture of electronics and electrical equipment, IT services, and manufacture of motor vehicles. The single largest contribution to the expansion of business R&D was made by R&D services (18.4% of the total increase in R&D expenditure). The increase in R&D expenditure in this industry has been particularly strong in recent years. Of the total increase in business R&D between 2007 and 2015 (equal to EUR 2.65 billion), 25.7% came from R&D services

(Figure 2.11, right panel). In the previous period (1998-2007), this industry contributed 11.2% to the total increase in business R&D expenditure. The R&D service industry includes most of the organisations belonging to the co-operative sector.

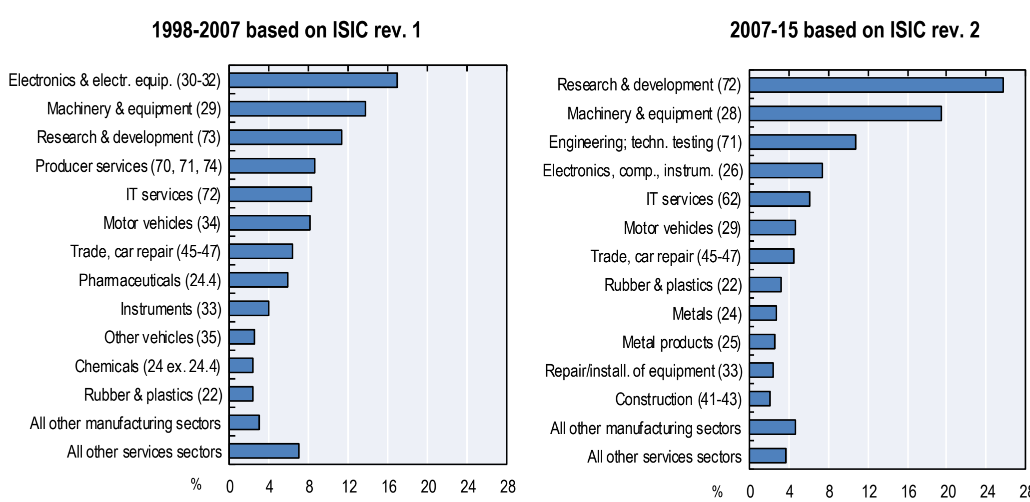
Figure 2.10. **Share of innovators by type of innovation, 2014**



Source: Eurostat (2014), *Community Innovation Survey (CIS)* (database), https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey.

StatLink https://doi.org/10.1787/888933882180

Figure 2.11. **Contribution to the increase in BERD by industry**



Source: Statistics Austria (2018), R&D Statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

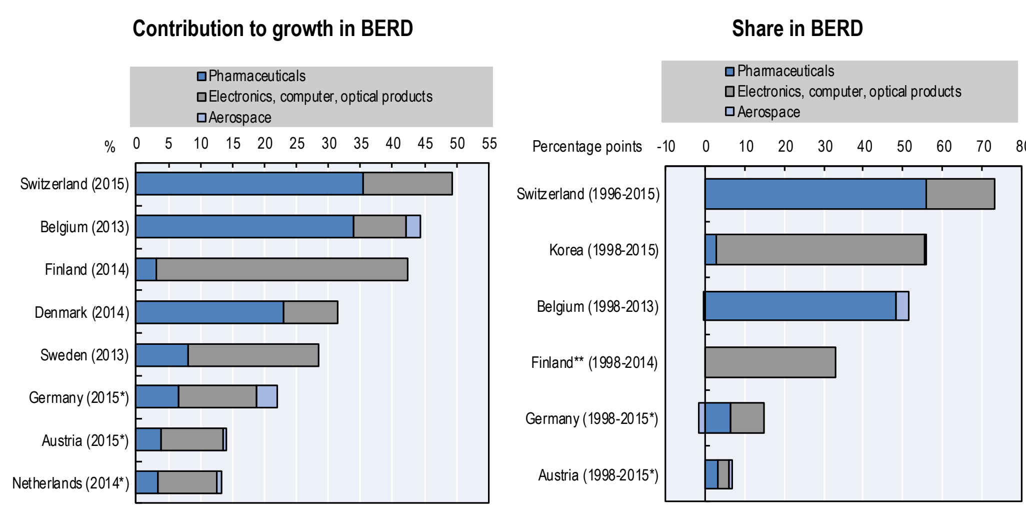
StatLink https://doi.org/10.1787/888933882199

Among manufacturing industries, machinery and equipment made the largest contribution to business R&D growth (15.8% over the entire period), followed by electronics and electrical equipment (12.4% over the entire period). IT services, engineering services and other business-oriented services accounted for more than 16% of the total growth of business R&D expenditure.

The high-tech sectors – which include the manufacture of pharmaceuticals, electronics, computers, optical and aerospace products – made a rather small contribution to the increase in Austria's business R&D expenditure, at just 7% (3.2% for pharmaceuticals, 2.9% for electronics/computer/optical products, and 0.9% for aerospace) (Figure 2.12, left panel). As a result, the high-tech sectors still accounted for only 14% of total business R&D expenditure in Austria in 2015, which is significantly lower than in other countries with a similar R&D intensity. The low contribution of high-tech sectors is an astonishing feature of the Austrian innovation system. High-tech sectors are characterised by a high R&D intensity (R&D expenditure per value added). Competition in these sectors depends more than in other sectors on R&D investment and the transfer of R&D results into innovative products and processes. Investment in R&D often shows higher marginal private and social returns than in other sectors, implying that expanding R&D in high-tech sectors results in larger impacts on productivity and competitiveness (Czarnitzki and Thorwarth, 2012; Ortega-Argilés, Piva and Vivarelli, 2015).

Other countries that have increased their R&D intensity substantially relied heavily on high R&D expenditure in the high-tech sectors. In Korea, for example, 56% of the total increase in business R&D expenditure between 1998 and 2015 took place in high-tech sectors (Figure 2.12, right panel).

Figure 2.12. **Share of high-tech sectors in growth of BERD and in total BERD**



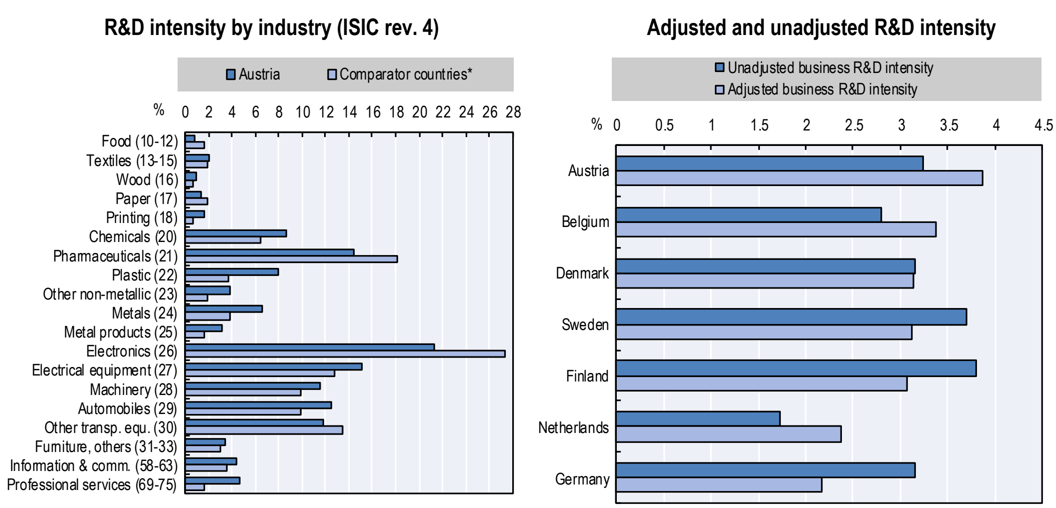
Notes: BERD: business enterprise sector expenditure on R&D. No data for Denmark, the Netherlands or Sweden on high-tech sector contribution to growth in BERD.
* Aerospace: 2014 for Germany, 2013 for Austria and the Netherlands. No data on aerospace for Denmark, Finland, Sweden or Switzerland.
** No data on the contribution of pharmaceuticals and aerospace to growth in BERD for Finland.
Sources: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en; Statistics Austria.

StatLink https://doi.org/10.1787/888933882218

In Switzerland, during the same period, the contribution of high-tech sectors to the increased business R&D was 73% and in Belgium 51%. In Finland, 33% of the increase in BERD during 1998 and 2015 was in the electronics industry. Germany is the only comparator country where the high-tech sector's contribution to R&D growth in the 1998 to 2015 period was small, though its share (15%) was still twice the share in Austria.The low significance of high-tech sectors in the Austrian innovation system implies that the impressive growth in business R&D happened in sectors that are generally characterised by medium or low R&D intensity. For almost all of these industries, Austria shows a significantly higher R&D intensity than the same industries in the comparator countries (with the food and paper industries being the only exceptions). In high-tech industries (pharmaceuticals, electronics, other transport equipment), however, the R&D intensity in Austria is lower than in the comparator countries (Figure 2.13, left panel). The Austrian innovation system is hence based on low- and medium-tech industries that specialise in more R&D-based competitive strategies. In contrast to most other OECD countries with very high R&D intensity, Austria did not follow a path of specialisation of high-tech sectors, but rather experienced structural upgrading without much change in the industry structure that developed historically.

The high R&D intensity across all industries is revealed by the exceptionally high "adjusted R&D intensity". This measure gives a country's R&D intensity, assuming it had the same industry structure as the OECD average. The adjusted R&D intensity in Austria's business enterprise sector is 3.87%, compared to 3.24% for the unadjusted R&D intensity (Figure 2.13, right panel). No comparator country shows a higher adjusted R&D intensity. In fact, Austria's adjusted R&D intensity is the highest among OECD countries. In terms of the capacity of businesses to invest in R&D, Austria is in fact the leading country in the world.

Figure 2.13. **R&D intensity of industries in Austria and the OECD and R&D intensity adjusted for industrial structure, 2015**



* Unweighted average of industry R&D intensities; no data for Switzerland.

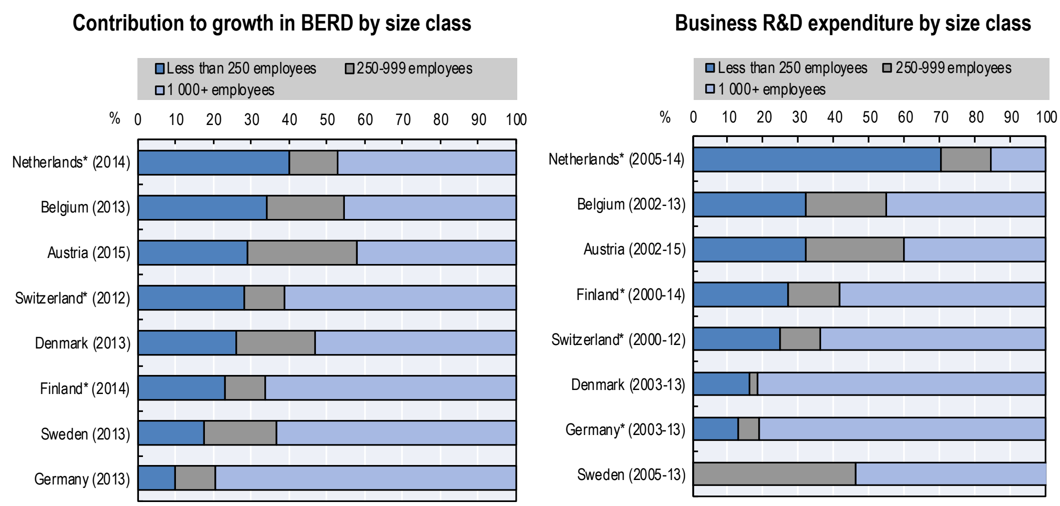
Sources: Statistics Austria (2018), R&D Statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml; OECD (2018b), *Analytical Business Enterprise R&D (ANBERD)* database, https://stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV4.

StatLink https://doi.org/10.1787/888933882237

In addition to its peculiar sectoral structure, for a country with a very high R&D intensity in the business enterprise sector, the Austrian innovation system has two more features that are special: a high share of small and medium-sized enterprises (SMEs) and a high share of foreign affiliates in total business R&D performance. In 2015, SMEs with less than 250 employees accounted for 29% of total Austrian BERD. Firms with 250-999 employees also contributed 29% of total BERD (Figure 2.14, right panel). However, the share of large enterprises (1 000 or more employees) was 42%, the lowest figure among all comparator countries.

Large enterprises contributed 40% of the total growth in business R&D expenditure in Austria between 2002 and 2015 (Figure 2.14, left panel). The role of large enterprises in expanding BERD is also smaller than in most comparator countries. In fact, the Netherlands, which shows significantly smaller business R&D intensity than Austria, and more sluggish BERD dynamics, is the only comparator country where large enterprises have made a smaller contribution to growth in BERD.

Figure 2.14. **Growth of BERD 2002-15 and BERD 2015 by size class**



* 250-499 employees and 500 and more employees.

Sources: OECD (2018b), *Analytical Business Enterprise R&D (ANBERD)* database, https://stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV4; Statistics Austria (2018), R&D statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

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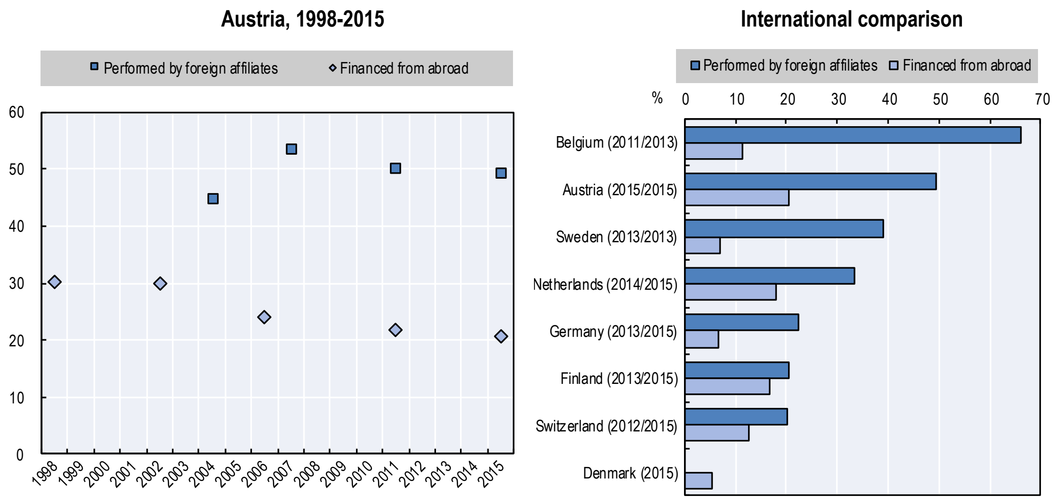
At the same time, Austria shows a high share of business R&D performed by affiliates of foreign-based enterprises. In 2015, 49.4% of total BERD was performed by foreign affiliates (Figure 2.15, left panel). Belgium is the only comparator country with a higher share. The significance of foreign affiliates for the Austrian innovation system has increased over the past decade (in 2004, 44.9% of total BERD was performed by foreign affiliates). The share of foreign affiliates in total business R&D is particularly high in pharmaceuticals (82%), automotive (80%), electronics (64%) and chemicals (60%). Foreign affiliates are also important R&D performers in service sectors (IT services: 40%, R&D services: 50%, media and telecommunications: 73%). Since most R&D in foreign affiliates is performed in large enterprises, the high share of foreign affiliates in total R&D implies that only a small fraction of R&D is conducted in large domestically owned firms. This is a distinct difference with respect to other small open and R&D-intensive economies such as Finland, Sweden and Switzerland.

The share of business R&D financed from abroad is also higher in Austria than in the comparator countries considered here. In 2015, 22% of total business R&D was financed through sources from abroad (Figure 2.15, right panel). Seventy per cent of this R&D

funding came from affiliated companies abroad, usually the foreign headquarters of affiliates in Austria. The share of R&D financing from abroad has continuously decreased over the past two decades (falling from 30% in 1998). This trend shows that an increasing share of R&D expenditure of foreign affiliates in Austria is financed from the affiliates' own resources or from other external resources, including foreign public funding.

Figure 2.15. **BERD performed by foreign affiliates and BERD financed from abroad**



* No data for Denmark on share of BERD performed by foreign affiliates.

Sources: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en; Statistics Austria.

StatLink https://doi.org/10.1787/888933882275

International innovation rankings: Persistent gap to innovation leaders

In its Research and Technology Strategy, the Austrian federal government set the goal of bringing Austria into the group of “'innovation leaders”, i.e. countries that perform best in innovation. A main reference point set by the Austrian authorities for progress in achieving this goal is Austria's ranking in the European Innovation Scoreboard (EIS), a European Commission initiative to measure innovation performance across countries in Europe. The EIS considers a large number of indicators aimed at representing the inputs and outputs of innovation activities as well as framework conditions for innovation (e.g. education) and qualitative features of innovation processes (e.g. international co-operation and the uptake of certain new technologies).

In the 2018 ranking, Austria held 10th position among 35 European countries (Table 2.2). This was outside the group of countries labelled “innovation leaders” in the EIS, which includes the top 7 countries in the ranking. All of the comparator countries referenced here, with the exception of Belgium, ranked above Austria. Since the first EIS was published in 2001, Austria has made little progress in moving up the ranking in the EIS (though comparing country rankings over time is complicated by changes in the EIS methodology and the number of countries covered in the analysis). In 2001, Austria ranked ninth, again behind all comparator countries except Belgium (while Switzerland was not included in the ranking). In 2007, Austria ranked 11th, ahead of two comparator countries (Belgium and the Netherlands).

There are several reasons why Austria – despite its impressive increase in R&D intensity – has been unable to move up in the EIS ranking.[4] In general, the EIS implicitly favours economies with a large high-tech sector (see Janger et al., 2017) and pays less attention to innovation in low-tech sectors in which Austria is mainly specialised. In addition, Austria underperforms on indicators measuring research excellence and venture capital investment. For indicators on the use of intellectual property rights (patents, trademarks), the lack of large domestic and research-focused multinational enterprises puts Austria behind most comparator countries. Box 2.2 provides key features of the development of the Austrian innovation system.

Table 2.2. **Ranking of Austria and comparator countries in international innovation rankings**

		2001	2007	2017/18
European Innovation Scoreboard[1]	Austria	9	11	10
	Belgium	10	14	9
	Denmark	4	5	3
	Finland	2	3	3
	Germany	7	6	8
	Netherlands	5	12	5
	Sweden	1	1	2
	Switzerland	..	2	1
Global Innovation Index[2]	Austria	..	22	21
	Belgium	..	15	25
	Denmark	..	11	8
	Finland	..	13	7
	Germany	..	2	9
	Netherlands	..	9	2
	Sweden	..	12	3
	Switzerland	..	6	1
Innovationsindikator[3]	Austria	21	17	9
	Belgium	8	8	3
	Denmark	17	16	7
	Finland	4	7	5
	Germany	7	6	4
	Netherlands	10	10	10
	Sweden	5	4	8
	Switzerland	2	1	1
Global Competitiveness Index[4]	Austria	16	14	13
	Belgium	13	17	14
	Denmark	12	7	9
	Finland	3	3	5
	Germany	15	6	4
	Netherlands	14	10	3
	Sweden	6	1	6
	Switzerland	24	2	1

Notes: .. No data available.

1. Based on 15 (2001), 37 (2007) and 36 (2018) European countries (and including Israel).
2. Based on 107 (2007) and 126 (2018) countries. No ranking made for 2001.
3. Based on 35 countries: 2001 and 2007 ranking based on the 2017 methodology.
4. 2001: only sub index "technology index"; 2007 and 2017: only sub-indices "human capital and training", "technological readiness", "business sophistication" and "innovation" based on 75 (2001), 125 (2007) and 137 (2017) countries.

Sources: European Commission (2001, 2007, 2018); Cornell University, INSEAD and WIPO (2017); Dutta and Caulkin (2007); Acatech and BDI (2017); Schwab, Porter and Sachs (2001), Porter, and Schwab (2007), Schwab (2017).

The result of the EIS in terms of Austria's sustained distance from the group of innovation leaders is confirmed by other international innovation rankings based on methodologies and indicators different from the EIS. In 2017, Austria ranked 20th in the Global Innovation

Index, significantly behind most comparator countries (except Belgium). Its ranking has not changed much since the first edition of this index in 2007. Although Austria has substantially improved its ranking in the "Innovationsindikator" published by the German National Academy of Science and Engineering and the German Federation of Industry, it has still stayed behind most of the comparator countries (except the Netherlands). In the World Economic Forum's Global Competitiveness Index, Austria ranked 13th in 2017 (when considering those areas of the index closely related to innovation). Again, Austria trails all comparator countries except Belgium. Austria's progress in this index since 2001 – when it ranked 16th – is not commensurate with its impressive growth in R&D intensity over the same period.

Box 2.1. **Key features of the development of the Austrian innovation system**

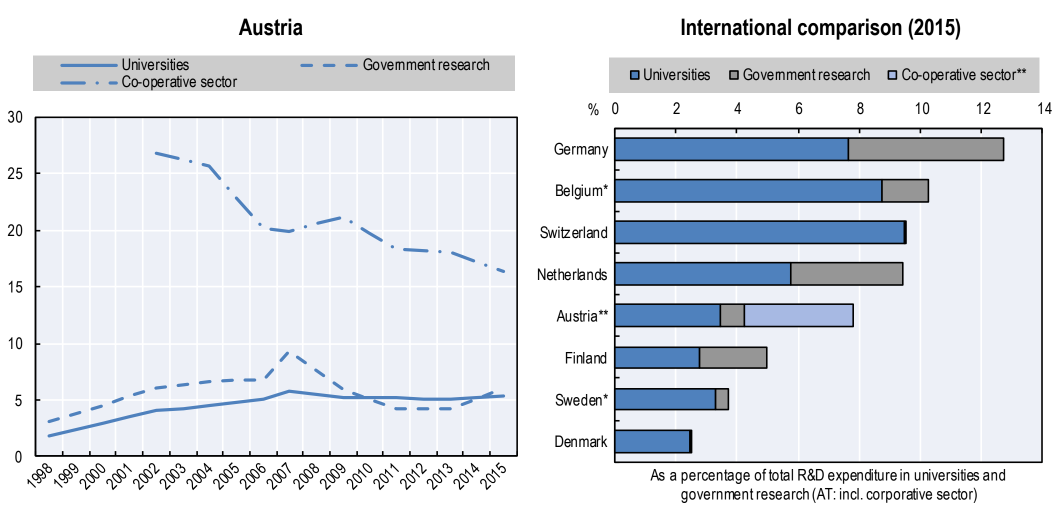
- Austria has made great progress in increasing R&D expenditure in all sectors of its innovation system, with a particularly strong growth in the business sector. It has the second highest growth in R&D intensity of all OECD countries, among the top 5 countries globally in terms of R&D intensity.
- There has been rapid expansion of the number of university graduates, but weak dynamics in new PhDs – shift of university priorities towards education.
- There has been little change in sector and size structure of business R&D; there is still a low share of high-tech industries, a high share of small enterprises, high significance of foreign affiliates and a lack of large domestic R&D performers.
- The R&D base has broadened in both industry (doubling the number of R&D performing enterprises within two decades) and science (universities of applied sciences, co-operative research centres).
- Little progress has been made towards entering the group of "innovation leaders", owing to a low high-tech share, little capacity of top-level research and a lack of domestic research-focused multinational enterprises.

Collaboration between industry and science

A key indicator for the extent of co-operation between industry and public science (universities, government research) is the share of R&D expenditure in public science that is financed by domestic business enterprises.[5] Business financing of R&D in universities and government research includes funding for joint R&D projects as well as contract research. For Austrian universities, this share has increased slowly but steadily over the past two decades, from 1.7% in 1998 to 5.3% in 2015 (Figure 2.16, left panel). The development has not been quite as steady in government research organisations. The indicator peaked in 2007 at 9.3% and declined to 4.2% in 2011 before rising again to 6.0% in 2015, which is twice the level of 1998 (3.1%). In addition to universities and government research organisations, the so-called co-operative sector is an important actor in the Austrian innovation system when it comes to linking industry and science. Though this sector is considered part of the business enterprise sector in R&D statistics, it is useful to analyse it separately since it shares features of contract research organisations such as Fraunhofer, TNO of VTT that are part of the government research sector in the comparator countries. The co-operative sector shows an opposite trend in business financing. In 2002, 26.8% of total R&D expenditure in this sector was financed by domestic businesses. This share fell to 16.3% in 2015. At the same time, financing from sources from abroad increased (from 41% to 54%, which includes EU funding and financing from foreign business enterprises). The share of government funding for R&D in the co-operative sector remained quite stable (at 28% in 2002 and 26% in 2015).

The share of business financing of R&D in public science is significantly higher in many comparator countries. In Germany, the share was 12.7% in 2015. Belgium, Switzerland and the Netherlands show shares of close to 10%. In Austria, 7.8% of total R&D expenditure in universities, government research and the corporative sector were financed from domestic business sources (Figure 2.16, right panel). If one would exclude the co-operative sector, this share would fall to 5.4%. In terms of receiving R&D financing from domestic businesses, the co-operative sector in Austria receives about the same amount as the entire university sector.

Figure 2.16. **Financing of R&D expenditure in science by domestic business enterprises**

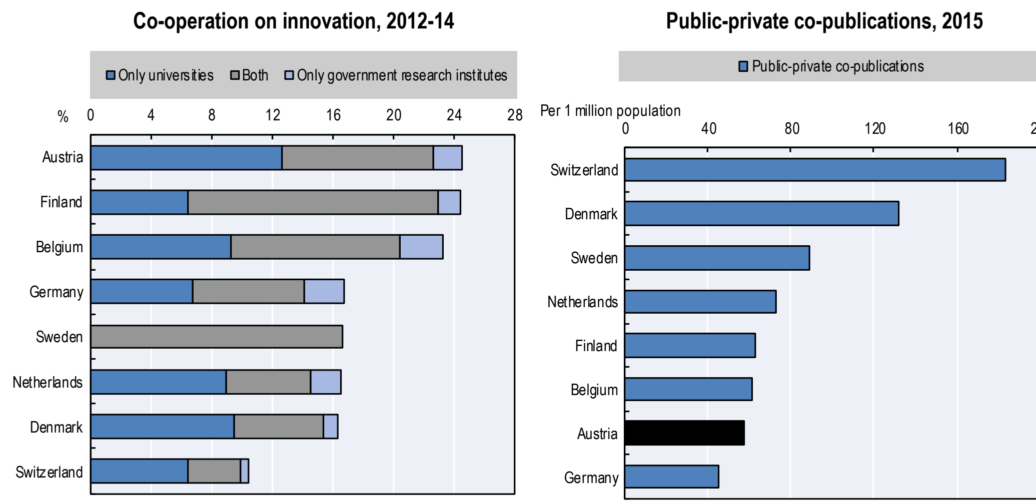


* Data for 2013.
** Corporative sector for Austria only. For Austria, business enterprise financing is related to total R&D expenditure in universities, government research and the corporative sector.
Sources: OECD (2017b), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2017-2-en; Statistics Austria.

StatLink https://doi.org/10.1787/888933882294

Business financing of R&D in public science does not capture all types of interaction between industry and science. Collaboration between the two sectors may take place without a direct transfer of money, e.g. as part of publicly funded R&D projects which often provide financial support for both the industry partner and the science partner but not involving direct funding of the science partner by the business partner. Data from innovation surveys inform about co-operation between industry and science form a broader perspective, including co-operation that does not involve direct financial flows among partners. Taking the share of innovation-active enterprises that co-operate with universities or government research institutes on innovation as a key indicator, Austria is in front of all comparator countries, with 24.6% of all innovation-active enterprises having such co-operation (Figure 2.17, left panel). The vast majority (92%) co-operated with universities while 48% co-operated with government research institutes. Whether the latter figure includes co-operation with organisations from the co-operative sector is unknown, but likely.

Figure 2.17. **Collaboration between industry and science**



Note: No breakdown by type of public science co-operation partner for Sweden.
Sources: Eurostat, *Community Innovation Survey (CIS)* (database), https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey; European Commission (2017), *European Innovation Scoreboard 2017*, https://ec.europa.eu/docsroom/documents/24829.

StatLink https://doi.org/10.1787/888933882313

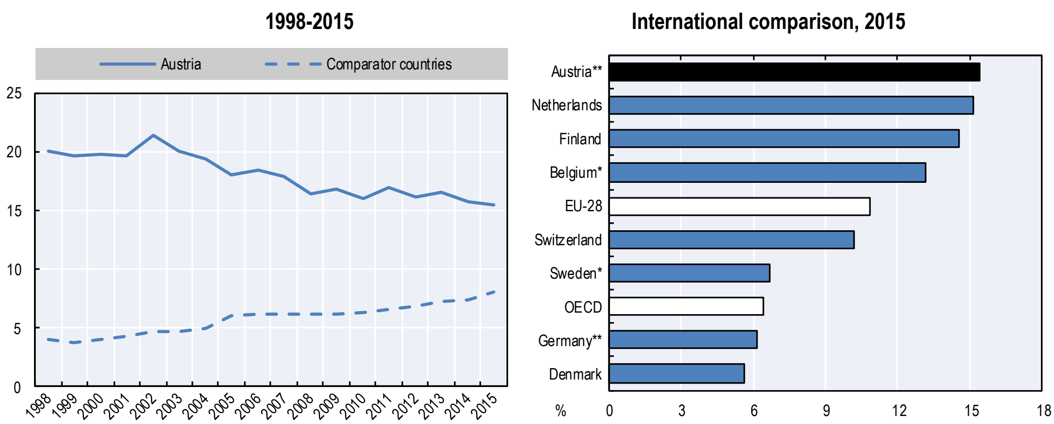
Another indicator on industry-science links are public-private co-publications. This indicator primarily relates to co-operation that is closely linked to academic research and often involves rather basic than applied research. On this indicator, Austria shows a rather low value *vis-à-vis* the comparator countries (Figure 2.17, right panel). Germany is the only country in the comparison group with a lower number of public-private co-publications when normalised by country size.

The indicators on industry-science co-operation suggest that co-operation is widespread, but focuses on rather smaller projects (as the small share of business financed R&D expenditure in public science insinuates) and applied R&D (reflected by a low number of public-private co-publications). The co-operative sector, including the COMET centres and the two large contract research organisations (AIT and Joanneum Research) is a very important player in linking industry and science in Austria.

International links

As a small and open economy, Austria is strongly integrated in international networks. This holds even more so for its innovation system. One indicator illustrating the extensive international links in R&D and innovation is the share of R&D that is financed from abroad. In 2015, 15.4% of all R&D performed in Austria was funded from sources outside Austria, including EU funding and funds provided by foreign enterprises (Figure 2.18, left panel). This share is almost twice the figure reported for the weighted average of the comparator countries (8.1%) and higher than in any of the seven comparator countries (Figure 2.18, right panel). Over the past two decades, the contribution of foreign sources to R&D performance in Austria has decreased (1998: 20.1%) while the comparator countries show an upward trend.

Figure 2.18. **Share of GERD financed from abroad**

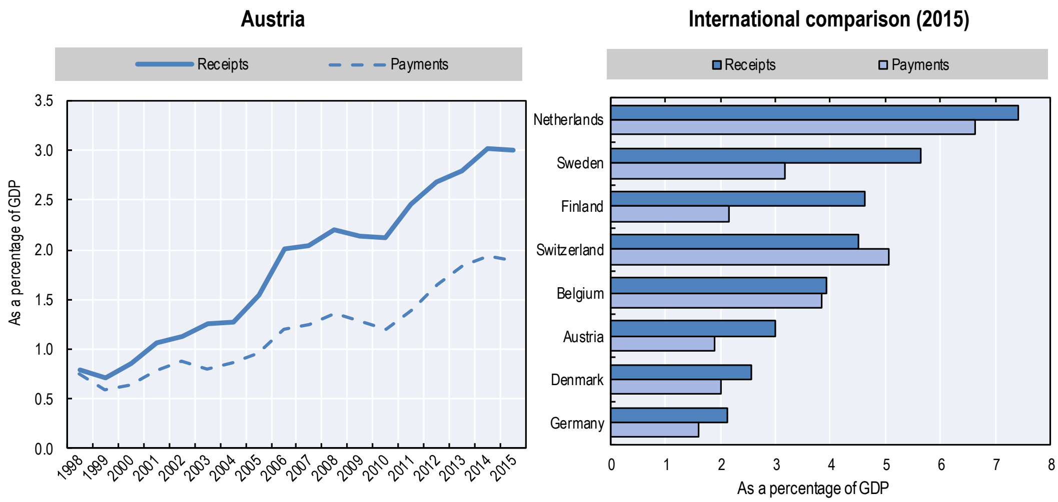


* Data for 2013.
** Data for 2016.
Source: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en.

StatLink https://doi.org/10.1787/888933882332

Another indicator for international links in research and technology is the technology balance of payments. Both receipts and payments by Austria increased significantly stronger than GDP. Austria's position as a net receiver in the technology balance of payments has increased over time. Nevertheless, the share of receipts and payments as a percentage of GDP is still significantly below the level in most comparator countries (Figure 2.19, left and right panel).

Figure 2.19. **Technology balance of payments, as a percentage of GDP**

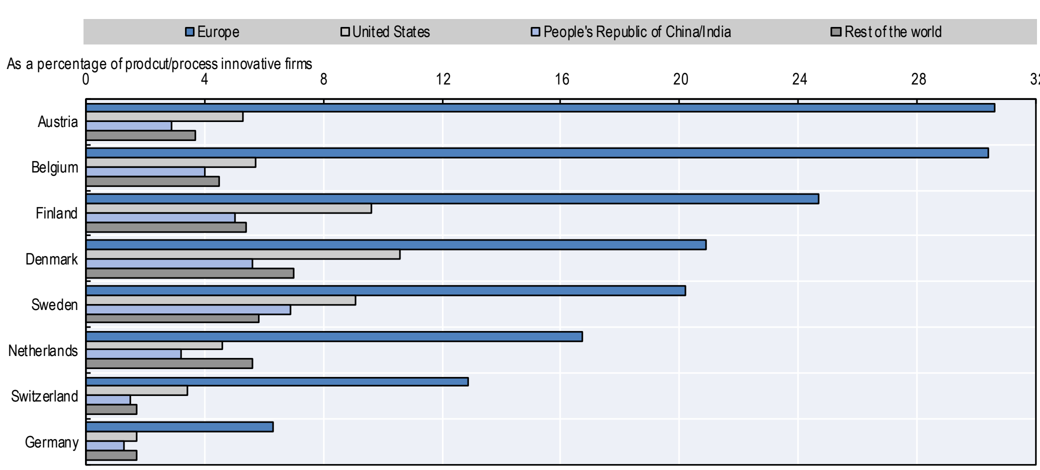


Source: OECD (2018a), *Main Science and Technology Indicators (MSTI)*, https://dx.doi.org/10.1787/msti-v2018-1-en.

StatLink https://doi.org/10.1787/888933882351

The share of innovation-active enterprises that co-operate on innovation with partners abroad primarily informs about the international orientation of innovative SMEs. Austria shows the highest share of firms with respect to co-operation partners in other European countries. In the period 2012-14, 30.6% of all innovation-active enterprises had co-operation with at least one partner located in another European country (Figure 2.20). No other comparator country reports a higher figure. In terms of co-operation with partners from outside Europe, the share of co-operating firms is lower than in the Scandinavian countries (Denmark, Finland, Sweden) and about the level of Belgium and the Netherlands. Innovation co-operation of the Austrian business enterprise sector is hence focused very much on Europe.

Figure 2.20. **Innovation co-operation with partners from abroad, 2012-14**



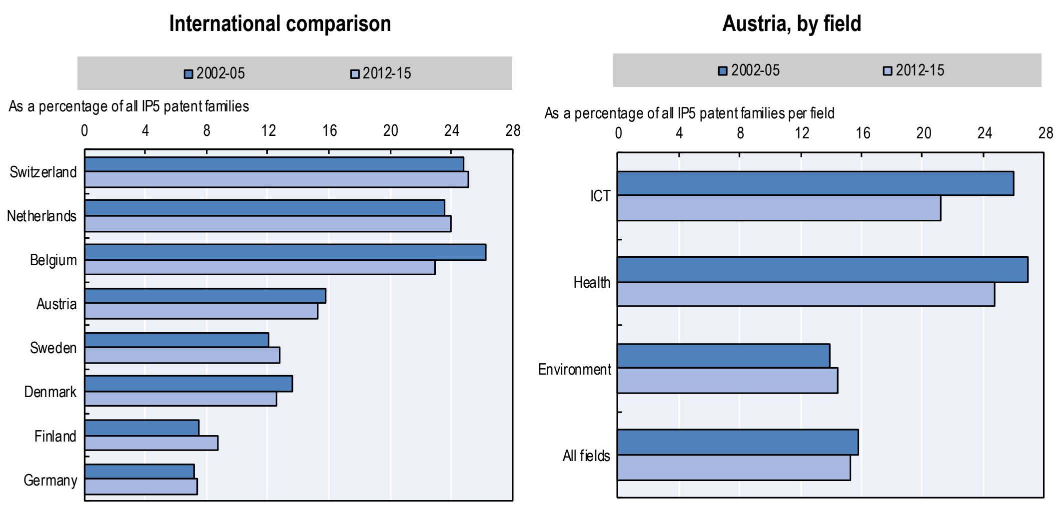
Source: Eurostat (2014), *Community Innovation Survey (CIS)* (database), https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey.

StatLink https://doi.org/10.1787/888933882370

The "international co-inventions" indicator gives the share of patents that have inventors from more than one country. It informs about the prevalence of international co-operation in the production of new technology. Austria ranks in the middle range of the comparator countries on this indicator (Figure 2.21). As in the other countries, the share of international co-inventions has not changed much over the past decade. International co-inventions involving inventors from Austria are more frequent in ICT and health than in other technology areas.

In public science, a common indicator for international linkages is the share of scientific publications written together with authors from other countries. In 2015, Austria ranked third among the group of comparator countries for this indicator, closely behind Switzerland and Belgium. Following the trend in other countries, the share of international scientific co-publication has increased in Austria over the past ten years (from 28.4% to 36.3% in all scientific publications) (Figure 2.22, left panel). As in the other countries, the majority of international scientific co-publication was led by domestic authors (Figure 2.22, right panel).

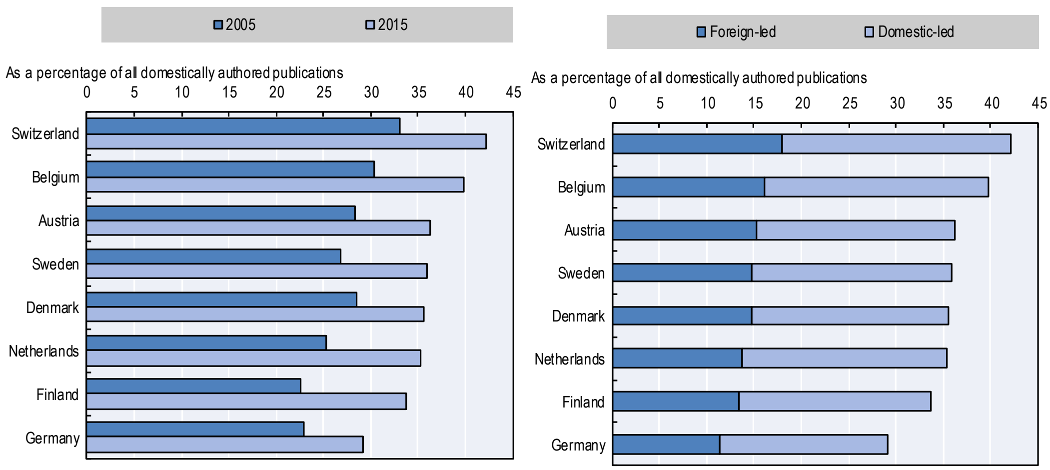
Figure 2.21. **International co-inventions**



Source: OECD (2017c), *OECD Science, Technology and Industry Scoreboard 2017: The Digital Transformation*, http://dx.doi.org/10.1787/9789264268821-en.

StatLink https://doi.org/10.1787/888933882389

Figure 2.22. **International scientific co-publication**

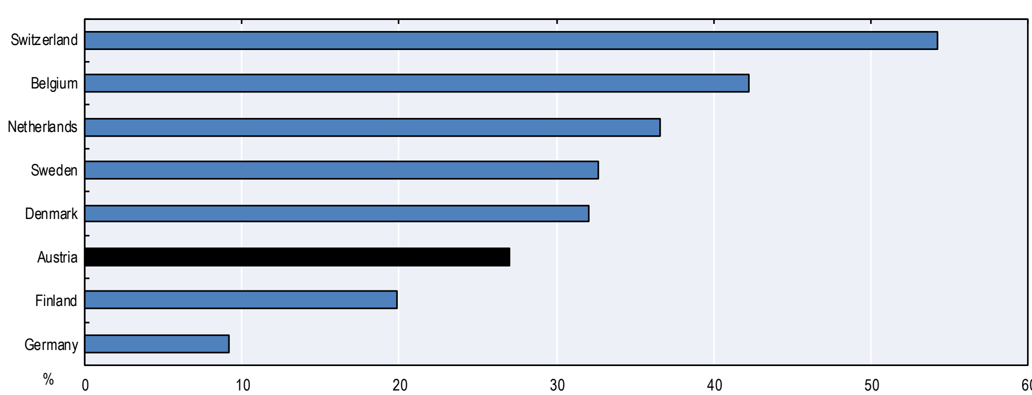


Source: OECD (2017c), *OECD Science, Technology and Industry Scoreboard 2017: The Digital Transformation*, http://dx.doi.org/10.1787/9789264268821-en.

StatLink https://doi.org/10.1787/888933882408

The share of doctorate students from abroad is another indicator on international links in science. For this indicator, Austria shows a rather low value (31% in 2017, Figure 2.23), which is significantly less than Switzerland, Belgium and the Netherlands, and 40% of beginning doctoral students came from abroad in the same year. Among the comparator countries, only Finland (which may have a geographical disadvantage) and Germany (which as a large country often performs worse than small countries when it comes to international linkages as border effects play a less prominent role) show a lower figure than Austria. However, in the set of comparator countries, it has to be taken into account that English is the common language at Scandinavian universities, making them more attractive to students from abroad, as well as a high proportion of doctoral students from France in Belgium.

Figure 2.23. **Foreign doctorate students as a share of all doctorate students, 2015**



Sources: BMBWF (2018), “Universitätsbericht 2017“ („University report 2017“), https://www.bmbwf.gv.at/fileadmin/user_upload/Publikationen/Universit%C3%A4tsbericht_2017_barrierefrei.pdf; Eurostat (2016), *Statistics* (database), http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database.

StatLink https://doi.org/10.1787/888933882427

Notes

1. Until 2015, R&D expenditures funded through tax incentives were considered as government funding.
2. All figures taken from the "Austrian research and technology report 2017".
3. Excluding doctorates earned as part of the first tertiary-level degree, which has been common in the Austrian higher education system in the fields of medicine and law.
4. See the chapter in the "Austrian research and technology report" on Austria's position in international innovation rankings.
5. Financing by business enterprises from abroad is excluded.

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Chapter 3.
Business innovation and Industry 4.0 in Austria

This chapter outlines the main business actors in innovation and their performance, and discusses the main innovation challenges facing the Austrian business sector today. It analyses public support for business innovation and entrepreneurship as well as the innovation capacity of the Austrian business sector. It discusses improving early stage equity financing and investment readiness as well as supporting management and leadership development. The chapter continues to illustrate the current policy mix to support business R&D and describes possible avenues to better respond to future needs in this area. The chapter further discusses Industry 4.0 by providing an overview of key areas that enable harnessing the benefits of respective technologies, including cloud computing, the supply and use of data, 5G networks and Austria's readiness for technology diffusion.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Business innovation in Austria

Main business actors

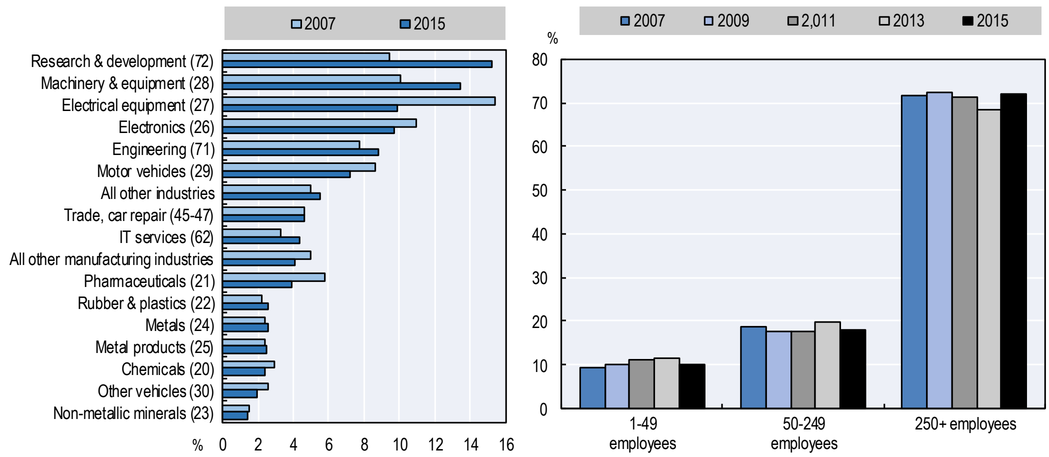
The panorama of business research and development (R&D) and innovation in Austria is characterised by a number of features, which have emerged over recent decades as a result of the specific development of Austrian industry and structural change in the Austrian economy. These include:[1]

- a high level of R&D intensity across all industries
- particularly high R&D activities in manufacturing sectors that are characterised by low R&D intensities globally
- a high share of business R&D performed in firms providing R&D services, which includes a group of so-called "co-operative research organisations"
- a high share of small and medium-sized enterprises (SMEs) in total business R&D and innovation activity
- a high share of R&D and innovation performed in affiliates of foreign-owned firms.

In 2015, the business enterprise sector in Austria spent EUR 7.5 billion on intramural R&D, of which 61.6% was spent by manufacturers. Within manufacturing, firms from the machinery and equipment industry had the highest R&D expenditure (13.4% of total business enterprise expenditure on R&D [BERD]), followed by the electrical equipment, electronics, motor vehicles, pharmaceuticals and chemicals industries (Figure 3.1). These six industries all belong to the group of high-tech or medium- to high-tech industries, according to the OECD taxonomy based on industries' global R&D intensity (Galindo-Rueda and Verger, 2016). They also contributed 76% of total BERD in Austrian manufacturing. This share has fallen slightly over the past eight years, while Austrian business R&D spending has grown rapidly (by 55%). This implies that manufacturing industries with medium or low R&D intensities (e.g. rubber and plastics products, metals, metal products and non-metallic mineral products) expanded their R&D expenditure at a slightly higher rate than the firms in industries with a high R&D intensity. Some of Austria's largest domestically owned R&D performers are found in industries which typically have medium or low R&D intensities.[2]

In 2015, 38.4% of total BERD was spent outside manufacturing. This is a high share by international standards (the OECD average is 29%). The single largest R&D performing industry outside of manufacturing is research and development (i.e. firms that specialise in providing R&D services). In 2015, 15.2% of total BERD was performed in this industry. More than 70% of R&D in this sector (and 11.0% of total Austrian BERD) takes place in the so-called co-operative research sector. This sector comprises a number of contract research and technology organisations, such as the Austrian Institute of Technology (AIT), Joanneum Research (JR) and Austrian Cooperative Research (ACR) as well as the COMET centres (see below). In addition, the largest domestic R&D performer in Austria, AVL (an automotive consulting firm and independent research institute specialised in the development of powertrain, instrumentation and test systems) is also included in the co-operative research sector.

Figure 3.1. **Business enterprise R&D expenditure in Austria by industry and size class**



Note: The left panel shows industries with more than EUR 100 million R&D expenditures in 2015.
Source: Statistics Austria (2016), R&D statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

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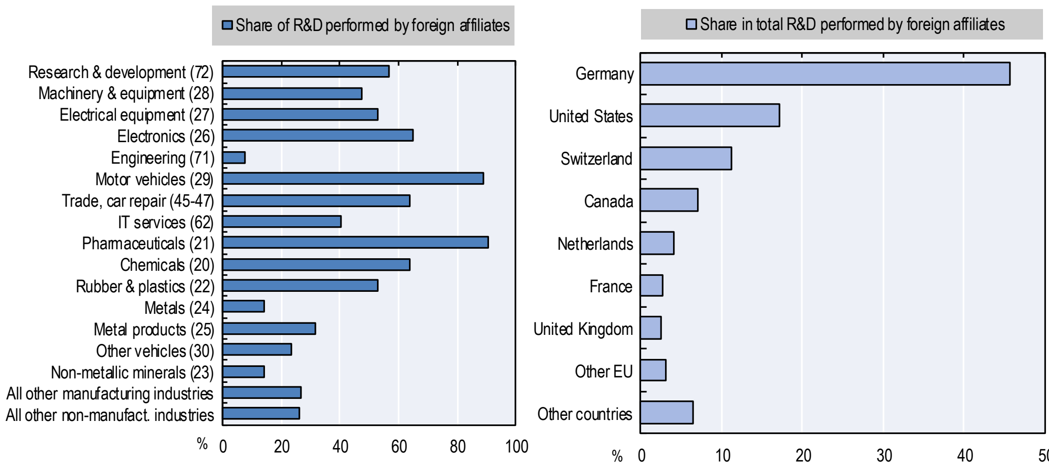
SMEs are important actors in the Austrian business innovation system. Out of the 3 611 firms that conducted in-house R&D in 2015, 3 154 had fewer than 250 employees. Their number had doubled since 2002, when only 1 585 SMEs performed R&D in house. In 2015, 28.1% of BERD was performed by SMEs. Their share in BERD continuously increased during the 2000s, peaking in 2013 at 31.5% (but dropping recently).

A distinct feature of the Austrian business innovation system is the high share of BERD performed by foreign affiliates (Figure 3.2). In 2015, this share was 49.4%. None of the comparator countries used in this report has a higher share. In five sectors –pharmaceuticals, motor vehicles, chemicals and electronics, and trade and car repair – foreign affiliates spend more than 60% of the sector's total BERD. Sectors with a lower share of R&D performed by foreign affiliates include several low-tech sectors such as metals, metal products, non-metallic minerals and engineering services. Almost 50% of foreign affiliates' R&D expenditure is performed in affiliates of German companies, including Infineon, Siemens, BMW and Boehringer. Other important host countries are Canada (e.g. Magna, Bombardier), the Netherlands (e.g. NXP), Switzerland (e.g. Novartis, ABB), and the United States (e.g. Shire, General Electrics). Over the past decade, the share of R&D performed in German and Dutch affiliates has decreased, whereas the share performed by US affiliates and affiliates from other EU countries and the rest of the world has increased. Most foreign affiliates have conducted R&D activities in Austria for many years and tend to be well-integrated in the Austrian innovation system, with activities that include co-operation with domestic firms, universities and research organisations (see Dachs, 2016).

The presence of foreign affiliates contributes to a significant net inflow of BERD funding from abroad. In 2015, the Austrian business enterprise sector received EUR 1.47 billion from abroad (excluding EU funding) for financing intramural R&D in Austria, of which EUR 1.09 billion came from parent firms funding R&D in their Austrian affiliates. In the same year, the Austrian business enterprise sector funded R&D abroad for an amount of just EUR 0.34 billion. Despite the high volume of funding by parent firms, most R&D expenditure in foreign affiliates (71%) is financed from own funds or from other sources, including government funding.

Figure 3.2. **Business enterprise R&D expenditure in Austria performed by foreign affiliates, 2015**



Note: The left panel shows industries with more than EUR 100 million R&D expenditures in 2015 in descending order.

Source: Statistics Austria (2016), R&D statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

StatLink https://doi.org/10.1787/888933882465

Innovation activities in the business sector

The results of the Community Innovation Survey (CIS) reveal several specific features of innovation activity in the Austrian business sector (Table 3.1). These include:

- ***A high share of innovators for all types of innovation.*** In 2014-16, 62% of firms with ten or more employees were innovation-active.[3] This figure is significantly higher than the EU28 average. A particularly high share of innovators, as compared to the EU average, is found for process innovators and for organisational innovators. For all four types of innovation (product, process, organisational and marketing), the share of innovators in 2014-16 clearly exceeded the share in 2006-08. The increase was particularly strong among organisational and marketing innovators.
- ***A high share of firms co-operate with other firms or organisations on product and process innovation.*** In 2014-16, just under a quarter of all firms undertook such co-operation. Half of firms active in product or process innovation were engaged in co-operation. In the EU28, this share is only 30%.
- ***A large share of firms, particularly SMEs, develop or implement product or process innovations without conducting in-house R&D.*** For example, in 2014-16, more than 8 000 firms engaged in product or process innovation, compared to about 3 600 firms conducting in-house R&D (in 2015).
- ***There is a low share of innovation expenditure beyond R&D.*** In 2016, firms within the CIS population spent EUR 8.94 billion on innovation, of which 69% was on in-house R&D and another 7% spent on extramural R&D. Firms in Austria with no in-house R&D contribute little to total business innovation expenditure. By contrast, in the EU28 in 2014, only 62% of total innovation expenditure was on in-house or extramural R&D.

- ***An innovation intensity (innovation expenditure as a percentage of sales) close to the EU28 average.*** The low share of non-R&D innovation expenditure results in an average level of innovation intensity, compared to the EU28, despite the high level of R&D expenditure in the Austrian business sector.
- ***A high share of firms having introduced new-to-market product innovations.*** In 2014-16, 22.7% of all firms reported new-to-market product innovations. This share has increased only slightly in the past ten years and at a much lower rate than the share of firms engaged in process, organisational or marketing innovations.
- ***A rather low share of sales from product innovation.*** In 2016, 12.6% of total sales originated from product innovation. The figure for the EU28 was 13.5% in 2014. The sales share of new-to-market products was also below the EU28 figure in 2014, but increased in 2016 to 5.4%. The share of sales of new-to-market products in Austria remained about the same in 2014, at 5.5%, as it was in 2008.

Table 3.1. **Innovation performance of firms in Austria**

In %

	Austria					EU28*
	2006-08	2008-10	2010-12	2012-14	2014-16	2012-14
Share of innovation-active firms[1]	56.2	56.5	54.4	59.5	62.0	50,0
Share of product innovators	31.2	32.0	26.6	30.8	34.4	24.4
Share of process innovators	32.0	31.2	28.7	32.8	36.0	22.0
Share of organisational innovators	34.9	33.7	36.4	37.3	41.1	27.8
Share of marketing innovators	27.3	27.9	29.5	29.8	35.1	23.2
Share of firms with market novelties[2]	21.3	21.4	18.7	21.9	22.7	12.7
Share of firms with innovation co-operation[3]	16.6	22.4	16.9	22.5	24.0	12.1
Share of sales from product innovations	11.2	11.9	9.8	12.0	12.6	13.5
Share of sales from market novelties[2]	5.5	5.1	4.1	4.8	5.4	5.3
Innovation expenditure as a share of sales[4]	1.7	1.7	1.8	2.0	2.2	1.9
Share of R&D in total innovation expenditure	72.1	79.6	74.5	76.6	75.9	62.2

Notes: * No data for the EU28 for 2014-16 had been released at the time of writing.
1. Firms with product, process, organisational or marketing innovations or with ongoing or abandoned product or process innovation activities.
2. Market novelties are product innovations that are new to the firm's market.
3. Innovation co-operation as part of product or process innovation activities.
4. Data for 2006-08 and 2008-10 only include R&D expenditures and expenditures for the acquisition of machinery, equipment, software and other external knowledge. Data for the periods 2010-12, 2012-14 and 2014-16 also include other innovation expenditures (training, market introduction, design, engineering, etc.).
Source: Statistics Austria (2017), R&D statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

Taking these features together, one can conclude that innovation is widespread among Austrian businesses. The propensity to innovate has increased in the past ten years, but this has not resulted in significantly higher sales involving product innovation. One reason is that the expansion in the number of innovating firms has not been accompanied by a corresponding increase in innovation expenditure. Firms that begin innovating seem to focus on incremental and non-technological innovation, with little if any link to product innovation. Another reason for the lack of increase in sales involving product innovation is that the share of firms with more ambitious ("radical") innovations, measured by new-to-market innovation, has not increased much in the past ten years.

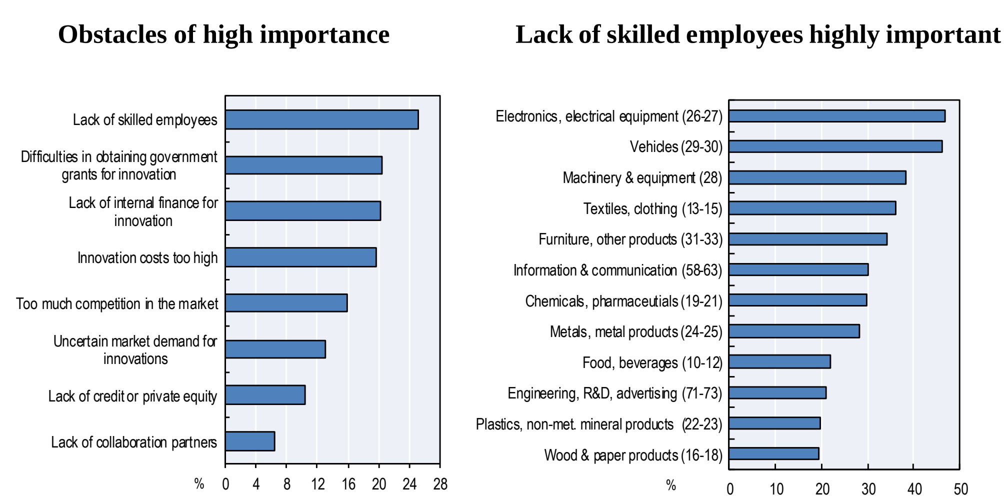
Innovation activities in the Austrian business sector seem to be divided between a relatively small group of "strong innovators", based on high R&D expenditure and a co-operative approach to innovation, while a larger group of firms refrain from R&D and focus on incremental and non-technological innovation. The former group includes so-called "frontrunner" firms (see Berger et al., 2013). These are highly internationalised technology leaders in niche markets. Though the number of these firms is small (100-300, depending on the exact definition), they are a salient feature of the Austrian business innovation system. International comparison shows that relative to country size, Austria hosts among the highest number of such frontrunners.

Barriers to innovation

The most recent CIS, for the reporting period 2014-16, collected information on obstacles that prevent firms from innovating or hinder innovation-active firms from innovating more or more quickly (Figure 3.3). The results show that a lack of skilled employees is currently the most important barrier to innovation. One-quarter of all firms report that this obstacle is highly important in impeding innovation. Other important widespread barriers include difficulties to obtain government grants for innovation, a lack of internal finance for innovation and excessively high innovation costs, each reported as being of high importance by about 20% of all firms. Competition and demand are less frequently reported barriers, while lack of credit or private equity, and lack of collaboration partners are experienced by only a small share of firms as important barriers to innovation.

A lack of skilled employees is most frequently cited as an important innovation barrier by firms in high-tech sectors, particularly in the electronics and electrical equipment industry and in the manufacture of automobiles and other vehicles. Skills are less often perceived as a barrier in service industries and in low-tech manufacturing.

Figure 3.3. **Barriers to innovation in firms in Austria, 2014-16**



Source: Statistics Austria (2017), R&D statistics, http://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.

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Public support for business R&D

Over the last decade, Austria has made very significant progress in increasing levels of R&D investment, to the point where it is now among those countries with the highest R&D intensity globally. This marks a significant change in Austria's position in the European and wider global innovation eco-system. Framework conditions and tax incentives for R&D are mature and have been successful both in attracting significant mobile R&D investment and in stimulating additional R&D investment by domestic firms, including many SMEs. Direct support instruments for R&D and innovation are also numerous and well-established.

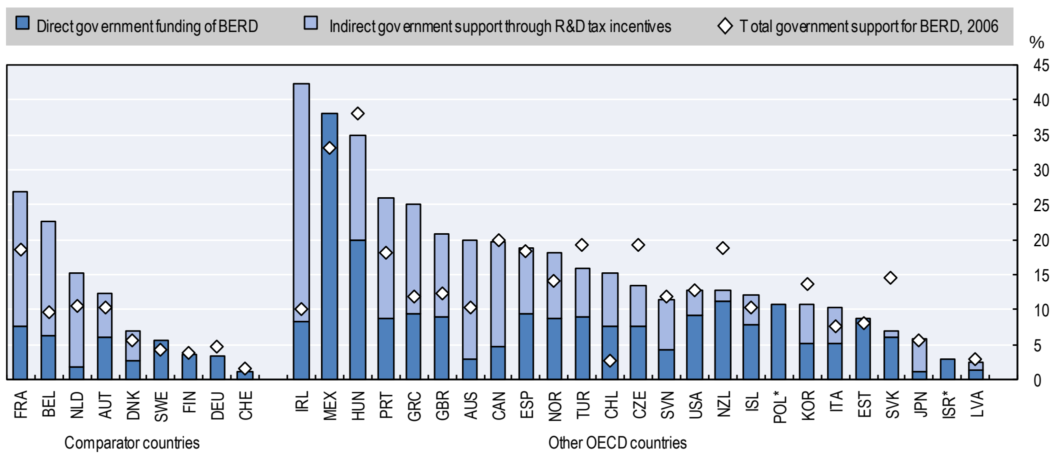
Looking forward, Austria aspires to be among Europe's innovation leaders. Achieving this objective will likely require adaptation in the Austrian innovation system away from a focus on expanding R&D investment towards ensuring evidenced-based impact and economic returns. This will involve developing a policy mix with a stronger focus on supporting continuing excellence in business and university R&D, maximising the effectiveness of knowledge transfer through university-business collaboration, and supporting innovative high-growth firms. Ongoing changes in technology – driven by digitisation – will also necessitate a broader vision of innovation beyond just R&D.

The Austrian government supports R&D in businesses both through direct government funding and through tax incentives. In 2015, both funding approaches contributed a similar share of total business enterprise R&D expenditure. Direct government funding contributed 6.0% and the tax incentive scheme (Research Premium) 6.4% (Figure 3.4). Among comparator countries, this dual approach to business funding from public sources is rather unusual. Finland, Germany and Switzerland rely solely on direct government funding (which includes contract research), while Belgium, France and the Netherlands focus on R&D tax incentives. Denmark has a strong emphasis on tax incentives, but also provides a significant share of support through direct funding. The share of government funding of business R&D in Austria, at 12.4%, is higher than in Germany, Switzerland and the Scandinavian comparator countries. However, governments in Belgium, France and the Netherlands contribute a higher share of total business R&D.

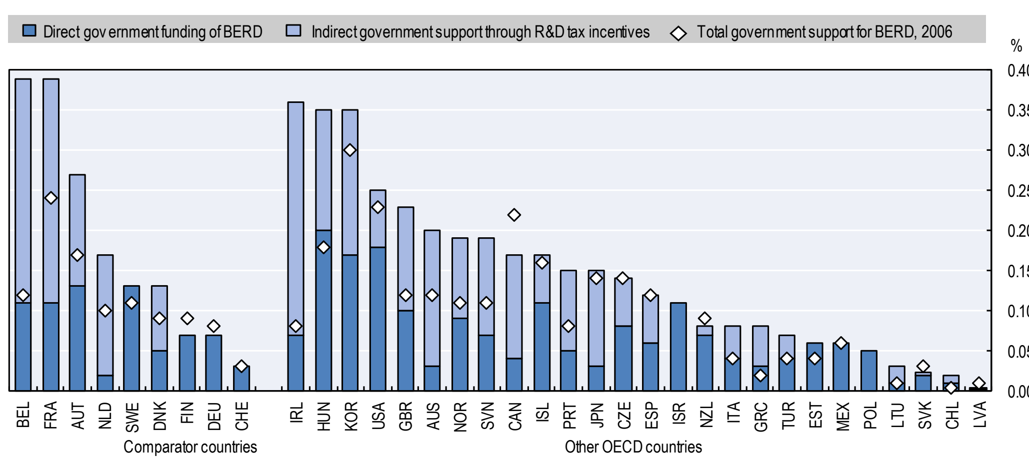
Recent years have witnessed a rise in business R&D spending in Austria supported by both tax incentives (Research Premium) and direct measures, such as the Austrian Research Promotion Agency (Forschungsförderungsgesellschaft, FFG) grants and the COMET centres. The increase of funding through R&D tax incentives was larger in absolute terms than the increase from other instruments (Figure 3.5). The Research Premium's contribution to business R&D grew from EUR 156 million in 2006 to EUR 508 million in 2015. Of the total increase in government funding of business R&D between 2006 and 2015, 68% can be attributed to the Research Premium. Funding by FFG programmes also increased, but by a smaller absolute volume (from EUR 116 million to EUR 196 million). Funding from other government sources increased from EUR 157 million to EUR 194 million. A large share of this funding from other sources is directed to the so-called co-operative sector, including AIT, JR and ACR as well as the COMET centres. In 2015, more than a third of total direct government funding of business R&D went to the co-operative sector.[4] For the (non-cooperative) business sector, tax incentives are therefore the most important government funding source, contributing more than two-thirds of total public funding of business R&D. From 2006 to 2015, about 75% of the increase in government funding of (non-cooperative sector) business R&D came from the Research Premium.

Figure 3.4. **Direct government funding and tax support for business R&D, 2015**

A. As a share in total business R&D



B. As a share of GDP



* No data available on the size of R&D tax support.

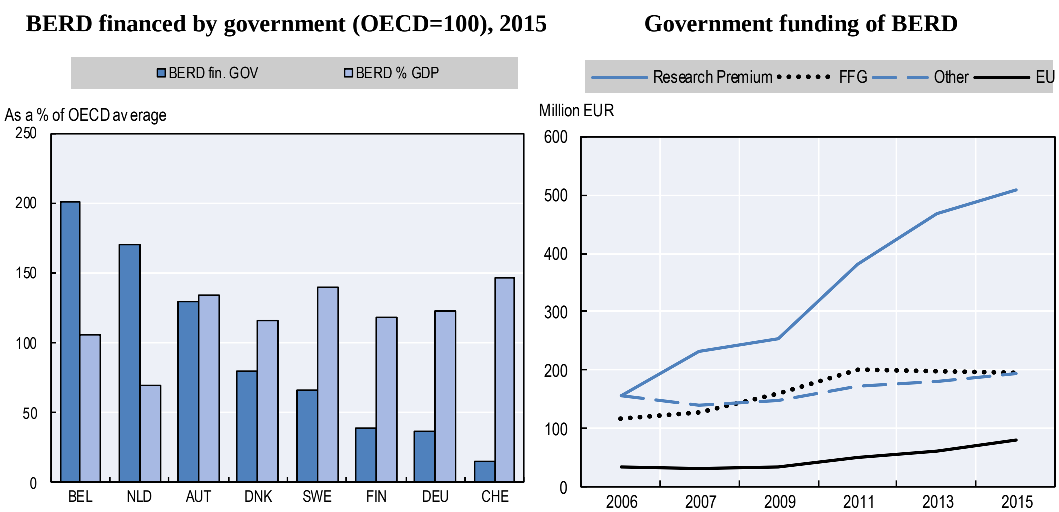
Source: OECD (2017e), R&D Tax Incentive Indicators, July, http://oe.cd/rdtax.

StatLink https://doi.org/10.1787/888933882503

Government funding of business R&D in Austria in 2015 was significantly above the OECD average – as a share of gross domestic product (GDP) – and notably higher than in comparator countries (Figure 3.5). At the same time, levels of business investment in R&D in Austria are broadly comparable with international competitors, although they have risen sharply over the last decade.

The Research Premium provides a reimbursable tax credit for R&D equivalent to a fixed percentage, currently 14%, of firms' validated R&D spending. As the rate of subsidy offered by the Research Premium has been increased in recent years, and the volume of business R&D in Austria has also increased, government spending on the Research Premium has grown sharply. However, by international standards the Austrian R&D tax incentive is not particularly generous. The implied tax subsidy rate on R&D expenditure provided by the Research Premium was 15% in 2017,[5] placing Austria in the lower half of OECD countries that offer an R&D tax incentive (19th out of 29 countries in terms of generosity). When looking at large firms only, the relative generosity of the Research Premium is higher (13th). This is because several OECD countries apply lower rates or ceilings and thresholds for large firms, which reduces their implied tax subsidy rate significantly. Austria’s generosity ranking further improves if loss-making firms are considered, since the Research Premium is applied independently of a firm’s financial results. By contrast, several other countries have lower implied subsidy rates for loss-making firms, particularly when the loss-making firms are large.

Figure 3.5. **Public support for business R&D in Austria: Volume of support by type of instrument, and level of support with respect to comparator countries**



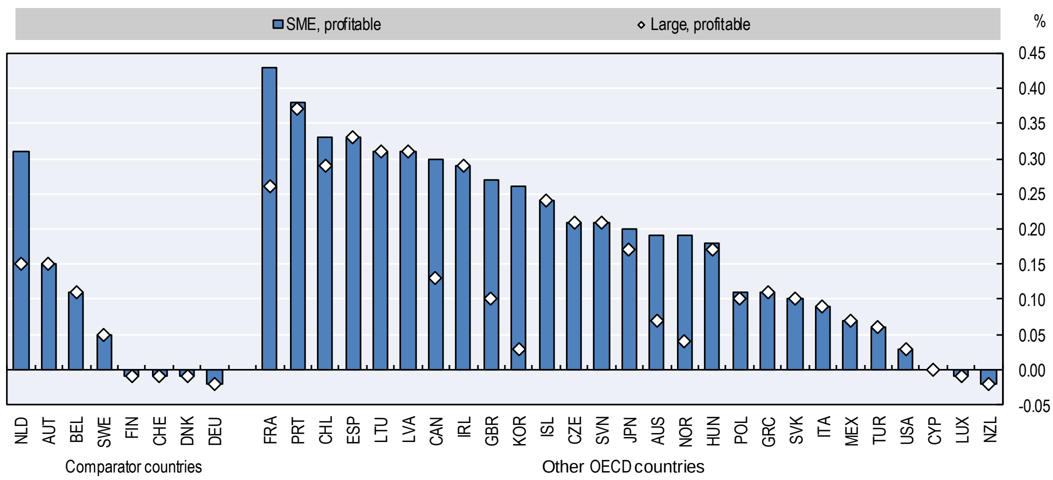
Sources: OECD (2015a), *OECD Science, Technology and Industry Scoreboard 2015: Innovation for Growth and Society*, https://doi.org/10.1787/sti_scoreboard-2015-en; Statistics Austria.

StatLink https://doi.org/10.1787/888933882522

Within the group of comparator countries, the Research Premium is more generous than the Belgian and Swedish schemes, whereas France and the Netherlands offer a higher implied R&D subsidy rate. In both France and the Netherlands, R&D tax incentives are significantly more generous for SMEs than for large firms (Figure 3.6). For the Netherlands, a thorough evaluation of the WSBO tax incentive showed that the scheme is somewhat effective for smaller firms, but is not effective for large firms (Lokshin and Mohnen, 2012). Four comparator countries do not offer R&D tax incentives (Denmark, Finland, Germany and Switzerland).

Most direct government support for applied research and innovation is provided through the FFG, the Austrian Research Promotion Agency (see below for an overview). The FFG supports R&D and innovation in firms, research institutes and universities. It operates a range of programmes that fund (applied) R&D and innovation in business enterprises, universities and public research institutes (including organisations from the co-operative research sector). A large share of FFG funding to companies is distributed through the Basic Programmes, with much of this focused on supporting R&D in SMEs, but also some funding of large enterprises. Basic programmes are demand-led, with proposals from individual firms assessed on technical and commercial grounds. Thematic programmes are linked to specific technologies or missions. A third type of funding is structural programmes such as the COMET competence centres. Figure 3.7 shows the cash value of funding by type of programme.

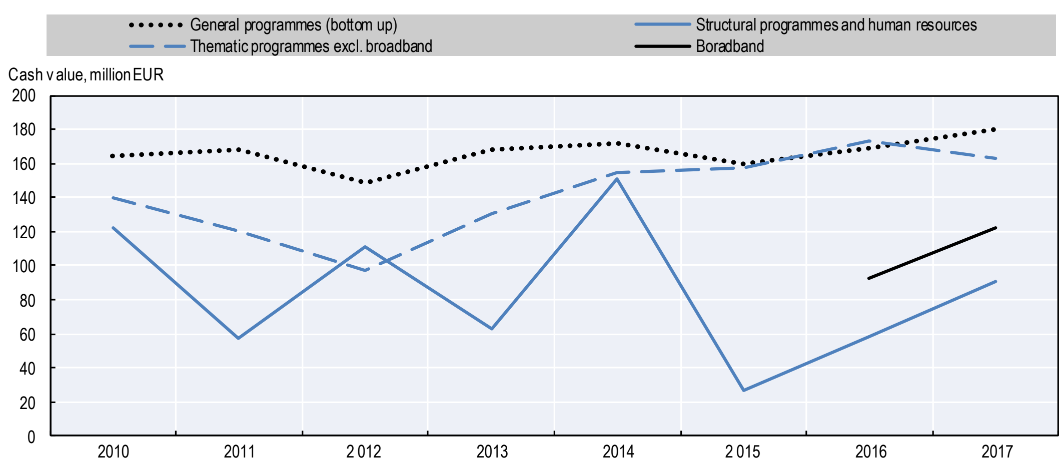
Figure 3.6. **Implied tax subsidy rates on R&D expenditures, 2017**



Note: The implied tax subsidy rate is 1 minus the B-Index for firms making profit.
Source: OECD (2017e), R&D Tax Incentive Indicators, March, http://oe.cd/rdtax.

StatLink https://doi.org/10.1787/888933882541

Figure 3.7. **FFG funding (approvals) by type of programme**



Source: Based on data provided by the FFG (2018).

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As the Research Premium has increased in importance, and the FFG's budget has increased only slowly, the policy mix for business R&D and innovation has altered substantially in recent years, placing the emphasis increasingly on tax incentives for R&D. This development was the reason for the evaluation of the Research Premium conducted and presented in the spring of 2017. However, evidence on the effectiveness of the different funding streams is limited since evaluations rarely apply econometric analysis based on control-group approaches but often focus on self-reported impacts of firms having received funding (see Box 3.1 on the Research Premium and Box 5.6 in Chapter 5 which reviews the methodological approaches used to evaluate tax incentives).

Box 3.1. **Evaluation of the Research Premium**

An evaluation by Ecker et al. (2017) provides an overview of the impact of the Research Premium on both domestic firms in Austria and inward investors. The evaluation is based on a mixture of quantitative and qualitative data and analyses, but does not include a quantitatively established control group of non-recipients. This is a significant limitation of the evaluation. Accepted best practice for the evaluation of firm-level R&D support measures of this type would involve developing a quantitative counterfactual using econometric technique such as difference in difference modelling (for an overview of evaluation methodology see Box 5.6 in Chapter 5).

The recent evaluation suggests that the Research Premium has only a medium to low impact in terms of input and behavioural additionality (Ecker et al., 2017: 102). The largest impacts seem to occur in large and research-intensive companies, with research intensity being the key factor. The evaluation also suggests that there are many companies where the Research Premium does not affect the level of R&D expenditure. Evidence from the evaluation suggests that the Research Premium plays a role in attracting internationally mobile R&D and related competences to Austria, notably in influencing decision-making processes within multinational enterprises. In some cases, effects may be limited by specific design features of the Research Premium, such as the expenditure limit on contract research, which may reduce the incentives for collaborative R&D and innovation (Walsh, Lee and Nagaoka, 2016; Vahter, Love and Roper, 2014).

An international comparison in 2017 shows that 15 out of 41 tax incentive schemes across the OECD give preferential treatment to small and medium-sized enterprises, young firms and start-ups (OECD, 2018b), where additionality is generally expected to be greater than in larger firms (Lokshin and Mohnen, 2012). The Research Premium provides the same rate of R&D subsidy to all firms and may be more advantageous to larger firms, as their costs of compliance are proportionately lower relative to the subsidy available. This may reduce the overall additionality of the Research Premium.

Sources: Ecker, B. et al. (2017), "Evaluierung der Forschungsprämie: Studie im Auftrag des Bundesministeriums für Finanzen (BMF)", https://www.bmf.gv.at/budget/aktuelle-berichte/BMF_Evaluierung_der_Forschungspraemie_Endbericht.pdf?67ruop; Walsh, J.P., Y.N. Lee and S. Nagaoka (2016), "Openness and innovation in the US: Collaboration form, idea generation and implementation", https://doi.org/10.1016/j.respol.2016.04.013; Vahter, P., J.H. Love and S. Roper (2014), "Openness and innovation performance: Are small firms different?", https://doi.org/10.1080/13662716.2015.1012825; OECD (2018b), *Main Science and Technology Indicators 2017/2*, www.oecd.org/sti/msti.htm; Lokshin, B. and P. Mohnen (2012), "How effective are level-based R&D tax credits? Evidence from the Netherlands", https://doi.org/10.1080/00036846.2010.543083.

Entrepreneurship and scale-up among Austrian firms

Innovative entrepreneurship and successful scale-up play an important role in economic restructuring and adaptation to challenges such as the emergence of Industry 4.0. Entrepreneurial activity is a transmission mechanism for introducing new processes, business models or marketing channels and transforming new research findings into marketable propositions (Global Entrepreneurship Monitor, 2016).

Perhaps the most detailed information on the extent of entrepreneurial activity in different countries comes from the Global Entrepreneurship Monitor (GEM) surveys.[6] The 2016 GEM report for Austria surveyed 4 594 members of the adult population and identified a total early-stage entrepreneurial activity (TEA) rate of 9.6%, higher than in most other EU countries. The TEA rate varied between Austrian *Länder*, from 10.8% in Upper Austria to 7.7% in Tirol. Evidence from the Chamber of Commerce suggests that across Austria this TEA equates to around 40 000 start-up businesses in 2016, up from around 31 000 a decade earlier. Austrian start-up companies are also strongly innovation oriented, with around 35% reporting the introduction of innovative products or services in 2016 (Table 3.2).

Table 3.2. **Proportion of early-stage entrepreneurs introducing new-to-market innovations: Selected countries, 2016**

	% innovative entrepreneurs
Switzerland	37.5
Austria	35.0
Sweden	33.6
Netherlands	29.5
Finland	29.4
Germany	24.7

Notes: An entrepreneur is said to be innovative if his/her product or service is new to all or some customers and few or no businesses offer the same product. Data are not available for Belgium and Denmark.
Source: Global Entrepreneurship Monitor (2016).

Aside from their impact on innovation and market transformation, recent evidence also suggests that in all countries for which data are available, it is younger firms – those less than five years old – which create the bulk of new employment (Anyadike-Danes et al., 2015). Here, Austrian start-ups perform less well, with the proportion of early-stage entrepreneurs which anticipate creating six or more jobs in five years (13.0%) being below that in key comparator economies (Table 3.3). The suggestion is that Austrian entrepreneurs are interested in starting businesses, but are less ambitious for growth than those in some comparator countries. One potential explanation is that the fear of failure is more significant in Austria – reportedly a concern for 46.2% of entrepreneurs – and a factor which appears to have increased in importance in recent years (as the 2016 Global Entrepreneurship Monitor report indicates).

Table 3.3. **Percentage of all early-stage entrepreneurs anticipating creating six or more jobs in five years: Selected European countries, 2016**

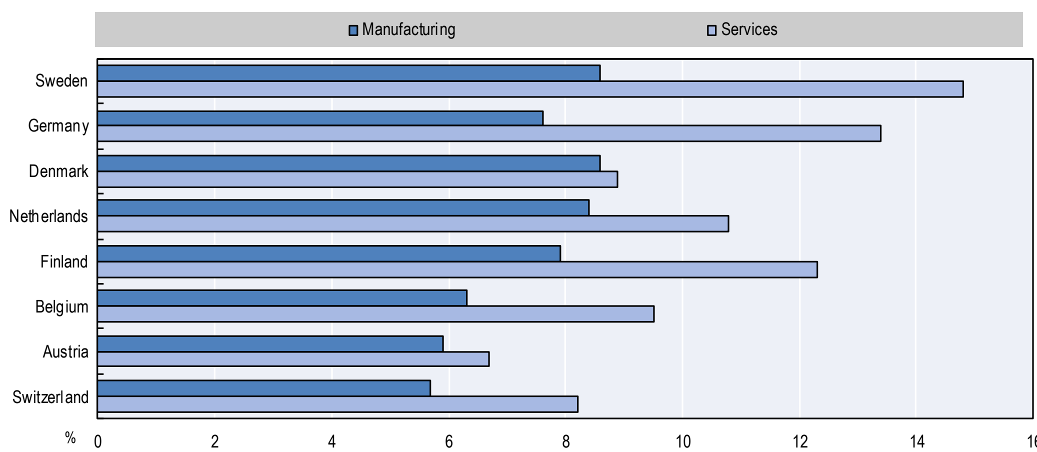
	% growth-oriented entrepreneurs
Switzerland	25.1
Germany	21.5
Finland	17.7
Netherlands	17.2
Austria	13.0
Sweden	12.2

Note: No data are available for the other comparator countries.
Source: Global Entrepreneurship Monitor (2016).

Evidence of relatively limited growth expectations among Austrian start-ups is reflected in other figures on growth, and particularly in the proportion of Austrian firms achieving medium or high rates of growth. Across manufacturing and services (Figure 3.8), the proportion of Austrian firms achieving medium or high growth – defined as 10% or higher employment growth per annum – lags behind that of most European economies and a range of comparator countries. In 2014, the latest year for which comparable data are available, 5.9% of Austrian manufacturing firms achieved 10% employment growth or more, compared to 8.9% in Denmark. Notably, around 7.6% of German manufacturing firms also achieved 10% or higher employment growth in the same year. A similar picture emerges in services, where 6.7% of Austrian firms achieved 10% employment growth or more compared to 10.8% in Norway and 8.6% in Denmark.

Figure 3.8. **Percentage of manufacturing and services firms achieving 10% or higher employment growth**

Annual average, 2012-14



Notes: For Belgium and Denmark, calculations are based on the period 2012-13. For Switzerland, values are only available for 2014. For services, the calculation for Germany is based on data for 2012.
Source: OECD (2017a), *Entrepreneurship at a Glance 2017*, https://doi.org/10.1787/entrepreneur_aag-2017-en.

Taken together, this evidence suggests a contrast between Austria's relatively strong start-up performance and a weaker performance in achieving scale-up. It is interesting to consider the employment implications of Austria's relatively low share of scale-up firms. Rates of medium to high growth in Norway, for example, are around 2.5 those in Austria, suggesting that matching Norway would increase the number of Austrian medium-high growth firms to around 6 300. Likewise, matching Denmark, where rates of medium-high growth are around 1.4 times those in Austria, would mean adding around 3 600 medium-high growth firms. Average employment in medium-high growth firms in Austria, across manufacturing and services, is around 60 (OECD, 2017a). This suggests that if all additional firms grew by a minimum of 10%, matching medium-high scale-up rates in Norway would generate at least an additional 23 000 jobs a year in Austria, or an additional 6 000 jobs a year if matching Denmark.

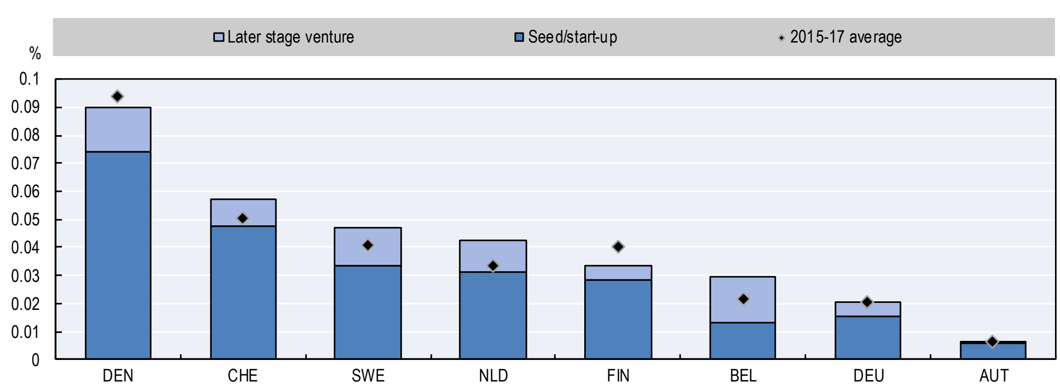
The evidence indicates that the current business environment in Austria is more favourable for business start-up than scale-up. In addition, evidence from other countries suggests that the conditions which favour start-up are different from those which favour growth (Stuart and Sorenson, 2003). For example, the presence of a research-intensive university in an area may increase the number of spin-out companies established, but will have less influence on their subsequent growth. Subsequent growth will depend more on the availability of local incubators or accelerators, funding, and the way in which the management team of the spin-out grows and develops. Developing relevant framework conditions – relating to the availability of equity funding, for example – and targeted policy initiatives which can support management and leadershhip development in scale-up firms can both help to raise the share of high-growth firms.

Early-stage equity finance in Austria

One of the key barriers to boosting the level of high-growth companies in Austria is the shortage of risk capital, including angel funding and formal venture capital. Comparisons of the scale of venture capital (VC) investments in Austria and comparator countries – Denmark and Sweden – suggest a relatively low volume of activity in Austria. VC investment in Austria could be around one-eighth of that in Denmark and one-ninth that of Sweden, a pattern that dates back to before the financial crisis (Joanneum Research, 2015). The implication is that Austrian companies – particularly those in the early stages of growth – depend more strongly on the banking system than those in competitor countries.

This is not simply an Austrian problem, however, with one study suggesting that across Europe innovative start-up companies are at a "significant disadvantage" compared to the United States in terms of the availability of risk capital (AFME Finance for Europe, 2017). However, the availability of risk capital in Austria is much more limited than in many EU countries (Figure 3.9). In 2017, for example, VC investment was equivalent to 0.08% of GDP in Denmark, more than 13 times higher than in Austria (0.006%).

Figure 3.9. **Venture capital investment as a percentage of GDP, 2017, and 2015-17 annual average**



Source: Invest Europe (2018), 2017 *European Private Equity Activity*, https://www.investeurope.eu/media/711867/invest-europe-2017-european-private-equity-activity.pdf.

StatLink https://doi.org/10.1787/888933882579

Recourse to VC investment is not just a supply-side issue. The lower level of VC activity in Austria may reflect both supply-side constraints as well as inadequacies in deal flow (i.e. in the number of firms willing to accept external equity funding and which have projects promising sufficient returns to risk capital investors). As indicated earlier, however, start-up rates in Austria compare well with those in comparator countries of a similar size, which suggests that the number of potentially investable projects in Austria should be sufficient to attract greater VC interest.

Furthermore, it is not just the volume of VC investment that differs between Austria and its international competitors; the sources of VC investment also differ significantly. More than half of VC funding available in Austria comes from government agencies, a situation rather similar to that in Finland and Norway (Table 3.4). Note, however, that the overall level of VC investment in Norway and Finland is more than twice that in Austria. The other key sources of VC investment in Austria are banks – which play a much more important role in Austria than elsewhere – and private individuals (Table 3.4).

The pattern of VC funding in Austria therefore differs markedly from that in some key benchmark economies. Denmark and Sweden also have very different VC funding models, with pension funds accounting for around half of all VC investment. Other countries (such as the Netherlands, Switzerland, the United Kingdom and the United States) also have a more diverse set of VC funders, including business angels, investment from which remains underdeveloped in Austria relative to leading EU and international comparators (Gassler and Sellner, 2015).

Table 3.4. **Type of investors in European venture capital, 2011-15, selected countries**

	Academic institutions	Banks	Corporate investors	Endowments	Family offices	Funds of funds	Government agencies	GP commitment	Insurance companies	Other asset managers	Pension funds	Private individuals
Austria	0	18	0	0	0	7	53	0	1	0	5	17
Belgium	1	10	9	0	6	14	27	0	3	15	0	16
Denmark	1	0	0	0	4	31	0	1	3	5	55	0
Finland	0	0	9	5	4	11	48	1	1	2	7	12
Germany	0	10	24	0	8	5	38	0	2	1	2	10
Netherlands	0	3	10	1	12	9	29	1	14	3	13	6
Sweden	0	3	2	0	17	6	4	2	16	0	48	1
Switzerland	0	6	30	1	23	11	3	0	0	0	15	12

Source: AFME Finance for Europe (2017), "The shortage of risk capital for Europe's high growth businesses", https://www.afme.eu/globalassets/downloads/publications/afme-highgrowth-2017.pdf.

Ensuring an adequate and consistent supply of growth finance and risk capital will be essential if Austria is to increase the number of scale-up firms and maximise the potential of its start-up businesses. In this sense, it is hard to argue with the verdict of one recent report that suggested that: "Overall, especially risk capital from the private sector has to be increased significantly in Austria. Innovation in high-tech branches involves high risks and large financial resources, which cannot be carried by the public sector alone. The main target of the public sector should be to provide a well-designed framework and a well-managed platform in order to attract venture capital investors" (Joanneum Research, 2015: 13). As Gassler and Sellner (2015) also suggest, developing a more effective supply of risk capital offers other potential benefits: businesses financed by external equity are generally quicker to grasp market opportunities, have a higher degree of professionalization, and have stronger innovation performance and faster employment growth. In addition, equity financing may positively signal the quality of a business for further rounds of investment.

Three areas are focused on here in which policy and legislation could potentially be developed in Austria to promote greater availability of risk capital. These are: tax incentives for individual equity investors (business angels); the role of pension funds in equity investment; and strengthening existing fund-of-funds activity to encourage further private sector equity investment. Each of these initiatives may help to address different stages of the "funding escalator" through which high-growth firms typically pass.

Tax incentives for individual equity investment

Individual investors can play an important role in providing early-stage equity for scale-up businesses, through either business angel funding or crowdfunding. Angel funding is well established in Anglo-Saxon economies, but less well developed across continental Europe. Since 2012, the European Investment Fund's (EIF) European Angels Fund has sought to develop angel funding across Europe. The EIF and the Austria Business Service (*aws*) established a co-investment fund in 2013, called the Business Angel Fund Austria. Administered from Luxembourg, with due diligence undertaken by the *aws*, this fund has to date committed around EUR 24 million – almost the whole of the allocated capital. Each investment supported by the fund matches investment from individual business angels. This initiative and other programmes such as the Risk Capital Premium (which ended in 2017), and the *aws* matching service I2 Business Angels,[7] have helped to stimulate interest in angel investing in Austria. However, business angel activity has not yet achieved significant scale. While data are limited, there are perhaps 10-20 very active angel investors concentrated in Vienna, although there are around 300 potential investors registered with the *aws* I2 Business Angels matching service.

Equity crowdfunding is a recent, but rapidly developing, form of finance, which offers firms the potential for significant investment while engaging a significant number of investors. Recent evidence from the United Kingdom suggests that crowdfunding (debt and equity) most often complements, rather than acts as an alternative to, more traditional financing mechanisms (particularly bank finance). For small countries such as Austria, moves towards a more integrated EU crowdfunding market are important, and will require clarity and transparency in national legislative approaches and tax incentives. Increasing co-ordination between crowdfunding and syndicated business angel investments also seems likely in the future as the importance of crowdfunding grows alongside the (further) growth of syndicated angel investments.

Registrations with the *aws* Business Angel matching service suggest the potential for expanding the scale of business angel activity in Austria. One potential limitation on individuals' interest in angel investing is the lack of any personal tax incentives for private equity investment. Such tax incentives are common in other countries. In the United Kingdom, for example, the Seed Enterprise Investment Scheme (SEIS) and Enterprise Investment Scheme (EIS) (Box 3.2) are used by around 90% of angel investors. Three-quarters of business angels report that the EIS/SEIS schemes benefited their decision to invest (AFME Finance for Europe, 2017).

Austria needs an increased supply of private equity investment, particularly for growth businesses. Angel investment is one element of this, and Austria is currently out of step with European best practice in not providing tax incentives for individual early-stage equity investments (European Commission, 2017b). Implementing tax incentives for individual and syndicated angel investment along the lines of the United Kingdom's SEIS and EIS would help change the investment landscape in Austria, support angel investment over the longer term and, in the short term, signal the importance of angel investments.

Box 3.2. **Enterprise Investment Scheme and Seed Enterprise Investment Scheme**

The Enterprise Investment Scheme (EIS) was established by the UK government in 1994 and offers tax breaks to equity investors in small private companies who maintain their holding for at least three years. The key elements of the scheme are: income tax relief equivalent to 30% of the value of the investment; no capital gains tax on any profits from EIS investments; any losses can be set against future tax liabilities; and any shares bought through EIS are exempt from inheritance tax.

The Seed Enterprise Investment Scheme (SEIS) was established in 2012 and provides more generous tax breaks to encourage investment in smaller, early-stage businesses. For the SEIS, businesses must also be less than two years old and have gross assets less than GBP 200 000. Maximum investment is GBP 100 000 in a qualifying start-up business and the key tax reliefs are: income tax relief at 50%; and, as with the EIS, no capital gains tax on profits, no inheritance tax and a provision that losses can be set against future tax liabilities. There is limited evaluation evidence on either the EIS or the SEIS, but it is estimated that 24% of EIS investments would not have been made without the EIS scheme (AFME Finance for Europe, 2017).

The role of pension funds

Pension funds, which form an important component of VC funding in other countries, are largely absent from the scene in Austria. Evidence from other countries provides some illustrative examples of how pension legislation can be changed to allow equity investment, while maintaining the stability of funds' investment portfolios. Historically, pension provision in Austria has been dominated by the state pension system. Since 1990, however, contributory pension funds have been established based on the Pension Fund Act and the Occupational Pensions Act. This led to the establishment of a number of multi-employer – most notably VBV – and single employer funds. Investment rules covering contributory pension funds in Austria are in line with EU prudent person rules for asset allocation, which allow equities to comprise up to 70% of portfolios. In practice, the equity allocations of Austrian pension funds remain well below this limit, with the Oak's figures showing average asset allocations of 35% to equities, and 63% in bonds, loans and cash.[8]

In other countries, reforms to pension fund legislation and structures have been key to developing VC investment. In particular, changes to the interpretation of the prudent person regulations in the United States in 1978 were instrumental in releasing capital for VC investment, while structural reforms in Sweden in 1996 reshaped public pension funds to allow investment in equity funding for SMEs. As described in the following paragraphs, both experiences provide potential learning points for Austria, particularly if the Austrian pension system moves towards a more private-sector focus over the next decade.

The key change in pension legislation in the United States dates from 1978, when changes were made to the Employee Retirement and Security Act to modify the prudent person rule. Under the original view, each individual investment was expected to adhere to the prudent person risk standards. But after 1978, the concept of portfolio risk was accepted, allowing risk to be measured at the level of the overall portfolio rather than at the level of the individual investment. In practice, this allowed pension funds to allocate a small proportion of their portfolios (around 10%) to the riskier VC asset class (Krumm, 2012). This type of regulatory change may be applicable in the Austrian case.

Reform models in Sweden may be more applicable to the Austrian context in the shorter run, in terms of orienting public pension funding towards equity investment in smaller companies. The key Swedish reform was the formation in 1996 of the Sixth Swedish National Pension Fund (the Sixth AP Fund) to manage public pension funds and invest in Swedish SMEs.[9] The Swedish Fund operates by both investing in private equity funds and directly owning shares in a number of unlisted SMEs, investments that are balanced with other asset classes to regulate portfolio risk. The Swedish Fund opened with around SEK 10.4 billion of investment capital in 1996, which had risen to SEK 19.9 billion by 2010.

The value of pension fund reform depends critically on other national regulatory structures. Neither the US nor the Swedish policy examples are therefore directly transferrable to Austria. Any changes to Austrian legislation will require careful consideration. However, the potential gains from pension reform are substantial: 55% of Swedish VC funding is currently provided by pension funds. It is therefore recommended that Austria consider whether current regulations surrounding pension funds could be updated to allow more equity investment in early-stage or scale-up businesses.

Strengthening fund-of-funds activity in Austria

Incentives to individual investors and pension fund reform may help to promote a flow of funds from within Austria into equity supply. Complementary to both such measures is to improve the attractiveness of Austria as a destination for internationally mobile equity investment from institutional investors. This requires a transparent and open regulatory environment. It also requires an institutional structure that shifts the risk-reward balance sufficiently to encourage a flow of funds to Austria, until markets mature sufficiently to be self-sustaining.

This suggests a fund-of-funds approach and a pump-priming role for public support in developing such a fund(s). From a practical perspective, public co-investment reduces the risk to external investors. From a signalling perspective, this type of approach clearly indicates the strong support of the Austrian government for high-potential SMEs, something that may be attractive to external investors. Existing fund-of-funds activity in Austria, endowed by the National Foundation for Research, Technology and Development, and operated by the *aws* as its Venture Capital Initiative, has been relatively small in scale. Nine equity funds have been supported, with a public contribution of EUR 34 million since 2010. A number of these funds would probably not have been established without the *aws* funding. Five of the supported funds are international, dominated by German funds that invest in Austria.

Internationally, fund-of-funds investments have a relatively long history, beginning with the Yozma Fund in Israel in the mid-1990s. However, a recent evaluation of the Danish Growth Fund (DGF) stresses both the continuing relevance of its activities and that the "DGF's indirect investments through funds and fund-of-funds (FoF) have helped to attract private investors to the funds and subsequently to develop essential expertise on the various management teams" (DAMVAD, 2013).[10] Other aspects of the DGF's activities – particularly its direct equity investments – are considered less significant and something of a distraction from its more valuable fund-of-funds investment function. Compared to the investment in the Austrian fund-of-funds (around EUR 34 million since 2010), the value of the DGF's indirect investments through fund-of-funds peaked at around DKK 600 million (around

EUR 80 million) in 2008 and have averaged between DKK 300 million and DKK 400 million (around EUR 40-55 million) annually since 2010.[11] The well-documented growth of the Swedish private equity sector, particularly since the Great Recession, also illustrates the potential for fund-of-funds activity to drive significant investments in SMEs with strong growth potential (Naess-Schmidt, Heebøll and Karlsson, 2017). In the Swedish case, growth in public investment in fund-of-funds activity has been matched by increasing investments from pension funds.

Austria is not alone in having a rather under-developed private equity and fund-of-funds sector. In Ireland, there have been recent calls for policy developments similar to those proposed here, with a view to increasing the availability of equity investment in early-stage growth companies (Taylor, 2018). In this context, it is recommended that Austria consider the experience of the Danish Growth Fund's indirect investment and examine the establishment of a similar Austrian Growth Fund to co-ordinate public support for equity markets.

Supporting management and leadership development for high-growth businesses

Alongside the financial challenges, scale-up firms, and those experiencing rapid growth episodes, face particular leadership and management challenges. As firms scale, the demands on the leadership team change markedly from "doing" to "leading". OECD (2012) notes that "fast business development is a disruptive process that alters the organisational dynamics and management practices of an enterprise, from production to logistics, from marketing to staff management. New leadership and management skills are often needed to cope with this process". Brown and Mawson (2013) point out that how well firms cope during these transitional periods rests largely on their "adaptive capacity" – an organisation's ability to recognise the value of new information, assimilate it and apply it to commercial ends. These observations focus attention on the potential value of developing targeted schemes to support management and leadership development in scale-up firms.

Austria has an increasingly well-developed network of incubators and accelerators. These provide valuable support for nascent and growing firms – as do angel investors – but in each case the primary focus is on the development of the business rather than the development of the capabilities of the leadership team. Experience from across the OECD suggests the value of a dual approach that develops the capabilities of firms' leadership teams alongside the development of their business (OECD, 2012). In many countries, this has led to the creation of bespoke programmes targeted specifically at high-growth or scale-up firms. Often these involve aspects of business and management development, peer group learning, and advisory and mentoring support, provided over a four- to six-month period. Schemes may also include support to assist companies with "investment readiness" to help scaling firms access either debt or equity (see below).

Internationally, high-growth support schemes differ in structure and delivery. Based on OECD experience, Roper and Hart (2013) identified seven guidelines for programmes to support sustained growth:

1. **Enabling effective self-selection:** A strong element of self-selection is inevitable in the provision of support for high-growth firms. Enabling effective self-selection by firms into a scheme requires a clear service proposition from the scheme as well as a clear statement of any required commitments by the firm, for instance in terms of staff attendance, etc.
2. **Selecting participants:** Selectivity by the scheme itself is also necessary because high-growth programmes are resource-intensive and often involve peer-group and shared-learning activities that require active participation.

3. **Recognising spillovers:** The process of selecting firms to work with should include considerations of “national benefits” or positive spillovers. These may be greater from some high-growth SMEs than others. For example, the growth of firms offering high-income high-tech jobs is also important in increasing demand for manual task-intensive work. In the United States, for instance, of the ten cities where waiters receive the highest pay, seven have a major presence of high-tech firms (Moretti, 2012).
4. **Maintaining engagement:** Schemes to support high growth are likely to involve continued engagement with a business over a period of years. This often occurs through an alumni network after the completion of the initial course.
5. **Using holistic approaches:** Supporting high-growth firms is likely to require a holistic rather than a thematic support model, with a dual focus on the development of the business and the capabilities of the firm’s leadership team.
6. **Being partnership-based:** Measures to support sustained growth should be partnership-based, drawing on the expertise and networks of a range of support organisations.
7. **Organising delivery regionally:** A regional model has proved valuable in facilitating attendance by firms at scheme events and sessions and making face-to-face mentoring and peer group sessions more feasible.

Programmes to support management and leadership for growth-oriented firms, such as the Goldman Sachs 10.000 Small Businesses programme in the United Kingdom (Box 3.3), provide an element of bespoke support and are therefore resource-intensive, and typically involve an element of public funding. Public investment may be offset by related increases in future tax revenues and the spillover benefits from high-growth firms. Such schemes also act as a complement to private incubator or accelerator initiatives. This suggests that to support its commitment to boosting scale-up growth, Austria should develop targeted schemes to strengthen management and leadership in firms with the potential to scale. Such an initiative should build on previous experience across the OECD, as described, for example, in Roper and Hart (2013). Engaging universities as co-ordinating partners would strengthen university-industry links and provide a mechanism for achieving national coverage but with regional delivery.

Strengthening investment readiness

Along with supply-side measures to address access to finance, initiatives to enhance the quality of deal flow can also be important. Investment readiness has been defined as “the capacity of an SME or entrepreneur – who is looking for external finance, in particular equity finance – to understand the specific needs of an investor and to be able to respond to these needs by providing an appropriate structure and relevant information, by being credible and by creating confidence” (European Commission, 2006). Achieving “investment-readiness” typically requires that three key issues be addressed: 1) equity aversion; 2) investability; and 3) presentational failings. Equity aversion may arise where business owners are unaware of alternative forms of finance external to the firm and their benefits, and/or where entrepreneurs are reluctant to relinquish full control of their firm. Helping growing companies to understand the benefits of external equity investment may overcome this issue. “Investability” may reflect weaknesses in firms’ leadership team or investment proposition, and/or the match between investment propositions and the interests of investors. Even where the investment proposition is sound, presentational failures may also undermine any pitch to investors. Financial education provided to chief executive officers or managers of growth-oriented SMEs may help overcome each of these issues.

Box 3.3. **The Goldman Sachs 10,000 Small Businesses UK Programme***

This programme, funded by Goldman Sachs, provides a period of intensive managerial and business support for firms in the United Kingdom with high growth potential. The programme is delivered through a series of business schools, and evidence suggests the programme is effective in boosting growth rates and helping firms to access external capital. To date, over 1 000 firms have participated.

Following rigorous screening, the programme provides high-quality, practically focused business and management education, and delivered over 12 sessions lasting approximately 100 hours over a 4-month period. Eligible firms are established businesses with annual turnover typically more than GBP 0.5 million, and with the potential and ambition to scale. Cohorts of 15-20 participants are drawn from across industry sectors, creating unique networking and peer-learning opportunities. During the course of the programme, every small business owner develops a customised plan to direct their organisation's strategy and expansion.

Participants also benefit from a range of business support services, including: specialist workshops; one-on-one business advice; a coaching and mentoring; access to experts; networking opportunities; and alumni services.

* www.goldmansachs.com/citizenship/10000-small-businesses/UK/about-the-program.

Measures of financial literacy in the population as a whole have developed rapidly in recent years and international survey evidence is now available. The OECD's definition of financial literacy is "a combination of financial awareness, knowledge, skills, attitude and behaviour necessary to make sound financial decisions and ultimately achieve financial well-being" (Cupak et al., 2018). Survey data for 2016 places levels of financial literacy in Austria marginally above the OECD average and similar to those in Belgium and Germany. In Austria, supporting financial literacy is part of the mission of the national bank (Oesterreichische Nationalbank, OeNB). While financial literacy measures are in place for primary and secondary school pupils (since 2015), Austria has yet to publish a national strategy for financial education.

Internationally, approaches to developing financial literacy in businesses vary, with some countries (such as Chile, Indonesia, Portugal, Serbia) targeting SMEs in their national strategies. For example, in Portugal, the National Plan for Financial Education targets entrepreneurs, business owners and managers of micro, small and medium-sized companies through a partnership between the financial supervisor IAPMEI (Public Agency for Competitiveness and Innovation) and Turismo de Portugal (the public authority for tourism). Other programmes focus more tightly on promoting financial literacy, such as the Elite programme run by the London Stock Exchange. More typically, however, financial literacy is one aspect of more general business development or entrepreneurship education programmes. There is currently little robust evidence on the effectiveness of such measures, however, perhaps reflecting a lack of measurement tools (Atkinson, 2017).

A number of EU projects funded by Horizon 2020 have also focused on investor-readiness in SMEs. One example is InvestHorizon, which developed online resources, investment-readiness "academies" and investor forums.[12] Early research for the programme (performed in 2016) highlighted the role of incubators and accelerators in providing advice about funding options, the capacity to develop business models, and other matters. In Germany, one organisation which provides this type of bespoke support is the High-Tech Gründerfonds, which operates a network of regional "scouts" to help scale-up businesses seeking equity to find local funders.[13] Investment managers then support individual businesses during the funding cycle. IPOready, a programme run by the Irish Stock Exchange, with support from Enterprise Ireland and the Irish Strategic Investment Fund, works in a similar way and has proved effective in supporting an initial cohort of nine high-potential companies which graduated in 2016 (Box 3.4).

A number of additional observations can be made about the design and operation of investment-readiness schemes:

- Different models exist. Some schemes are publicly sponsored, as in Ireland and Spain. Others are privately run, as in Austria and France. In the United Kingdom, both public and private programmes operate. It is unclear if a particular model is best.
- Many sources of advice might be used, from retired entrepreneurs – as in Ireland – to recent business school graduates – as in France. However, a generic insight from the literature is that greatest value is typically attached to advice coming from others with business experience.
- Many schemes exclusively target young firms (Toschi and Murray, 2009). This focus should probably be broadened, because fast-growth firms can also be relatively old. Indeed, as the achievement of rapid rates of growth involves some unpredictability, it is important not to use overly rigid eligibility criteria that could exclude potential beneficiaries.
- Among the services offered, attention should also be given to the management and use of intellectual property, both as a source of competitiveness and as a means to raising finance.

To maximise the potential impact on scale-up success of developments in equity supply in Austria, action on investor-readiness may be necessary. However, there is little systematic evidence on either the level of investor-readiness of Austrian scale-up firms or the provision of programmes that can support investor-readiness in Austria. Individual programmes such as the "Investment Ready programme" run by Impact Hub Vienna are well-established but focus on specific market segments.[14] A useful next step in policy development in this area could be for Austria to map and internationally benchmark its existing investor-readiness programmes. This evidence base could then inform the subsequent development priorities.

Enlarging the scope of innovation policy and capitalising on creativity

Creativity is a core component of economic success. Two notions – creative industries and the creative economy – are useful here. "Creative industries" is an umbrella term covering the cultural, digital creative and craft sectors. Each of these sectors plays a different role in shaping innovation and competitiveness. Cultural industries help define national and regional identities, and play a significant role in shaping an image of "place" and supporting the tourism and leisure sectors (Corsale, 2017). Digital creative industries cover a range of manufacturing and digitised service activities relating both to content development and delivery. Digital creative industries provide the bridge between creativity and production across a range of manufacturing and service sectors, and can contribute to urban regeneration (Evans, 2009). Emerging sectors such as autonomous vehicles, for example, will draw heavily on the combination of digital and creative inputs. Craft sectors – including activities such as cuisine and artisan food and drink manufacture – can also stimulate tourism and support leisure and place-based development (Alonso, Sakellarios and Bressan, 2017).

Box 3.4. **The Irish IPOready programme**

IPOready is a publicly funded programme run by the Irish Stock Exchange with the aim to equip firms with substantial growth potential with the skills needed for raising strategic finance, becoming investor-ready, and attracting investment from domestic and foreign shareholders. The fist cohort of nine companies graduated from the programme in 2016 and have collectively raised around EUR 130 million in funding and plan to create around 625 new jobs.

The programme provides around 150 hours of financial education over 15 months, provided by experts in corporate finance, the law, accounting and tax. Crucially, firms are also provided with a mentor with significant fundraising experience to help firms develop their equity pitch and identify the most appropriate investors. Companies are eligible for the programme if they have annual revenues greater than EUR 5 million, have a track record of growth and the potential to scale further, and are prepared to commit two senior executives to the full programme.

IPOready builds on a scheme design involving a combination of education, peer learning and mentoring successfully used by Enterprise Ireland in other business and management development programmes such as “Innovation 4 Growth”.

Other evidence suggests that creative jobs are also less easily automated. One recent report from the United Kingdom, for example, suggested that 87% of creative workers are at low or no risk from automation, compared with 40% of all jobs in the United Kingdom. Creative occupations may also provide higher than average levels of job satisfaction and happiness, although this is balanced by higher levels of anxiety and issues around the potential exploitation of self-employed creatives (Bakhshi and Windsor, 2015).

The creative industries themselves are only one element – perhaps less than half – of the broader creative economy. The creative economy also includes those creatives working in other sectors, such as industrial designers in the automotive or textiles sector. Comparable estimates of employment in the creative economy are given in Table 3.5. In 2011-13, around 5.9% of employment in Austria was accounted for by creative industries, significantly below the 9.8% in Sweden and 9.0% in Finland. In terms of employment, this difference is significant, matching Sweden in terms of creative industries employment would add around 130 000 jobs in the creative industries. Levels of creative employment embedded in other sectors were, however, more comparable, at around 2.8% of the workforce in non-creative industries (Fleischmann and Daniel, 2015). Interestingly in this regard, Austria had a higher level of “embedded” creatives than those working directly in the creative industries, with the potential to generate strong indirect benefits. This is a similar pattern to that in France and Germany, but differs from that in Finland, Sweden and the United Kingdom (Table 3.5).

Table 3.5. **Benchmarking creative employment, 2011-13**

	Creative industries		Non-creative industries		Total		Creative industries share (%)	Creatives in non-creative industries share (%)
	Creatives	Others	Creatives	Others	Creatives	Others		
Austria	86	145	107	3 818	193	3 963	5.9	2.8
Sweden	164	248	142	4 078	306	4 326	9.8	3.5
Finland	89	113	62	2 185	151	2 298	9.0	2.8
Netherlands	190	377	187	6 806	377	7 183	8.1	2.7
Germany	806	1 450	851	37 034	1657	38 484	6.0	2.3
Belgium	38	68	124	4 284	162	4 352	2.4	2.9

Source: Nathan, M., A. Pratt and A. Rincon-Aznar (2015), "Creative economy employment in the EU and UK: A comparative analysis", https://media.nesta.org.uk/documents/creative_economy_employment_in_the_uk_and_the_eu_v8.pdf.

Over more recent years, the creative industries in Austria have grown significantly. From 2012 to 2014, export sales rose 5.7% annually (compared to 4.4% annually for Austria overall) and value added increased 8.5% annually (compared to 1.3% annually for Austria overall) (KAT, 2017). No more recent information is available on the number of embedded creatives or how this number may have changed in recent years.

Chapain et al. (2010) suggest that creative industries have strong complementarities with other sectors. Advertising and software firms, for example, are often co-located with high-tech manufacturing and knowledge-intensive business services. The mechanisms through which these complementarities arise are often complex, but may reflect value chain links, knowledge spillovers, shared infrastructures or the movement of creatives across employers. Key policy initiatives relate to both supporting entrepreneurship in the creative industries and enabling and supporting collaboration between the creative industries and other sectors (Chapain et al., 2010).

There is a track record of policy support for the creative industries in Austria. In 2008, the Austrian Federal Ministry of Science, Research and Economy initiated the "Evolve" programme to promote innovation in and by means of the creative sector. In the 2011 Austrian RTI Strategy, there was an indication of intent to "expand upon the Austrian economy's strengths … [including] stronger exploitation of the potential of creative industries" (p. 26). A Creative Industries Strategy was ultimately published in 2016, following a period of stakeholder consultation. This outlined a range of activities designed to strengthen:

- Austria's innovation system by supporting other strategic initiatives
- the competitiveness of the creative industries
- the "creative industries transformative effect on other economic sectors"
- Austria's international image as a country of culture and innovation.

The vision outlined for 2025 was for "the creative industries to enjoy high esteem in Austria", with ideal conditions for dynamic, knowledge-based entrepreneurship making "Austria one of the best places in Europe for creative enterprise" (Federal Ministry of Science Research and Economy, 2016: 11). The potential contribution of the creative industries to broad-based innovation, and the intent of the 2011 RTI Strategy and the 2016

Creative Industries Strategy to strengthen policy support for creativity, may be limited, however, by the current scale of public support for implementing the Creative Industries Strategy – around EUR 8 million annually over the period 2016-20 (Federal Ministry of Science Research and Economy, 2016: 25).

Austria already has some well-functioning and effective support measures targeted at creative industries and supporting links between these industries and other sectors. The Creative Industries Voucher is an example. This scheme was recently evaluated, with the evaluation suggesting that "the measure has a stimulating and supporting effect on the creative industries in conjunction with service providers … the programme has comparatively high additionality … [and] that the Creative Industries Voucher is in a position to sustainably encourage SMEs to use creative industries-related services" (Volante Research, 2014). However, in 2013, of 934 applications, 611 were approved, while in 2014 of 2 042 applications only 612 were funded (based on a random allocation). This reflects the limited budget for the scheme during 2014 and the scope for expansion.[15]

Alongside scalable policy instruments such as the Creative Industry Voucher, Austria also has a creative community that is ambitious to develop the sector. This is evident from the strong bottom-up engagement in the development of the 2016 Creative Industries Strategy. The result is a wide-ranging and potentially impactful strategy directly supporting creative industries as well as embedded creatives. This strategy provides a strong basis on which to build, with the key question relating to the availability of finance. International comparisons of levels of public or private investment in creative industries or the creative economy are limited due to institutional differences and differences in policy approaches. Some illustrative examples are, however:

- "Creative State, Victoria's Creative Industries Strategy" developed by the state government in Victoria, Australia (population: 5.8 million) for the period 2016-20 has a budget of AUD 115 million over four years, equivalent to around EUR 73 million, and is in addition to federal spend on the creative industries.[16]
- Scotland's creative industries lead agency "Creative Scotland" had a budget of GBP 33.6 million in 2015-16 for informing and supporting the work of creative industries and delivering its Creative Industries Strategy.[17]
- The Dutch Cultural Industries Fund aims to support design practice and has an annual budget of around EUR 15 million that is used to provide development grants for practitioners and firms in the disciplines of architecture, design, fashion, games and digital storytelling.[18]

None of these examples is directly comparable with the Austrian situation, but in each case budgets are significantly larger than that available for supporting the Creative Industries Strategy in Austria. Austria could benefit from systematic evaluation of the current support measures with a view to identifying activities with high direct and indirect economic returns that might in future be expanded.

The policy mix in support of business R&D and innovation – Assessment and future needs

The current policy mix in support of business R&D in Austria is well designed to support further growth in business R&D expenditure. The Research Premium provides a co-funding incentive to all firms performing R&D. The increase of the subsidy rate to 14% in 2018 will provide additional stimulus. The FFG programmes largely respond to the demand from firms for co-funding R&D projects and can therefore leverage private R&D efforts. The programmes supporting industry-science co-operation (including COMET and the Christian Doppler Laboratories) provide further incentives to firms for undertaking additional collaborative R&D.

Austria's extensive and generous R&D support system raises issues of appropriateness, particularly in view of the Austrian government's objective of driving Austria into the group of innovation leaders. On the one hand, crowding-out of private R&D investment by public investment may become a more significant issue as levels of R&D subsidy rise. Problematic questions of subsidy dependence might also arise (Brüggemann and Proeger, 2017; Becker, 2015). On the other hand, becoming an innovation leader requires more than just higher levels of R&D. R&D capacities must be transformed into more innovation, stronger market positions and growth. In addition, in businesses, R&D should aim for excellence, and needs to be translated into impacts. Achieving higher impacts from R&D is usually linked to more ambitious and path-breaking innovation, addressing new topics and technology trends (particularly those related to emerging societal challenges), entering new business areas and newly emerging sectors and markets, and better harnessing the impulses for innovation coming from science. This requires adaptation of the policy mix (OECD, 2010). To achieve a well-adapted policy mix requires high-quality evaluation evidence based on robust assessments and comparisons of Austria's major science and technology funding instruments – using qualitative and quantitative evidence (with evaluators having access to data in ways that conform to international best practice).

The Austrian R&D funding system has been responding to the challenges associated with becoming an innovation leader through changes in its policy mix. In recent years, new thematic programmes and initiatives have been launched, and existing programmes have been adapted to better support more ambitious types of innovation. The FFG, for example, introduced additional funding elements to its basic programmes (e.g. Frontrunner, early-stage projects and the Start Programme), along with several new thematic programmes and programmes fostering industry-science links (e.g. COIN and the COMET Projects initiative). Hence, the Basic programme has significantly evolved while some overlaps with the Research Premium may still exist. The *aws* also extended its funding programmes for innovative start-ups (e.g. AplusB scale-up).

Austria has also strengthened the thematic programmes of the FFG in recent years, following a trend across OECD countries to develop structured or issue-driven (often collaborative) R&D programmes, for instance around new markets (such as personalised medicine or autonomous vehicles) and societal challenges (such as the aging population or low-carbon growth). Trends at the EU level also seem to be shifting towards supporting R&D and innovation which is more "mission driven" (High Level Group, 2017). The recent "Lamy report", for example, while supporting the prioritisation of public investment in R&D programmes and the simplification of R&D support structures, also recommends that the EU "Adopt a mission-oriented, impact-focused approach to address global challenges" (High Level Group, 2017). The same report suggests that countries should act to "set research and innovation missions that address global challenges and mobilise researchers, innovators and other stakeholders to realise them."

The changes made to the Austrian policy mix in support of business R&D are important for progressing towards innovation leadership. To succeed, however, additional efforts are needed. The development of a new RTI Strategy 2020+ is an excellent opportunity in this respect. A key issue in the redesign of the policy mix is the role of the Research Premium. This instrument has become by far the most important instrument of public funding of business R&D. As previously discussed, there is limited evidence on its effectiveness (see

Box 3.1). A sound evaluation of the scheme could help to identify areas of high effectiveness (e.g. in terms of whether recipients are small, young or start-up firms, or possess other characteristics) and adapt the instrument accordingly. Most countries operating R&D tax incentives apply a differentiated approach. That is, they differentiate the tax subsidy rate by company size or by type of R&D performed and use ceilings or thresholds to ensure an efficient use of public money and maintain a balanced policy mix.

While an adapted, sustainable tax incentive scheme will remain an important element of a sound overall policy mix, there should be sufficient room provided in the policy mix to respond to new needs that arise along Austria's path to becoming an innovation leader and cannot simply solved with a tax credit. There is no one-size-fits-all solution. Changes in the policy mix should include:

- Strengthening structured or issue-driven collaborative programmes, for instance around new markets (such as personalised medicine or autonomous vehicles), societal challenges (such as the aging population and low-carbon growth), and transitions (such as in advanced manufacturing and digitalisation).
- Expanding existing thematic programmes to cover all steps relevant for developing, implementing and exploiting new technologies, including infrastructure, regulation and collaboration. With respect to deploying new production technologies, the section which deals with Industry 4.0 below describes issues to be considered in such a comprehensive approach.
- Linking funding programmes to a broader strategy, and developing missions for certain thematic areas to guide private R&D towards the attainment of societal goals. Joining resources to achieve critical mass (which is particularly important for a small country with limited resources in each thematic area) and to make Austria more attractive for international co-operation (both within the EU and beyond).
- Advancing industry-science linkages towards a better and faster uptake of new scientific findings for industrial innovation by setting joint research agendas, experimenting with new institutional arrangements to link university research and industrial R&D, and linking collaborative research internationally (and also beyond EU projects). Indicators of transfer activities of universities and public research institutes can be used to provide additional incentives for joint activities with businesses (see Chapter 4).
- Promoting new innovative firms in new sectors and markets by offering more early-stage equity financing (through tax incentives, mobilising pension funds and expanded funds-of-funds activities), supporting management and leadership for high-growth businesses, and strengthening investment readiness.
- Enlarging the scope of innovation support beyond R&D-based programmes, particularly by capitalising on creativity and the innovative potential of the creative industries.
- Better co-ordinating individual programmes to leveraging the synergies among programmes of different agencies (see Chapter 5).

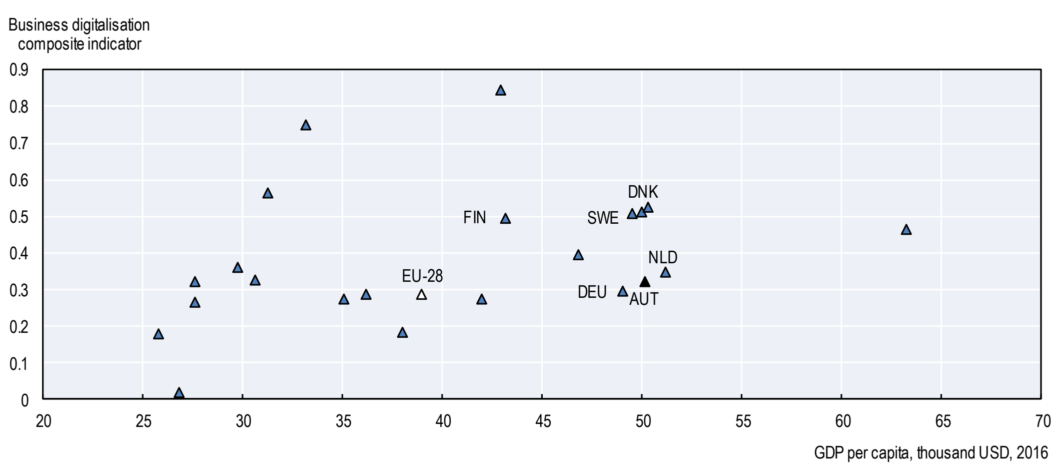
Industry 4.0 and its future development in Austria

An overview of Industry 4.0 in Austria

At around 19%, Austria has a relatively high share of manufacturing in GDP, much higher than in the United Kingdom (10%) or in the Netherlands (12%), and more similar to its neighbours Switzerland (18%) and Germany (23%). Developments in manufacturing are thus of particular importance for Austria and are also, as a consequence, a major theme in Austrian innovation policy.

The term "Industry 4.0", or the fourth industrial revolution, refers to the use in industrial production of recent, and often interconnected, digital technologies that enable new and more efficient processes, and which in some cases yield new goods and services. The associated technologies are many, from developments in machine learning and data science, which permit increasingly autonomous and intelligent systems, to low-cost sensors, which underpin the Internet of Things (IoT), to new control devices that make second-generation industrial robotics possible. The term "Industry 4.0" is not a precise technical concept. Rather, it is a generic description of a shifting category of technological possibilities. One implication of this non-specificity is that an assessment of progress in Industry 4.0 in Austria – or other countries – must be accompanied by caveats on metrics. Measurement on a single parameter, such as the use of robots, or artificial intelligence (AI), may vary in importance across sectors, and only illustrate one part of a multi-faceted phenomenon. Overall, measures of the diffusion of digital technologies suggest that the Austrian business sector stands in an intermediate position relative to other OECD countries (Figure 3.10).

Figure 3.10. **Business sector digitalisation**



Notes: The business sector digitalisation indicator is computed as the average percentage share of enterprises: 1) selling on line at least 1% of their turnover; 2) connecting to the Internet via a mobile broadband; 3) buying cloud computing services over the Internet; and 4) exchanging electronic messages with public authorities. It is normalised between 0 (less) and 1 (more digitalisation).

Sources: European Commission, Digital Economy and Society Index (DESI) 2017, https://ec.europa.eu/digital-single-market/en/desi; OECD (2018f), *National Accounts* (database), https://stats.oecd.org/Index.aspx?DataSetCode=NAAG.

StatLink https://doi.org/10.1787/888933882598

Developing and adopting new production technologies is a key to raising living standards and countering the declining labour productivity growth seen in many OECD countries over recent decades.[19] Rapid population ageing – the dependency ratio in OECD countries is set to double over the next 35 years – makes raising labour productivity more urgent. In addition, the high tradability of manufactured goods adds to the importance of successfully adopting new generations of industrial technology.

Many aspects of the policy context for Industry 4.0 in Austria are positive. For instance, the government has given full recognition to the importance of digitalisation. Through a variety of channels, information on Industry 4.0 is widely available to Austrian firms (a 2015 survey in 5 branches of industry – albeit of just 100 firms – found a high level of awareness of the importance of digital technologies to a variety of business functions [PwC, 2015]). Public events on Industry 4.0 targeted to the business community are frequent. Major activities on Industry 4.0 are underway at various universities, applied universities and public research organisations.[20] The Association Industry 4.0 Austria has been established, with a significant programme of activities and online presence.[21] Broadband coverage is high and policy makers are moving to introduce 5G. In addition, robot sales are growing fast. The remainder of this chapter focuses on strategic opportunities and on policies which may require additional attention in future.

Expanding capabilities in key areas of Industry 4.0

Austria could expand its capabilities in key areas of Industry 4.0. The suggestion in this study is to do so by significantly strengthening universities in the strategically important fields of AI, big data analytics and their applications in production.

In terms of public support, most funding related to Industry 4.0 currently comes from the "Basisprogramme" of the FFG. Industry 4.0 related centres are also being set up as part of the COMET system. Both systems of funding allocation will likely result in a distribution of resources that reflects current capabilities, rather than strategic opportunities. This could represent a limitation for Austria, and is exacerbated by constraints stemming from Austria's relatively small size. In part because of the country's small size, in some subject areas only a few professors have international renown (even though excellent academics work in such fields as industrial engineering, informatics, mechatronics and bio-technology). The ability to perform internationally relevant research in some important fields is limited. These observations partly explain why a widespread view exists among many Austrian experts that government support for Industry 4.0 is often too fragmented, lacks critical mass and budgets, and operates over time horizons which are too short.

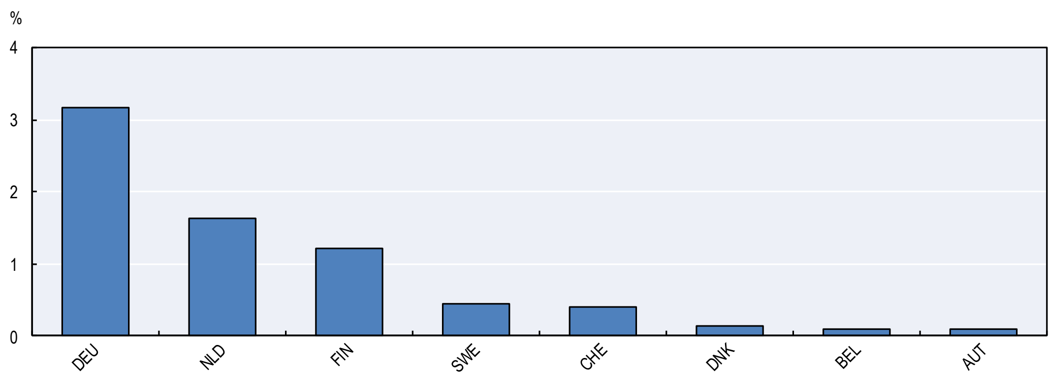
Benefit could be had by greater concentration of research support on subjects in which leading professors are working, or in a few fields which will matter for production in the long run. For a variety of reasons, it is proposed here that policy seeks a major strengthening of universities in the fields of AI, and big data analytics, including complex systems, with a focus on applications in production.

AI is the ability of machines and systems to acquire and apply knowledge and carry out intelligent behaviour. Intelligent systems have been used in industry for over 30 years. However, recent increases in computational power, new statistical methods and advances in data creation have brought breakthroughs in AI, and related transformations in industrial products and processes. For instance, manufacturers often need to develop new materials to upgrade products, and AI is being used to explore decades of experimental data to radically shorten development times (Chen, 2017). AI is also creating new semiconductor designs. It is helping robots adapt to new working environments without reprogramming. AI-enabled robots will become increasingly central to logistics. And sectors likely to experience AI-based transformations in production include agriculture, chemicals, oil and coal, rubber and plastics, footwear and textiles, transport, construction, defence, surveillance and security (ESPAS, 2015).

AI will also be deployed in many services, including medicine, marketing and finance. Furthermore, AI is starting to become a source of new scientific knowledge, and helping to augment research productivity. Among many other applications, AI is tackling computational problems in genetics, analysing medical imagery, and helping discover the rules of chemical synthesis (Science, 2017). And forms of AI that recognise human facial expressions and emotions will help deliver public services. The range of AI's applications will grow as companies like Data Robot, and others, work to automate the machine learning process, so that businesses, scientists and other users can more readily employ this technology.[22]

Austria has core industrial competencies in fields such as autonomous car control systems, mechatronics and embedded systems, with pockets of research excellence at certain faculties and in institutions such as the Academy of Sciences and the IST. Support in these areas should be continued. At present, production of AI-related patents, at least among major Austria-based R&D performing firms, is relatively low when compared to innovation-leading countries (Figure 3.11).

Figure 3.11. **Artificial intelligence patents by top R&D companies, by headquarters' location, 2012-14**



Source: OECD (2017c), *OECD Science, Technology and Industry Scoreboard 2017: The Digital Transformation*, https://doi.org/10.1787/9789264268821-en.

StatLink https://doi.org/10.1787/888933882617

Nevertheless, developing lasting strengths in AI and big data, and their links to production, offers particular benefits. AI has the potential to raise productivity in industry and in services (Nolan, 2018). This is a pressing challenge as Austria's population ages. Successful application of AI in industry will help in meeting the productivity challenge and maintaining industrial capacity in Austria in the face of increasingly stiff global competition in manufacturing. AI is also a general purpose technology, which means that competencies developed in this area will spill across the entire economy. Evidence suggests that an eventual increase in AI-related skills will not only help companies adopt AI, it will also help them to conceive new information-intensive business processes that lever AI. In addition, developing internationally recognised excellence in using AI in production will likely attract talented students (who also might otherwise be drawn to using AI for less socially constructive purposes). In addition, AI is unlikely to be superseded by other technological developments: the future will only require better AIs, not something entirely different.

The strategic allocation of resources needed to pursue an AI-focused strategic objective could be channelled through an existing instrument, namely the Federal Ministry for Transport, Innovation and Technology's programme of Stiftungsprofessuren (endowed professorships). Eight such professorships have been contracted to date, with six professors appointed as of November 2018. Universities should receive the new professorships, because the universities award doctorates. Doctoral degrees are essential because of the technical sophistication of the field and because it is important to develop new generations of researchers and teachers in this area.

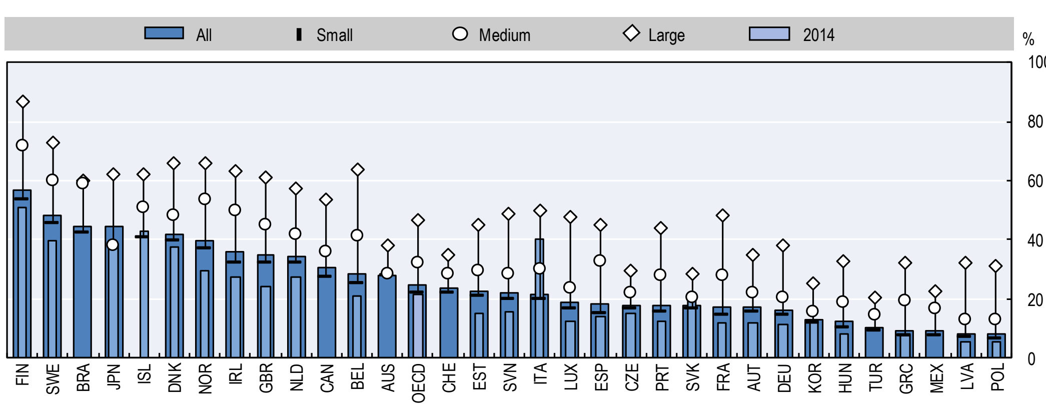
Activities to strengthen Austria's research capacities in AI, and its applications in production, should include initiatives to enhance data sharing for AI (see also below). For example, the United Kingdom's Digital Catapult operates the Pit Stop open-innovation activity. Pit Stop brings together large businesses, academic researchers and start-ups in collaborative problem-solving challenges around data and digital technologies. Also in the United Kingdom, the Turing Institute operates the Data Study Group, to which major private and public sector organisations bring data-science problems for analysis. Institute researchers are thereby able to work on real-world problems using industry datasets, while businesses have their problems solved and learn about the value of their data.

Creating an international focus of excellence in research and teaching on AI and big data analysis for industry is a medium-term endeavour. Policy must be patient as experts are recruited and programmes of research and training established. But given the rapid pace of development in AI, and the large private and public investments in this field being undertaken elsewhere in the world, combined with the possible "winner takes all" features of this technology, action should occur sooner rather than later. Austria should also synchronise with EU-wide programmes and co-operation in this field.

Trust in cloud computing

In 2016 only 17% of Austrian firms used cloud computing (Figure 3.12). In the manufacturing sector, this rate was around 20% (Figure 3.13). By comparison, in Finland – the country with the highest incidence of cloud use in manufacturing in the OECD – the rate was 69%. The share of non-financial firms in Austria that use cloud computing for advanced applications – employing large accounting, management and marketing software – is below the EU28 average. Evidence is not available of the economic impacts to date of Austria's cloud-related deficits, but for various reasons these shortfalls are a concern.

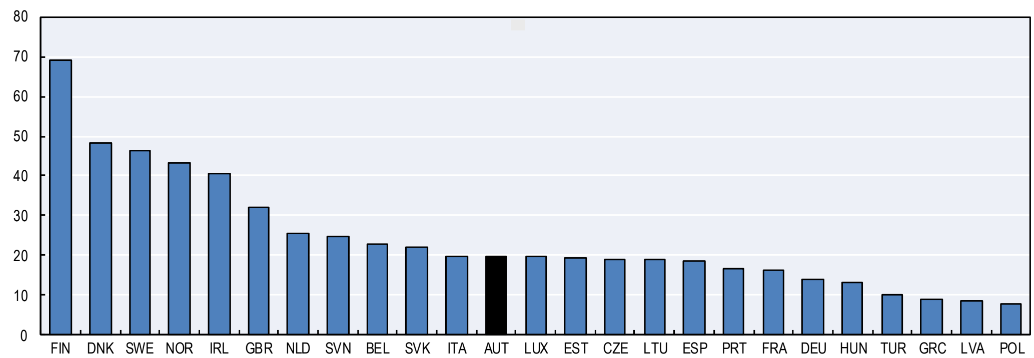
Figure 3.12. **Enterprises using cloud computing services, by firm size, 2016**



Source: OECD (2017c), *OECD Science, Technology and Industry Scoreboard 2017: The Digital Transformation*, https://doi.org/10.1787/9789264268821-en.

StatLink https://doi.org/10.1787/888933882636

Figure 3.13. **Percentage of manufacturing businesses purchasing cloud-computing services, 2017 or latest available year**



Source: OECD (2018d), *ICT Access and Usage by Businesses* (database), http://oe.cd/bus (accessed in February 2018).

StatLink https://doi.org/10.1787/888933882655

Cloud computing can bring sizeable efficiency gains for firms. European Commission (2012) reports survey data indicating that 97% of cloud users had made savings (typically in the range 10-20% of their IT cost). A little more than a third (36%) of cloud users saw savings of 20% or more. Energy savings from cloud computing can also be significant. Other benefits are also possible, such as more effective mobile working, and an increased ability to enter new business areas and locations. Greater understanding of how to use different types of cloud service will also affect the cloud's impact (Harris, 2015). Industry 4.0 will require increased data sharing across sites and company boundaries. For example, BMW has a goal of knowing the real-time status of all important items of production equipment at every company that produces key components for its vehicles (Ezell, 2018). The performance of cloud technologies will also improve. Consequently, machine data and data analytics, and even monitoring and control systems, will increasingly be situated in the cloud. The cloud will also enable independent AI projects to start small, and scale up and down as required. Indeed, Google's chief AI scientist, Fei-Fei Li, has argued that cloud computing will democratise AI.[23]

In considering cloud use, many business representatives in Austria cite fears over data security and uncertainty in placing data in extra-territorial servers. While such concerns are real, it should also be borne in mind that many high-profile failures in data security – the recent hacking, for instance, of Sony and TalkTalk – took place on hosted, onsite servers. In fact, an advantage of cloud use, especially for SMEs, is the increased data security it can bring. For example, Amazon Web Services, a market leader, reportedly provides more than 1 800 security controls, affording a level of data security beyond that which most firms could provide themselves. Indeed, customers of some cloud-computing companies can retain the keys used to encrypt data before it is uploaded, preventing third parties (and the cloud companies themselves) from access to the data (Castro and McQuinn, 2016). Provided that users understand the terms of service and security practices of service providers, cloud computing should improve security overall. Trust in the cloud might also rise if companies such as Kapsch, Telecom Austria and others invest in an Austria-based cloud. It is understood that these companies are currently building data centres in Austria.

The Austrian government could seek to increase trust in the cloud and stimulate cloud adoption. Steps might be taken, for instance, to expand the availability of information tailored to SMEs that need to understand the technical and legal implications of cloud service contracts. This could include providing information on the scope and content of certification schemes relevant for cloud computing customers. Innovative proposals for certification might also be explored. Prüfer (2014), for example, proposes a scheme built around a non-profit organisation, governed by representatives of cloud service providers and customers, which would source auditing and certification tasks to independent certifiers. Lessons might also be learnt from the "Mittelstand-Digital" initiative of the German Federal Ministry of Economic Affairs and Energy. This initiative sought to demonstrate the importance of digital technologies – including cloud computing – for SMEs and craft businesses.

Data supply and use

Advances in data generation and analysis open new possibilities for innovation and research. In the United States, for example, output and productivity in firms that adopt data-driven decision making are 5-6% higher than in other firms with similar investments in information and communication technology (ICT) (Brynjolfsson, Hitt and Kim, 2011). Data-intensive applications of AI are enabling research in new and productivity-enhancing ways, from analysis of large databases to hypothesis generation, comprehension and exploration of scientific literature, and facilitating data gathering and experimentation. In this context, it is unlikely that Austria, or any other country, could consistently lead in global innovation without a world-class data ecosystem.

Several data-related activities and initiatives exist in Austria. These include the Digital Roadmap for Austria,[24] open data activities (at data.gv.at), the Open Data Portal Austria (ODP)[25] and the Data Market Austria.[26] Existing initiatives align with the European Digital Agenda and the Strategy for the Digital Single Market. However, as a recent review indicated, initiatives for data use at local, national and international levels are not well integrated with each other and are at early stages of development (Fenández et al., 2016). Various observations suggest that further progress on the data economy in Austria would be helpful:

- In both government and business, consultation with practitioners suggests little active rollout of AI solutions, beyond proof-of-concept. Practitioners familiar with a wide spectrum of Austrian firms indicate that big data analytics is often treated as an add-on, handled by firms' chief information officers rather than chief technology officers or chief executive officers. Emphasis is often placed on digitalising existing processes, rather than creating new or improved digitally enabled processes and business models.
- Many practitioners indicate an overall lack of awareness of the economic importance of data across Austrian industry, the research community and the public. This has been exacerbated by uncertainty linked to the EU's General Data Protection Regulation.
- In terms of measures to make government data available, Austria has one of the lowest scores in the OECD's 2017 Open-Useful-Reusable Government Data Index (but ranks higher on the parameters "data accessibility" and "government support for re-use").
- In part because of regulation, opportunities for data-centred value creation in both the private and public sectors are often missed. For instance, ASFiNAG – the publicly owned corporation which plans, finances, builds, maintains and collects tolls for the Austrian autobahns – has to delete data within 24 hours. Medical competence centres in Salzburg, Graz, Innsbruck and Vienna collect research data.

However, privacy regulations preclude data collaboration with other centres of expertise in places such as Heidelberg and Zurich. Only around 29% of health general practitioners in Austria share data electronically with other healthcare provers and professionals, compared to 92% in Denmark (Wallace and Castro, 2017). The Austrian administration has a well-developed system of registries. However, access to registry data and administrative data for researchers is difficult and unsystematic.[27] Moreover, local authorities are even limited in developing data-based projects to profile tourists, hindering the development of more efficient ways of marketing Austria as a tourist destination.

- Interviewees consulted for this review often reported that data hubs are not yet working well. In addition, companies that are publicly owned, if obligated to provide data, have no incentive to provide data in a useable format and of adequate quality. It is reported that government data often sit in separate silos.
- Persons with the requisite data science skills can be hard to find (Berger et al., 2014) (this, of course, is not a challenge unique to Austria, with demand for data science and machine learning skills outstripping supply in most countries). Austria ranked seventh in Europe in a recent index of the data skills of the workforce.[28] In addition, the first dedicated university programmes began in 2015-16. However, while there are significant numbers of software programmers, data scientists – i.e. persons who can think in abstract ways, with knowledge in maths and physics, which can be translated into industry – are far fewer.

A number of steps may be considered:

- The availability of government data could be increased. The UK government makes around 45 000 databases publicly available. However, a key is to expand the availability of data that are useful and usable (a goal which is not measured simply in terms of the number of databases available). Various approaches are possible. For instance, data.gov.uk (the United Kingdom's central open data portal) allows users to request the opening of data that are not yet available for public access. Having an option for online data requests can also provide governments with helpful information on potential data uses and users (research, business, personal, etc.), and the benefits users expect from data access and reuse. Australia has even added a "voting" approach for data requests through its national open data portals. Members of the public can view previous data requests, which must receive a threshold number of votes from other users in order to be processed by government agencies. In Mexico, Open Data 100 – the Mexican chapter of Open Data 500, an international network of organisations that seek to study the use and impact of open data – seeks to map post-disclosure open data causality (from publication on the central portal to its reuse by private organisations, and the broader creation of economic value). The mapping helped identify 100 companies using open government data for business purposes (OECD, 2016). Austrian authorities might also consider monitoring the creation and use of apps that build on government data.
- The Austrian authorities might consider encouraging the development of a network of open data app developers.
- Austria might replicate the approach taken in the United States, in April 2016, when a bipartisan bill was introduced to Congress which would make public sector information open by default.

- Austria might replicate the experience from a number of countries, which suggests the value of having a national strategy or plan for open data. Such a strategy can guide the goals and actions on open data of national and local authorities.
- The public sector could also use platforms that it encourages the private sector to use, such as Data Market Austria. This would help encourage trust.
- For firms and individuals, access to legal advisory services might be created to help increase knowledge of legal issues that can arise when using some types of data, from matters of license clearance to data protection, product liability and consumer protection (Fenández et al., 2016).
- Given Austria's historical strengths in fields such mathematics, physics and aspects of computer science, improvement in knowledge transfer from universities to companies would also be beneficial (Fenández et al., 2016).
- Educational initiatives in the data economy could begin at secondary level. At the UAS level, in Vienna and Krems, a number of courses address data science. The Technical University in Graz also has initiatives. But scope exists to integrate studies of data science and the data economy much earlier in the education system.
- Specific initiatives can also be organised to help develop and share training data for AI. Many firms hold valuable data that they do not use effectively (whether because of a lack of in-house skills and knowledge, a lack of a corporate data strategy, a lack of data infrastructure, or other reasons). To help address this mismatch, governments can act as catalysts and honest brokers for data partnerships. Among other measures, they could work with relevant stakeholders to develop voluntary model agreements for trusted data sharing. For example, the US Department of Transportation has prepared the draft "Guiding Principles on Data Exchanges to Accelerate Safe Deployment of Automated Vehicles".

Preparing for other data challenges on the horizon

At present, the General Data Protection Regulation protects only personal data. But protection of machine-generated data is likely to be a growing issue as Industry 4.0 advances. This is because sensor technologies are developing rapidly, with sensors becoming ubiquitous, increasingly linked to embedded computation and streaming large volumes of often-critical machine data. A single machine may contain many parts made by different manufacturers, each equipped with sensors that capture, compute and transmit data. These developments raise many legal and regulatory issues. For instance, are special provisions needed to protect data in value chain networks from access by third parties? Which legal entities should have ownership rights of machine-generated data and under what conditions? What rights to ownership of valuable data should pertain in circumstances of business insolvency? In addition, might novel liability rules be needed in cases where data-driven systems cause harm?

On 10 January 2017, the European Commission issued a Communication concerning the building of a European data economy (European Commission, 2017c). The Communication highlighted a number of emerging questions around data ownership, including issues raised by machine-generated data. The Communication reflects the findings of an initial consultation, not a European Commission conclusion. An assessment of such issues in the Austrian context could be helpful because needs and priorities reflect the specifics of each country's laws and economic structure (as data-related problems and opportunities vary across sectors). A comprehensive review would also signal Austria's intent to develop a leading digital ecosystem.

High-performance computing for firms and awareness of potential high-performance computing applications

Increasing firms' access to high-performance computing (HPC) and raising business' awareness of potential HPC applications are steps that could help future-proof the digital eco-system needed for Industry 4.0. HPC is increasingly important for firms in industries ranging from construction to pharmaceuticals, semiconductors, the automotive sector and aerospace. Airbus, for instance, owns 3 of the 500 fastest supercomputers in the world. Two-thirds of US-based companies that use HPC say that: "increasing performance of computational models is a matter of competitive survival" (Council on Competitiveness, 2014). The uses of HPC in manufacturing are also growing, going beyond applications such as design and simulation to include real-time control of complex production processes. A 2016 review of the contribution of HPC to competitiveness observed that "Making HPC accessible to all manufacturers in a country can be a tremendous differentiator, and no nation has cracked the puzzle yet" (Ezell and Atkinson, 2016). In addition, HPC is aiding the process of scientific discovery, with many prospective industrial applications.[29]

As Industry 4.0 progresses, demand for HPC will rise. However, like other digital technologies, the use of HPC in manufacturing falls short of its potential. One estimate is that while 8% of US firms with fewer than 100 employees use HPC, half of manufacturing SMEs could potentially use HPC for prototyping, testing and design (Ezell and Atkinson, 2016).

Austria's Vienna Scientific Cluster works to facilitate access to HPC for scientists. However, responses to the questionnaire carried out for the 2017 *OECD Science, Technology and Innovation Outlook* suggest that initiatives to enlarge access to HPC for firms are few. Firm-level evidence of deficits in access to HPC in Austria are not available. But it will be important to monitor this issue, and take action when necessary, because of HPC's growing criticality. Various international experiences exist which Austria could draw from. For example, the National Centre for Manufacturing Sciences has created a dozen centres throughout the United States (near to universities and national labs) to connect manufacturing firms with HPC resources. Different industries use HPC in different ways. Each company's HPC software requirements may be unique. Greater outreach to SMEs is frequently needed. Possible ways forward – a number of which are described in European Commission (2016) – are set out in Box 3.5.[30]

Technology diffusion

Austria should make technology diffusion an explicit policy priority. This effort should include off-the-shelf technologies, not just advanced technologies. Technology diffusion institutions should be stimulated to upgrade their current methods and to trial promising new approaches. Austria could consider the creation of an arrangement similar to the nationwide Manufacturing Extension Partnership (MEP) in the United States.

Most firms are technology users, not technology creators. However, for a variety of reasons, gaps can persist between actual and potential technology use. These gaps are often the greatest between SMEs and larger firms (in Europe, for example, 36% of surveyed companies with 50-249 employees use industrial robots, compared to 74% of companies with 1 000 or more employees (Fraunhofer, 2015). The Austrian economy has a relatively high share of SMEs.[31] Research indicates that a high share of SMEs and micro-firms in the business sector is likely to hinder technology diffusion. Indeed, the OECD's *Science, Technology and Industry Scoreboard 2015* suggests that SMEs in Austria are less innovative than large firms, especially in regard to innovations in marketing and organisation

(OECD, 2015a). More generally, the balance of evidence suggests that the diffusion of digital technologies in firms and households in Austria lags behind peer countries.

Box 3.5. **Getting supercomputing to industry: Possible policy actions**

- Raise awareness of industrial use cases, with quantification of their costs and benefits.
- Develop a one-stop source of high-performance computing (HPC) services and advice for small and medium-sized enterprises (SMEs) and other industrial users.
- Provide low-cost, or free, limited experimental use of HPC for SMEs, with a view to demonstrating the technical and commercial implications of the technology.
- Establish online software libraries/clearing houses to help disseminate innovative HPC software to a wider industrial base.
- Give incentives for HPC centres with long industrial experience, such as the Hartree Centre in the United Kingdom or TERATEC in France, to advise centres with less experience of industry.
- Modify eligibility criteria for HPC projects, which typically focus on peer review of scientific excellence, to include criteria of commercial impact.
- Engage academia and industry in the co-design of new hardware and software, as has been done in European projects such as Mont-Blanc (http://montblanc-project.eu).
- Include HPC in university science and engineering curricula.
- Explore opportunities for co-ordinating demand for commercially provided computing capacity.

Institutions for technology diffusion are intermediaries with structures and routines that facilitate firms' adoption and use of knowledge, methods and technical means. There are many different types of institutions that aim to accelerate diffusion and they can vary considerably in terms of their organisation and the services they provide. To help simplify analysis, OECD (2017b) developed a typology of publicly oriented technology diffusion mechanisms. The typology includes the following categories and their primary operational modalities:

- dedicated field services (which provide firms with diagnostics, guidance and mentoring)
- technology-oriented business services (which give advice linked with finance, as well as services for capacity development)
- applied technology centres (which provide contract research and applied collaborative research, prototyping and support with standards)
- targeted R&D centres (which perform advanced research on emerging technologies intertwined with commercialisation missions)
- knowledge exchange and demand-based instruments (providing technology community networking and knowledge transfer instruments such as innovation vouchers)

- open technology mechanisms (offering shared technology libraries and virtual networking).

Differences between these institutional types are not always clear-cut, as service offerings can be broad and changing. An overview of the landscape of Austria's diffusion institutions indicates that:

- There is no national dedicated field service intermediary (such as the United States' MEP programme).
- Some technology-oriented business services operate in Austria. Austria's ICT of the Future programme falls under this heading. This programme provides financial support to companies that explore new ICT research topics and their possible applications.[32] Many of Austria's technology-oriented business services target start-ups rather than established SMEs. For university spin-offs/start-ups, there is the "Academia plus Business" network (AplusB). Other incubator/start-up initiatives have recently been established.[33]
- Applied technology centres are a focus of diffusion efforts in Austria. In 2015, there were 61 legal non-profit service institutions providing R&D-services. Combined, these 61 institutions had 5 336 full-time employees and spent EUR 825 million on R&D. These institutions include the Austrian Institute of Technology (AIT), Joanneum Research, the Austrian Cooperative Research (ACR) – with its 18 institutes – and COMET centres such as the Linz Centre for Mechatronics.[34] Fraunhofer also operates in Austria (but with around 100 employees, compared to some 25 000 in Germany). Beginning in 2015, various pilot plants have also been created – such as the Pilot plant Industry 4.0 on the premises of the Graz University of Technology – where companies can research and test digital manufacturing innovations before they become a part of day-to-day production.
- A variety of knowledge exchange and demand-based mechanisms also exist. Cluster policy in Austria has a long track record.[35] A majority of the clusters work to mediate knowledge exchange and diffusion. Innovation vouchers are also widely used. For example, the FFG's Innovation Voucher aims to help SMEs begin research and innovation activity.[36] The Patent Voucher supports SMEs, start-ups and founders to check the patentability of their ideas and speed preparation and submission of patent applications.[37] In addition, the *aws* implements the Creative Economy Voucher, which facilitates co-operation between non-creative industries and creative industries.[38]
- As regards open technology mechanisms, the Platform Industry 4.0 fulfils some of the relevant criteria, particularly as regards networking. The Platform was established in 2015 in collaboration between BMVIT and social partner organisations (the Association for the Electrical and Electronics Industries, Association of Metal-Technology Industries, Austrian Federal Chamber of Labour, Austrian Trade Union for Production Workers, Federation of Austrian Industries) to use new technological developments and innovations in digitalisation in the best way for enterprises and employees and manage change in a socially responsible manner. The Platform also helps share information on standards and interfaces for Industry 4.0. However, it is not established as a repository of scientific information in the way that, for instance, the BioBricks foundation is (which serves in the United States as a registry of standard biological parts). Each category of institution merits separate assessment, which exceeds the scope of the current Review. Nevertheless, it is possible to make a number of overarching observations for policy.

Each category of institution merits separate assessment, which exceeds the scope of the current review. Nevertheless, it is possible to make a number of overarching observations for policy:

- For Industry 4.0, the goal of accelerating diffusion should be a visible priority. In the fast-moving environment of digital production technologies, the conventional market failure rationales for establishing institutions for diffusion are likely to strengthen. Potential users will need support to sift through burgeoning amounts of information and take decisions in a context of rapidly changing technologies and expertise requirements.[39] This accords with the frequent view in Austria that many SMEs are overwhelmed by fast-emerging technology choices. It is also consistent with some survey evidence that a barrier to business investment in Industry 4.0 technologies in Austria is inadequate understanding of – and difficulties in assessing – the economic returns of the possible investments (PWC, 2015).
- A predominant theme in Austria's diffusion institutions is the transfer of leading-edge technologies. There is less emphasis on deploying known methods to new users, although this occurs in some of Austria's institutions. International experience suggests that a large share of companies would benefit most from assistance in choosing and adopting off-the-shelf technologies, rather than advanced technologies. Indeed, many enterprises and users lack absorptive capabilities for highly sophisticated methods. Such cases warrant pragmatic approaches to technology diffusion, coupled with long-term relationships that can build capabilities for more advanced business strategies later on. This observation is consistent with evidence of relatively low demand for sophisticated digital technologies in many Austrian firms. The importance of helping to diffuse medium-level technologies is also consistent with survey findings in Austria, which reveal companies' concerns with relatively prosaic issues such as standards, norms, certification and data security (PWC, 2015).
- Technology diffusion institutions need realistic goals and time horizons. Introducing new ways to integrate and diffuse technology takes time, patience and experimentation. Evidence is not yet available to the OECD on typical funding time frames for Austria's various diffusion institutions. But funding cycles of around three to four years have been cited in some cases. This may be too short. Upgrading the ability of manufacturing communities to absorb new production technologies takes time (five to ten years or more). Accordingly, technology diffusion institutions need to be empowered and resourced to take longer term perspectives. Assumptions that diffusion institutions can become financially independent in, for example, five years, are problematic. Evaluation metrics should often emphasise longer run capability development.
- Ongoing review and analysis should be undertaken of organisational designs and models for technology diffusion. Given the primacy of the diffusion challenge, and the many institutions involved, more and better evaluation is appropriate. A 2015 evaluation of the COMET centres used case studies and a difference-in-difference assessment, comparing participants with non-participating firms in the same sector with similar levels of R&D (Dinges et al., 2015). Much use was made of monitoring data generated as part of the programme. Such a quantitative assessment should be more widespread. Placing evaluation data in the public realm, in anonymised form, could facilitate (cost-free) academic analysis and serve as a form of evaluation quality control (this approach has been used by the US Department of Labor, which has placed anonymised evaluation data of training programmes on its website). Indeed, a number of international experiences could provide models for what could

be a national platform on the evaluation of diffusion initiatives. For instance, in the United States, the Washington State Institute for Public Policy has, since the 1990s, been directed by the Washington state legislature to identify well-researched and evidence-based public policies that can, with a high degree of certainty, lead to better policy outcomes and a more efficient use of taxpayer dollars.[40] The institute is widely respected for its marshalling of evaluation evidence and the publication of benefit-cost results in a form designed to facilitate comparison across programmes. All of the above observations on evaluation highlight again the previously mentioned need to facilitate the use of micro-data for policy, and to expand open data approaches more generally.

- New diffusion initiatives are emerging internationally, some of which are still experimental. For example, the Mayfield Commission in the United Kingdom, and its proposals to create an app on best-practice technology use in different sectors, has already been referenced. With respect to test beds, some institutions (in France for example) have gone from working with individual companies to a situation where start-ups accompany such one-on-one projects, with a view to the start-ups possibly becoming manufacturers of the new technically validated technologies. New production technologies have also stimulated partnerships that cross sectoral boundaries and address problems of scaling up from research to production (Singer and Bonvillian, 2017). Assessment of these and other novel experiences should feed back into Austrian institutions.
- Pilot factories and demonstration facilities are particularly important, given the high share of SMEs in Austria's industrial structure. Pilot factories are also needed in the regions.
- Austria could examine the creation of an arrangement similar to the Manufacturing Extension Partnership in the United States. The MEP has a number of features that commend it to Austria's circumstances. Austria does not yet have a national dedicated field service intermediary. The MEP is a public-private partnership operating nationwide but with local flexibility, and in this sense aligns with Austria's regional character. The MEP programme has been thoroughly evaluated, showing it to provide positive economic returns to public funding. The MEP programme focuses on capacity building and raising technological capabilities in manufacturing SMEs, not just start-ups or high-tech firms. The national character of the programme also affords learning opportunities across regions, types of client firm and sector. This helps avoid replicating documented patterns of error in service design. It also helps to counter problems of small scale, which can arise when initiatives are primarily local.

Competence centres for excellent technologies

The competence centres for excellent technologies (COMET)[41] – launched in 2006 and funded since 2008, although based on initiatives running since 1998 – combine collaborative research with technology transfer and related training and development. In terms of annual budgets, the COMET programme is the largest funding scheme for knowledge and technology transfer in Austria. COMET has funded two types of centre as well as individual projects. K2 centres have been funded on an eight-year horizon around new and promising fields of technology seen as high risk. The Virtual Vehicle K2 centre in Graz is the largest, with 300-400 employees, and has been able to attract international funding and link to international networks. K1 centres have been funded for shorter funding periods and focus on R&D, which is closer to market. Now, for both types the funding period is 4+4 years. For both types of centre, about 50% of the budget is provided by the COMET programme and provincial sources. The remaining shares come from industry partners and scientific partners. COMET projects provide funding for collaborative R&D projects involving firms, universities, research institutes or COMET centres. For K1 centres, a special funding scheme called COMET Modul offers funding for high-risk research in new research areas. The COMET programme is very application-oriented overall. Since the first call of the programme in 2008, 22 centres (17 K1, 5 K2) have been established. In 2017, the centres had 1 641 full-time employees[42] and a combined budget of significantly more than EUR 100 million.[43] There is a great deal of variety among the centres; some are embedded in universities while others are more like companies.

The 2015 COMET impact assessment showed that the programme has been successful in creating new competencies. The programme has proved effective in achieving high-impact publications, innovation outcomes, qualification of young researchers and the establishment of long-term (international) partnerships and mutual trust (Dinges et al., 2015). The impact assessment also highlights some problematic issues with the existing K1 and K2 centres. While recognising the important contributions to innovation made by the centres, the report comments that the development of new approaches to innovation were limited, and that planned projects, which focused on developing new innovation practices, were not undertaken or were scaled back. K2 centres, while more visible at the international level, have not yielded radical innovations. A key to the impact of competence centres is the access to skilled human resources, but the COMET programme did not affect the *modus operandi* of universities (such as participation in projects of the European Institute of Innovation and Technology (EIT), or the development of new PhD programmes). Dinges et al. (2015) also note that while the COMET scheme was originally meant to be temporary, it has evolved into a systemic entity with declining marginal returns in terms of new co-operation.

The OECD understands that the division between the two centre types is about to end, following the results of the 2015 impact assessment showing that the scale of the different centres has not been associated with more or less research ambition or excellence. The programme line K2 will not be continued, and the COMET centres will operate in the manner of the current K1 programme line.

International comparisons suggest the success of the industry-led, co-operative research competence centre model and its contribution to R&D, innovation, skills and cluster growth. But effectively supporting scale-up businesses may require a different – more risk-tolerant – governance approach and a more entrepreneurial attitude to centre development. Dinges et al. (2015), drawing on the experience of competence centres across Europe, identify three governance approaches. The “management model”, under which centres are often industry- or cluster-driven, with the centre often virtual and contracting out research activity. Such centres may be most responsive to changing industry needs, but lack a critical mass of resources or a long-term horizon or objective. The second governance approach is the “host model”, in which centres are hosted by universities and where employees and ownership typically rest with the university. Here, academic goals may conflict with the needs of industry, making these centres less flexible. Finally, the authors identify “strong entity” governance models, such as those in Austria, where centres are independent legal entities and may be less flexible due to their legal structure and owned infrastructure. Such centres may also be more difficult to close due to the accumulation of physical infrastructure and contractual commitments to researchers.

The challenges of adopting Industry 4.0 technologies, and the disruptions of rapid technological change more generally, will require flexibility and a more entrepreneurial approach to technology transfer. As the 2015 evaluation comments, any redesign of the COMET programme should pay "particular attention … to ensure that the programme is able to provide new impulses for the economy, science and society" (Dinges et al., 2015: 8). This, it is argued, will require a greater openness to working with firms that are not shareholders in the centres, greater internationalisation and a stronger integration with the science community.

In this sense, a positive evolution is the development of COMET projects and COMET modules that provide a more flexible mechanism for collaborative innovation than the longer term K1 and K2 centres (only K1 centres can apply for COMET modules). In the 2015 impact assessment, it is also notable that K projects were rated more positively than the K centres by some participants. In the context of these developments, as the COMET projects mature, with the possibility of becoming a COMET centre, alternative governance structures could be considered. The development of centres built around the virtual "management model" of governance outlined earlier would help to maximise flexibility, ensure industry relevance and prevent the accumulation of long-term commitments which make exit more difficult. The lesser need for capital investment in such centres – which would make use of existing research capacities – would also reduce the tendency to focus collaboration on shareholder businesses and open up possibilities for wider engagement.

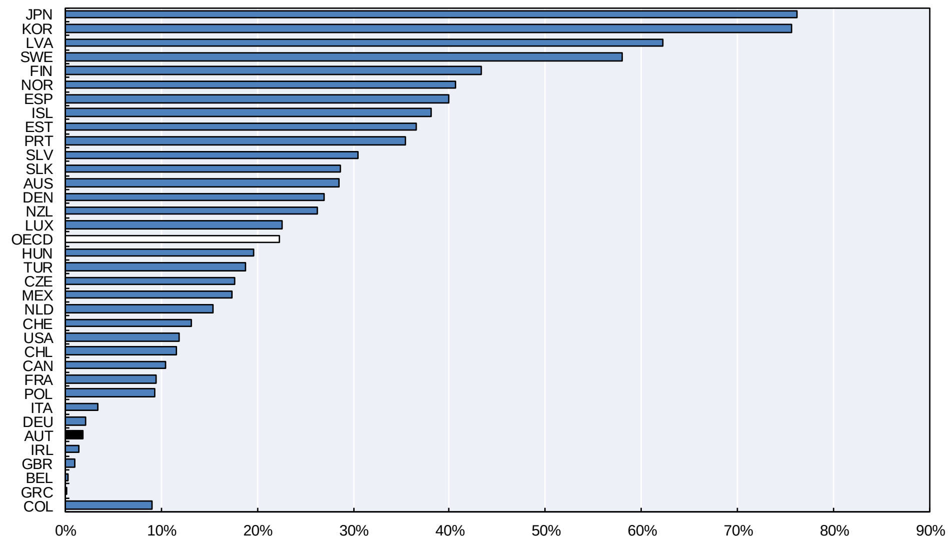
Undertaking collaborative research with SMEs is often difficult due to their limited financial and technical resources and absorptive capacity. Changing technological regimes mean, however, that scale-up enterprises bringing new technologies to market will be critical to the long-term competitiveness of the Austrian economy. Supporting continuous innovation in scale-up firms and helping them develop their internal innovation capabilities should be a key focus of the competence centres. Ideally, competence centres should have elements of SME engagement as part of their performance targets, recognising, however, that this outreach activity may require a different funding formula to mainstream project activity.

Broadband and the deployment of fibre-optic cable

Overall, broadband coverage in Austria is high: in 2016, around 98% of Austrian firms with less than ten employees had a broadband connection. However, by a number of measures, various broadband deficits affect Austrian firms. Rates of mobile broadband connectivity, at around 77% in 2015, are lower than in leading economies (this was the sixth highest rate among European countries in 2015). Only 10% of firms have fast broadband connectivity of at least 100 Mb/s. This is less than half the shares in Denmark, Finland, Lithuania and Sweden. The difference between connection rates in large and small firms is larger than in peer countries, which may mean that even larger gaps exist in micro firms (OECD, 2017d). In addition, in June 2017, the percentage of fibre connections in total broadband subscriptions, at just 1.8%, was one of the lowest in the OECD (Figure 3.14). Japan and Korea, by comparison, had fibre-based connection rates above 75%.

Fibre-optic connectivity has advantages over copper-cable based Internet. These advantages matter for Industry 4.0 and include: faster speed, with a current upper range of 100 Gbps; faster access to cloud-hosted information; greater reliability, signal strength and bandwidth; lower latency, which is important for many digitally controlled machines, as well as for collaboration among employees and for accommodating new technologies such as haptics (which permits a replicated remote sense of touch); improved security (because breaches of fibre-optic cable cause the signal to be lost); resistance to interference (stemming, for example, from proximity to machinery); and lower cost (for instance from avoiding slower or less reliable Internet connections). Moreover, 5G networks rely on fibre connectivity.

Figure 3.14. **Percentage of fibre connections in total broadband subscriptions, June 2017**



Source: OECD Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

StatLink https://doi.org/10.1787/888933882674

Austrian policy makers have established plans to address the broadband deficits. The "Digital Roadmap" aims to establish state-of-the-art broadband and mobile digital infrastructure, and to close the infrastructure gaps between urban and rural areas. In January 2017, the then government coalition parties agreed to double funds coming from private telecom operators for a EUR 1 billion scheme for comprehensive high-speed Internet coverage by 2020. Recent OECD *Economic Surveys of Austria* have called for more public investment in the fibre network (as foreseen in the Broadband Plan 2020) and more active policy to encourage competition among service providers (OECD, 2017d).

Austrian policy makers may wish to take account of recent OECD work on bridging broadband gaps in rural and remote areas, as well as policies being implemented among peer countries to expand access and uptake (because relatively low broadband use in firms likely reflects firms' own demand for advanced digital services) (OECD, 2018c). Among other issues, this recent work addresses technological developments that are likely to influence the provision of services in underserved areas, such as the delivery of broadband services through "white spaces", the gaps in radio spectrum that exist between digital terrestrial television channels.

5G networks

It will evidently be important for Austria to continue to expand the early preparations for 5G, bearing in mind a variety of regulatory challenges this will bring and early experiences had in other countries. 5G is the first generation of broadband network technology built with the IoT in mind. 5G will have many implications for leading-edge production, enabling lower latency, greater reliability and ultra-fast speeds. In robotics, for instance, haptic technology – which permits users to experience a physical sense of touch in remote environments – is advancing and will be enabled by 5G. Machines that operate in terms of milliseconds will need the low latency and fast speeds afforded by 5G. Applications in manufacturing will be accompanied by uses in fields such as surgery and transport, in particular autonomous vehicles.[44] The European Commission has identified 5G as a priority in the Digitising European Industry initiative.

The industry standardisation process for 5G is ongoing. The accompanying spectrum for 5G is expected to be finalised in 2019 at the ITU's World Radio Communications Conference. While the technology is still experimental, a number of countries are running trials. Japan, for instance, is preparing for the 2018 winter Olympics with a 5G trial system. And during the PyeongChang Olympics, Korea deployed the first large-scale pilot service. Its provider, the local telecommunications company KT, has announced plans to roll out 5G across Korea by the end of 2019. Austria is advancing in this area too. For example, in February 2018, T-Mobile Austria, in partnership with Huawei, demonstrated the first 5G live drone flight. Austria's Regulatory Authority for Broadcasting and Telecommunications launched a consultation on the award procedure for frequencies in the 3.4GHz-3.8GHz band and a spectrum auction in this range is expected in late 2018. The successful bidder will have to construct in up to 1 000 locations, with 50% coverage expected by mid-2020. Nevertheless, Austria is somewhat lagging in 5G rollout behind leading countries such as Japan and Korea.

5G will raise regulatory and competition policy issues that Austria must be prepared for. These are diverse. One trend is that 5G networks will require smaller cell sites, complementing traditional large cell towers. This will require bringing smaller cells closer to connected devices through a process called 'network densification'. Policy approaches aiming at improving investment conditions for 5G will be needed. Because 5G will necessitate many more antennae, changes to right-of-way legislation might be required, among other considerations. Another concern for stakeholders relates to power density regulation (or electromagnetic limits in a given location) and the implications for public health. In the future, the probability is also high that countries will foster infrastructure-sharing agreements for practical and cost considerations. It will be important to monitor such developments in peer countries and prepare early for the accompanying regulatory challenges.

Machine-to-machine communication

Consideration might be given to liberalising SIM card numbers for machine-to-machine (M2M) communication. For producers of Internet-linked devices, a potential difficulty is SIM card lock-in (OECD, 2015b). Historically, it has been difficult, or prohibitive due to cost, to switch mobile operators during the lifetime of a device. Any change in operator required the physical replacement of the SIM card, which locked the device to a single operator. This hindered competition among operators. It could also preclude continuous connectivity for the devices themselves, as a single network might not have full geographical or location (e.g. indoor) coverage.

For its part, the wireless industry has developed the eSIM, a global Groupe Spéciale Mobile Association (GSMA) specification which enables remote SIM provisioning of any mobile device. The eSIM now allows users to store multiple operator profiles on a device simultaneously and switch between them remotely (though only one can be used at a time).[45] If mobile operators permit eSIM use on their network, manufacturers can now enable consumers to select the operator of their choice and then securely download that operator's SIM application to any device, including smaller IoT devices.

Flexibility has particular significance for manufacturers and large enterprises that may have millions of such devices being used domestically or internationally. Regulators in some countries may, for example, require the use of local services rather than permanent roaming and sometimes no single operator can provide the necessary connectivity in all locations. Meanwhile, the high cost of international mobile roaming is a consideration for some businesses and consumers using such devices.

A further way to promote flexibility could be to allow easy switching between networks by permitting device manufacturers or large enterprises to have their own, operator-independent SIM cards. Governments can change regulations to allow private companies to hold the numbers necessary for use in mobile networks, such as International Mobile Subscriber Identity (IMSI) numbers for SIM cards. In the Netherlands, the government has changed the existing regulations, partly at the request of its energy sector for the rollout of smart metres. The Netherlands was the first country to liberalise access to IMSI numbers for SIM cards. Both Belgium and the Netherlands have increased M2M subscriptions at a much faster pace than other European countries after liberalising SIM card numbers for M2M communication.

Making evidence on the development of Industry 4.0 in Austria more systematic

In recent years, a number of reports on Industry 4.0 have been published on the websites of government ministries and Austrian research and technology organisations. These are helpful in publicising technological trends and their implications for business. However, relatively little published quantitative data exist with which to assess the diffusion of Industry 4.0 technologies. Perhaps the most comprehensive overall assessment is Rhomberg, Zahradnik and Leitner (2017). This unpublished analysis builds on the responses of 239 firms to questions in the 2015 European Manufacturing Survey. Various studies of Industry 4.0 appear on the FFG website, but awareness of this work appears somewhat limited. Various studies consider generic challenges raised by Industry 4.0, rather than detailed empirics on Austria.

Policy making could benefit from planned data collection and quantitative benchmarks with which to assess progress in Austria over time, ideally against peers. In so doing, the analytic focus on digital technologies and cyber physical systems, while justified, might be broadened. Digital technologies have special importance because of their general purpose character, and therefore the potentially large impact of good policies. However, other technologies will also be critical to future manufacturing. In this regard, a European Commission High-level Strategy Group on Industrial Technology recently identified the following key enabling technologies for industry in Europe (European Commission, 2018): advanced manufacturing technologies; new materials and nanotechnology; photonics and micro- and nano-electronics; life sciences technologies; AI; digital security and connectivity. Similar work at the National Academies of Science, in the United States, has emphasised the growth possibilities of bio-based manufacturing. These perspectives include, but are broader than, "Industry 4.0". Austrian automotive companies, for example, consider battery and energy technologies, and new materials, as important areas for future competitiveness (PWC, 2017).

Quantitative monitoring of technology diffusion also matters because, among other reasons, actual survey data can yield surprising results. For instance, a 2015 survey of 4 500 German businesses found that only 4% had implemented digitalised and networked production processes or had plans to do so (ZEW-IKT, 2015).[46] Furthermore, Industry 4.0 encompasses a rapidly changing set of technologies and policy themes, for instance: the standards for 5G are currently under development; new intellectual property challenges are emerging, for example around ownership of some types of production, data and legal liability associated with autonomous systems; and new digital security threats and solutions are arising constantly. Timely responses to and understanding of such developments are likely to benefit from data on how technologies are diffusing and being used. In the United Kingdom, for example, evidence of growing productivity dispersion across firms, and of major differences in technology use and business models among companies, prompted the recent Mayfield Commission to recommend introducing online tools to help businesses compare themselves against industry best practices (Medland, 2017).

Following through on plans to strengthen digitalisation education at secondary level

Many countries are introducing emphases on digital technologies in their education and training systems. The People's Republic of China's Ministry of Education, for example, has begun developing teaching guidelines for robotics in primary and middle schools (OECD, 2017b). In Austria, much was done by the former Ministry for Education to support education on digital technologies in initial education. For instance, the "DigiComp" initiative teaches digital competences for students of various ages.[47] And digital content is included in academic teacher education in the pedagogical universities. Digital education is a priority for the new government. And, institutionally, the integration of education, science and research in the new Ministry for Education, Science and Research could facilitate relevant educational initiatives. It is key, however, to follow-up on existing plans and ensure effective implementation and evaluation.

Other issues affecting Industry 4.0 that require monitoring

Recent OECD analysis of efficient economic resource allocation highlight the importance for leading-edge production of conducive economic and regulatory framework conditions (OECD, 2017b). Competitive product markets, flexible labour markets, efficient bankruptcy regimes, low costs for starting and closing a business, low costs of contract enforcement, openness to trade and foreign direct investment – and other framework conditions – all facilitate efficient resource (re)allocation. Efficient resource (re)allocation helps incumbent firms and start-ups to adopt new technologies and to grow. One study estimates that up to half of the difference in multifactor productivity between "frontier" and "laggard" firms could have been avoided and the diffusion of new organisational models accelerated, if countries undertook greater market liberalisation, especially in services (Andrews, Criscuolo and Gal, 2016).

Current framework conditions in Austria are quite positive overall, and progress is being made in various fields, for instance through adoption of the 2017 Deregulation Act and the Deregulation Principles Act, and by the reform of bankruptcy law to lower the cost of failure for entrepreneurs. However, OECD (2017d) points to several areas in which regulatory frameworks could be improved. These include: improving the environment for financing start-ups (treated earlier in this chapter) and reducing regulation of professional services and retail trade. Better skills matching in labour markets also benefits the diffusion of leading technologies, and is an area of policy where Austria has room for improvement.

Notes

1. See also the chapters on Innovation in Firms in the various editions of the Austrian government's "Research and technology report".
2. Examples include Voest, OMV, RHI, Wienerberger and Semperit (see European Commission, 2017a).
3. This only includes firms in the sectors covered by the Community Innovation Survey (NACE 5-39, 46, 49-53, 58-66, 71-73). Innovation-active firms include firms with product, process, organisational or marketing innovations or with ongoing or abandoned product or process innovation activities.
4. R&D statistics do not disclose the exact figures of government funding to the co-operative sector by type of funding instrument. Based on estimates of the amount of R&D funding through tax incentives in this sector, direct government funding would be at around EUR 150 million in 2015.
5. The implied subsidy rate is based on the so-called B-Index calculation (OECD, 2018a), which takes into account the corporate tax rate and the net present value of allowances and credits applying to the marginal R&D outlay.
6. Some care is necessary in the interpretation of GEM data. Overall samples are often large – as in Austria – but the sub-group of early-stage entrepreneurs captured in each survey is much smaller. Some year-on-year volatility is therefore evident in both TEA rates and any sub-group statistics.
7. https://i2.aws.at.
8. www.europeanpensions.net/pages/features/Sep%2008/Pensions%20in%20Austria.htm.
9. https://www.apfond6.se.
10. See: www.vf.dk/~/media/files/analyser/evalueringer%20og%20effektanalyser/evaluering%202014.pdf.
11. *Op. cit.* Figure 3.1, page 13.
12. www.investhorizon.eu/default.aspx.
13. https://high-tech-gruenderfonds.de/de/#facts-figures.
14. http://investment-ready.org/program.
15. http://volanteresearch.com/wp-content/uploads/2014/04/140331-Comparative-study-voucher-schemes_Final2.pdf.
16. https://creative.vic.gov.au/creative-state.
17. https://beta.gov.scot/policies/creative-industries.
18. http://stimuleringsfonds.nl/en/the_fund/organization/about_the_fund.
19. Digital technologies can increase productivity in industry in many ways. For example, they can reduce machine downtime, as intelligent systems predict maintenance needs. They can also perform work more quickly, precisely and consistently, as increasingly autonomous, interactive and inexpensive robots are deployed.
20. The Federal Ministry for Transport, Innovation and Technology has developed the following production research list: http://bmvit-forschungslandkarte.produktion.derzukunft.at/site/index.

21. See: http://plattformindustrie40.at/?lang=en.

22. For instance, the New Zealand company, Soul Machines, has recently developed an AI-based digital assistant to help older adults understand and access welfare entitlements.

23. Professor Li's full remarks at the 2017 Global StartupGrind Conference: https://www.startupgrind.com/blog/cloud-will-democratize-ai.

24. https://www.digitalroadmap.gv.at/de.

25. https://www.opendataportal.at.

26. https://datamarket.at.

27. Austria has recently created the legal basis for new opportunities to access research data from administrative registers. The Data Protection Amendment Act 2018 – Science and Research – (WFDSAG 2018) references the GDPR in this regard. Concrete implementation has to be agreed between the Minister of Education, Science and Research and the minister in charge of the respective register.

28. The index comprised three measures: ICT specialists as a percentage of the workforce (weighted 50%), the percentage of the population with better than basic ICT skills (weighted 30%) and the number of R&D personnel per 1 000 population (weighted 20%) (Wallace and Castro, 2017).

29. For instance, the UC San Diego Press Release, 19 February 2018, entitled "Supercomputers aid discovery of new, inexpensive material to make LEDs with excellent color quality", available at: http://jacobsschool.ucsd.edu/news/news_releases/release.sfe?id=2476.

30. It is understood that since work on this *Innovation Policy Review* began, the Austrian authorities have decided to join the European High Performance Computing Joint Undertaking.

31. Firms with up to 250 workers account for almost 70% of total business sector employment, compared with around 60-65% in other OECD countries.

32. https://www.ffg.at/en/ictofthefuture.

33. These include: https://wexelerate.com; https://vienna.talentgarden.org; https://vienna.impacthub.net; http://www.startup-salzburg.at; www.baseeins.at in Tyrol; and, https://tabakfabrik-linz.at.

34. https://www.lcm.at/en.

35. A list of the clusters is available on the website of the Austrian Clusterplattform at: https://www.bmdw.gv.at/Innovation/ClusterplattformOesterreich/Seiten/default.aspx.

36. https://www.ffg.at/en/innovation-voucher.

37. https://www.ffg.at/en/patent-voucher.

38. https://www.aws.at/foerderungen/aws-kreativwirtschaftsscheck.

39. The initial task of collecting sensor data can be challenging. A typical industrial plant might include machinery of different vintages from different manufacturers. Control and automation systems might come from different vendors and operate with a variety of communication standards.

40. www.wsipp.wa.gov/BenefitCost.

41. https://www.ffg.at/en/comet-competence-centers-excellent-technologies.

42. FFG, Monitoringbericht 2016/2017 COMET-Zentren, Vienna, March 2018.

43. In 2013, the combined budget was EUR 114 million.

44. https://www.ericsson.com/en/cases/2017/abb.

45. https://www.gsma.com/esim.

46. A 2016 survey showed that only one in five manufacturing companies in Europe had used advanced manufacturing solutions (Innobarometer, 2016).

47. https://www.digikomp.at.

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Chapter 4. Improving the performance and attractiveness of higher education institutions and public research institutes in Austria

This chapter examines the performance and attractiveness of Higher Education Institutions (HEIs) and Public Research Institutes (PRIs) in Austria. It outlines the evolution of the higher education landscape and assesses the performance of HEIs in human capital formation, research and in "third mission" activities. It continues by discussing the strategic steering and funding of public universities and the role of competitive funding. The chapter concludes by discussing the role of different types of PRIs in the Austrian innovation system.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

The higher education landscape in Austria

Evolution of higher education institutions in Austria

Austria has a long history of university education and research, dating back to the Middle Ages. The culmination of science and intellectual life more broadly, in the late 19th and early 20th centuries, was followed by destruction and loss of human capital after the annexation of Austria to national-socialist Germany (Box 4.1). Recovery from this period has been a difficult and slow process. Austria's higher education system has changed profoundly in recent decades. This has reflected change in the economy and society at large, leading to an increase in the number of students and diversification of the disciplines taught. In the 1960s and 1970s, new universities were established in Linz and Klagenfurt.

From 1994 onwards, the universities of applied sciences (UAS) – a new type of higher education institution (HEI) for Austria – complemented the universities' offering of scientific research and research-oriented education. The UAS provided practically oriented higher education and application-oriented research, adapted to the demand for tertiary skills and research in the regions in which they were located. The creation of the UAS helped to diversify the supply of higher education degree programmes, to narrow the gap between demand and supply for skills on the labour market, and to increase the permeability within the higher education system. In addition to their mission in education, the UAS are legally required to perform practice-oriented R&D conducted by scientifically qualified staff.

Starting in 1999, the accreditation of private universities added new types of institutions offering academic degrees in Austria. The former academies of music and arts were transformed into universities. In 2004, the medical faculties of Austrian universities became autonomous medical universities. In addition, in 2007, the former educational schools for teacher education for primary and non-academic secondary schools were restructured to become university colleges for teacher education leading to bachelor degrees. The expansion and diversification of the higher education sector was complemented by institutional change, as well as reforms of university governance and funding mechanisms.

Austria's higher education sector currently comprises 22 public universities, 21 UAS, 13 private universities and 14 university colleges for teacher education. This is a rather large number of institutions given the size of the country, for example compared to Denmark and Switzerland. The relatively large number of institutions partly results from a high degree of institutional specialisation: there are six universities of arts,[1] three technical universities, three medical universities, two life sciences universities, and one university of economics and business. Only 5 of the 22 public universities – the Universities of Vienna, Graz, Innsbruck, Linz and Salzburg – offer a broad range of study programmes and scientific disciplines. The University of Klagenfurt covers the following fields: humanities, technical sciences, management and economics, and interdisciplinary research with an emphasis on social and ecological topics and public goods.

All universities offer education at graduate and postgraduate level (usually at bachelor, master and PhD level according to the Bologna three-cycle structure, but also diploma and doctoral studies according to the pre-Bologna regime). The Danube University for Continuing Education, also known as Danube University Krems, offers master and PhD studies as well as diplomas in selected fields, focusing on the needs of in-work professionals.[2]

Box 4.1. **A history of universities in Austria**

Austria is home of some of Europe's historical universities. The University of Vienna was founded in 1365 (as the second university north of the Alps, 17 years after the University of Prague). The University of Graz was founded in 1586, the University of Salzburg in 1622 (discontinued in 1810 and re-established only in 1962), and the University of Innsbruck in 1664. The predecessors of today's technical universities as well as the predecessors of today's University of Economics and Business, the University of Natural Resources and Life Sciences Vienna, and the University of Veterinary Medicine at Vienna date back to the 19th century. Similarly, today's universities of music and arts have strong historical roots.

Austria's, and especially Vienna's, contribution in the development of ideas in many areas (Johnston, 1983) – making the city an intellectual hotbed of "modernity" at the end of the century (Schorske, 1980) – reached an apex before World War I. However, even after the political and economic disintegration of the Habsburg empire and the distress that befell the city, it remained one of the world's prime locations of creativity, literary and artistic production, and scientific excellence (Kandel, 2012). Vienna's great variety of achievements has been demonstrated, for instance, in a recent intellectual history of the Vienna Circle, which involved physicists, philosophers and mathematicians (Sigmund, 2017).

With the annexation of Austria to the German Reich in 1938, German laws were introduced to the Austrian university system. This resulted in the exclusion of students and scientists of Jewish descent from universities (BMWFW, 2016) as well as the oppression of political opponents. Many of the best minds were forced to emigrate in order to escape national-socialist persecution and extermination. With the loss of many of the best scientists (Stadler, 2004), Austria's universities suffered a disastrous drain of intellectual resources. Many of the scientists who escaped persecution made outstanding and globally recognised contributions in the countries that provided them the opportunity to build a new career. Among those who were forced to leave were numerous Nobel laureates (Aizenman and Noy, 2007).

After the end of the war, Austria was reconstituted as a democratic republic. University laws were reinstituted, but recovery from the damage suffered since 1938 proved slow, with much of the universities' prestige lost, and only a relatively small number of qualified scientists remaining (BMWFW, 2016). Researchers and scientists who wished to return often faced obstacles in finding a suitable position.

Sources: Aizenman, J. and I. Noy (2007), "Prizes for basic research: Human capital, economic might and the shadow of history", https://doi.org/10.1007/s10887-007-9018-y; BMWFW (2016), *Higher Education in Austria*; Johnston, W.M. (1983), *The Austrian Mind*; Kandel, E.R. (2012), *The Age of Insight*; Sigmund, K. (2017), *Exact Thinking in Demented Times. The Vienna Circle and the Epic Quest for the Foundation of Science*; Schorske, C. (1980), *Fin-de-Siècle Vienna*; Stadler, F. (2004), *Vertriebene Vernunft. Emigration und Exil österreichischer Wissenschaft 1930-1940*.

Leading countries in innovation such as Denmark and Sweden operate a considerably smaller number of universities per capita than Austria. Denmark's consolidation of universities and public research institutes is credited with having contributed to its outstanding improvements in performance and international visibility (Polt et al., 2015).

A new and unique institution in the Austrian research and higher education landscape is the Institute of Science and Technology (IST) Austria, founded in 2006 and modelled after Israel's Weizmann Institute. The IST Austria is a research institution offering postgraduate education (PhD and postdoctoral). Senior staff can be appointed as professor. The IST Austria is financed by the federal government through institutional (including performance-based) funding and additional financial support from the state of Lower Austria. Performance-based funding includes matching funds for the third-party revenues it attracts as well as other components based on pre-defined research goals (research-immanent quality criteria). The IST Austria is further detailed below.

Although their share of students has decreased by about 10 percentage points since 2003/04, public universities remain by far the most important providers of tertiary education in Austria, accounting for 79% of all regular students in 2015/16, and among them a large share is concentrated at the University of Vienna.[3] In contrast, UAS account for 14% of students. The number of students at private universities and university colleges for teacher education has increased, but their combined share remains low.

Human capital formation

An adequate supply of tertiary educated individuals is widely recognised as critical in enabling economies to shift towards higher levels of knowledge intensity. Skilled human resources are also a prerequisite for industries to move up global value chains and diversify by entering knowledge-based activities. For economically advanced countries, in particular, tertiary education is typically a prerequisite for the absorption of cutting-edge technologies and innovation, and the enhancement of national innovation capabilities. A workforce with high tertiary attainment contributes through specialised and wider transversal skills acquired through education.

Tertiary education in Austria is institutionally differentiated, aiming at the provision of education and training that responds to the varied needs and interests of students, business enterprises, the public sector, and society at large. In addition to the education and training provided at the HEIs, Austria has a strong vocational school sector. These higher technical and vocational schools cover a wide array of professional specialisations including commerce, tourism, communication, the arts, fashion and technical professions. Among them is Höhere Technische Lehranstalten (HTL). The HTL offers education in various technology-related professions during five-year programmes. Students finally obtain the *Matura*, the general qualification for university entrance. Around 50% of students from the HTLs continue pursuing a degree at the UAS or technical universities, and are able to roll-over credits from the HTLs to the extent agreed on by the individual institutions involved (Schmid, Gruber and Nowak, 2014).

Human capital formation at higher education institutions

Through a massive expansion of the higher education sector, the share of the labour force with tertiary attainment doubled from a mere 15.4% in 2000, to 31% in 2017 (Figure 4.1). By comparison, in Germany, the share of the labour force with a tertiary education increased from 24% to 28% over the same period. In the Netherlands the share rose from 24% to 34%, and in the EU-28 from 24% (2005) to 33%. Austria is among the countries with the highest share of international students in tertiary education in the OECD (16% in 2015). About half of the international students remain in Austria after graduation, with wide differences between nationalities and academic area. Overall, the share of international graduates remaining in Austria is increasing. Continued growth in the graduation of Austrian nationals with advanced degrees, and the attraction of foreign talent in relevant scientific disciplines, are both essential for Austria to become an innovation leader.

In 2017, 77% of all students in a tertiary education programme were enrolled at public universities. UAS accounted for 14% of all students. This share has been evolving at a rather moderate pace in recent years, and the share of students in private universities reached 3% (Statistics Austria, 2018). The Shaping HEIs for the Future (*Zukunft Hochschule*) project aims at a clear division of labour between universities and UAS. Under this project, the share of students attending the UAS is expected to increase to 30% over the medium term, and to 60% in the longer term (BMWFW, 2016). An additional 3 000 study places at UAS are planned by 2022-23, following a political decision in November 2018 that outlined pillars of the next development plan for the UAS sector. Further increases will be needed to meet a student share at UAS of 30% by 2030. Joint PhD programmes with universities are foreseen to strengthen academic talent at UAS, provide new perspectives for researchers and improve permeability by mitigating institutional barriers to ease a transition from the UAS to a PhD programme. The new UAS development plan should improve research perspectives at UAS and intensify co-operation with industry, and support the economy's digitalisation and transition toward Industry 4.0.

However, this will require a substantial acceleration of growth in UAS student numbers, but also the provision of funding adequate to ensure a high quality of education. Unlike universities, UAS are not financed through a global budget but according to their number of study places. In order to maintain the high quality of practices-oriented education that distinguished Austrian UAS up to now, financial resources allocated to UAS should not only reflect the increase in student numbers, but also consider improved financing for research and research infrastructure, and resources to improve the transfer of innovation between UAS and industry over the long-term.

The Netherlands, where tertiary education has shifted predominantly to the UAS, provide an example of a country where higher education that has the challenges that may be encountered (Box 4.2).

While Austria has made notable gains in increasing the number of tertiary graduates, it should be noted that half (49%) of all first-time graduates in 2016 came from short-cycle tertiary programmes. Short-cycle tertiary programmes hold a special position in Austria's education system, awarding both a full professional qualification and an entrance qualification to higher education (OECD, 2017c).[4] They are practice-based and occupation-specific, preparing students either to enter the labour market or to continue with other tertiary education programmes.

The emphasis on short-cycle tertiary education is mirrored by a comparatively smaller proportion of tertiary graduates with a bachelor's or master's degree. These programmes help to deepen knowledge obtained at previous education levels by imparting new techniques, concepts and ideas not covered in upper secondary education. Austria's first-time graduation rate at the bachelor level (32%) is well below comparator countries such as Switzerland (98%), the Netherlands (90%) and Finland (89%). As regards the master level, the graduation rate in Austria – at 18% – is comparable to that in Germany (17%), ranks above Finland (10%), but lags behind the Netherlands (34%) (OECD, 2017c). While the UAS provide a link between post-secondary non-tertiary and tertiary education, strengthening the existing pathway to advanced degrees would positively affect the quality of human capital in Austria.

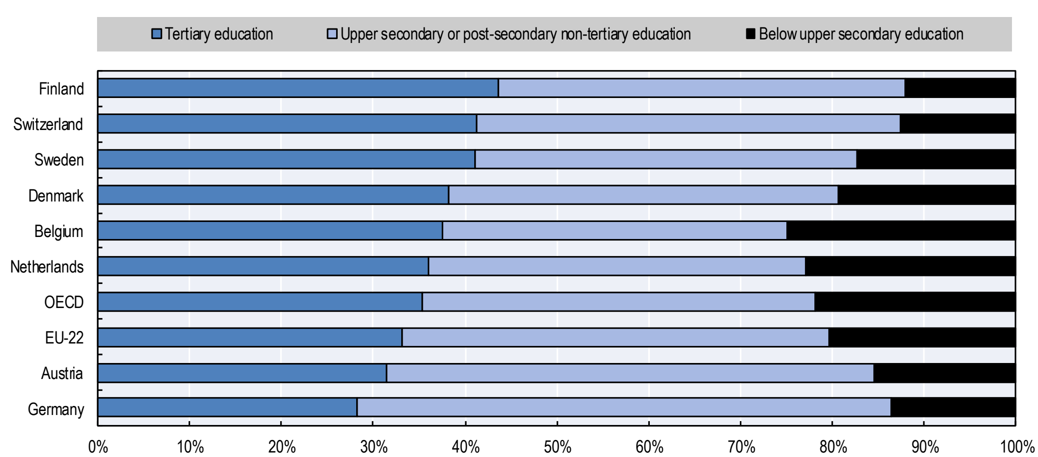
Box 4.2. **Universities of applied sciences in the Netherlands**

There are 37 universities of applied sciences (UAS) in the Netherlands, which offer practical and professional higher education. They are mainly oriented to professional practice-based teaching. In contrast to most OECD countries with binary tertiary education systems, the Netherlands has far more students in the UAS (around 65% of tertiary enrolments), compared to a range of between 5% in France and 46% in Finland. Eighty per cent of block grants to the UAS are distributed in proportion to the number of students enrolled and the number of degrees earned, with the remainder allocated on the basis of percentages per institution and for specific policy objectives. In addition to block grants, higher education institutions receive tuition fees, separate resources for research and revenue from work performed for third parties.

With strong links to industry, the Dutch UAS are well placed to support the development of innovation capabilities in firms. However, their research capacity is limited, although it has increased in recent years. Consequently, the government has taken specific initiatives to promote their research capabilities and to help strengthen their knowledge transfer function, especially towards small and medium-sized enterprises (SMEs) and public sector organisations.

Source: OECD (2014), *OECD Reviews of Innovation Policy: Netherlands 2014*, http://dx.doi.org/10.1787/9789264213159-en.

Figure 4.1. **Share of the population (aged 25-64) by educational attainment in Austria and selected countries, 2017**



Source: OECD (2018c), *OECD Education Statistics* (database), https://doi.org/10.1787/edu-data-en (accessed 15 August 2018).

StatLink https://doi.org/10.1787/888933882693

Austria's labour force is characterised by a comparatively high share of workers with a tertiary-level education in a STEM (science, technology, engineering and mathematics) discipline. At 34% in 2016, Austria was second only to Germany (35%), and well above the OECD average of 25% (Figure 4.2). In the field of engineering, this share is 28%, the highest share across all OECD countries (compared to 25% in Germany and the OECD average of 16%). However, reflecting the country's traditional industrial specialisation, the share of the labour force with tertiary-level ICT-related education is the lowest among comparator countries at only 2%, as compared to Finland (7%) and the OECD average of 4%. Austria will need to adapt and strengthen the skills of those who are already part of the labour force. To some extent, these concerns may be addressed directly by industry. However, acknowledging the need to strengthen the skills of working adults also creates an opportunity for the Austrian education system to improve collaboration with industry, not just in research, but also in educating and training the labour force (Box 4.3). Austria ranks high in student enrolment in technology-related disciplines considered important for innovation (OECD, 2017a).

Box 4.3. **Innovative and interdisciplinary learning opportunities**

The adaptability of education programmes to emerging labour market demands is as important as enrolment and graduation numbers. Expanding the number of graduates should be complemented by developing and expanding new educational and experimental learning opportunities.

It is important to create innovative opportunities for students to develop new skills. Innovative approaches to new forms of education have been pursued, for instance, in Finland, where the Aalto Design Factory grew out of research focused on creating an ideal physical and mental working environment for product developers and researchers. It is intended to be open to students from any discipline, and act as a bridge to firms and other non-academic institutions.

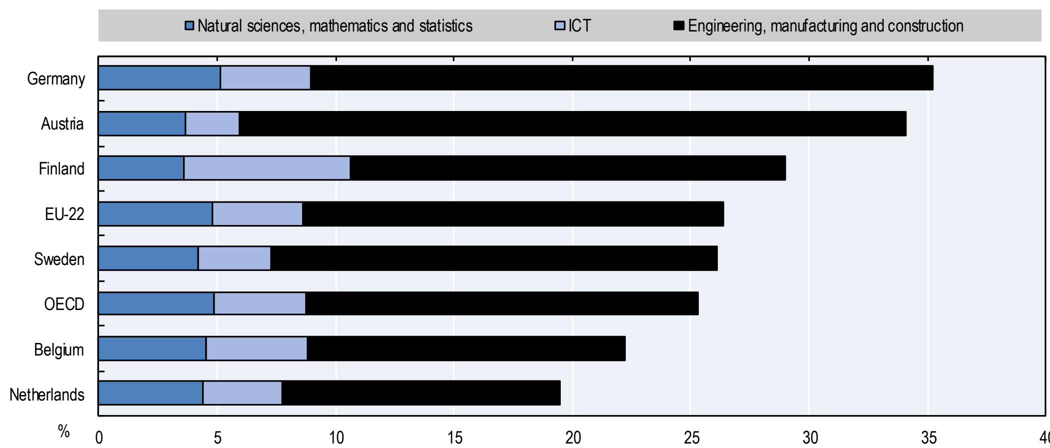
There may be opportunities to incorporate Austria's internationally renowned arts schools with the broader innovation community. Examples following this approach include the Rhode Island School of Design, whose "Nature Lab" is staffed with artists and scientists aiming to bring arts-based thinking to scientific questions. The Nature Lab attracts faculty and students from surrounding universities and provides a forward-thinking approach to collaboration, visualisation and communication in science.

Among comparator countries, Austria ranks third, after Germany (37%) and Finland (32%), in this regard, with over 28% of graduates holding degrees in STEM fields. However, with a low total share of workers with a tertiary education in Austria (46%) relative to comparator countries such as Switzerland (68%) and Finland (72%), Austria could face shortages in the supply of qualified workers if the economy shifts towards more high-tech firms.

Gender equity

A wider gender gap persists in STEM education than in other degree areas. Closing this gap could significantly strengthen the Austrian innovation system. Female graduates remain highly concentrated in education (74%) and service-related disciplines (75%), and make up notably low graduate shares in natural sciences, mathematics and statistics (46%); information and communication technologies (15%); engineering, manufacturing and construction (24%).

Figure 4.2. **Share of tertiary attainment in STEM* disciplines in the Austrian labour force and selected countries, 2016**



* STEM: science, technology, engineering and mathematics.
Source: OECD (2018c), *OECD Education Statistics* (database), https://doi.org/10.1787/edu-data-en (accessed 15 August 2018).

StatLink https://doi.org/10.1787/888933882712

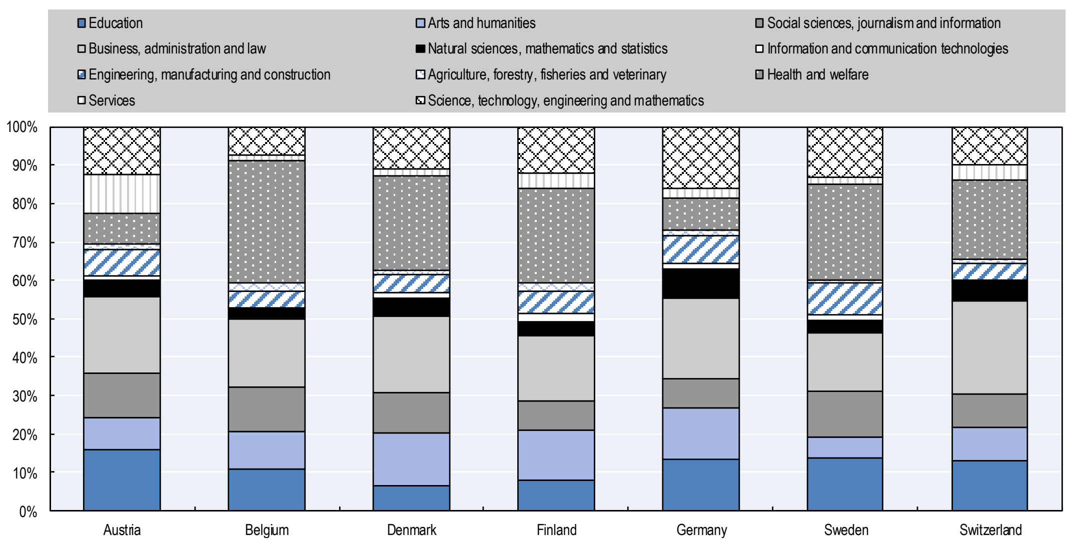
While in some EU countries over 40% of researchers are women, this share is below 25% in Austria, a proportion similar to that in the Czech Republic and Germany (OECD, 2017a). In established as well as young and highly innovative firms, comparatively few employees are women, at just around 26% (BMBWF, BMVIT and BMDW, 2018). The share of female doctoral graduates in 2015 was 44%, markedly lower than the share of male graduates (56%), and below the shares in Finland (53%), Denmark (48%), Sweden (46%) and Germany (45%).

Approximately one-quarter of PhDs in engineering are women, and only about 30% in the natural sciences overall, which is below the shares in comparator countries. In contrast, representation in education, social sciences and agriculture is strong. Among female tertiary-level graduates in 2016, the majority studied education and business administration (Figure 4.3). This is similar to Austria's comparator countries. However, only 1% of Austrian female graduates studied in the field of ICT, and 14% in science, technology and engineering.

The low overall share of female participation in research is evident. In the aggregate of all areas of research, the share of women in 2017 was 23.5% in Austria, compared to 50.5% in Denmark, the Netherlands and Sweden. Furthermore, as many women work part time, the opportunities for leadership and full participation in the research enterprise are limited (BMBWF, BMVIT and BMDW, 2018). Women also remain under-represented in publication co-authorship, showing little to no improvement in recent years on this metric in any discipline. The exception is in the agricultural sciences.

Women in Austria also remain under-represented in faculty or staff positions in higher education. In 2017, only 21.5% of professors in higher education were women. While this represents a slight improvement compared to 2016 (by 1 percentage point), Austria ranks below the EU average of 23.5% and below Denmark, Sweden and the Netherlands, which all stand at 31.5% (BMWFW and BMVIT, 2017). On the positive side, women in Austria have been successful at achieving parity with men as regards the proportion of internationally co-authored publications, which is well above the EU average, and in the impact of their publications as measured by citation rates. Austria also ranks above the EU average in terms of the proportion of women leaders of HEIs, and in the proportion of women serving on scientific boards and commissions relevant to innovation (EC, 2016).

Figure 4.3. **Share of female graduates by field, select countries, 2016**



Source: OECD (2018a), *OECD.Stat* (database), https://stats.oecd.org (accessed on 10 October 2018).

StatLink https://doi.org/10.1787/888933882731

To strengthen women in research, specific programmes have been initiated. The Hertha Firnberg Programme, for instance, offers highly qualified female scientists aiming for an academic career financial support to start their career for a total of six years. Support for senior postdocs is provided by the Elise Richter Programme. Laura Bassi Centres of Excellence encourage cooperation between highly-skilled male and female researchers from academia and the private sector. Female scientists are encouraged to apply for top positions within these Centres of Excellence to address the lack of women in leading scientific roles.

Doctoral education

Doctoral education in Austria is offered by public and private universities (provided the university has obtained accreditation), and the IST Austria. In 2016, the share of tertiary students enrolled in a PhD programme was 7.5%, of which almost half (46%) were women. Approximately a third of all doctoral students were enrolled at the University of Vienna (BMBWF, 2018). Though not authorised to award doctoral degrees, the UAS are involved in co-operative doctoral research with universities. In practice, co-operative research is pursued through the shared use of research infrastructure (Österreichischer Wissenschaftsrat, 2012).

To pursue a doctoral degree in Austria, students can pursue either traditional doctoral studies (*Doktoratsstudium*), or a structured PhD programme. Since the amendment of the university act (BGBL. I Nr. 129/2017), qualitative entrance restrictions can be set by all universities for all doctoral programmes. The *Doktoratsstudium* has a number of shortcomings, including advisors acting as examiners to their students, enrolment without secured supervision still being common or insufficient integration into the scientific community, and selection processes which are subpar or non-existent. This impedes these programmes' international comparability, and hinders the quality of research.

Structured PhD programmes apply strict and standardised selection processes, involve a team of supervisors, are based on structured education and course work, and have theses evaluated by external reviewers (FWF, 2010). One core objective of structured PhD programmes is to better integrate doctoral students into the scientific community, and ensure active monitoring and supervision to guarantee independent and high-quality research (BMWFW and BMVIT, 2016).

Building on the recommendations of the Austrian Higher Education Conference (Hochschulkonferenz, HSK)[5] for PhD education, EUR 30 million has been made available for structured doctoral programmes over the 2016-18 period through the Higher Education Area Structural Funds (*Hochschulraumstrukturmittel,* a component of institutional funding).[6] The recommendations included measurable framework conditions for PhD programmes at universities that required the submission of a dissertation exposé within the first year after admission to study, a public presentation of the dissertation project, advice and support by a team, and the personnel separation of dissertation supervision and assessment.

Structured doctoral programmes in Austria follow international standards, and the number of students enrolled in this type of programme is increasing. This is a rather recent development, but PhD education in Austria is currently in transition, with 14% of doctoral students being enrolled in structured programmes in 2016 (BMBWF, 2018). Moreover, while doctoral education is fairly accessible, the supporting structure to ensure timely completion is not always present. This is also reflected in the average length of study for PhDs, which is very long, at 9.1 years in 2015/16 (BMWFW, 2018).

In response to these challenges, a high-quality doctoral education, together with an institutional affiliation and networking within the scientific community, is paramount for the promotion of young scientists. Consequently, improving doctoral education is a priority to elevate the quality of teaching and research at Austrian HEIs. Critical in this context is improved funding for PhD students. The RTI Strategy 2011-20 concluded that increased funding should be coupled with the diffusion of structured programmes as an instrument to improve the conditions of doctoral education at Austrian universities, where in 2016 only 47% of doctoral students were employed (either directly by universities or via third-party funding [BMWFW, 2018]).

In 2013, the BMBWF initiated stakeholder discussions including the Austrian Higher Education Conference, resulting in a set of recommendations for the enhancement of quality in doctoral training (BMWFW and BMVIT, 2016). The measures specifically target: research and training through structured PhD programmes with standardised degree requirements; and better funding for junior scientists and research infrastructure.

Austria has taken two main approaches to funding doctoral education, either as part of government institutional university funding or through competitive funding schemes. The FWF's DK programme (FWF Doktoratskollegs) was one such scheme. This programme was replaced by the doc.funds programme in 2016, through which the FWF allocates funds received from the Austria Fund for doctoral programmes, which are designed and hosted by universities and research institutes with the right to grant PhDs. The FWF ensures the quality of the doc.funds programme. The funds are provided through competitive calls and finance (for up to eight years) doctoral programmes deemed excellent and that have been in operation for at least two years. PhD contracts are expected to be part of all doctoral programmes.

Since the transition from two- to three-year doctoral degree programmes, qualitative development towards quality criteria of structured doctoral programmes is also reflected in the 2016-18 performance agreements with universities, which gave special attention to expanding structured doctoral training (BMWFW, 2018). With the new university funding model (see below) implemented for the first time in the 2019-21 performance agreement period, research funding is influenced by a competitive indicator reflecting the number of students in structured PhD programmes employed by the respective university.

Tenure track and career development

The quality of working conditions and career paths of academics are key to the attractiveness and performance of universities and other research institutions. Empirical work shows that early research, financial independence and tenure perspectives are important factors for researchers in the earlier phases of their career, while later-stage researchers favour jobs that make it easy to take up new lines of research (Janger and Nowotny, 2016).

The attractiveness of Austrian universities for researchers – both young and advanced, established scientists – is lagging behind that of leading international research universities, and also not on par with the IST Austria and some of the institutes of the Austrian Academy of Sciences. Empirical work on the attractiveness of countries with regard to academic jobs reveals a familiar pattern. Using an index of job attractiveness, Janger, Strauss and Campbell (2013) find that Austria holds a middle position among 11 countries studied. It is slightly ahead of France and Germany, and has a more pronounced lead in relation to Italy. But it is clearly lagging behind the leading comparator countries in the sample (the Netherlands, Sweden, Switzerland), and finds itself far behind the United Kingdom and the United States.

The RTI Strategy 2011-20 recognised that there is much to be gained from introducing a fully-fledged tenure track model. If career perspectives in Austria do not match international good practice, the most mobile young researchers – who are often among the brightest – may seek more attractive careers abroad. At the same time, unattractive career prospects may prevent talented young students and researchers from coming to Austria in the first place. Other factors considered to have a negative impact on the attractiveness of Austrian universities are the dearth of competitive funding for basic research and limitations in institutional funding (see below).

Academic career paths at Austrian universities have long been shaped by the traditional "habilitation model" of German-speaking and other continental European countries. The Anglo-American tenure track model, adopted by many modern universities around the globe, has long been absent from Austria's university system. This has come to be seen as a major obstacle to the supply of attractive career paths. Pechar (2017) summarises the main differences between the habilitation and tenure track models (Box 4.4).

A first tenure track model was introduced through the 2009 Collective Agreement. Under this agreement, academic staff holding a PhD can be offered a "qualification agreement"

(*Qualifizierungsvereinbarung*) and, if they accept, become an assistant professor on a temporary basis. Pending an evaluation and achievement of the objectives of the qualification agreement, the assistant professor could obtain a permanent position as associate professor. Introducing this model as the standard career model at Austrian universities was a significant step forward. Nevertheless, this model was limited insofar as the continuous career path under the 2009 Collective Agreement ended with the associate professorship (BMBWF, 2018).

Box 4.4. **Comparison of the traditional habilitation to the North American tenure track model**

At North American universities, the most important decisions relevant for a career take place at a relatively early stage. The selective recruitment of academics from an applicant pool does not take place at the final step of the career (entry into the full professorship), but at the time of entry to the tenure track (the assistant professorship). The term "assistant professor" is misleading in the North American context, because that person is not assigned to a full professor in order to assist him/her. Rather, this career step allows and requires independent research and teaching. Much earlier than the habilitation model, the tenure track thus enables autonomous professional activity (Pechar and Andres, 2015).

The position of assistant professor in North America involves a probationary period limited to six or seven years, with an evaluation at the end. In positive cases, this leads to promotion to associate professor. In negative cases, it leads to exiting the tenure track ("up or out"). People who pursue an academic career path thus receive a signal at a relatively early age following their postdoctoral period as to whether they are able to establish themselves successfully. In the habilitation model, this signal is often given at a later life phase, as soon as the chain contract regulation no longer permits temporary employment.

As mentioned, the assistant professor in the tenure track is an independent position, while the assistant in the habilitation model is dependent on a professorial mentor. The "up or out" evaluation at the end of the assistant professorship could be compared with the habilitation. The difference is that in North America, a positive evaluation leads to tenure, with employment for life with protection against being fired. A successful habilitation process, by contrast, leads to a full teaching license, but not necessarily to employment.

Source: Pechar, H. (2017), "Career options and working conditions of academics".

It was as recently as 2015 that a tenure track model with a continuous career path leading to full professorship was introduced, through an amendment to the University Act 2002, which came into force in 2016. This amendment covers two aspects. First, it offers the legal option to appoint associate professors to full professors through a "simplified procedure".[7] Furthermore, from October 2016, tenure track positions offering a "qualification agreement" now provide a continuous career perspective from the selection process to professorial membership. The selection process is subject to requirements that are intended to assure transparency and quality. Notably, the position has to be advertised internationally. Candidates who have passed the required selection process conforming to international competitive standards, and who at the end of the qualification period have met the qualification objectives, become members of the professors' "curia" according to organisational law without any further appointment procedure.

Implementation of the new tenure track model is ongoing. "In 2017 a number of universities have already laid down the modalities for the simplified appointment procedures in their statutes, while others are still undergoing its implementation and respective discussion" (BMBWF, 2018). As it takes time to gather sufficient experience and information on the new model, it is reasonable that an evaluation is foreseen after five years. However, it will be useful to carefully monitor and analyse the experience across Austrian universities as successful implementation of a comprehensive tenure track is of critical importance for the future of the Austria's university and research performance. Moreover, the newly created option for "opportunity hiring" offers universities with a simplified procedure to hire a certain number of international top scientists.

Research performance

Higher education expenditure on R&D

In Austria, higher education expenditure on R&D (HERD) accounted for close to one-quarter (23.5%) of total gross domestic expenditure on research and development (GERD) in 2016 (Table 4.1). This share is just above the EU average (22.9%), but exceeds the OECD average (17.8%) by nearly 6 percentage points. Nevertheless, it falls short of comparator countries, with the exception of Belgium and, notably Germany (18.3). Moreover, in contrast to all other comparator countries, Austria's HERD-to-GERD ratio declined continuously over the period 2002-16.

Table 4.1. **Higher education expenditure on R&D (HERD) as a percentage of GERD**

	2000	2010	2012	2016
Austria	27.03	25.84	24.57	23.51
Belgium	20.24	23.51	21.32	20.17
Denmark	18.91	30.32	31.64	31.64
Finland	17.85	20.44	21.58	25.14
Germany	16.09	18.18	17.67	18.28
Netherlands	31.93	40.35	31.59	31.51
Sweden	22.18	26.35	27.12	26.82
Switzerland	22.86	24.17	26.09	26.60
EU28	21.24	24.34	23.49	22.95
OECD	16.03	18.67	18.24	17.84

Note: 2002 for Austria; 2001 for Denmark, Norway and Sweden; 2008 and 2015 for Switzerland.
Source: OECD (2018d), *Main Science and Technology Indicators, Volume 2018 Issue 1*, https://doi.org/10.1787/msti-v2018-1-en.

Austria's HERD as a percentage of GDP (0.73%) is nearly two-thirds above the OECD average. Even so, the Austrian ratio is exceeded by comparator countries Denmark (0.91), Switzerland (0.90 in 2015) and Sweden (0.87) by a significant margin. Germany (0.54) and Belgium (0.50) stand out as recording significantly lower shares of HERD in GDP (Table 4.2).

Bibliometric performance

One way to capture the research performance of Austria's top-publishing universities is through the impact of their publication output as measured by the number of citations. Bibliometric evidence from the *Leiden Ranking database*[8] for the period 2006-16 provides a general comparison of the research performance of Austrian public universities in relation to those in comparator countries.

Table 4.2. **Higher education expenditure on R&D (HERD) as a percentage of GDP**

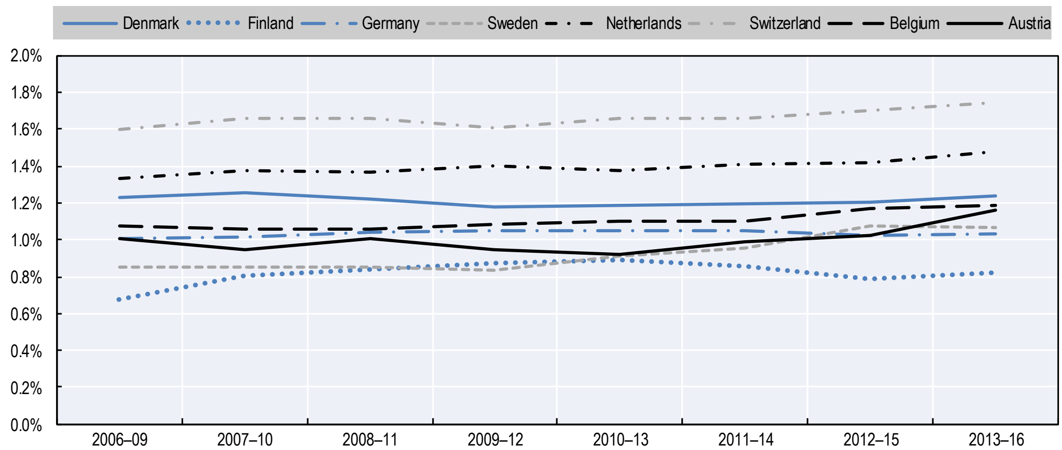
	2000	2010	2012	2016
Austria	0.51	0.70	0.72	0.73
Belgium	0.39	0.48	0.48	0.50
Denmark	0.43	0.88	0.94	0.91
Finland	0.58	0.76	0.74	0.69
Germany	0.38	0.49	0.51	0.54
Netherlands	0.58	0.70	0.61	0.64
Sweden	0.77	0.85	0.89	0.87
Switzerland	0.53	0.73	0.83	0.90
EU28	0.35	0.45	0.45	0.44
OECD	0.34	0.43	0.42	0.42

Note: 2002 for Austria; 2001 for Norway and Sweden; 2015 for Switzerland.
Source: OECD (2018d), *Main Science and Technology Indicators, Volume 2018 Issue 1*, https://doi.org/10.1787/msti-v2018-1-en.

As regards the top 10% of most frequently cited publications in their respective fields by the top publishing universities, the variation over the period 2006-16 is rather limited. Austria is above Finland, with the gap widening after the 2011-13 period when Finland underwent serious cuts in R&D, and on par with Germany and Sweden, both countries known for their strong scientific base. However, despite gaining some ground, Austria remains below Belgium and Denmark. The Netherlands, and, in particular Switzerland, are far above all the other comparators.

As regards the share of the top 1% of most frequently cited articles contributed by top-performing universities over the period 2006-16, Austria has clearly made progress in relative terms, especially after 2010-13, staying ahead of Finland and Sweden, overtaking Germany, and narrowing the gap with Belgium and Denmark. The Netherlands, and especially Switzerland, perform far better than any other country in the comparator group (Figure 4.4).

Figure 4.4. **Share of top 1% most frequently cited articles in their respective fields by the top publishing universities, selected countries, all sciences, fractional count**



Source: Centre for Science and Technology Studies (2018), *CWTS Leiden Ranking 2018*, www.leidenranking.com/ranking/2018/list.

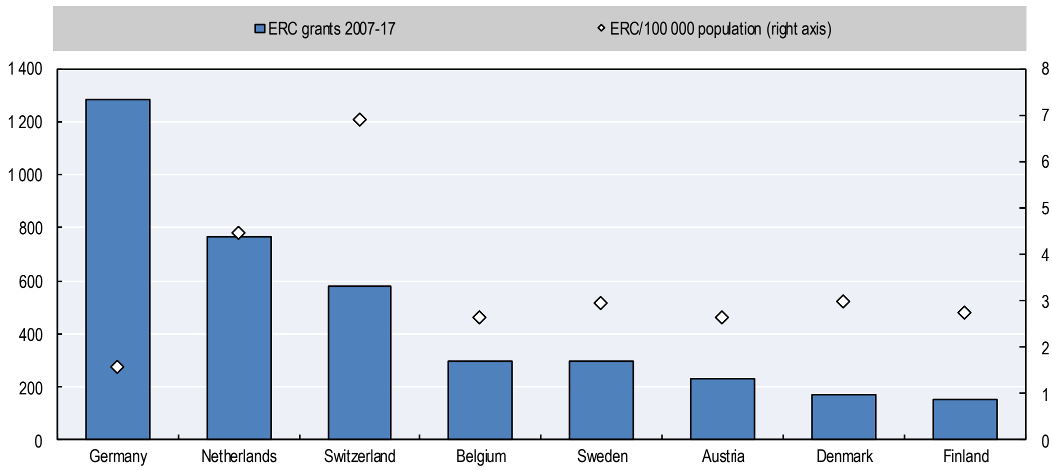
StatLink https://doi.org/10.1787/888933882750

Performance of Austrian universities and research institutes in European Research Council calls

In the context of EU research funding, the creation of the European Research Council (ERC) has been a landmark innovation in competitive funding based on scientific excellence as the core criterion of project selection (OECD, 2017b). With its focus on competition and excellence, the number of ERC grants awarded provides a benchmark for research quality, both for national research systems and individual institutions (Edler et al., 2014). Consequently, data on ERC grants have become a widely used indicator of high-quality research in Europe. Since more than 70% of ERC grants go to university-based researchers,[9] data on ERC grants are also useful for comparing HEIs across Europe.

Overall, Austria has performed rather well, given the composition of the group of comparator countries which comprises European innovation leaders that all have a strong, and some a globally outstanding, science base (Figure 4.5). Austria accounts for 2.6 ERC grants per 100 000 inhabitants, which is similar to Belgium and Finland, not far behind Sweden and Denmark, and considerably ahead of Germany. The two countries clearly in leading positions are the Netherlands, and – by a long shot – Switzerland (6.8).

Figure 4.5. **European Research Council grants, absolute and relative numbers per 100 000 inhabitants, selected countries, 2007-18**



Source: ERC (2018), *European Research Council Statistics* (database), https://erc.europa.eu/projects-figures/statistics (accessed on 11 August 2018).

Over the period 2007-17, Austria received a total of 232 ERC grants. PRIs and other research institutes obtained almost half of these (Table 4.3). While the large University of Vienna and the Technical University of Vienna together received 29% of all ERC grants, the remaining universities obtained 25%. This indicates that there is room for improvement of universities' performance in the competition for ERC grants.

International mobility of researchers and students

Important motives for researcher mobility relate to the benefits deriving from working with leading experts (including reputational gains), financial incentives and better career opportunities. In the most advanced countries, both nationals and non-nationals tend to move in and out of the respective country in significant numbers. In 2016, the share of Austrian scientists moving to a scientific institution abroad was 8.5%, while the share of scientists returning to Austria was 3% (Figure 4.6). At the same time, the share of foreign researchers coming to Austria was 6.3%, resulting in a slightly positive net flow of 0.6%.

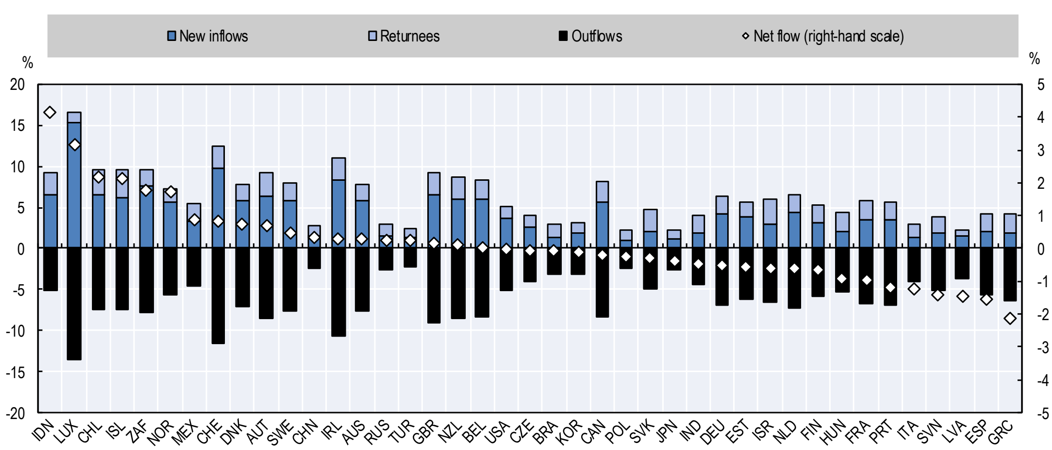
Table 4.3. **Number of European Research Council grants awarded to Austrian universities and research institutes**

Institution	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	Total
University of Vienna	3	4	4	6	5	1	5	6	4	3	1	42
Institute of Science and Technology (IST) Austria	3	10	6	1	4	3	4	3	2	0	1	37
Technical University of Vienna	3	4	3	2	2	4	3	2	2	1	0	26
Austrian Academy of Sciences	4	2	2	1	3	0	2	3	0	0	0	17
Institute for Molecular Pathology Ltd. (IMP)	1	2	2	1	3	1	3	0	1	1	1	16
Institute for Molecular Biotechnology Ltd. (IMBA)	0	0	3	0	4	0	1	1	1	1	1	12
Centre for Molecular Medicine Ltd. (CeMM)	1	1	3	0	0	1	1	0	1	0	0	8
Gregor Mendel Institute for Molecular Plant Biology Ltd.	0	1	0	1	1	0	0	1	0	0	0	4
Other universities and research institutes	7	11	9	10	4	5	7	5	4	3	5	70

Source: ERC (2018), *European Research Council Statistics* (database), https://erc.europa.eu/projects-figures/statistics (accessed on 11 August 2018).

Figure 4.6. **International mobility of scientific authors, 2016**

As a percentage of authors, by last main recorded affiliation in 2016



Source: OECD calculations based on Scopus Custom Data, Elsevier, Version 4.2017, July 2017.

StatLink https://doi.org/10.1787/888933882769

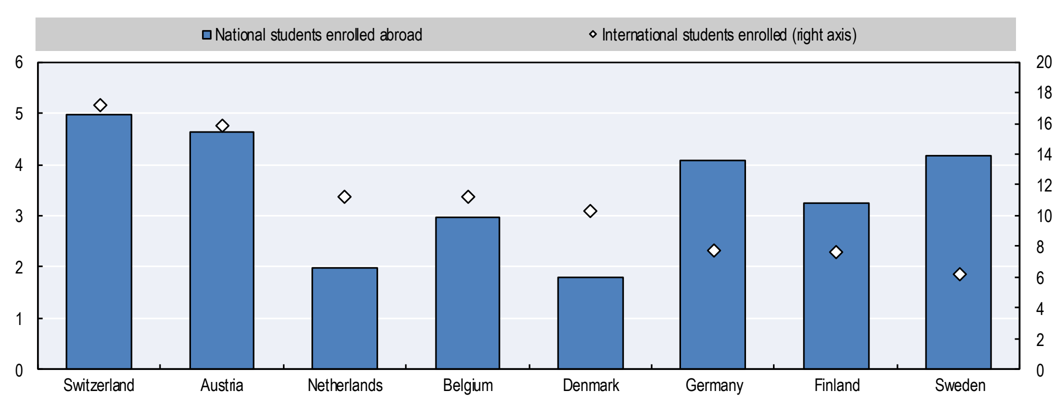
Internationalisation plays an increasing role in the strategic objectives of Austrian universities. Orientation and strategic objectives towards European and other international developments and benchmarks are anchored in the performance agreements. Universities' internationalisation and mobility strategies comprise, among other things, ensuring a "mobility window" in the curricula, transparent degree and course recognition practices, and measures to facilitate quality in mobility and increasing the number of outgoing and incoming students and teachers.

Qualified experiences abroad are increasingly recognised and promoted as a desirable step in the professional career of teachers and researchers. A number of universities have concluded qualification agreements with academic staff in this regard. In addition, universities promote the mobility of their staff by providing additional financial support (through mobility grants and allowances [EC, 2018]).

The international mobility of students has a number of potential benefits. It can contribute to knowledge absorption, technology upgrading and capacity building in home countries, provided students return home after studies or maintain strong linkages with the home economy. Mobile students gain tacit knowledge that is often shared through direct personal interactions and enables their home country to better integrate into global knowledge networks. Recent data suggest that numbers of students leaving to study overseas are a good predictor of future scientist flows in the opposite direction, providing evidence of a significant brain circulation effect (Appelt et al., 2016). In addition, student mobility appears to be more impactful on future international scientific co-operation networks than considerations such as having a common language, or even geographical or scientific proximity.

The mobility of Austrian students enrolled in tertiary-level study programmes is above average compared to the comparator countries (Figure 4.7). In 2015, Austrian nationals studying abroad constituted 4.6% of all students enrolled in a Bachelor's, master or doctoral programme. This share is higher than in all other comparator countries except Switzerland (5%) (Figure 4.7). On the other hand, 15.3% of all tertiary enrolled students in Austria (2015) come from abroad, a share surpassed only by Switzerland. However, a specificity of Austria is a relatively high share of German nationals enrolled in the HEIs. This reflects geographic proximity, a shared language, push factors such as admission restrictions in Germany, and more generally the high quality of life in Vienna and other Austrian university cities.

Figure 4.7. **Distribution of international and foreign students in Austrian higher education institutions, 2015**



Source: OECD (2017c), *Education at a Glance 2017: OECD Indicators*, http://dx.doi.org/10.1787/eag-2017-en.

StatLink https://doi.org/10.1787/888933882788

Although mobility increases with educational level, mobility patterns at doctoral level differ substantially from lower tertiary levels, as some countries become more attractive than others (OECD, 2017c). This is also evident in Austria, where in 2015 27% of PhD students came from abroad. This is markedly lower than in Switzerland (54%), Belgium (42%), the Netherlands (34%) and Denmark (32%), but above Finland (20%) and Germany (9%) (OECD, 2017c).

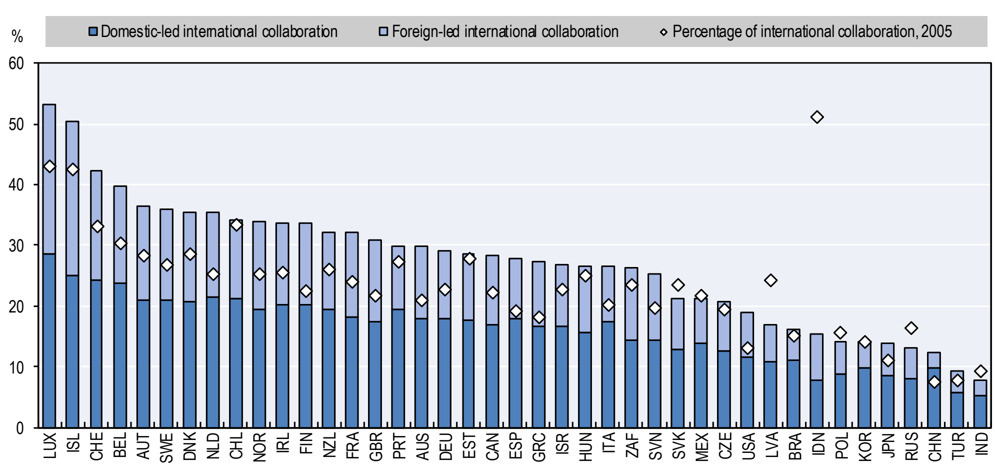
International scientific collaboration

Scientific research collaboration can be an effective means to overcome the limitations of scientific production that are often positively correlated with smaller economies (OECD, 2017a). Scientific co-publication helps participating more intensively in global networks. Joint analysis of excellence and leading authorship (i.e. affiliation of the leading author) provides further insight into the source of a country's top-cited publications, as many are underpinned by international collaborations, often led by authors with foreign affiliations. Some countries have high overall excellence rates thanks to the contribution of collaborative articles led by authors abroad.

Austria scores high in terms of international co-authorship of scientific publications (Figure 4.8), as well as in the share of public R&D expenditures for transnationally co-ordinated R&D. Although these two indicators are natural features of small countries given the national scientific community being limited in size, they indicate that Austria is generally well connected with foreign partners within science and innovation. The share of domestically led foreign co-publications in Austria is 22% (2015) and ranks behind Luxembourg, Iceland and Switzerland only.

Figure 4.8. **International scientific collaboration, 2015**

As a percentage of domestically authored documents, fractional counts



Source: OECD (2017a), *OECD Science, Technology and Industry Scoreboard 2017: The Digital Transformation*, http://dx.doi.org/10.1787/9789264268821-en.

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Research performance of universities of applied sciences

While research is not primary in the mandates of the UAS, they are legally required to perform practice-related R&D (AIT et al., 2017). Currently, the UAS perform a small share of the R&D conducted at the HEIs (3.6% of HERD in 2015). This corresponds to 0.8% of

GERD in 2015, compared to 18% from universities (BMBWF, 2018). Within their research activities, the UAS focus on applied research (accounting for 80% of R&D expenditures at UAS in 2015), which is conducted in close co-operation with industry. Local SMEs accounted for 62% of all research cooperation (FHK, 2018). In 2015, the UAS had an R&D budget of EUR 104 million and employed 960 full-time equivalent researchers (BMWFW, 2016).

Since 2012, 13 Josef Ressel centres (JRC) have been established to strengthen the integration of regional business partners in applied research activities at the UAS by establishing long-term co-operation. The JRCs facilitate business access to the UAS' research expertise. They also help increase the exposure of the UAS to applied research questions (FHK, 2018). The JRCs are funded via the Christian Doppler Research Association (CDG) and run for up to five years, with an annual budget of up to EUR 400 000. JRCs – which are not a priori restricted to particular research areas – currently operate in two clusters: 1) mathematics, informatics and electronics; and 2) non-metallic materials. Since 2008, the UAS have been very successful in the successor programme COIN "Aufbau" (capacity building) that aims at strengthening providers of applied research, who are core partners for enterprises in terms of R&D, and increasing the co-operation between applied sciences and companies, especially SMEs. In 2015, the UAS obtained revenues from R&D co-operation amounting to EUR 40 million (FHK, 2018). The business sector financed R&D at the UAS with EUR 13 million (13% of all R&D performed at the UAS, compared to 4.8% for universities [Statistics Austria, 2017]).

Third mission of universities: Knowledge transfer, commercialisation and civic engagement

Engagement with the wider world is recognised as one of the main functions of HEIs, in addition to research and teaching. This broad function is also referred to as the "third mission". The term "engagement" reflects the widely accepted responsibility of HEIs to generate social benefits (Goddard et al., 2016; Benneworth, Pinheiro and Karlsen, 2017).

In recent decades, HEIs have become more entrepreneurial in many countries, with the development of on-campus business incubators, technology accelerators, science parks and spin-offs. This trend has been accompanied and driven by increased policy attention to the economic outputs of commercial activities of universities.[10] In view of the large public investment in R&D, and budgetary pressures faced by many countries, governments have placed more emphasis on enhancing impact, notably by strengthening science-industry links (OECD, 2018b). Accordingly, government efforts to promote and remove obstacles to science-industry relations have gained in importance (OECD, 2002; 2013). Active engagement between HEIs and communities, industry and others can help ensure that higher education is more responsive to the wider needs of society, and enhance the relevance of both educational and research activity (OECD, 2018b). Recent years have also seen greater attention given to the contribution of universities and PRIs to addressing challenges in such areas as climate change, public health, sustainable energy, food and water supply (OECD, 2018b; 2018e).

Commercialisation of research and transfer of knowledge

Science-industry knowledge transfer includes the commercialisation of academic knowledge through patent transactions and the creation of spin-off companies, as well as collaborative research, contract research, consulting, informal networking and exchanges with society at large (OECD, 2018b).

HEIs and research institutes are encouraged to engage in outreach activities, including industry co-operation ("third mission"). All universities have support infrastructure for knowledge and technology transfer activities. Attracting contract research from industry is also a relevant source for funding R&D at HEIs. In recent years, contract research from industry contributed about 5% to HEIs' total R&D budget. Programmes such as the FFG's "Research competences for the business sector" mainly aim at pooling specific qualification needs relevant to the competences of innovation teams in the business sector and providing support for the development of tailor-made qualification measures.

Third-mission activities of Austrian universities are anchored in the Austrian University Development Plan and the performance agreements between individual universities and the BMBWF. The performance agreements for the period 2016-18, for instance, emphasised third-mission activities, requiring universities to contribute to sustainable development, integrate the concept of the entrepreneurial university (including entrepreneurship education) into strategic institutional planning, and outlining projects and targets for co-operation with industry and the commercial exploitation of research results (BMWFW and BMVIT, 2016). The "third mission" in its broad understanding is also among the priorities of the performance agreements for 2019-21.

Important, albeit partial, indicators of science-industry linkages in the innovation system are the share of HERD financed by business enterprises, and the share of publications co-authored with one or more industrial organisations. Austria's comparative performance on these two measures is somewhat mixed. At 5.1% in 2015, the share of HERD financed by the business enterprise sector in Austria exceeded that of Denmark, Finland and Sweden, and was somewhat below the OECD and EU averages of 6.2% and 6.4% respectively (Table 4.4). Much higher levels of business funding are seen in Germany (13.9% in 2015), Belgium (12.9%) and the Netherlands (7.9%). It should be noted, however, that Austria is in the leading group regarding the share of innovation-active enterprises that co-operate on innovation with universities (92%) or public research institutes (48%), and that a large part of interactions between industry and science in Austria also take place in research institutes that are part of the so-called co-operative sector (see below).

Table 4.4. **Percentage of HERD financed by the business sector**

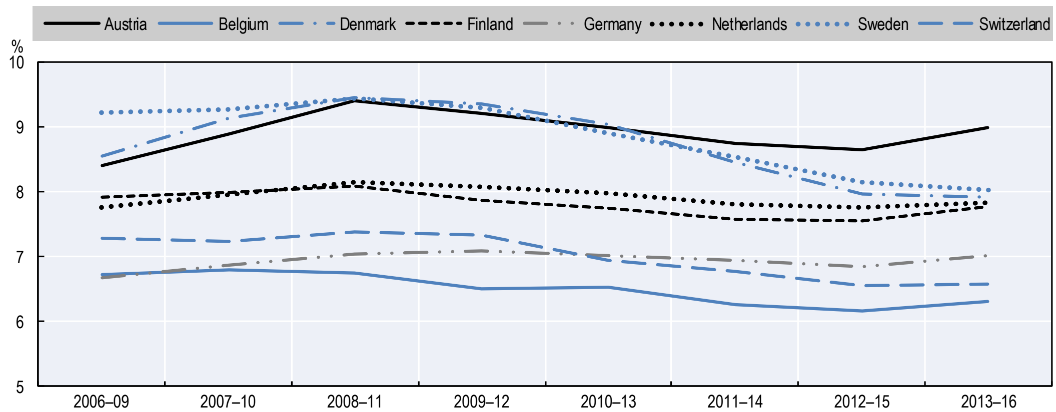
	2000	2010	2012	2016
Austria	4.1	5.	5.1	5.2
Belgium	11.8	10.1	11.3	12.8
Denmark	2.0	3.1	2.7	2.6
Finland	5.5	5.7	5.1	3.7
Germany	11.6	13.8	14.0	13.8
Netherlands	5.2	8.2	8.3	7.8
Sweden	5.4	4.1	3.8	4.0
Switzerland	5.1	9.1	10.9	9.7
EU28	6.2	6.3	6.4	6.4
OECD	6.4	5.7	5.7	6.1

Note: 2002 for Austria; 2001 for Netherlands, Norway and Sweden; 2011 for Austria, Netherlands, Norway and Sweden; 2013 for Austria, Norway and Sweden.
Source: OECD (2018d), *Main Science and Technology Indicators, Volume 2018 Issue 1*, https://doi.org/10.1787/msti-v2018-1-en.

The number of co-publications with industry partners increased over the 2013-16 period, compared to 2009-12, almost returning to the levels in 2008-11 (9%) (Figure 4.9). An upward trend is observable in all comparator countries with the exception of the

Netherlands and Sweden. In terms of co-publications per million of the population, Austria's corresponding number (80) is twice as high as the EU average (40). However, Austria lags behind Switzerland (260) and Denmark (156) by a large margin, and Sweden and the Netherlands to a lesser extent. To some degree, these numbers reflect the lesser role of science-based business activity in Austria's overall industrial structure, which is skewed towards medium-technology intensive industries.

Figure 4.9. **Proportion of publications co-authored with one or more industrial organisations**



Source: EIS (2018), *EIS 2018 Database*, https://ec.europa.eu/docsroom/documents/30282 (accessed in August 2018).

StatLink https://doi.org/10.1787/888933882826

A number of policy instruments and institutional arrangements target science-industry linkages in Austria and the commercialisation of knowledge. These instruments include public support programmes such as the COMET competence centre programme, the largest funding scheme for technology transfer in Austria with a total budget well above EUR 100 million in 2018, of which EUR 112 million were allocated for new calls. COMET's objective is to support collaborative development between science and industry based on three different funding schemes that provide a maximum funding of EUR 1.7 million per year, over a maximum duration of eight years, depending on the level of risk involved in the collaborative research project (see also Chapter 3). Other initiatives have included the AplusB centres, a network of business incubators to support academic spin-offs. The aim of the AplusB scale-up programme is to support the utilisation of academic research results via academic spin-offs and start-ups. The programme responds to comparatively low start-up activity in Austria, in particular for the high-technology sector, which accounts for less than 10% of all new companies (Ecker et al., 2017). The AplusB impulse programme aims to bring about a sustainable increase in the number of innovative, technology-oriented spin-offs from the academic sector. The programme funds the AplusB-centres that provide professional support for scientists in the process of translating research into a marketable commercial activity, and supporting activities that target fast growing start-up projects. The programme is funded by the BMVIT and operated by the *aws*.

Direct funding for knowledge transfer from scientific research to enterprises is provided by the FFG's BRIDGE programme. BRIDGE further develops results from basic research, in co-operation between scientific and business partners, with the goal to identify commercial applications of research for firms. An interim evaluation of the programme in 2018 found that BRIDGE contributes towards improved linkages between science and industry in Austria as well as knowledge transfer (BMBFW, BMVIT and BMDW, 2018). According to the evaluation, only 4-7% of the projects funded by BRIDGE between 2009 and 2016 would have been implemented in a similar form without the programme, pointing to its importance for knowledge transfer. To stimulate the application of scientific knowledge for technological development and innovation in SMEs, the Cooperation & Innovation (COIN) programme supports the establishment of knowledge transfer structures, and the funding of co-operation between SMEs and research institutions and universities on a project basis. In addition, knowledge transfer centres are designed to support knowledge and technology transfer by strategically bundling research outputs by universities, the UAS and the PRIs (AIT et al., 2017). Evaluations suggest a positive view of the quality and impact of science-industry links in Austria (Schibany et al., 2013). Evaluations of the various schemes and organisations have generally shown a positive overall impact on the level and the quality of industry-science relations.

Civic engagement

Both with regard to the commercialisation of new technologies and the transfer of knowledge supporting broader social goals, universities and research funders are reframing their roles and institutionalising processes to include civic engagement and outreach in research activities, and use results in local communities (Butterfield and Soska, 2013).

Relatively strong linkages exist between firms and the HEIs in Austria. However, there is room for extending co-operation between the HEIs and society, as suggested by a low level of societal interest in science and research, and the need for more adults to participate in formal lifelong learning (in Austria, only 14% of high-skilled workers receive firm-based training, as compared to 38% in Finland [OECD, 2017a]).

Two initiatives provide examples of how targeted audiences are being approached though outreach activities. With regard to the public, the Centre for Citizen Science is a recent addition to the Austrian innovation system, established in 2015 by the BMBWF. Its main goal is to support amateur scientists and people interested in different areas of science to contribute to new knowledge through their expertise and collaboration with the science community.

Another initiative, Sparkling Science, addresses elementary and high school students in an effort to instil and grow interest in science and scientific careers in the younger generation. The Sparkling Science programme blends the notion of citizen science with outreach to schools. The notable characteristic of this programme is that it involves students of all ages in scientific research projects, and offers the opportunity for students to produce genuine scientific output. Through this involvement in research, students increase their learning abilities and get a better understanding of scientific careers. The ability to join human and technical resources from the partnering HEIs offers considerable learning opportunities for the high schools involved (Schauppenlehner et al., 2012). However, the initiatives could benefit from using evaluation to derive conclusions on how to improve and sustain their impact among students.

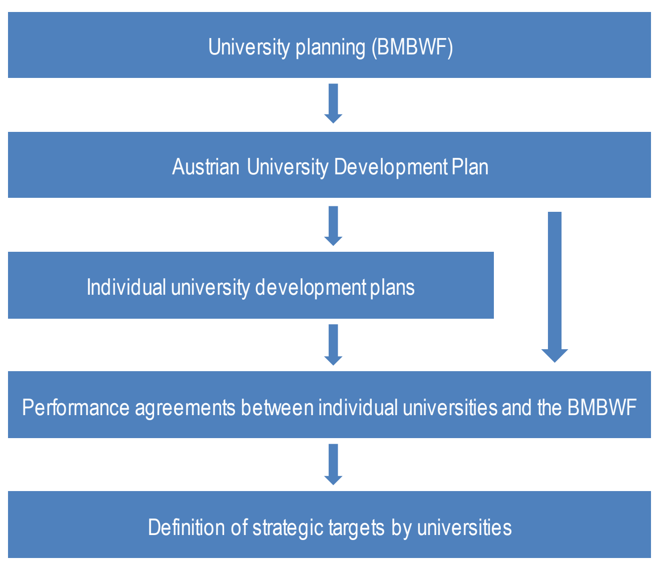
Steering and funding of universities

Strategic steering of universities

With the implementation of the University Act 2002, public universities became legal entities under public law. They are free from any instructions by the government and are self-regulated through their statutes. The BMBWF legally supervises the universities' activities and is in charge of higher education planning. The RTI Strategy 2011-20 set out central development objectives for the higher education sector. These include improving the quality of university instruction and the conditions for researchers, promoting gender equity in research, and excellence in basic research and research infrastructures. To steer public universities towards achieving the government's strategic objectives for tertiary education and research at universities, the BMBWF has a number of instruments at its disposal. The framework for steering public universities consists of the following key components: the Austrian University Development Plan; the individual university development plans; and the performance agreements concluded between individual universities and the BMBWF (Figure 4.10).

The current Austrian University Development Plan (redrafted in 2017 for the period 2019-24) presents eight systemic objectives providing a strategic framework that takes into account the development of individual university development plans. Individual university development plans are a strategic planning instrument and provide an important basis for the performance agreements. While individual university development plans define institutional strategic targets, the performance agreements are the basis for allocating public institutional funding to the universities and are therefore a key steering instrument. The performance agreements define a concrete set of measures and services based on the respective university's development plan. The performance agreements have a duration of three years, for which the university receives public funding.

Figure 4.10. **Key elements in the strategic planning and steering of public universities in Austria**



Note: BMBWF: Ministry of Education, Science and Research.
Sources: Adapted from BMBWF (2018), "Universitätsbericht 2017" ("University report 2017"), https://www.bmbwf.gv.at/fileadmin/user_upload/Publikationen/Universit%C3%A4tsbericht_2017_barrierefrei.pdf; Unger, M., D. Wagner-Schuster and W. Polt (2016), "Place-based higher education policies in Austria: Austrian case study for the OECD".

Performance agreements

Appropriate funding and adequate steering mechanisms are prerequisites for high-performing, entrepreneurial and innovative universities. As shown above, a central device in the system of strategic steering of autonomous Austrian universities and their institutional funding are the performance agreements. These agreements are negotiated on a three-year cycle between the government (BMBWF) and each university. The first of these cycles covered the period of 2007-09. Currently, the fifth round of performance agreement, which contain some new features, is concluded for the period 2019-21,

The negotiation of these agreements through several rounds constitutes an important learning process for both sides of the negotiation. The Austrian Science Board (Österreichischer Wissenschaftsrat, 2016) has analysed previous performance agreements in depth and has pointed at what are considered areas for improvement. These included: the extensive coverage of the performance agreements, which the Science Board related partly to the absence of a clear distinction between routine activities of universities on the one hand, and strategic priorities and projects of strategic character and importance on the other hand; an ambiguity arising from differences in the understanding of what profiling and profile development means for individual universities; and, a lack of clarity on the consequences of non-achievement of particular projects and goals.

Up to now (including the performance agreements 2016-18), the activities covered have often been considered too numerous and their alignment with institutional profiles, particularly with respect to improving the universities' performance and international competitiveness, weak overall, reducing the ability of performance agreements to steer the Austrian universities towards higher quality and excellence. Performance agreements contained a mix of activities and target outcomes, over-emphasising activities at the expense of a clear focus on a limited number of desired outputs and impacts.

In particular, the performance agreements have lacked a reward-based objective setting and clearly articulated consequences when targets are not met. Performance-based systems – including performance agreements – in other countries have used metrics to help understand why specific goals have not been achieved and in a number of cases provided a direct link to funding. As such, performance agreements can be an efficient means of improving the institutional performance of universities and other research institutions.

The introduction of the new system of capacity-oriented, student-based model of university financing is an opportunity to strengthen the steering capacity of the performance agreements and make them more effective in practice.

The new model of institutional university funding

In August 2017 the National Council set the total amount of university funding at EUR 11.07 billion for the 2019-21 performance agreement period (which was an increase by EUR 1.3 billion compared to the previous period)[11] and tasked the federal government with implementing a model for capacity-oriented student-related university funding (BMBWF, 2018). The corresponding revision to the Universities Act 2002 became law on 4 April 2018.[12]

The new capacity-oriented student-related university funding model is being applied for the first time in the performance agreements for the 2019-21 period. This new model aims at:

- increasing the quality of teaching on the one hand and research and advancement and appreciation of the arts on the other, by improving support and supervision ratios (teacher-to-student ratios) and reinforcing research
- achieving more transparency through separating funding for the performance areas (pillars) of "teaching", "research/advancement and appreciation of the arts" and "infrastructure/strategic development"
- increasing the proportion of students actively taking exams.

In Austria, the traditionally open policy towards student admission has increasingly come under strain as the funding and staffing of universities has not kept pace with the increasing number of students. This issue has been addressed gradually. Complementing the new university funding model, the 2018 amendment of the University Act 2002 extended already existing admission regulations to additional fields of study in high demand, including the fields of education of "law", "foreign languages" and "educational sciences". Under certain conditions, university-related access regulations were made possible for relevant degree courses.

The ratio of students to teaching staff compares the number of full-time students to the number of full-time teaching staff. Lower student-to-teacher ratios are generally associated with better learning environments and improved working conditions for teachers. The ratio of students to teachers is also an indicator of the resources devoted to education.[13] In Austria, the ratio of professors to students at HEIs was 119 in 2017 while comparator countries[14] record much more favourable ratios (Finland at 61 [2015], Germany and Sweden at 60, respectively, and Denmark at 40. In Switzerland, this ratio is as low as 37).

In the new funding model, the universities continue to receive a global budget. The global budget that each university receives for a three-year performance agreement period will be composed of separate funding for the three pillars: 1) teaching; 2) research (for research universities) and advancement and appreciation of the arts (for the universities of art); and 3) infrastructure and strategic development.[15]

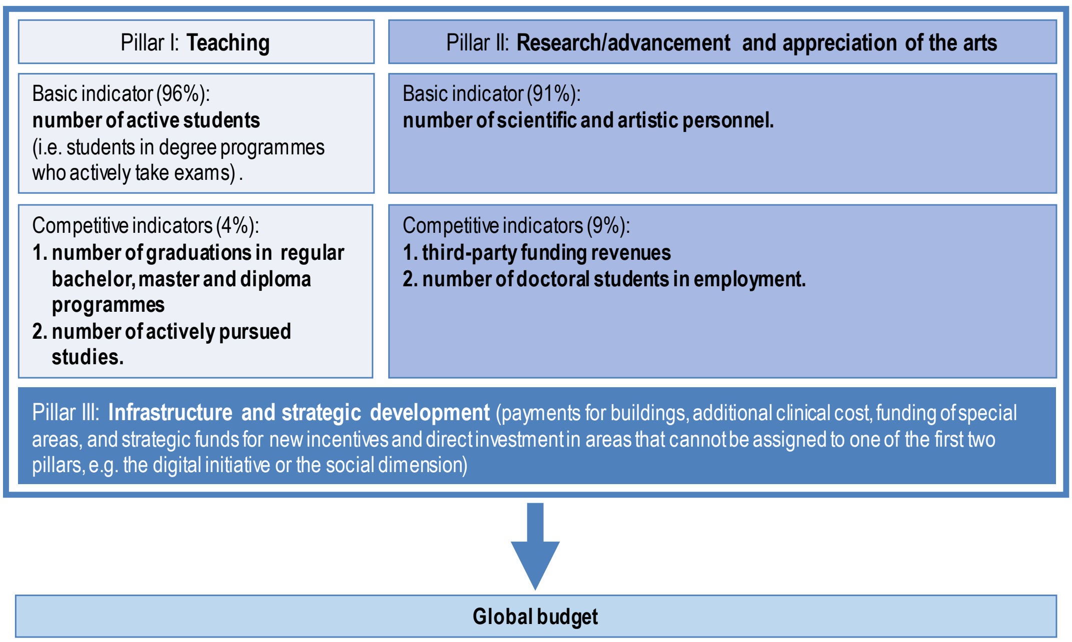
- For the first pillar ("teaching"), the basic indicator is the number of active students, i.e. students in degree programmes who actively take exams (student places). In addition, two "competitive indicators" are used to provide specific incentives in each of the two pillars. For teaching, the competitive indicators are the number of graduations in regular bachelor, master and diploma programmes and the number of studies actively pursued by students.
- For the second pillar ("research/advancement and appreciation of the arts"), the basic indicator is the number of scientific and artistic personnel. For research, the competitive indicators will be third-party funding revenues and the number of doctoral students in employment.

The reference value for these basic indicators of the first and second pillars are agreed upon in the negotiations of the performance agreements. These reference values will determine the indicator-based part of the global budget for each university.

- The third pillar (infrastructure and strategic development) – in addition to payments for buildings, additional clinical cost and funding of special areas such as art galleries etc. – comprises strategic funds for new incentives and direct investment in areas that cannot be unambiguously assigned to one of the first two pillars, e.g. the social dimension or digital initiative.

Overall, the new model of university funding is an important step in the right direction. First, the new model provides a higher degree of transparency by separating the funding streams for teaching and research. Austria will thereby follow a practice numerous countries have adopted (e.g. Finland in the 1990s). Second, the new model establishes a direct link between indicators and university funding. At the same time, Austria has chosen to take a "soft" approach of introducing the new funding model through the initial specification of the indicators. A high share of the budget for teaching and (less so) for research is distributed through the basic indicators. In the area of teaching, the basic indicator is responsible for the allocation of 96% of the respective budget. In the area of research, the basic indicator accounts for 91% of the budget. This is mirrored by a relatively modest weight given to the "competitive indicators": 4% for the two competitive indicators for teaching, and 9% for those for research (Figure 4.11). This leaves considerable scope to expand the competitive dimension of institutional university funding by increasing the weight of the competitive indicators. These weights might indeed be increased, based on the experience over the current performance agreement period.

Figure 4.11. **New university funding model in Austria**



Sources: BMBWF (2018), "Universitätsbericht 2017" ("University report 2017"), https://www.bmbwf.gv.at/fileadmin/user_upload/Publikationen/Universit%C3%A4tsbericht_2017_barrierefrei.pdf; BMBWF, BMVIT and BMDW (2018), "Austrian research and technology report 2018", https://www.bmvit.gv.at/en/service/publications/downloads/downloads_ftb/ftb_2018_en.pdf.

While the use of the indicators mentioned above can be expected to have a positive impact in a number of dimensions (such as the quality of doctoral education, the student-to teacher ratio, etc.), it may be questioned whether the currently used set of indicators is likely to have significant impact on research excellence in the short and medium term. Among the indicators for research, there is currently no direct output indicator (such as qualified publications, for instance).[16] The third-party revenue indicator may be interpreted as being influenced by the quality of research performed, but this may not be the case throughout. Moreover, the success in winning research grants is, to some extent, dependent on the budget of the FWF. While the increase of the FWF budget for 2018-21 is a commendable step, it remains low (e.g. on a per capita basis) relative to the budgets of similar funding organisations in comparator countries (see the following section), and this limits, in relative terms, the impact of the corresponding competitive indicator. More broadly, while the funding model applied in the new performance agreements 2019-21 – combined with the increase of university funding by EUR 1.3 billion – are an important step towards a capacity-oriented student-based system. However, a sustained effort, including in terms of investment, will be necessary to roll out a fully-fledged system of this kind with all the desired properties in terms of funding of student places.

Competitive research funding

A significant proportion of public research funding is distributed via competitive research funding mechanisms. Competitive funding schemes can be classified in different ways depending on the scope and purpose of the analysis (OECD, 2018f). Increasingly, many of these "individual" awards actually support teams of researchers, including technicians, students, post-doctorates and investigators. In addition, competitive funding can vary according to the type of research, whether basic or applied research, where especially the latter often involve business enterprises and research cooperation between enterprises and HEIs or PRIs. In Austria, the mix of competitive research funding comprises a variety of instruments, covering all types of support, both for basic and applied research. The main public funding organisations for competitive research in Austria are the Austrian Science Fund (FWF), providing funding for basic research, and the Austrian Research Promotion Agency (FFG), which is mainly responsible for applied research. See also Chapter 5 for an assessment of the role of major federal funding agencies for STI governance in Austria.

Research funding through the Austrian Science Fund

The FWF is the main funding agency for basic research in Austria. Its funding is awarded competitively and primarily to applicants at universities and research institutes. In 2017, approved project funding by the FWF reached EUR 217.3 million. This constitutes a EUR 95 million increase (77%) since 2005. Funding reached EUR 203 million in 2014, before dropping to EUR 184 million in 2016, and then rebounding to the current level. Over the 2005-17 period, the total application volume increased by 51%, to EUR 879.4 million (FWF, 2018). Overall, this marks a positive development for competitive funding for basic research in Austria over the past decade and a half. However, as described below, compared to the leading innovation countries, there is still considerable room for improvement regarding funding of basic research.

Looking at per capita funding for competitive basic research, Austria's EUR 22 (2016) has remained rather stagnant since 2007. Countries leading in research and innovation substantially increased their per capita funding over the same period. On a per capita basis, Austria funds only 20% the volume of Switzerland (SNSF); less than half the volumes of Finland, Sweden, the United Kingdom and the Netherlands; and just above 50% of the per capita funding in Germany (DFG) (RFTE, 2018).

For the 2018-21 funding period, an additional EUR 110 million have been made available to the FWF for competitive funding of basic research. While this is a positive development, it nevertheless falls far short of catching up with the group of innovation leaders, and limits Austria's potential as a location for competitive science and research (Box 4.5).

The core of FWF funding consists of thematically open project-specific funding for researchers in all subject areas. The development of human resources is also supported, e.g. through structured doctoral programmes, support for international mobility and career development for researchers (BMBWF, BMVIT and BMDW, 2018). Basic research funding at the FWF is additionally supported through the allocation of funds and the contributions of private foundations, including the Dr. Gottfried and Dr. Vera Weiss-Science Foundation, the ASMET research award, the Herzfelder Foundation, and the Internet Private Foundation Austria (IPA). In total, these foundations provided financing for FWF research projects totalling EUR 1.6 million in 2017. The FWF portfolio will be expanded by a number of new initiatives to strengthen competitive elements in research funding. The "1,000 Ideas Programme", will focus on support for new, innovative fields of research which have great potential but are also high-risk, and a programme to finance

100 additional futures professorships between 2018 and 2021 aims to help strengthen the international attractiveness of Austria as a location for science. In addition, in 2018 a postdoc programme for innovative, interdisciplinary teams, a programme for quantum research and technology, and a networking programme for interdisciplinary or multidisciplinary teams across research institutions have been placed on the agenda to expand the FWF programme portfolio.

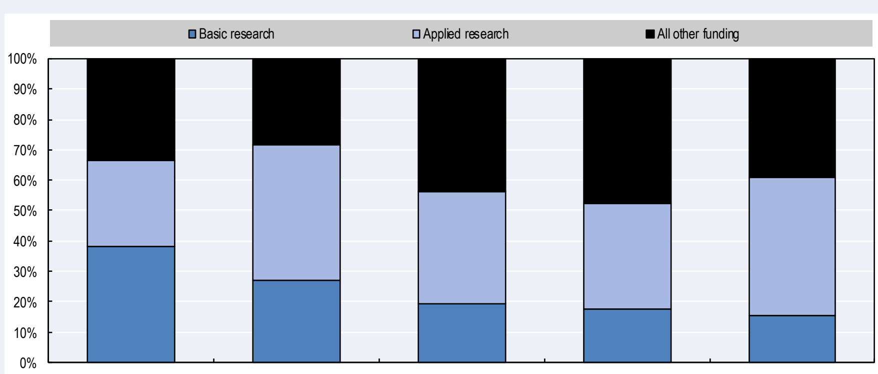
Box 4.5. **Basic and applied research**

The comparatively low level of competitive funding for basic research in Austria is widely seen to have potentially adverse effects on research excellence.

Under the definition of the *Frascati Manual* (OECD, 2015), basic research in Austria was 18% of total R&D in 2016 (Figure 4.12). This same share was 19% in Denmark, 27% in the Netherlands and 38% in Switzerland. Austria's R&D is tilted towards experimental development (the "D" component of R&D) and, to a lesser extent, applied research (35%). Belgium and the Netherlands are specialised in applied research, which accounts for 45% of total R&D in both countries. The Netherlands stand out through a very small share of "D", which reflects the country's industrial structure.

It should be noted, however, that the distinction between basic and applied research has become increasingly blurred. Some countries (such as Sweden and others) do not report these categories separately.

Figure 4.12. **Basic and applied research as a share of total R&D expenditures in Austria and selected countries, 2016**



Note: 2015 for Switzerland.

Source: OECD (2018d), *Main Science and Technology Indicators, Volume 2018 Issue 1*, https://doi.org/10.1787/msti-v2018-1-en.

The FWF's specific funding instruments and programmes for top-quality research can be grouped into four categories:

1. **Stand-alone projects** target researchers of all disciplines who are performing research in Austria. Their objective is to fund individual research in the area of non-profit oriented scientific research that promises high research quality,

measurable on an international scale. The funding period of these projects is up to 48 months (FWF, 2018). Total funding for this programme in 2017 was EUR 104 million.

2. **International programmes** include the funding of international research projects, seminars, ERA-net calls and support for graduate research opportunities worldwide. Joint projects aim at funding closely integrated, bilateral research projects whose funding is co-ordinated with that of the respective partner agency. Depending on the partner countries involved, the funding period covers three to four years. In 2017, the budget for FWF international research programmes was EUR 28 million.
3. **Special research programmes (SFB)** support research groups. The SFBs are open to scientists from all disciplines performing research at Austrian universities. They aim at establishing research networks based on international standards through autonomous research over a long period. Funded research needs to be interdisciplinary and tackle complex scientific questions. Funding for the SFBs is available over an eight-year period, with an interim review after four years. The maximum amount of funding for the SFBs is EUR 1 million per year. The maximum available funding through this programme is EUR 300 000 per year. Altogether, SFBs provided funding of EUR 12 million in 2017.
4. **Awards and prizes** funded by the FWF include the START Programme, Wittgenstein Award, Weiss Prize, ASMET Research Award, netidee SCIENCE projects and the Herzfelder Foundation. Overall, the goal of these awards is to support outstanding researchers across scientific disciplines by providing extensive financial security to perform excellent research. In 2017, awards and prizes totalled EUR 8.4 million.

Research funding through the Austrian Research Promotion Agency

The Austrian Research Promotion Agency (FFG) is Austria's national funding agency. It offers a diversified programme portfolio that primarily targets Austrian businesses, specifically their R&D departments, as well as research facilities. The FFG manages and finances research projects and supports co-operation between science and industry, co-operative programmes, and projects with the EU and other European and international partners.

FFG funding and support instruments consist of:

- basic programmes to strengthen the competitiveness of Austrian companies through tailored funding in each R&D project phase
- structural programmes to optimise research and innovation infrastructure; thematic programmes that encourage research and development activities in strategic research fields of future importance
- European and international programmes (EIP) to support participation in the EU Framework Programme and international R&D co-operation
- support for aeronautics and space agencies.

The range of funding instruments provided by the FFG includes projects exploring possible R&D themes for innovation and specific R&D projects, from targeted basic research to market-oriented development projects.

Researcher-specific projects promote young talent and improve the qualifications of R&D personnel (BMBWF, BMVIT and BMDW, 2018).

Basic programmes are the central funding instruments of the FFG, directly addressing R&D activities in the business enterprise sector (see also Chapter 3). Based on a bottom-up approach, they focus on lowering entry barriers for start-ups and SMEs, and provide tailored funding, through a mix of loans and grants. Basic programmes address financial barriers and the risks associated with bringing innovation to the market. The basic programmes aim to strengthen Austria's competitiveness and are thematically open, demand-driven R&D project funding instruments. Support is provided in different forms, such as grants, loans or guarantees. Basic programmes focus mainly on: 1) newcomers, i.e. small firms that are new to starting R&D activities; 2) start-ups and SMEs that can receive a mix of loans and grants that help mitigate financial barriers and the risk of innovation; and 3) large firms that receive strategic R&D support in areas that are critical for Austria to become an innovation leader. In 2017, EUR 179 million were provided to innovation activities in firms through the basic programmes. Within the basic programmes, funding for bottom-up firm projects and through the frontrunner programme make up the largest share with 63% and 15% respectively of total funding available through basic programmes. Bottom-up funding provides generic R&D support for firm projects through a mix of loans and grants, without thematic restrictions. Available funding through this programme increased by 14% between 2014 and 2017. The frontrunner programme supports the development of headquarter functions of firms, as well as regional co-operation networks. It saw a slight increase in funding between 2014 and 2017 through funds from the Austrian National Fund that provided additional EUR 18.6 million in 2017-18.

Other important funding programmes among the basic programmes are BRIDGE and Eurostars, that together account for 10% (2017) of funding in the basic programmes. The BRIDGE programme supports co-operation between science and industry and aims to close the funding gap between basic and applied research. It also acts as an umbrella for projects, which predominantly involve basic research. Eurostars co-funds firms and research institutions to improve international collaboration in research (FFG, 2018).

Structural programmes aim at optimising infrastructure for research and innovation and improving competencies in science and business over the long term. Structural programmes create preconditions for efficient co-operation of all actors in the innovation system, e.g. through the COMET competence centres programme. COMET combine research co-operation with technology transfer and is the largest funding scheme for knowledge and technology transfer in Austria. (The COMET centres are discussed in detail in Chapter 3). Box 4.6 provides an overview of recent additions to the FFG's programme portfolio.

Aeronautics and Space Agency represents Austria at international bodies in this sector. The programmes support the involvement of Austrian researchers in international and bilateral aerospace partnerships and encourage the establishment and expansion of international networks in this area.

European and international programmes help to strengthen Austria's participation the European framework programme for research and innovation, Horizon 2020 and in multilateral initiatives. Moreover, with other partners the FFG is also responsible for providing support services for EUREKA, COSME and the Enterprise Europe Network. EIP support rests on four key objectives:

- support successful participation by means of information and advice
- system-orientated support of Austrian RTI organisations
- expert partner for European RTI programmes and ERA developments
- analysis and RTI policy support.

In 2014, the FFG was also entrusted with monitoring Austria's involvement in Horizon 2020 and ERA.

Box 4.6. **Recent additions to the Austrian Research Promotion Agency's programme portfolio**

To further deepen co-operation between science and industry in specific areas, the Austrian Research Promotion Agency (FFG) has increased thematic calls with a specific focus on manufacturing, energy and mobility research. It initiated eight new COMET projects in 2016, with a total funding of EUR 12 million. The COMET programme was redesigned, complementing the two categories (K1 and K2) by a more flexible, modular approach (BMWFW and BMVIT, 2017). Since 2016, two new funding instruments complement the FFG's instrument portfolio. These aim to improve research infrastructure at firms and research institutes and support patent checking through the Patent.Check programme, which is run jointly with the Austrian Patent Office.

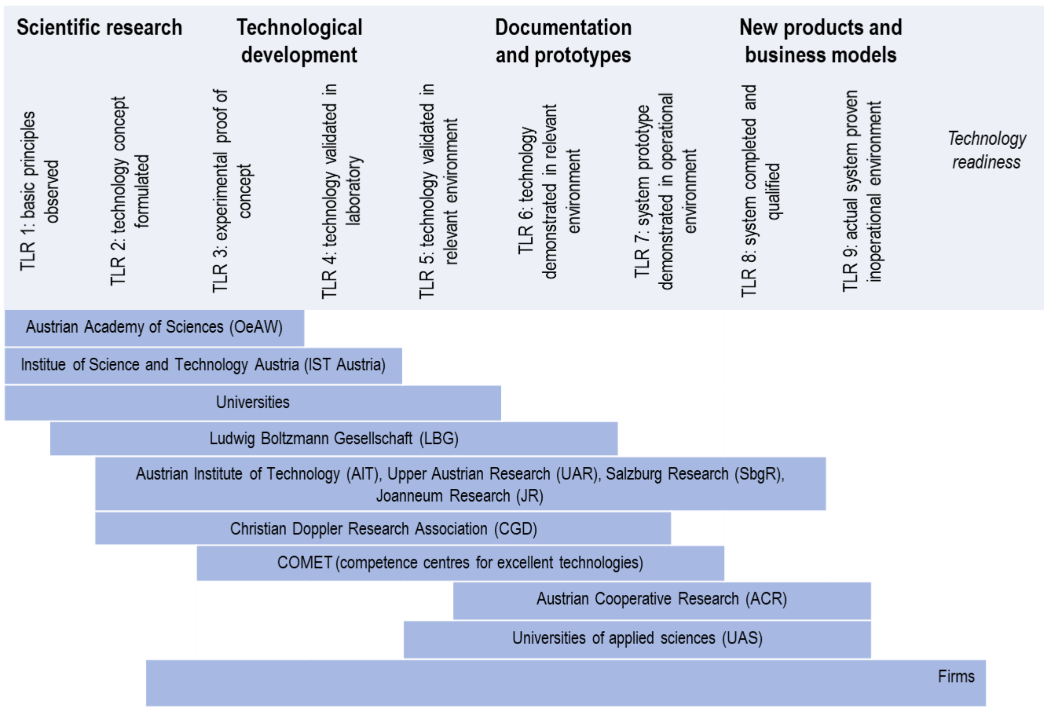
Since 2017, the FFG applies a more open approach to innovation through a number of instruments in the Impact Innovation programme. This programme supports the development of innovative ideas and solutions through intensive interaction with all relevant stakeholders. Additional programmes in the FFG's portfolio include the Ideas Lab 4.0 initiative, launched in 2017, which supports the development of novel research ideas through innovation workshops (BMBWF, BMVIT and BMDW, 2018). To support companies with high growth potential in new areas of business and technology fields, or in a changing market environment, the Early Stage programme funds individual projects that entail extraordinarily high risk (BMBWF, BMVIT and BMDW, 2018). The Spin-off Fellowship targets scientists and students interested in founding start-ups (BMBWF, BMVIT and BMDW, 2018).

Sources: BMWFW and BMVIT (2017), "Austrian research and technology report 2017", https://www.bmvit.gv.at/en/service/publications/downloads/downloads_ftb/ftb_2017_engl.pdf; BMBWF, BMVIT and BMDW (2018), "Austrian research and technology report 2018", https://www.bmvit.gv.at/en/service/publications/downloads/downloads_ftb/ftb_2018_en.pdf.

Public research institutes

Austria hosts a large number of public research organisations dedicated to performing R&D and innovation. Many of these organisations are important partners for industry and provide a link between university research and applied research in businesses. Most PRIs can be understood as research technology organisations (RTOs), which have as their core mission to harness science and technology in the service of innovation, to improve quality of life and strengthen economic competitiveness. The RTOs "occupy nodal positions within innovation eco-systems, bringing together key players across the entire innovation chain, from fundamental to technological research, from product and process development to prototyping and demonstration, and on to full-scale implementation in the public and private sectors."[17] These PRIs are briefly presented below. The variety of organisations in the PRI sector differ with regard to their activities (Figure 4.13). Taken together, they cover all technology readiness levels.

Figure 4.13. **Position of actors in the Austrian innovation system by technology readiness level**



Source: Joanneum Research.

Austrian Academy of Sciences

The Austrian Academy of Sciences (OeAW) is dedicated to innovative basic research, interdisciplinary exchange, and progress in science and society. It functions as a learned society, a non-university research organisation and a funding body. The OeAW currently operates 28 research institutes that support research activities in life sciences, mathematics, physics, space science, materials sciences, technology assessment, humanities, cultural studies and social sciences. The Research Centre for Molecular Medicine (CeMM), the Institute of Molecular Biotechnology (IMBA), and the Gregor Mendel Institute of Molecular Plant Biology (GMI) (OeAW, 2018) are among its largest institutes.

The OeAW further offers funding in the form of fellowships and prizes for young researchers, as well as promotional research programmes on themes such as digital humanities, quantum science or earth system science. It also provides advice to the government. Through additional research commissions, the OeAW acts as a key intermediary, advising and informing the government and society of current developments in science (BMBWF, 2018).

The OeAW has approximately 1 600 employees, of which 770 are member scientists including international scholars (BMBWF, 2018). Fourteen per cent of its members are female. Active members recruit internally, electing new members to the OeAW once a year based on suggestions. The OeAW operates under public law and negotiates performance agreements every three years with the BMBWF. Governing bodies of the OeAW include the Presiding Committee, the Academy Council, the Research Board, the Conference of the Institute Directors and the Senate.

In 2016 the OeAW had a total budget of EUR 161 million, an increase of 3% compared to 2015. The largest part of the OeAW budget in 2016 consisted of global institutional funding (66%), followed by third-party funding (25%). Among third-party funding, 30% came from the FWF, followed by 21% from the Austrian National Foundation and 19% from the EU (OeAW, 2018). For the 2018-20 funding period, the OeAW had a total budget of EUR 363 million, an increase of 8% from the previous funding period. Priority has been given to the promotion of young talent. In addition, new interdisciplinary "thematic platforms" should intensify the networking of research in the humanities with the natural sciences.

The OeAW's 927 research staff produced a total of 1 649 peer reviewed articles (among other publications), and 950 publications in the web of science in 2016. Within the latter, about 30% of publications appeared within the top 10% journals of the respective fields of study. Another 30% belonged to the top 11-25% of journals within the respective research fields (OeAW, 2018). The OeAW secured 6 new ERC grants in 2017 (18% of all new ERC grants in Austria), and held 31 ongoing ERC grants. In addition, the OeAW received four Wittgenstein prizes and eight start-up prizes from the FWF. The OeAW was granted 31 new patents in 2016 (OeAW, 2018). Furthermore, the OeAW is part of research clusters, such as the Vienna BioCenter (Box 4.7).

Box 4.7. **Vienna Biocentre**

Since 1988, the Vienna Biocenter (VBC) has developed into one of the most outstanding and prominent life sciences hubs in Austria and central Europe. With the founding of the Research Institute of Molecular Pathology (IMP) in 1985, the nucleus for the Biocentre was established. Shortly after, five departments of the University of Vienna were relocated to the same location. In 1998, the spin-off company Intercell (now Valneva) was founded at the VBC. Subsequently, the Austrian Academy of Sciences founded two new research institutes: the Institute of Molecular Biotechnology (IMBA) and the Gregor Mendel Institute of Molecular Plant Biology (GMI).

The VBC has continued to develop rapidly and now includes more than 18 complementary players in the life sciences. Since access to state-of-the-art infrastructure has become a decisive element for cutting-edge research in the field, the VBC developed a strategy for shared use of research infrastructure. As a result, in 2010, the new Vienna Biocenter Core Facilities GmbH (VBCF) was set up with a comprehensive range of new technologies, substantially funded by the Austrian Ministry of Education, Science and Research and the city of Vienna.

Sources: Vienna Bio Centre (2018), "About", webpage, http://viennabiocenter.org/about; Wirth, M. (2013), *Der Campus Vienna Biocenter. Entstehung, Entwicklung und Bedeutung für den Life Sciences-Standort Wien*.

The Institute of Science and Technology Austria

The Institute of Science and Technology Austria (IST Austria) performs basic research and provides graduate education in the form of PhD and postdoctoral programmes in the natural sciences and mathematics. Its structure is unique and represents an institutional innovation within the Austrian science and research landscape, with its high degree of independence. It is internationally oriented and modelled after Israel's Weizmann Institute. Research, training and the appointment of staff meet high international standards, with English as the working language as well as that of instruction. The IST Austria is structured around research groups (48), which are designed to facilitate interdisciplinarity. Research is carried out by 155 PhD students, 134 postdocs, 49 professors, 19 scientific interns and 4 staff scientists. Among the IST Austria's professors, 18.4% are female. The IST Austria's staff and students are from highly international backgrounds (IST Austria, 2018).

The IST Austria is based on a federal law and a legal agreement between the Republic of Austria and the state of Lower Austria. It is largely funded by these two entities through institutional block grants and matching funds for third-party funding, as well as funding based on the accomplishment of pre-defined goals. The law mandates the IST Austria to be reviewed every four years. Its institutional administration consists of a Board of trustees, a president, a managing director, as well as a Scientific Board.

The IST Austria's total budget for the 2018-20 performance agreement period totals a maximum of EUR 219.2 million. This sum comprises EUR 129 million in global institutional funding, and a maximum amount of EUR 90.2 million to be allocated based on performance (IST Austria, 2017). In 2017, the cumulative third-party funding of the IST Austria totalled EUR 108 million. Table 4.5 shows that ERC grants make up the largest share in this regard, followed by other EU funding, the FWF, as well as a number of national and international funding sources that include the private sector (IST Austria, 2018).

Table 4.5. **Cumulative research funding by funding source (in EUR), 2017**

EU other	18 546 000
FWF Austrian Science Fund	17 843 000
HFSP Human Frontier Science Program	2 052 000
DFG German Research Foundation	1 469 000
NOMIS Foundation	1 400 000
ÖAW Austrian Academy of Sciences	1 225 000
EMBO European Molecular Biology Organisation	901 000
NFB NÖ Forschung und Bildung	640 000
WWTF Vienna Science and Technology Fund	434 000
ONR Office of Naval Research	326 000
Simons Foundation	267 000
SNF Swiss National Fund	216 000
Microsoft Research	151 000
BAYER	150 000
NSF National Science Foundation	119 000
FFG Austrian Research Promotion Agency	87 000
Other	1 739 000
Total	**108 432 000**

Source: IST Austria (2018), "Annual report 2017", https://ist.ac.at/fileadmin/user_upload/pdfs/Annual_reports/IST_AnnualReport_2017.pdf.

Since its inception, 34 out of 49 professors were able to secure research funding from the ERC. The IST Austria's rate in the competition for ERC funding is 48%, making it one of the leading organisations in Europe in this respect, ahead of Oxford University and ETH Zurich (IST Austria, 2018).

The IST Austria operates a technology transfer office (TTO) to support scientists to gain economic returns for their work. The TTO assists in patent protection, licensing and creating spin-offs; handles material transfer agreements and supports scientists in collaboration agreements with industry. The "TWIST" programme supports researchers to translate their research results into product ideas. The institute thus intends to commercialise results through licensing and the support of start-ups (IST Austria, 2018). In 2017, the IST Austria and a private investment firm set up IST CUBE, an investment platform that supports the creation and development of technology start-ups. Moreover, the IST Austria is currently building a science and technology park for research-intensive enterprises adjacent to its campus (IST Austria, 2018).

The Christian Doppler Association

The Christian Doppler Research Association (CDG)[18] was established in its current form in 1995 and has expanded substantially since the early 2000s. It has played an important role in efforts to strengthen and improve industry-science linkages, which have come to be seen as a weakness in the Austrian innovation system. Jointly with business representatives, scientists and policy makers, the CDG developed a pioneering public-private partnership (PPP model to promote long-term co-operation between business enterprises and science in Austria. The CDG model is well adapted to the Austrian context but – due to a unique combination of design and governance features, and its focus on application-oriented basic research – has also met with international interest.

Today, the CDG promotes industry-science co-operation through the establishment and funding of two types of research unit:

5. Christian Doppler (CD) laboratories, which are research units hosted at universities or non-university institutions, designed to perform application-oriented basic research at a high level
6. Josef Ressel (JR) centres[19] (since 2012), which are research units hosted at the UAS, and designed to perform application-oriented research (CDG, 2018).

Unlike the larger COMET centres, CD laboratories and JR centres are not established as separate legal entities, but remain fully integrated in the host institution, and hence avoid the disadvantages of parallel structures. They use the host institution's infrastructure for their administrative and research activities. They also remain open to include additional business partners as they evolve.

In 2017, there were 76 CD laboratories at 15 Austrian universities and non-university research institutions, and 11 JR centres at 8 UAS (BMBWF, BMVIT and BMDW, 2018), with 830 and 130 employees respectively (CDG, 2018). Their total budget was approximately EUR 27 million. Most CD laboratory research groups consist of 5-15 people, while those of JR centres are somewhat smaller, generally comprising 3-10 people (CDG, 2018).

Due to their origins, the thematic range covered by the CD laboratories was rather narrow initially (with a focus on materials science, notably steel, and chemistry, reflecting the structure of Austria's state-owned industry at the time). Supported by the programme's thematic openness, the scope of work has broadened considerably over time. Today the CDG portfolio comprises eight thematic clusters: 1) chemistry; 2) life sciences and environment; 3) engineering and instrumentation; 4) mathematics, computer science, electronics; 5) medicine; 6) metals and alloys; 7) non-metallic materials; and, since the establishment of a CD laboratory at the Vienna University for Economics and Business in 2013, 8) the social sciences, economics and law (CDG, 2018).

CD laboratories and JR centres are funded in equal parts by public and private sources. The Ministry for Digital and Economic Affairs (BMDW) and the National Foundation for Research, Technology and Development provide 50% of the financial resources, while the remaining 50% is contributed by the respective business partner. The public share can go up to 60% if SMEs are involved. The annual budget for CD laboratories is between EUR 110 000 (minimum) and EUR 700 000 (maximum), and for JR centres EUR 80 000-400 000. The maximum duration of funding is seven years (without exception) for CD laboratories, and five years for JR centres.

CDG funding – both for CD laboratories and JR centres – is thematically open, and strictly applies a “bottom-up” approach. Each laboratory or centre focuses on a research programme around a theme of relevance for the business partner. Research co-operation at CD laboratories and JR centres involves fundamental research to develop new products and processes for their industrial partners, which enables enterprises, including SMEs, to keep abreast of new developments in science and technology (CDG, 2018).

CDG governance and funding provide an original model for engaging industry while, at the same time, providing adequate incentives for academic partners. Sustained industry involvement is achieved through a combination of elements. First, the initiative for establishing a new laboratory has to include at least one industry partner. Second, industry partners become members of the CDG, which allows them to exert influence on the association’s general orientation and to engage in its Executive Board and the Scientific Board. Moreover, business partners are given the (annual) option to leave the partnership, while the specific mode of funding ensures the scientific freedom needed for the academic partner to pursue independent basic research (CDG, 2018). The importance attributed to the scientific dimension of the collaboration is reflected in the selection process, which emphasises the scientific competence of the prospective head of the laboratory according to strict scientific quality measures, and the use of an international peer review in evaluating the research plan. Combined with an evaluation of scientific excellence after two and five years, these factors contribute to high performance by the laboratories (BMWFJ, 2013).

In 2017, researchers of the CDG laboratories contributed to 371 publications in peer-reviewed scientific journals, and 4 issued patents in 2017 (CDG, 2018). In the same year, JR centres contributed to 19 peer-reviewed publications and 99 conference participations, 14 of them as invited lecturers, and 30 with peer-reviewed conference papers.

The CDG was evaluated in 2012 (Alt et al., 2012), and jointly with the CR centres in 2016 (Alt et al., 2016). The study identified the CDG as a good practice model of long-term PPP. A survey carried out as part of the evaluation indicates that partners in science and industry are highly satisfied with the instrument.

Ludwig Boltzmann Society

The Ludwig Boltzmann Society (LBG) is a public research institution with a thematic focus on medicine and the life sciences. Research activities in the social sciences and humanities include cultural studies, such as archaeology, contemporary history and literature. Of its 779 publications in 2017, two-thirds were in the area of health and medical research. The majority of its publications (67%) had been authored in co-operation with other academic partners, while 13% of publications had been prepared in co-operation with private businesses (LGB, 2018). The LBG aims to act as a research incubator in the above-mentioned fields, focusing research on socially relevant areas (BMBWF, 2018). Together with academic and private partners, the LBG develops new forms of co-operation between science, the private sector, public actors and civil society.

As of November 2018, the LBG operated 18 Ludwig Boltzmann institutes (LBI), one thematic cluster and 2 research groups in the areas of medical research and health. In 2017, the LBG had approximately 700 employees, of which 86% were scientific staff. Approximately a third of its research staff was third-party funded. The total budget for 2017 was EUR 28.9 million, of which 26% was funded by the BMBWF. In addition, the LBG counts the National Foundation, the Austria Fund, the city of Vienna, state governments, municipalities and private sponsors among its funders, accounting for 80% of its total budget. Twenty per cent of its funding was derived from foundations and other public actors, with 16% from states and municipalities. Funding agencies such as the FWF and the FFG contributed 5% of the LBG budget, while the EU and supranational or international organisations provided 7% (LBG, 2018). LBIs are aimed at incubating sustainable research and innovation structures, and to anchor new research areas in the science system. The incubator role is challenging, as the LBIs are created for a fixed term of usually seven years to be integrated in a university.

To develop new approaches to science and innovation, the LBG’s Open Innovation (OI) programme provides a new instrument for research development, while also being strongly linked to societal challenges. By experimenting with OI research practices, the LBG generates and disseminates insights into the use of OI principles and methods in science, along the entire research process. The objective of this programme is to redesign scientific research through a shift towards working more openly, collaboratively and in more interdisciplinary ways, and to test new methods for integrating OI principles into scientific research and innovation processes.

The LBG serves as a laboratory for new initiatives and research questions in the area of health-related policy. This area is a complex one, and faces major governance challenges. In Austria, health-related research seems to be primarily centred on the biomedical responses to diseases while public health aspects and interdisciplinary approches to prevention, diagnosis and therapy are less developed. This implies a need for a research actor who helps to develop and incubate new ideas, issues, approaches and modes of collaboration, allowing a wider spectre of groups (including patient organisations, social scientists, etc.) to contribute to progress in the field. The LBG has a track record of taking on such challenges, including with regard to health technology assessment, health sociology, rare diseases and forensic imaging with its own institutes. In this regard, the LBG is fulfilling a role that is currently not being covered by any other institution in the Austrian innovation system.

The LBG model requires the continuous creation of new LBIs through various mechanisms, including OI processes or competitive calls to maintain a sufficient range of institutes, and a strong LBG as an actor of change. A key challenge for the LBG's co-operation model is to maintain the long-term sustainability of its research institutes beyond their seven-year research phase. The model intends to integrate institutes with universities once this phase terminates. However, this may not be frictionless and exert pressure on the universities and the wider system, as the universities face the challenge to cover the additional costs for staff and infrastructure.

To avoid friction, the rules and regulations of the LBG must be sufficiently "light" and compatible from the start with those of the partner universities which might integrate the respective LBI at the end of the funding period. This implies that LBG rules, contractual arrangements and related practices need to be well aligned with the legal and organisational practices of the universities. Double affiliations for senior LBI personnel would help establish better research co-operation between the LBI and universities and facilitate their integration.

The LBG also operates a Career Centre that supports young scientists (PhDs and postdoctoral researchers) in pursuing careers beyond academia, given that career opportunities within the academic system are limited. The LBG Career Centre provides advice and accompanies young researchers in their career development. The programme is funded through the Austria Fund for an initial period of three years.

The LBG model requires enough institutes to experiment and to sustain the cost and overhead associated with the OI and career initiatives.

Research and technology organisations

This group of PRIs, which is considered part of the business enterprise sector in Austrian R&D statistics, includes the Austrian Institute of Technology (AIT), Joanneum Research (JR), the Austrian Cooperative Research Association (ACR) as well as the 22 COMET centres. In 2015, total R&D expenditure of these organisations was close to EUR 400 million, which is about a fifth of the R&D expenditure of public universities in Austria. This group of PRIs conducts both contract-research and directed basic research in fields of relevance to industrial application. Some organisations also offer R&D and innovation-related services such as measurement and testing. The PRIs are connected to the university sector in several ways, including through joint research projects, appointments of university professors as heads of research units within the PRIs, and joint supervision of PhD students.

Austrian Institute of Technology

The AIT is the single largest research technology organisation in Austria outside the university sector. The AIT is a PPP, with 50.5% of the shares held by the federal government (BMVIT) and the remaining shares being held by the Federation of Austrian Industries. Institutional funding for the AIT is provided by its shareholders through research grants and amounted to EUR 47.4 million in 2017 (32% of total budget). EUR 7.4 million is also provided by the federal government for nuclear activities (AIT, 2018).

The AIT employs about 1 100 people (FTE) with an annual budget of EUR 146 million in 2017. It is a national and international network node at the interface of science and industry, enabling innovation through scientific-technological expertise, market experience, close customer relationships and a high-quality research infrastructure.[20] The AIT performs R&D aiming at basic innovation for next-generation infrastructure in the fields of energy, mobility systems, low-emission transport, health and bio-resources, digital safety and security, vision, automation and control, and technology experience. In addition, the AIT also runs a centre on innovation systems and policy, as well as on nuclear research and engineering.

The AIT's role at the interface of academic research and industrial innovation is reflected in its performance indicators. In 2017, it received 37 patent grants and EUR 45.0 million for contract R&D (31% of total budget). In the same year, EUR 34.8 million (24% of total budget) was received from public R&D programmes (mainly from the federal government and the EU). AIT staff published 243 scientific publications in peer reviewed journals in 2017. The AIT is closely linked to universities, as revealed by the 229 PhD students that work there, along with 28 AIT staff qualified to conduct self-contained university teaching ("habilitation"). Two centres are headed by university professors.

The special role of the AIT in the Austrian innovation system is not only linked to its size: it has also served as a reference for other RTOs in terms of financing structures, types of interaction with industry, and links to universities. The AIT has also been at the forefront of actively engaging in the academic qualification of its staff, through joint PhD programmes with universities. In addition, the regular reorientation of the AIT's mission and thematic research focus has provided an important input to redirecting the Austrian innovation system and to meeting upcoming societal and economic challenges.

Joanneum Research

The JR is Austria's second largest RTO, with an annual budget of more than EUR 40 million and 378 full-time employees (2016). It facilitates co-operation with partners from business, science and the public sector to follow its three main missions: 1) developing innovation; 2) transferring knowledge; and 3) actively engaging in national and international research networks. Research at the JR is organised into seven research units. In contrast to the AIT, the JR focuses more explicitly on business innovation as its main corporate goal. At the same time, links to university and PhD programmes for JR staff are less prominent compared to the AIT. The JR holds shares in eight COMET centres. The state of Styria holds 80.75% of the JR's shares; while Carinthia and Burgenland own 14.25% and 5% respectively through their holding agencies. The share of institutional funding was 21% in 2015/16, while about a third of the JR's total budget came from contract research and another third from R&D projects funded through public programmes (Joanneum Research, 2017a; 2017b). Spreading the JR's research and innovation activities into the regional environment is a priority for Joanneum Research. At the same time, the organisation has strong international ties, reflected in a large number of EU-funded projects and a high share of contract research performed for clients abroad (about 30%).

Austrian Cooperative Research Association

The ACR is an umbrella organisation of 18 independent institutes located in 5 different states and comprising 5 thematic priorities: 1) sustainable construction; 2) environmental technologies and renewable energy; 3) products, processes and materials; 4) food quality and safety; and 5) innovation and competitiveness.[21] The 18 institutes had more 800 full-time employees and a budget of more than EUR 64.4 million in 2017 (ACR, 2018). The common feature of the 18 institutes is the conduct of applied R&D and the offering of R&D-related services such as measurement, testing, inspection, certification, technology consulting and knowledge transfer. The main customer group of ACR institutes are SMEs, which distinguishes them from the AIT, the JR and COMET centres. Some ACR institutes are also important intermediaries for linking large enterprises and SMEs in innovation activities.

The larger part of the institutes' returns are generated by R&D-related services (51%). Contract research has a15% share in total income, 21% being generated by R&D projects funded from public programmes (including industry contributions to funded projects). The larger part of R&D funding is provided from national sources. Knowledge transfer (e.g. training services) account for 13% of the ACR's income. Some ACR institutes are strongly involved in standardisation activities at the national, European and international level.

The ACR is not an RTO, but an organisation that represents the interest of 18 privately organised, independent institutes, each following its specific mission and each having a specific governance structure, often involving companies or industry associations. The thematic focus of ACR institutes is on traditional sectors and technologies, while few activities directly address new and emerging areas such as digitalisation or Industry 4.0. Within the system of co-operative research and technology transfer, ACR institutes are closest to market-related R&D and innovation activities, while they do not engage in basic research. This focus is also reflected in a low priority of PhD programmes and fewer formal links to universities.

Austrian states (*Länder*) operate research organisations with a similar profile to co-operative research organisations. This group includes, among others, Upper Austrian Research (UAR, hosting Profactor, Recendt, RISC Software as well as some COMET centres), Salzburg Research (SbgR), Vorarlberg Research, Forschung Burgenland and Carinthian Tech Research. Silicon Alps is in the process of being established.[22] The largest research organisation operated by a state government, the Styrian research organisation Joanneum Research, is considered part of the co-operative research organisations. A common feature of these PRIs is a focus on R&D co-operation within their region. Box 4.8 illustrates the key features of Silicon Austria Labs, a new research co-operation between three Länder and the private sector.

Box 4.8. **Silicon Austria Labs**

The Silicon Austria Labs will conduct research in the field of microelectronics and will be located in Upper Austria, Carinthia and Styria. Silicon Austria Labs will start full operations in 2019. Its mission is to further develop the Austrian electronics and microelectronics sector, and to strengthen research capacities in the field of electronics-based systems. The Ministry of Transport, Innovation and Technology and the three participating states together contribute EUR 70 million each to the project over an initial period of five years (EUR 140 million), with industrial partners doubling public support to an overall funding of EUR 280 million. By 2023 it is expected that around 400 researches will be working at the three business locations in Graz, Linz and Villach, with Graz (Styria) hosting its headquarters, creating significant leverage for the Austrian microelectronics ecosystem.

Sources: https://silicon-austria-labs.com; https://www.bmvit.gv.at/presse/aktuell/nvm/2018/0823OTS0097.html.

Challenges and options for research and technology organisations

The entire PRI sector in Austria as described above is of significant size, employing almost 10 000 people and commanding an annual R&D budget of more than EUR 650 million, which represents almost a third of R&D expenditure in the entire Austrian university sector. Due to their organisational diversity, difference in ownership and heterogeneous governance structures, RTOs are a diversified group of actors in the Austrian innovation system. For these reasons, a coherent policy for steering the RTOs is lacking. The very different set-up and funding system of the individual organisations implies heterogeneity in the challenges faced by the organisations, and a diversity of responses. As a consequence, there is a lack of common standards and criteria for assessing the contribution of RTOs to research and innovation in Austria, despite the similarities in their main mission, which is to translate basic or applied research into economic and social applications and industrial innovation. The fragmentation of the RTO sector can lead to uncoordinated overlapping activities, an unclear presentation of the sector for potential industrial partners (particularly for partners from abroad), and an ineffective use of the RTOs' research and education potential (e.g. for doctoral and post-doctoral studies).

Notes

1. The equivalent of the "research" mission is called "development and appreciation of the arts" (*Entwicklung und Erschließung der Künste*) at the universities of the arts.
2. The Danube University Krems is the only university that receives basic funding (about a quarter of its total budget) from the state of Lower Austria. It also stands out by having the right to charge tuition fees autonomously.
3. Figures relate to winter semesters. Among the relatively large number of HEIs, the University of Vienna accounts for nearly one-third of all regular students (Schmid et al., 2017) and 15% of public university funds in the period 2016-18 (BMBWF, 2018).

4. According to the International Standard Classification of Education 2011, qualifications at VET colleges are classified as tertiary short-cycle programmes (ISCED Level 5) since 2015 (BMBWF, 2018: 294).

5. In order to underline the recommendations of the Austrian Higher Education Conference (HSK) the UNIKO, as part of the HSK, also published more detailed recommendations regarding the further development of doctoral programmes.

6. The allocation of these additional funds has been based on the number of students in structured doctoral programmes at universities who are employed at least 30 hours per week (BMBWF, 2018).

7. This also applies to the "*Universitätsdozentinnen und -dozenten*" of the previous system (preceding the associate professors). This procedure is subject to requirements which are intended to assure transparency and quality. Notably, the position has to be advertised internationally. Candidates who have passed the required selection process conforming to international competitive standards and have met the qualification requirements become members of the professors' "*curia*" without any further appointment procedure.

8. The Leiden Ranking measures, among others, the impact of publications based on the number of citations. It takes into account the number and the proportion of a university's publications that, compared with other publications in the same field and in the same year, belong to the top 1% (or 10%) of the most frequently cited publications. A higher percentage value indicates a better performance.

9. Compilation based on European Commission (2015, Tab. 7.02), https://era.gv.at/object/document/1883/attach/ERC_funding_activities_2007_2013_pd.pdf. Around 75% of the ERC grant holders in EU FP7 (2007-13) were located at universities, when the top 100 ERC host institutions are taken as a basis for analysis.

10. Some concerns have been voiced that the emphasis on commercialisation and business engagement in research might overshadow civic engagement, and there have been calls for greater social and public accountability of HEIs (Benneworth, 2013; Hazelkorn and Gibson, 2017).

11. Federal Law Gazette I No. 129/2017.

12. Federal Law Gazette I No. 8/2018.

13. Comparisons for this measure at the tertiary level should be interpreted with some caution due to the difficulty to calculate comparable full-time equivalents for students as well as teachers (OECD, 2017c). When considering only those students taking exams for an equivalent of 16 ECTS (European Credit Transfer System) per semester, the students-to-professor ratio drops to 76 in Austria. Both these ratios have been constant overall since 2013. An additional measure applied in Austria is the ratio of students actively participating in exams to professors and professor equivalents. The corresponding ratio has recently been stable at 42.5 (BMBWF, 2018).

14. Country data from: DESTATIS (2018), Statistics Denmark (2018), Statistics Finland (2018), Statistics Sweden (2018) and Statistics Switzerland (2018).

15. In the performance agreement period 2016-18, funding consisted of the basic budget for all services to be delivered by the universities on the one hand, and Higher Education Structural Funds on the other hand (BMBWF, 2018: 66).

16 With the exception of Austria, all EU member countries (Croatia, Czech Republic, Estonia, Italy, United Kingdom, Finland, Norway and Sweden) taking part in a recent

Mutual Learning Exercise on performance-based funding of university research use an output indicator for research (Debackere et al., 2018).

17. According to the European Association of Research and Technology Organisations (EARTO).

18. The association is named after the 19th century Austrian physicist and mathematician, after whom the phenomenon known as the "Doppler effect" was named.

19. Josef Ressel was an Austrian inventor known for designing one of the first working ship propellers.

20. https://www.ait.ac.at/en/about-the-ait.

21. https://www.acr.ac.at/english.

22. https://www.silicon-alps.at/en/silicon-austria-oesterreich-bekommt-forschungszentrum-fuer-mikroelektronik-auf-weltniveau.

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Chapter 5. Reconfiguration of science, technology and innovation governance in Austria: Structures for innovation leadership

This chapter examines science, technology and innovation governance in Austria. It begins with an overview of the main government actors in science, technology and innovation policy: ministries, funding agencies (and the role of private foundations), as well as advisory councils for research and innovation. It then examines agenda setting, co-ordination and evaluation of science, technology and innovation policy including the role of societal challenges and support for international linkages and cooperation,

Main science, technology and innovation policy actors and their interplay

Government ministries

The main government actors responsible for science, technology and innovation (STI) policy in Austria, including the design and implementation of respective policy instruments, are the Federal Ministry of Education, Science and Research; the Federal Ministry for Transport, Innovation and Technology; and the Federal Ministry for Digital and Economic Affairs.

Federal Ministry of Education, Science and Research

The Federal Ministry of Education, Science and Research (BMBWF) is responsible for the areas of education, science and research. It is in charge of providing excellent framework conditions for schools and higher education and research institutions. In particular, the BMBWF oversees, steers and funds public universities through a set of strategic planning instruments, including the Austrian University Development Plan and the performance agreements concluded with individual universities. The BMBWF is also in charge of important research institutions, including the OeAW and the Institute of Science and Technology (IST) Austria, and funds part of the Ludwig Boltzmann Society's activities. It supports the profiling of research organisations, and promotes the education of highly qualified human resources at higher education institutions (HEIs) and public research institutes (PRIs). In addition, it is in charge of and allocates financial resources to the Austrian Science Fund (FWF). The BMBWF represents Austria's interests in the area of education, science and research at the international level, including through international co-operation.

Federal Ministry for Transport, Innovation and Technology

The Federal Ministry for Transport, Innovation and Technology (BMVIT) promotes the reconciliation of interests in the areas of communication and mobility, as well as in support of innovation and technology. The ministry supports the collaborative and innovative development of cutting-edge infrastructure and technologies, with the objective to optimise infrastructure for rail, road, water, air transport and telecommunications. In the area of innovation and technology, the ministry's main tasks include funding of applied and market-related research of business enterprises and universities, and support and financing of non-university research institutions and research and development (R&D) infrastructure. The BMVIT supports thematic programmes, including for societal challenges. It supports the evaluation of research, technology and innovation (RTI) programmes and institutions. Together with the Federal Ministry for Digital and Economic Affairs (BMDW), it oversees the Austrian Research Promotion Agency (FFG) and the Austria Business Service (Austria Wirtschaftsservice, *aws*).

Federal Ministry for Digital and Economic Affairs

The Federal Ministry for Digital and Economic Affairs (BMDW) promotes Austria as an international location for advanced economic activity and technology, and supports the best use of the opportunities offered by digitalisation for business and society. It supports entrepreneurship by providing favourable framework conditions and promoting R&D and wider innovation activities in businesses in Austria. The ministry provides support for collaborative application-oriented basic research between business and universities and universities of applied sciences through the Christian Doppler Association. The BMDW oversees and financially supports the activities of the *aws* and FFG funding agencies (jointly with the BMVIT).

Other line ministries

Other government ministries oversee sector-specific research institutions or develop sectoral programmes in support of research and innovation in the area of their competence. These are, above all, the Ministry of Sustainability and Tourism, the Ministry of Health, and the Ministry of Defence.

Table 5.1 provides an overview of the expenditures for research and research support across the three main ministries involved in funding research and innovation in Austria.

Table 5.1. **Federal expenditures for research and research support, 2017-19**

Million EUR

	FP 2017	FP[1] 2018	FP[1] 2019
Federal Ministry of Education, Science and Research	2 065	2 124	2 287
Federal Ministry for Digital and Economic Affairs	104	101	99
Federal Ministry for Transport, Innovation and Technology	409	440	446
Other	223	218	218
Total	2 753	2 808	2 977

1. Financial proposal.
Source: BMF (2018), Bericht der Bundesregierung, Budgetbericht 2018/2019 https://www.bmf.gv.at/budget/das-budget/Budgetbericht_2018_2019.pdf?6dj8e5.

Federal Chancellery and Federal Ministry of Finance

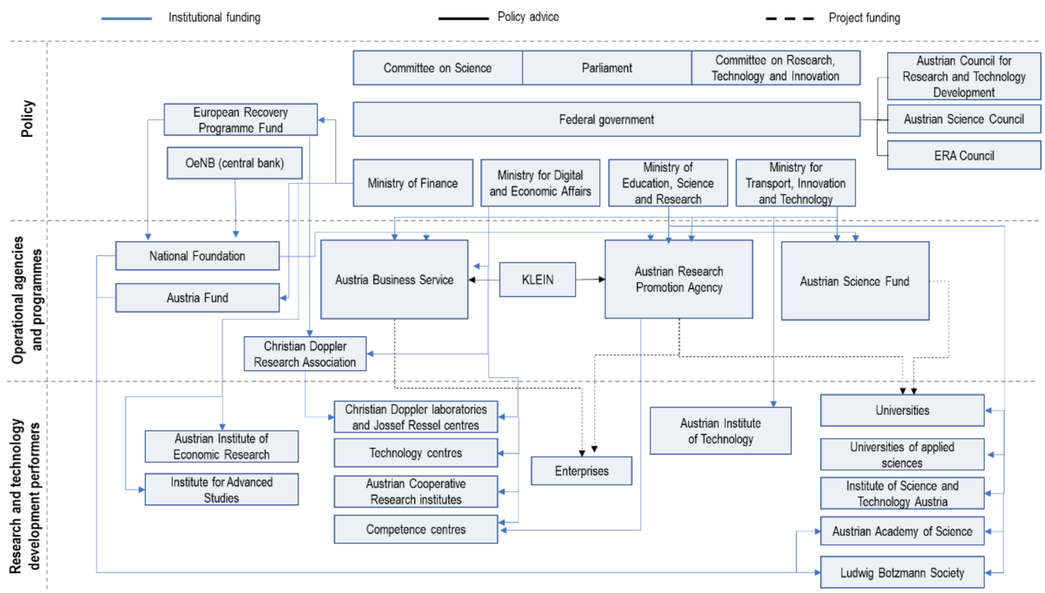
The Federal Ministry of Finance (BMF) – as well as the Federal Chancellery – also play an important role in terms of their general responsibilities for policy co-ordination and allocation of public budgets. The BMF is also in charge of the Research Premium's administration and evaluation. The BMF plays a role to the extent that operational decisions of the line ministries depend on its approval.[1] The BMF and the Federal Chancellery are also represented on STI policy co-ordination bodies such as the inter-ministerial RTI Task Force.

Figure 5.1 provides a stylised representation of the main (public) actors in research and innovation in Austria.

Major federal funding agencies

Research and innovation funding agencies and are important actors in advanced research and innovation systems. Fifty years ago – and with some contribution from the OECD (Pichler, Stampfer and Hofer, 2007; Stampfer, Pichler and Hofer, 2010) – Austria established two dedicated agencies, one for basic research (the Austrian Science Fund, FWF) and one for applied industrial research (the Austrian Industrial Research Promotion Fund, FFG). During the 1990s, new needs emerged that could not be matched by the traditonal funding instruments. This included new demand for multi-actor, strategic programmes for collaborative research and innovation, the internationalisation of R&D and participation in the collaborative, largely thematically oriented European programmes, which received a boost during the process of Austria's accession to the EU. To serve these new needs, new funding agencies such as the Office for International Research and Technology Co-operation and the Technology Impulse Society were established alongside the existing ones. While this seemed to be a necessary step, the landscape of funding organisations at the turn of the millenium was considered to be overly complex.

Figure 5.1. **Main public actors in the Austrian research and innovation system**



Source: Adapted from Schuch, K. and G. Testa (2018), *RIO Country Report Austria 2017*, https://rio.jrc.ec.europa.eu/en/country-analysis/Austria/country-report.

Following an evaluation published in 2004 (Arnold, 2004), the structure has been simplified to create today's FFG and *aws*. The FFG was the result of a merger of the former Austrian Industrial Research Promotion Fund, the Technology Impulse Society, the Office for International Research and Technology Co-operation, and the Austrian Space Agency. The *aws* emerged from the fusion of four enterprise finance institutions: BÜRGES, ERP Funds, the Austrian Financing Guarantee Association and Innovationsagentur, while the FWF was retained. Today, as a result, the structure of major funding agencies is analogous to that in other countries, with one agency responsible for basic research (FWF), one responsible for applied research and experimental development (FFG), and a third mainly responsible for direct and indirect support for entrepreneurship and business development (Austria Wirtschaftsservice, *aws*).

The Austrian states (*Länder*) also play a role in the funding of research and innovation activities, as well as foundations such as the National Foundation for Research, Technology and Development, and the Austria Fund. The Austrian Academy of Sciences and the Christian Doppler Association also have mandates for funding research (see below).

The Austrian Science Fund

The Austrian Science Fund (FWF) is Austria's funding agency for basic research and the advancement and appreciation of the arts. Its responsibilities include the enhancement and development of the scientific research system, and increasing Austria's attractiveness as a location for research. Approved project funding increased by 18.2%, from EUR 183.8 million in 2016 to EUR 217.3 million in 2017. This includes funding of new and ongoing projects (BMWFW and BMVIT, 2018). To expand the FWF's grant funding capacities, an additional EUR 110 million are being made available over the 2018-21 funding period.

The FWF's core instrument is project-specific research funding across all scientific disciplines. This includes single project funding, international co-operation programmes, priority research programmes, awards and prizes, the development of human resources though structured doctoral programmes, international mobility, career development for researchers, and supporting practical basic research, funding artistic research, publication and communication. For project funding decisions, the FWF draws exclusively on the expertise of international evaluations, using scientific quality as the only criterion for awarding competitive funds. The majority of FWF grants are allocated to finance research staff (accounting for approximately 84% in 2017), most of them at the level of pre-doctoral and postdoctoral researchers. Under the Lead Agency Process, the FWF, together with Germany's DFG (Deutsche Forschungsgemeinschaft) and the SNF (Swiss National Science Fund), provides a simplified application process for joint project funding for transnational research projects.

Austrian Research Promotion Agency

The Austrian Research Promotion Agency (FFG) is the Austrian agency for funding applied research and experimental development. The FFG's funding instruments include direct support for stand-alone R&D projects in and structural programmes to promote co-operation between science and industry. In addition, specific and thematically oriented programmes help to develop "critical mass" of research in strategically important fields for the future.

The FFG originates from the merger of four organisations in 2004: the Austrian Industrial Research Promotion Fund, the Technology Impulse Society, the Austrian Space Agency, and the Office for International Research and Technology Co-operation. The objectives of the merger of these agencies were reducing organisational complexity, improving "downstream" (agency-level) co-ordination through the creation of inter-ministerial agencies (jointly overseen by the BMDW and the BMVIT), increasing the focus on target groups, and improving the efficiency and intensification of resources used. A recent evaluation of the FFG and the *aws* found that the two agencies should be provided with more financial and operational autonomy, and should transition toward results-oriented management. This would provide the agencies with a greater degree of flexibility to implement more clearly communicable products, address target groups more effectively, and allow short feedback loops and a flexible combination of instruments to ensure greater leverage of the funds deployed (BMBWF, BMVIT and BMDW, 2018).

Austria Wirtschaftsservice

The Austria Wirtschaftsservice (*aws*) is the federal development bank mandated to support the translation of technological and social innovation into economic growth and business creation (BMWFW and BMVIT, 2017). Its activities and instruments are designed to prioritise small and medium-sized enterprises (SMEs) and start-ups. In 2017, the *aws*' total financing amounted to EUR 1.15 billion. The introduction of broad-based grant programmes tripled the volume of grants, from EUR 74 million in 2016 to EUR 223.7 million for 2017 (BMWFW and BMVIT, 2018).

The *aws* was created as a result of the merger of the former Austrian Financing Guarantee Association, the Innovation Agency and the BÜRGES promotional bank in 2002. Since its creation, the *aws* has also been responsible for the operations of the ERP Fund and the management of the National Foundation, which is funded by the Austrian National Bank, the ERP Fund and the federal government (BMWFW and BMVIT, 2018). The *aws* focuses on different phases of enterprise development, with two core priorities: "new venture" and "growth and industry". The *aws* guarantees compensate for a lack of bank collateral, which provides firms with the opportunity to obtain third-party financing and therefore mitigate capital market failures that particularly affect innovative ventures, innovation projects and business growth, as insufficient collateral, uncertainty and a limited track record are common in these projects and activities (BMWFW and BMVIT, 2017).

Other funding sources

The National Foundation for Research, Technology and Development (NFTE), established in 2004, finances STI projects which potentially bring long-term benefits and are interdisciplinary in nature. The NFTE's financial resources are allocated to federal funding agencies based on annual decisions of the foundation's board. The agencies in turn allocate these resources to programmes and projects through a variety of programmes for research institutions and enterprises. The Austrian National Bank allocates the main share of financial resources to the NFTE, amounting up to EUR 100 million annually.

The Austria Fund supports in equal parts two pillars of Austrian research and innovation policy. This includes both basic and applied research, as well as technology and innovation development. Its endowment is based on the federal revenue shares of Austrian income tax. Its financial resources are limited until 2020. Over this period, applications for its funds (amounting to EUR 33.7 million annually) can be brought forward by the beneficiaries of the NFTE (FWF, FFG, OeAW, LBG, CDG and *aws*).

The anniversary Fund of the Austrian National Bank is a long-standing research funding source. It also contributes to the endowment of the NFTE. Its purpose is to provide additional financial resources to the Austrian research and innovation system, in particular concerning interdisciplinary research (AIT et al., 2017).

The role of foundations in Austria as a source of research funding

Austria was home to extensive philanthropic activity at the end of the 19th century, with 5 700 philanthropic foundations existing before 1938. This philanthropic tradition almost vanished after first half of the 20th century and has barely recovered since. The private foundations that remained were later subsumed under the federal law for charitable foundations (Bundes-Stiftungs- und Fondsgesetz 1975) and nine provincial laws for charitable foundations (Landes-Stiftungs- und Fondsgesetze). Up until 2015, 460 foundations existed under these legal regimes.

In 1993, at a time when private philanthropy was promoted with tax exemptions and incentivising legal frameworks in neighbouring countries such as Germany and Switzerland, Austria took a different path. With the introduction of the Law for Private Foundations (Privatstiftungsgesetz) Austria aimed to attract foreign private capital and prevent outflows of domestic capital. To this end, the government supported the formation of private foundations with considerable tax advantages. This resulted in the creation of more than 3 000 private foundations, the vast majority of which were entirely devoted to private interests. Around 60% of the asset base of these foundations – estimated to be around EUR 100 billion – consists of companies and company shares. Only around 200 private foundations are considered purely charitable in nature.

There are currently around 700 foundations in Austria that can be identified as purely philanthropic, representing estimated annual expenditures for public purposes in the range of EUR 29-61 million (Meyer and Millner, 2016). This picture is to be complemented by 35 savings bank foundations ("*Sparkassen Privatstiftungen*"), that have been established by the Austrian Savings Bank sector with the goal of holding the respective regional branches of the Savings Banks, but which are legally philanthropic entities with the aim to support various regional and local charitable causes (or in the single case of the ERSTE Foundation, international charitable causes).

The proportion of R&D expenditures attributable to the private non-profit sector is rather low, with a funding volume of around EUR 51 million (0.4% of total R&D expenditure in Austria in 2015). And, overall, the Austrian philanthropy sector is under-developed compared to countries of similar size such as Denmark, the Netherlands or Sweden, or countries with a similar socio-economic tradition such as Germany. Due to the lack of a continued tradition of philanthropy in Austria, research institutions have not been in a position to develop expertise in foundation or large donor fundraising. Among existing foundations engaging in science, research or academic education, support largely takes the form of stipends and scholarships.

Data availability with regard to the non-profit sector in general and the foundation sector in particular is limited. Available information is based on single studies and research efforts, and comprehensive data are lacking. Improving data quantity and quality would help to better assess current and future contributions of philanthropic foundations to research and science.

Recent efforts and developments

In an effort to increase the number of philanthropic foundations (also run under the label "philanthropy package") and their respective financial contributions towards public causes, the Austrian government introduced a new law for philanthropic foundations in 2015 (Bundes-Stiftungs- und Fondsgesetz 2015, based on its predecessor from 1975) that came into effect at the beginning of 2016. The aim of this law was to boost financial contributions of foundations up to EUR 1.2 billion by 2030 and to quintuple the number of philanthropic foundations by a set of measures concerned with tax incentives and easing regulatory framework conditions such as facilitating the formation of new foundations.

With respect to tax incentives, this law was accompanied by tax regulations that will allow different entities (public limited companies, family businesses, private foundations, non-profit foundations, associations and private individuals) to make tax-deductible donations to non-profit foundations. These tax deductions are limited to EUR 500 000 over five years. Donations are deductible in each business year provided that they do not exceed 10% of profit before accounting for the tax-free profit allowance. This is a rather low amount internationally, for instance when compared to Germany.

More than two years after the introduction of the new law for charitable foundations, the respective Foundation Register at the Federal Ministry of Internal Affairs indicates that this law has not yet spurred the formation of a significant number of new foundations. Nevertheless, some private interest groups have formed initiatives over the last few years to promote organised philanthropy (e.g. Association of Foundations), the Austrian Fundraising Association, the House of Philanthropy and the Sinnstifter (a group of currently 11 foundations), all of which share the ambition to foster collaboration among foundations, to showcase philanthropy to a wider public, and also to call for further improvements in the (regulatory) environment for philanthropic engagement. Moreover, some initial collaboration on this topic between the public sector and these initiatives can be observed. Under the label of "Sciencefundraising", the Austrian Federal Ministry of Education, Science and Research supports a series of events, trainings, webinars and conferences organised by the Austrian Fundraising Association to foster and improve fundraising activities among Austrian universities and research institutions. However, this ecosystem needs to be enhanced, and further efforts in advocating philanthropy need to be made across all of the stakeholders involved. Moreover, the knowledge base for philanthropic action needs to be enhanced.

Box 5.1. **The Vienna Science and Technology Fund**

The Vienna Science and Technology Fund (WWTF) is a private non-profit research funding organisation (one of the very few in Austria). Its budget, around EUR 13 million annually, comes primarily from a private foundation. The WWTF's mission is to strengthen Vienna as a top research location in important fields, with larger grants for scientific research, based on a strict international review- and jury-based quality control.

As a niche player, the WWTF defines broad thematic areas for funding calls. As Vienna has a large researcher population (with nine universities and numerous non-university research organisations), competition is strong for WWTF grants. Currently the following areas are subject to regular calls:

- life sciences (with various calls ranging from fundamental to translational research)
- mathematics and interdisciplinary calls with a strong emphasis on modelling
- information and communication technologies
- cognitive sciences
- environmental systems research (pilot).

The WWTF regularly screens its own portfolio in the Vienna research landscape. To qualify for a thematic priority, a research field in Vienna (not necessarily a single discipline) has to fulfil a number of criteria; these include scientific strength and visibility, a large number of research groups, and potential impacts on industry and society.

The WWTF places emphasis on inter- and transdisciplinary research as well as on funding of emergent topics. Evaluations show that the fund can do that successfully, both in selecting topics and in entrusting the assessment and project selection to strictly internationally composed juries with a broad thematic background.

Two instruments are employed: project funding up to EUR 800 000, in some cases EUR 1 million per grant; and Vienna research groups EUR 1.6 million each. The latter programme aims to bring bright post doctorates to Vienna and to fund a group for a number of years, while the host universities provide additional resources and tenure track positions.

Due to a lack of a continued tradition of philanthropy in Austria, research institutions have not been in a position to develop expertise in foundation fundraising, large donor fundraising and alike. Moreover, investments in building up relevant organisational capacities (e.g. fundraising departments, foundations or large donor fundraising) are – if in place at all – in their infancy. Increasing these efforts and striving for greater private R&D funding would need to take into account questions of how to strategically align the interests and grant-making procedures of large donors and foundations with the research agendas of universities and other research institutions.

Organised philanthropy is only loosely rooted in Austrian society. As the nature of philanthropy is its voluntary character, philanthropic engagement can only be fostered by creating a favourable environment and putting relevant incentives in place. Hence, it will take a long-term approach and a series of steps to create philanthropic engagement in Austria on a larger scale.

Austria has recently taken some first steps towards a friendlier environment for philanthropy and has seen a number of initiatives contribute to this development. To be able to achieve the goals that were formulated in 2015 alongside the introduction of a reformed foundation law, continuous efforts will be needed to showcase the value of philanthropy and the difference it can make with respect to societal development. This is even truer if trying to promote additional private support for research and science and will demand specific actions from governments and research institutions alike.

Advisory councils for science, technology and innovation

Currently, Austria operates three research and innovation councils with experts who provide guidance and strategic advice for science and innovation policy. Unlike in other countries (e.g. Finland), there has not been any review or evaluation of any of the Austrian councils.

Austrian Council for Research and Technology Development

The Austrian Council for Research and Technology Development (Rat für Forschung und Technologieentwicklung, RFTE) was established in 2000 and became a legal entity under public law in 2004. It is the most comprehensive of the three Austrian STI advisory councils. Its mandate covers the entire national research and innovation system, and its recommendations are wide-ranging, including topics such as public procurement, social entrepreneurship and education in addition to more traditional advice on research priorities and funding. During its first years, the council was also involved to a considerable extent in budget allocation, reviewing proposals from ministries, acting as a *de facto* gatekeeper for the Ministry of Finance. This function ended in 2007. Since then, the RFTE (with some exceptions) acts first and foremost as an advisory body with a strategic function, including the monitoring of the current RTI Strategy 2011-20 towards its goals.

The RFTE, including its chair, consists of eight voting members, appointed in their personal capacity. Among the voting members, three are currently non-Austrian nationals (of Germany, Sweden and Switzerland), and gender parity prevails. In addition to the voting members, ministers who play a key role in STI policy hold seats in the Council, but without voting rights. The remit of ministers represented on the council has varied over the years. As of 2018, the Minister of Transport, Innovation and Technology, the Minister of Education, Science and Research, the Minister for Digital and Economic Affairs, and the Minister of Finance are formally members of the RFTE. While the RFTE is a separate legal entity, it is under the responsibility of the BMVIT which provides the funding for its activities, including for a dedicated secretariat of about ten staff members.

The RFTE presented its own "Strategy 2020" in 2009, based on a process of e-consultation and stakeholder involvement. The strategy argued for a national ambition of moving from a position of innovation follower to that of an innovation leader, which was echoed in the federal RTI Strategy 2011-20. Another major contribution of the council is the monitoring of the progress towards the goals set out in the RTI Strategy 2011-20. In 2015, the RFTE presented a mid-term review of the federal RTI Strategy (RFTE, 2015a; 2015b), indicating that despite progress in many areas, the achievements so far were not sufficient to bring Austria into the group of "innovation leaders" by 2020. In this regard, the RFTE argued for an "RTI reform agenda" under the supervision of the Federal Chancellery and in co-operation with all of the ministries responsible for RTI.

The RFTE plays a particularly active role in performing and publicising analyses and evidence-based recommendations for innovation policy on a wide range of issues relating to the Austrian research and innovation system, which are published on its website. In addition, the RFTE commissions analyses of the Austrian innovation system. It produces statements and recommendations. Periodical publications are the "Annual report" and an annual "Report on Austria's scientific and technological performance", which are submitted to parliament together with the "Austrian report for research and technology", which is drafted by a consortium of research institutes.

The Austrian Science Board

The Austrian Science Board has a more narrowly defined mandate than the RFTE and serves as the main advisory body to the Federal Minister of Education, Science and Research; parliament; and the universities, in all university-related matters, including questions of scientific policy and the arts. Its creation of the Science Board in 2003 followed the adoption of the University Act 2002, which transformed the universities into legal entities under public law, with a high degree of autonomy and full legal responsibility. This change in status created a need for new types of steering, monitoring and co-operation that require adequate advice and analysis. Currently, the Science Board comprises 12 members, mainly representing science and the arts, while some members have a background in industry and other parts of society. The Science Board observes and analyses the Austrian university and wider research system and, like the other councils, produces and publishes statements and recommendations on a range of pertinent issues. Every three years the Science Board submits a report of its activities to the National Assembly.

The Austrian ERA Council Forum

The Austrian ERA Council Forum is a relatively new high-level expert body advising the Austrian Minister of Education, Science and Research on matters concerning the relation between the Austrian research and innovation system and European policies in the context of "Europe 2020", "Innovation Union", the "ERA Partnership" as well as "Horizon 2020". The forum is currently composed of five members; the chair is Austrian (with an eminent international career in science and science policy) while the other four members come from other European countries (Belgium Germany, Slovenia and the United Kingdom). Two of the members of the ERA Council Forum, including the chair, are also currently members of the RFTE, thus ensuring a direct connection between these two advisory bodies. The ERA Council Forum provides advice and opinions, published as recommendations on specific matters regarding Austria's relation to the EU and ERA participation and development. The ERA Council Forum provides a platform for discussion and dialogue around questions related to Austria's position and role in the ERA, notably at the annual "Europatagung", which is a major forum of R&D and policy debate in Austria.

Research and innovation councils in an international perspective

Research and innovation councils have seen a remarkable expansion among OECD countries and beyond. Only a few OECD countries do not have such a council, and those that do not often have a similar institution in place.

> Box 5.2. **Research and innovation councils in the OECD**
>
> Research and innovation councils have become widely used as a "strategic intelligence" or governance tool by countries around the world, as shown in a number of *OECD Reviews of Innovation Policy* (e.g. OECD, 2017a). Recent OECD work (Borowiecki and Paunov, 2018) finds that in 2017, 31 out of 35 OECD countries had such a council. Moreover, the number of countries operating an innovation council has expanded rapidly. No fewer than 15 countries have established their current innovation council since 2010, i.e. their number has doubled within less than a decade. Some countries, including Austria, operate several councils focusing on different tasks or covering specific parts of or functions in the research and innovation system.
>
> Today, there are only few OECD countries without a council. These are Ireland, Italy, New Zealand and Norway. However, Ireland and New Zealand have a chief scientific adviser in the Anglo-Saxon tradition, while Norway's government is following a pronounced "sector principle" based on strong "line ministries". In response to the lack of structured co-ordination at ministerial level, co-ordination functions are partly delegated to the Research Council of Norway, a comprehensive funding agency for research and innovation used across ministries. This type of delegated co-ordination to the agency level has been shown to have limitations (OECD, 2017b).
>
> Nearly all councils (90%) in the OECD offer advisory functions, and three-quarters contribute in some way to strategic priority setting. Approximately half of them engage in policy evaluation and policy co-ordination, respectively. In contrast, decisions on budgetary allocations are only taken by one-quarter of the councils. Operational co-ordination of science, technology and innovation institutions and policies (as distinct from providing analysis and expert advice on policy co-ordination) typically requires a strong political mandate and involvement of the political level.
>
> *Sources:* Borowiecki, M. and C. Paunov (2018), "How is research policy across the OECD organised? Insights from a new policy database", https://doi.org/10.1787/235c9806-en; OECD (2017a), *OECD Review of Innovation Policy: Finland 2017*, https://doi.org/10.1787/9789264276369-en; OECD (2017b), *OECD Reviews of Innovation Policy: Norway 2017*, http://dx.doi.org/10.1787/9789264277960-en

Both the role a council is assigned to play in the innovation system and its structure represents a deliberate choice of the government. Seen in this way, governments that want to establish or remodel a research and innovation council differ in their role and composition. An OECD (2009) study concluded that the councils reviewed at the time provided three possible choices:

- A **joint planning model** (typically found in Asian countries such as Japan), where the government uses the council as a virtual "horizontal ministry of innovation", much as engineering companies build project teams by bringing together people across different disciplines.

- A **co-ordination model**, where the intention is that the council should communicate horizontally across ministry responsibilities so as to align policies in support of innovation, without this alignment always being binding.
- An **advice model**, where the council proactively or reactively advises government on research and innovation policy, but this advice is not binding.

Schwaag Serger, Wise and Arnold (2015) – extending and updating the analysis in OECD (2009) – found that this categorisation was still useful but suggested adding:

- A **"platform for interaction" model**, where the council lacks a clear mandate or substantial resources, e.g. to plan and co-ordinate policy but functions more as a "sounding board".

The planning and co-ordination models (the Finnish Research and Innovation Council is a good example of a co-ordination council) require significant commitments of ministers' time as well as willingness across the political and institutional spectre to see research and innovation as permanently central aspects of government policy (OECD, 2009). As mentioned above, the anchoring of councils in government differs widely. In both the planning and the co-ordination models, ministers typically are members of the council (in some cases, like Austria and Chile, as non-voting members). Councils in many countries effectively provide analysis and advice across government ministries or to other state institutions, including parliament, regional governments, etc.

Box 5.3. **Finland's Research and Innovation Council**

An emblematic council that has served as a reference for numerous such councils across the world is the Finnish Research and Innovation Council (RIC), which has been in operation since 1986 (initially as the Finnish Science and Technology Policy Council). The RIC's role has changed over time. It has been much more than an advisory council, with important functions in priority setting in science, technology and innovation (STI) policy and co-ordination. The council is chaired by the Prime Minister and gathers together the Minister of the Economy and the Minister of Higher Education, and a limited number of other cabinet members, and experts on research and innovation. The Finnish RIC has inspired policy makers in countries at widely different levels of income per capita and scientific and technological capabilities. The attractiveness of the Finnish council was due to its perceived role as a highly successful process, punctuated by recessions, of catching up and structural transformation of Finland into one of the leading knowledge-based, high-technology goods exporting economy, with Nokia at the core of the electronics industry. The Finnish economy was hit hard in the aftermath of the global financial crisis of 2008. Nokia and the Finnish electronics sector suffered from the effects of disruptive technological change symbolised by the introduction of the iPhone in 2007, and exacerbated by problems affecting Finland's traditional specialisation, in particular traditional paper products which were facing a technology-induced decline in demand. This has put economic policy and the STI governance system under severe strain. The RIC itself stopped operation for a period of time during the crisis, and was re-established in 2016 in a different form and apparently with a lesser role overall in the Finnish innovation system (OECD, 2017a).

Source: OECD (2017a), *OECD Review of Innovation Policy: Finland 2017*, https://doi.org/10.1787/9789264276369-en

Over time, demands on research and innovation councils have evolved.

While initially their scope tended to be limited to issues of science and technology in a narrow sense, their remit has been progressively expanded to include broader "innovation" in a wider sense (including non-technical innovation), a trend that has changed the issues dealt with by the council. Long-standing councils have, in a number of cases, changed their names to reflect this development. For example, the Finnish Research and Innovation Council began as the Science and Technology Policy Council.

Conceptual and empirical work on innovation systems, networks and processes have underpinned this wider approach of contemporary councils. "Whole-of-government" approaches calling for a co-ordination of policies across different policy areas (and hence organisational borders such as those of line ministries) seem to be particularly pertinent for innovation policy which cuts across many policy areas (OECD, 2013). New perspectives on reform processes, in particular on increasing efficacy by combining reforms in various areas and adequately sequencing action, have also been drivers of change.

The increasing need to tackle societal challenges and other broad-based transitions (such as digitalisation or Industry 4.0) reinforce the need for cross-cutting approaches and the involvement of a broader set of actors. Inevitably, there are tensions between new demands and the compartmentalised manner in which governments often work in practice.

The Austrian RFTE falls between the co-ordination and advice model, in its first phase, it had, in some specific ways, stronger elements of co-ordination. However, in practice it seems fair to say that it has been for the most part essentially an advisory council with some elements of co-ordination. The other two councils clearly fall under the advisory category.

The composition of a council should be aligned with its mandate, i.e. the role it is supposed to fulfil in the innovation system. Many innovation councils have a secretariat, but the size of these units varies. Having a secretariat with its own staff sends a strong message of independence from particular actors in the research and innovation system and being at "arm's-length". To be able to fulfil its role, a council's secretariat will have to have the "absorptive capacities" to effectively monitor ongoing national and international work on STI indicator developments, assess and interpret analysis of STI, and translate and apply this work to the national policy context. The scope of its task varies with its mandate, reflecting the council's role in the national system of innovation.

The relevant choices seem to be between a strong advisory council and a co-ordination council (or a hybrid solution).

- Option 1: A strong advisory council (this would largely conform to the RFTE model, perhaps with stronger involvement of ministers).
- Option 2: A co-ordination council with ministers as members, and chaired by the Federal Chancellor, including a hybrid model where an advisory council meets periodically with government ministers under the presidency of the Federal Chancellor.

Agenda setting, co-ordination and evaluation

Current research, technology and innovation and related strategies

RTI Strategy 2011-20

The RTI Strategy 2011-20 intended to advance Austria from the group of innovation followers to the group of innovation leaders, i.e. to be among the most innovative countries in the EU (BMWFW and BMVIT, 2016). The strategy set the target of an aggregate R&D intensity of 3.76% by 2020, and a range of initiatives to drive innovation in education, research and industry. Its strategic framework sets out improvements in the access to and permeability of the education system, increased international mobility of students and graduates, and making academic careers more attractive. Through a reform of university financing and performance agreements, and an expansion of competitive third-party funding and the implementation of clusters of excellence, basic research is supposed to be strengthened. With the innovation capacity of Austrian businesses as an essential factor in becoming an innovation leader, a broad package of measures improves access to private equity and venture capital, and the intensification of links between science and business. As regards governance, the RTI Strategy 2011-20 placed high importance on co-ordination and co-operation across policy areas, including clear and transparent funding structures, and coherence in the distribution of responsibilities from regional co-ordination to internationalisation.

However, due to the impact of the 2008 financial crisis and the subsequent deterioration of the macroeconomic environment in Europe, the environment for the implementation of the RTI Strategy 2011-20 has been significantly altered. According to the interim assessment of the RTI Strategy 2011-20 conducted in 2016, major achievements include the introduction of a new tenure-track system, as well as a new university financing model, and increased competitive research funding through higher education sector structural funds. Overall, the mid-term evaluation found the strategy to be an important steering tool for the co-ordination and diffusion of RTI-related topics (BMWFW and BMVIT, 2016).

Research, technology and innovation-related strategies

Austria was the first EU member state to formulate a comprehensive national Open Innovation Strategy in 2016. A range of initiatives are bundled under the umbrella of this strategy that "pay special attention to the need for a focused expansion of knowledge and innovation processes in science and research, civil society and in politics and public administration" (BMWFW and BMVIT, 2015). The strategy sets out a vision for stakeholders from civil society, science, the arts, business, public administration and government to work together to tackle social, environmental and economic problems by jointly developing innovative solutions. Activities implemented involve open consultations (e.g. as part of the efforts to develop the energy research strategy for Austria), innovation laboratories, as well as test environments, such as for automated driving (BMBWF, BMVIT and BMDW 2018). Other initiatives aim at making certain topics, such as smart cities, more accessible to a wider professional audience. A monitoring group follows the implementation and development of the Open Innovation Strategy. The group found that there is a considerable degree of readiness for open innovation in industry, science, research and the administration (BMWFW and BMVIT, 2017).

Demand-side policies to support innovation, such as public procurement, are increasingly recognised as a potential strategic instrument and a policy lever to boost innovation, as public procurement accounts for 12% of gross domestic product (GDP) across OECD countries (OECD, 2017c). Austria established the "Austrian Action Plan on Public Procurement Promoting Innovation (PPPI)" in 2012, which aims to use public procurement as one of the levers of a systemic, modern innovation policy.

The Intellectual Property Strategy, launched in 2017, aims to improve the services and funding provided to prospective holders of property rights. It includes a series of measures to improve the portfolio of services offered to firms in need of protecting their intellectual property. These include the creation of the IP Hub, an online platform at the Austrian Patent Office that provides the central contact for prospective holders of property rights (BMBWF, BMVIT and BMDW 2018). The platform offers a wide range of services to advise and help firms fund intellectual property in Austria.

A Digital Roadmap was developed in 2017 to address new opportunities and challenges offered by digitalisation and automation, the newly established Ministry of Digital and Economic Affairs (BMDW) is in charge of developing new Digital Strategy. The Broadband Strategy 2020 presents a plan for the deployment of broadband, with a specific target of making high-speed broadband available across all regions of Austria by 2020. The strategy's masterplan outlines the expansion of digital infrastructure and is supported by funds from the federal government's "broadband billion" fund (BMBWF, BMDW and BMVIT, 2018).

The eGovernment Strategy sets out a number of steps to improve communication between citizens, firms and the public administration in a simple, electronic and barrier-free way. The strategy aims to consider the wider trend towards mobility and the need for unrestricted availability of administrative services (Digital Austria, 2018). The strategy includes activities that help to accelerate administrative processes through digital solutions and alleviate red tape for citizens and business.

The Austrian Cyber Security Strategy, first introduced in 2013, addresses civilian as well as military security issues and aims at ensuring the availability, reliability and confidentiality of data exchange as well as the integrity of the data themselves. The strategy comprises instruments in the areas of "political strategic management, education and training, risk assessment, prevention and preparedness, recognition and response, limitation of effects and restoration as well as the development of governmental and non-governmental capabilities and capacities" (Digital Austria, 2018).

The Strategy for the Future for Life Sciences and Medicine (2016) aims to reinforce Austria's position as an international hub for research, innovation and industry in life sciences. The strategy also raises issues such as the use of big data in life sciences and personalised medicine. The strategy contains recommendations for improving Austria's science base and the quality of research within relevant disciplines in universities and university hospitals. The strategy contains short- and medium-term measures to further improve the Austrian life sciences and boost innovation in and the benefit from the life sciences.

The Creative Industries Strategy (2017) aims to facilitate collaboration between businesses of all sectors and the creative industries. A pilot programme developed for lighthouse projects addresses an increase in the use and visibility of creative industries know-how along the entire value creation chain and across sectoral boundaries.

Other strategies with links to innovation include the Energy Strategy Austria, the Energy Research Strategy, the Austrian Strategy for Sustainable Development and the Austrian Strategy for Adaptation to Climate Change.

Overall, the large number of strategies is indicative of the broad range of new initiatives to spur research and innovation in Austria. While many sectoral and thematic strategies are in line with the priorities of the RTI Strategy 2011-20, there is no guarantee that all of the initiatives are coherent and efficiently connected to each other.

Co-ordination and alignment between the federal and state levels of government

Austrian states play a role in the financing of research and innovation activities. The estimated R&D funding contribution of the states (Länder) in 2018 is EUR 525.8 million, which corresponds to an increase of approximately 5.4%, or EUR 27 million, compared to 2017 (BMWFW and BMVIT, 2017). Other public bodies, such as municipalities and social security funds, are expected to contribute EUR 116.7 million to R&D funding, an increase of 4% compared to 2017.

Other innovation activities supported by the states include, for example, the so-called matching funds by the National Foundation for Research, Technology and Development that are based on co-operation agreements between the FWF and most states (Länder). Through these agreements, projects that the FWF, due to budgetary constraints, is unable to finance but are assessed favourably, are recommended for funding by the states. They can then provide a matching fund and cover 50% of the total costs of the respective projects, while the other half is covered by the National Foundation through the FWF (BMBWF, BMVIT and BMDW 2018).

The federal nature of the Austrian state requires co-ordination of innovation policies between the federal and the state (*Länder*) level. Both the federal government and the state governments pursue innovation policies in their own right, though with a different scope and different degrees of financial sources. In terms of public R&D spending, the regional component is rather modest, amounting to less than 15% of total public R&D funding in

Austria. The majority of R&D funding by the *Länder* is for public research institutes and higher education institutions, while programmes that fund R&D and innovation in firms are largely limited to regional development policy schemes co-funded by the European Regional Development Fund (ERDF). Nevertheless, the regional level in Austria plays an active and relevant part in innovation policies. *Länder* governments have a major role in funding the universities of applied sciences, which are closely linked to the knowledge needs of local industry and society. Several *Länder* governments also run their own public research institutes, sometimes linked to COMET centres. Furthermore, ERDF co-funding and the more recent emphasis of the EU on smart specialisation have contributed to a more active role of the Austrian regions both in innovation policy and in shaping the innovation system.

According to the European Commission's biannual Regional Innovation Scoreboard (RIS), all three main regions in Austria (Eastern Austria, Southern Austria and Western Austria) are placed in the category "strong innovators+", which means they are situated closely behind the leading innovation regions in Europe. The scoreboard also indicates that these regions have improved their performance and relative position in Europe over time (EC, 2017).

The capital, Vienna (which is also a state), accounts for around one-third of total Austrian R&D. The regions of Styria and Upper Austria also contribute substantial shares of R&D. Together with Tyrol, these regions also perform the bulk of Austrian basic research, while applied research and experimental development is more evenly spread across regions.

The role of the states in the Austrian innovation system evolved through the adoption of cluster concepts, competence centres and academic spin-off infrastructures in the 1980s and 1990s. New universities were created in some state capitals in the 1960s and 1970s, and private universities more recently. The states have played an important role in the development of the universities of applied sciences system since 1994. After 2000, the regions' economic strategies and visions have been replaced by, or supplemented with, strategies that focus more on research and innovation, often in the context of developing operational programmes for co-funding through the ERDF.

In recent years, all nine *Länder* governments have developed their own regional RTI strategies, with priorities that align with and supplement the thematic priorities addressed in the federal strategy. The regional strategies are also based on the common European framework for smart specialisation, which again is an integral part of EU cohesion policy. Box 5.4 shows the introduction of each regional strategy during the last decade. The regional strategies usually place a strong emphasis on the role of higher education institutions and research institutes since they provide a localised knowledge infrastructure that can be linked to the more mobile innovation activities of firms. All regional strategies define thematic priorities built upon smart specialisation considerations. Some *Länder* governments also stress the role of inter-regional co-operation, e.g. in the case of Vienna.

Box 5.4. **Innovation strategies of the *Länder* governments**

- **Burgenland** is a predominantly rural region with few research-intensive economic branches or large industrial enterprises. Since Austria's accession to the EU, Burgenland has gone through a catching-up process with respect to infrastructure, economy and education. Its closeness to the central place of Vienna and the ties of its southern part to the region of Graz gives the region access to research competence. The current innovation strategy has identified the following strategic areas: raise awareness for RTI; increase human resources; enlarge research infrastructure; provide services for pre-start-ups, start-ups and new industry; and set up RTI co-ordination. Burgenland has also highlighted a set of thematic fields: sustainable energy; sustainable quality of life relating to segments of life sciences; and intelligent processes, technologies and products.
- **Carinthia** has experienced a considerable rise in R&D expenditure, from below 1% to 2.8% of regional GDP. The RTI strategy "Carinthia 2020 – Future through Innovation" was adopted in 2009 and complemented by the economic strategy for Carinthia 2013-2020. The strategy builds on a general and thematically neutral ambition of strengthening the regional knowledge triangle (education, research and innovation). A particular focus is placed on the areas of ICT (self-controlled networked systems), sustainability technologies and materials, and production technologies at the interfaces of IT, control technology and module switching technology (Industry 4.0).
- **Lower Austria** puts an emphasis on technology and industry, with the objective to support companies located in the region and strengthen their competitiveness. Clusters are created within defined areas such as: environmentally benign construction, food, plastics and mechatronics. The priorities at the technopoles for research, which concentrate on excellence and critical mass, are on medical biotechnology (Krems); agricultural and environmental technology (Tulln); bio-energy, agriculture and food technology (Wieselburg); and medical and materials technologies (Wiener Neustadt).
- **Salzburg** is characterised by a rather heterogeneous and small-scale science and research structure. The innovation strategy (WISS 2025) was adopted in 2016 and is based on the following five guiding principles: 1) science, research and innovation are key competitive factors for Salzburg; 2) specialisation and co-operation are prerequisites for the further development of the regional innovation system; 3) success in science, research and innovation requires consistent internationalisation; 4) education, further education and career opportunities based on high standards; and 5) governance for strategic steering, implementation and evaluation. In addition, five thematic fields are highlighted: 1) life sciences; 2) ICT; 3) smart materials; 4) smart construction and settlement systems; 5) creative industries and innovation in services. The Salzburg strategy aims to bring university and non-university research closer to the needs of business,

Box 5.4. **Innovation strategies of the *Länder* governments** (*continued*)

especially within these thematic priorities.

- **Styria** is an industrialised and R&D-intensive region. The innovation strategy is integrated in the scheme "Economic and Tourism Strategy Styria 2025 – Growth through Innovation". The strategy is mainly focused on applied research and science-business collaboration, especially through COMET centres. The key market-driven themes are mobility, green-tech and health-tech These are supported by the core technology competencies: materials technology, production technology, machinery and plant engineering, digital technology and microelectronics. The creative industries are not prioritised specifically, but positioned as "innovation supporters".
- **Tyrol** is home to three universities, three specialised colleges and several research institutions. Entrepreneurial R&D is concentrated in a few large R&D-intensive companies. Furthermore, the alpine location implies both strengths in terms of tourism and challenges in terms of transport, infrastructure, etc. The research and innovation strategy was adopted in 2013 and defines the following thematic priorities: life sciences, materials and production (mechatronics, materials, especially timber), information technologies and environment and energy (renewable energy source), wellness/tourism as well as the creative industries for the services sector.
- **Upper Austria** has long focused on location policies to build up a specialised regional innovation system. The strategic programme "Innovative Upper Austria 2020" pursues a productivity-oriented growth strategy, with a focus on location development, industrial market leadership, internationalisation, and future technologies. The following five fields of action were specifically selected: 1) industrial production processes; 2) energy; 3) health and aging society; 4) food and nutrition; and 5) mobility and logistics. Upper Austria also focuses on innovation in services.
- **Vienna** is the metropolitan region, with a strong presence of central R&D institutions, R&D and knowledge-intensive companies, and with a corresponding high level of R&D. The current strategy, "Innovative Vienna 2020", was adopted in 2015 and has the overall objective of positioning Vienna as one of the top five research centres in Europe by 2050. The strategy also seeks to take advantage of the innovation triangle of Vienna-Brno-Bratislava as one of the most promising regions in Europe. In terms of thematic focus, the strategy emphasises priority areas within life sciences, information and communication technologies (ICT), creative industries, humanities, cultural and social sciences, and certain areas of mathematics/physics. The objectives defined in the research, technology and innovation (RTI) strategy follow a generally systemic approach, with overarching ambitions related to the strengths and opportunities of Vienna as a metropolitan area.

Box 5.4. **Innovation strategies of the *Länder* governments** (*continued*)

- **Vorarlberg** is one of the fastest growing regions in Europe. The economy in Vorarlberg is export-oriented and has the highest share of company-financed R&D spending in all of Austria. Over the years, Vorarlberg has managed to reorient from specialisation in the textiles and garments industry towards metallurgy and the production of food and beverages. The strategies for innovation and location policy are formulated in the science and research strategy for Vorarlberg 2020+. Besides general schemes for strengthening the region's R&D and innovation, the strategy prioritises: smart textiles, energy and energy efficiency, humans and technology, education and health, and intelligent production.

Source: ÖROK (2018), "Facts and figures 2018", www.fhk.ac.at/index.php?eID=tx_nawsecuredl&u=0&file=uploads/tx_sbdownloader/FHK-Zahlen_Daten_Fakten_02082018.pdf&t=1535722049&hash=550a9a3b3a5914a39d5322b22fdb2722a318e699

Co-ordination between the federal and the *Länder* levels on innovation policy is needed in different areas:

- On a strategic level, the federal government's RTI strategy and the regional innovation strategies should be closely interlinked in order to fully utilise synergies and to align policy activities at the two levels. While the federal level should define the key framework for R&D and innovation, as well as the strategic goals for the Austrian innovation system, it is important to fully involve the *Länder* governments in the process of developing a federal RTI strategy. This is particularly true with respect to thematic priorities and societal challenges. Since some regions have better preconditions for taking up such initiatives, a regional differentiation in close co-ordination between the federal and the *Länder* levels of some thematic policies could lead to greater policy impacts.
- To address institutional needs and support the connection of research to European missions, strategic investments and funding instruments should be better aligned across regional, national and EU levels.
- Localised knowledge infrastructures such as universities, UAS, COMET centres and other public research institutes play an important role in the regional context. Since the regional level strongly influence the setting for the operation of these infrastructures, and the ways they engage in transfer and co-operation, it is important to involve the regional governments in federal infrastructure-related policy initiatives.

Limiting regional disparities is an important dimension of policy making in the federal system of Austria. Innovation policy can and should contribute to this goal by further developing and deploying existing regional strengths in research, innovation and economic activities; by encouraging co-operation and exchange across regions; and by linking regional clusters to national thematic priorities. Altogether, the *Länder* governments in Austria demonstrate high ambition and strong political commitment to strengthen their respective regional innovation systems. The regional strategies also seem well aligned with the federal priorities in Austrian innovation policy. On the other hand, there is reason to question whether the regional strategies actually complement the RTI Strategy 2011-20, or whether they might create an overly complex and dispersed landscape. The two levels of governance and priorities do not seem to follow a common plan or division of labour.

With a few exceptions, there are also few signs of collaboration and co-ordination between regions. Collaboration and co-ordination will be useful whenever regions target similar thematic priorities or address similar societal challenges. Developing joint, cross-regional initiatives in common priorities can help to achieve critical mass and a more sustainable level of funding. Many of the regional strategies seem to embrace a broad set of such priorities. Given the limited amount of funding on the regional level (from regional authorities and EU Structural Funds), more targeted and measurable targets could be feasible too.

Tackling societal challenges

Tackling challenges such as climate change, population ageing, poverty, social exclusion, and food and energy insecurity have become a major task for humankind. These challenges profoundly affect society and the economy, while the associated timelines, and scale and scope of impacts, are often highly uncertain. Any viable attempt to deal with these challenges must draw on research and innovation, in combination with other actions. Innovation policy cuts across policy areas, and this is perhaps even to a greater extent true for policies directed towards societal challenges. Tackling societal challenges also requires elements of systemic transition, necessitating policy action influencing attitudes and patterns of behaviour. In addition, these type of policies require the inclusion of actors some of which are not at the core of traditional innovation policy. A main task for public policy in this context is to guide research towards areas where societal needs are most urgent and where innovation can yield the highest social benefit. Another function is to co-ordinate actors and put conducive framework conditions in place (e.g. legal and other frameworks, from regulation to standardisation) so that individual actors interact in the most effective way.

The Lund Declaration of 2009 called for European research to focus on grand challenges and saw the need for EU institutions and member states to align European and national instruments more effectively. The new Lund Declaration of 2015 confirmed the importance of increased efforts to link innovation activities with societal challenges. This new declaration called for, among other things, strengthening the link between innovation and societal outcomes, increasing the impact of R&D and innovation by stronger involvement of public sectors and industry, as well as more focus on open innovation and the role of end users.

Societal challenges in Austrian innovation policy

Austria’s current RTI Strategy 2011-20 has emphasised the importance of R&D and innovation in tackling major societal and economic challenges. These explicitly include climate change, natural resource scarcity, demographic change, health, quality of life and food safety. In addressing societal challenges through RTI, the strategy outlines the following priorities: strengthen Austria’s competitiveness across relevant scientific and technological fields, with particular attention for the competences of Austrian firms that are key to implement and deploy research results; define new priorities regarding specific challenges to co-ordinate activities in a comprehensive system approach, involving all ministries concerned in the areas of the RTI Task Force; establish comprehensive system priorities to address grand challenges of the future.

The Government Programme of the new federal government further pursues the need to make better use of innovation in the context of grand societal and ecological challenges (Government Programme 2017-22, 2017). To make better use of innovation for societal challenges, the government aims to improve framework conditions that help funnel investment to relevant research, including additional private investments, in particular in addressing climate change, energy, demographic change and education. The agreement emphasises the role of open innovation in this context as a means to reach target audiences, and further, as a means to better integrate non-technological innovation into funding programmes. In addition, better alignment of national and EU funding programmes has been identified as important to increase synergies supporting Austria's innovation activities for societal challenges (Government Programme 2017-22, 2017).

Improving priority setting to addressing societal challenges

While the RTI Strategy 2011-20 explicitly addresses societal challenges and the relevance of STI for developing possible solutions to such challenges, unlike other countries, such as Germany or the United Kingdom, a systematic identification of the challenges most relevant in the Austrian context, for instance through systematic foresight activities, has been conducted only recently (in the context of providing input for the next EU framework programme Horizon Europe). Furthermore, some areas that would lend themselves to being a priority in RTI policy related to societal challenges are not sufficiently addressed in the Austrian RTI Strategy 2011-20. One example is health, which is mentioned in the strategy document as important, but for which no dedicated inter-ministerial working group for joint priority setting and implementation has been formed. A reason for this can be seen in the fragmentation of the governance and funding structure of the health system, with responsibilities divided between the states (*Länder* and municipal governments), as well as across social insurance funds (19 in total). The fragmentation of the governance of the Austrian health system is an impediment to its efficiency (LSE, 2017), as is the lack of a dedicated R&D programme in health.

Research funding for societal challenges

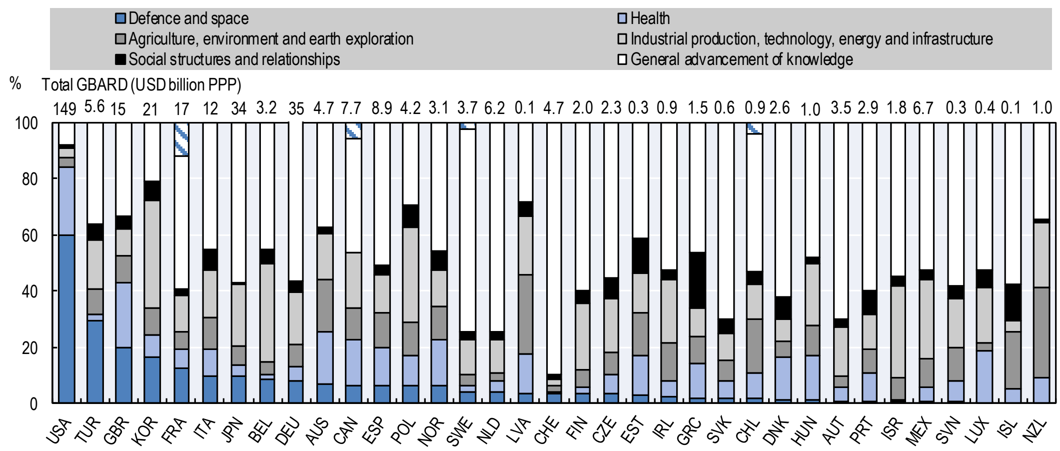
Overall, there is room for improvement in Austria's approach to addressing societal challenges through mission-orientation (AIT et al., 2017). This is apparent in public R&D funding related to socio-economic objectives related to societal challenges. More than two-thirds of public R&D funding is allocated to non-thematic research. R&D funding in Austria for specific societal challenges is hampered by insufficient priority setting across respective policy areas.

Competitive funding of basic research by the FWF has not employed a targeted approach to address societal challenges, and public R&D funding of the business enterprise sector rests largely on thematically open research funding, while mission-oriented funding that could emphasise societal, economic and security challenges (AIT et al., 2017).

A proxy for assessing the emphasis placed on societal challenges is government budget allocations to R&D according to main socio-economic objectives. The evidence shows that the shares of R&D allocations for health, environmental, education and social programmes are comparatively low in Austria (Figure 5.2). These data reflect, to some extent, the predominance of thematically open allocation of R&D funding in Austria.

Figure 5.2. **Government budget allocations to R&D by main objectives**

Percentage of civil government budget allocations to R&D, 2017



Note: Data from 2016.
Source: OECD (2018d), *Main Science and Technology Indicators* (database), https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB.

StatLink https://doi.org/10.1787/888933882845

While non-thematic research funding prevails, a number of programmes and instruments exist that address societal challenges through funding R&D. An important instrument in this regard is the Austrian Climate and Energy Fund (KLIEN). KLIEN was designed to increase R&D in sustainable energy technologies, reduce greenhouse gas emissions and help implement Austria's climate strategy. KLIEN's energy research programme provides R&D funding for targeted research for the introduction and implementation of climate-relevant and sustainable measures and energy technologies. Current focus areas include research on buildings, mobility, production and energy supply, with a focus on sectors that are currently responsible for most greenhouse gas emissions. Through its thematic focus on energy, KLIEN contributes substantially towards expanding the scientific capacities of Austria in the area of sustainable energy technology. KLIEN has become critical in Austria's climate policies, with a EUR 150 million for funding respective research activities.

Other issues-driven research addressing societal challenges has emerged from the various RTI working groups that followed the implementation of the RTI Strategy 2011-20. These include climate change and resource scarcity, as well as the creation of a mobility roadmap in the context of quality of life and demographic change (BMBWF, BMVIT and BMDW, 2018).

With regards to increasing security and security awareness, the Austrian security research programme KIRAS addressed the development of knowledge needed to design better security policy. In addition, national security and defence are addressed through the research programme FORTE. This programme aims to build Austria's capacities in the area of national security and supports research and technology through a new format that fosters collaboration between relevant research institutes and industrial firms. FORTE provides the first thematic programme in Austria that is entirely dedicated to R&D in the area of defence. The programme started first calls in October 2018 and is designed not only to contribute to building competencies in national security and defence, but also to better exploit existing synergies with and better alignment of national and EU research objectives.

It is an example of how to design thematic policies to reflect national research investments in accordance with European developments in the area of defence research.

Other thematic programmes relevant to societal challenges are funded through the BMVIT, which supports R&D in the areas of energy and transport. A good example of a target-oriented funding programme is the Mobility of the Future programme (Mobilität der Zukunft). This programme focuses on innovative transport systems to ensure increasing demand for mobility can be met while reducing negative impacts, such as greenhouse gas emissions and congestion. This mission-oriented initiative also attempts to create a future-oriented framework for mobility research. Its annual budget varies between EUR 13 million and EUR 19 million, and is available to universities and non-university research groups, enterprises, non-governmental organisations, and public agencies, including transport providers.

Addressing societal challenges in the European context

Other indications of national orientation towards societal challenges are participation and success in the EU Horizon 2020 programmes dedicated to societal challenges. In general, Austrian actors have performed well in the ongoing Horizon 2020 funding calls. By September 2018, Austria had received 2.9% of total funding dedicated to societal challenges in H2020, with a success rate of 20% of application calls (FFG, 2018) (Table 5.2).

Table 5.2. **Austrian performance in Horizon 2020 – Societal Challenges, September 2018**

	Total	Health	Food	Energy	Transport	Environment	Society	Security
Funding (million EUR)	415	71	34	100	120	41	25	24
% of total funding	2,9%	2.2%	1.8%	3.6%	3.5%	2.6%	4.2%	3.1%
Participations	1113	151	127	234	307	141	86	67
% of total participations	3.0%	2.2%	2.0%	3.6%	4.0%	3.0%	3.7%	2.8%
As co-ordinator	148	21	14	34	50	12	9	8
% of total co-ordination	3.0%	2.4%	2.1%	3.4%	3.8%	2.2%	2.8%	2.8%
Success rate	20%	14%	22%	19%	39%	26%	11%	12%

Source: FFG (2018) EU-Performance Monitoring (September 2018). https://www.ffg.at/monitoring.

For Austria, 43.1% of national participation in H2020 projects relates to societal challenges, where the Austrian participation is particularly high in the areas of energy, transport and society, with success rates well above the EU average. Austria's performance here implies that funding from the EU for societal challenges constitutes an important additional source of funding in these areas, but also raises the question of appropriate alignment of activities between the national and the international levels.

To tackle societal challenges effectively, the EU started a Joint Programming Initiative to pool national efforts and make better use of resources by the alignment of funding. Austrian research organisations participate in eight out of ten such initiatives. However, while joint programming initiatives are important instruments for aligning national policies and programmes, one of the challenges is the effective implementation of joint research activities. Uptake of this programme by member countries was limited, as was its subsequent impact regarding a better pooling of resources and alignment of strategies.

To improve alignment between Austrian and RTI policies at the European level requires the identification of priority areas for mission-oriented programmes on the European level to help outline national and EU complementarities. The identification of priority areas for a mission-oriented approach to research funding both at the EU as well as at the national level is currently underway. Examples of efficient alignment between national and EU-level priorities already exist, such as the national defence strategy FORTE (see above).

Mission-oriented approaches to research funding

Alongside the increased emphasis on societal challenges, so-called mission-oriented approaches have gained renewed interest in the discussions of R&D and innovation policies. Mission-oriented policies are by no means a new phenomenon (see, for example, Ergas [1986]). The current debate about missions should be seen in the context of societal challenges as drivers of R&D and innovation (Kuittinen, Polt and Weber, 2018). However, the concept of mission-oriented research should not be confused with research on societal challenges per se. The term "mission-oriented" refers to initiatives that "typically are ambitious, exploratory and ground-breaking in nature, often cross-disciplinary, targeting a concrete problem or challenge, with a large impact and a well-defined time frame" (Kuittinen, Polt and Weber, 2018). Mission-oriented research can have different, clearly defined goals which may include societal or technological goals. An example of mission-oriented policies to address societal challenges is the German "Energiewende" (energy transition), which relies on research and innovation as well as complementary changes in regulatory and institutional frameworks.

Against this background, mission orientation emerged as a "device to bridge the gap between societal challenges and specific R&I projects" (Kuittinen, Polt and Weber, 2018). In a report to the European Commission, Mazzucato (2018) describes missions as a necessary level of action between broad societal challenges and concrete research and innovation projects, where the former are "too broad to be actionable" and the latter are "isolated in their impacts", if not linked to a broader societal agenda. In addition to bridging the gap between challenges and actions, the mission approach seeks to combine top-down and demand-driven approaches, with missions being open for a range of solutions to solve the problem in question. Box 5.5 provides examples of the development of a mission-oriented research programme addressing societal challenges in the area of climate change.

An interim evaluation of Horizon 2020 highlighted the need for an impact-focused mission-oriented approach for the forthcoming Horizon Europe framework programme. In the ongoing preparatory process for Horizon Europe, mission-oriented funding and RTI policy will play a greater role than in the current Horizon 2020 programme. The current discussions aim at contributing to a better impact of RTI policies in Horizon Europe by better articulating research capabilities, and linking innovation policies with societal challenges. In Horizon Europe, the European Commission will emphasise a stronger use of policy missions to ensure the effectiveness of research and innovation funding through clearly defined targets. A mission-oriented policy approach, according to EC (2018), is essential to steer public investments in the direction of the desired outcomes.

Box 5.5. **The global fight against climate change: Mission Innovation**

Austria is part of the initiative Mission Innovation (MI), a global initiative of 23 countries and the European Union aiming to accelerate the clean energy revolution by doubling public clean energy R&D over a period of five years. It encourages greater levels of private sector investment in transformative clean energy technologies. The MI was officially launched at the Paris UN Climate Change Conference in 2015 and involves private actors alongside governments. The official target is to have public R&D funding in clean energy research reach USD 30 billion per year by 2020, or to increase cumulative research funding over the five years to USD 100 billion, from the baseline estimate of USD 75 billion. Besides the main objectives, a complementary action, Innovation Challenges, was announced in June 2016. The eight Innovation Challenges include: 1) smart grids; 2) off-grid access to electricity; 3) carbon capture; 4) sustainable biofuels; 5) converting sunlight; 6) clean energy materials; 7) the affordable heating and cooling of buildings; 8) renewable and clean hydrogen.

Austria's engages in the MI by actively contributing to the challenges in the areas of smart grids and affordable heating and cooling in buildings, sustainable biofuels, solar energy, and clean energy materials. These interests are synergistic with Austria's governmental programme 2018-22 that commits to international climate goals and sets ambitious objectives, such as the achievement of 100% use of renewables in the power sector by 2030. Participation in the MI is also aligned with the national strategy on climate and energy.

Sources: Fischer, R. et al. (2018), Mission-Oriented Research and Innovation, p. 210, https://publications.europa.eu/en/publication-detail/-/publication/3b46ce3f-5338-11e8-be1d-01aa75ed71a1/language-en; Mission Innovation (2018), "Austria", webpage, http://mission-innovation.net/participating-countries/austria.

Following an online survey by the European Commission in April 2018 asking for feedback on potential mission-oriented research areas, a number of potential subjects for Horizon Europe were identified. Survey respondents saw the need for investments in the areas of digitalisation (14%), health and well-being (11%), social and economic transformations (10%), sustainable production (7%), transport and mobility (6%), diseases (6%), and energy production and consumption (6%). Independent of the missions that will be adopted in the Horizon Europe programme, the further definition of missions will need to involve strategic decisions on cross-cutting technological changes, type of finance required, and the types of regulations and taxes that reward investments by the private sector.

The current discussions on mission orientation by the EU are mirrored at the national level in Austria, where priority areas are currently being identified. Mission-oriented RTI policies and programmes are likely to play a prominent role in Austria's new RTI Strategy 2020+. The government programme of the new federal government also emphasises the need to play a more active role on the European level, and to use funding through Horizon Europe more synergistically to further develop Austria's STI capacities.

Given the increased emphasis on thematically oriented research, Austria should systematically explore the possibilities for increasing the role of initiatives addressing societal challenges; giving a greater role to mission-oriented policy approaches; and striving for an appropriate good alignment of activities on the national and international level, in particular through Horizon Europe.

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Supporting international linkages and co-operation

The role of international linkages for innovation

International linkages play a critical role for innovation as they allow enterprises and other innovation actors to tap into a larger base of ideas and technology, find complementary expertise, and pool competencies. In particular, small open economies such as Austria benefit from international linkages, as they are conduits for knowledge and technology spillovers, provided countries possess the required absorptive capacities, and they connect their research community to advanced research and innovation networks. These linkages are increasingly important as research is more and more globalised and innovation increasingly depends on the integration of technologies and the combination of various types of knowledge and skills. International linkages can help overcome barriers, such as deficiencies in funding and management resources.

International knowledge linkages in Austria

Austria is very well integrated in European research activities and participates strongly in European R&D programmes, particularly in Horizon 2020. In addition, Austria shows high levels of international co-authorship of scientific publications and R&D financed from abroad. Austria is actively involved in EU networks such as ERANET, joint programming initiatives and joint technology initiatives.

To improve international linkages of start-ups and SMEs, the BMWFW endowed EUR 4 million to the Global Incubator Network, launched in 2016. The network serves as a platform for international and Austrian start-ups, investors, business angels, and start-up agencies. The network's objective is to promote Austria as a start-up hub and improve international networking for Austrian companies by providing improved access to international incubators and accelerators, international investors, and potential international strategic partners. It provides support for entry in international markets, connects to international start-ups and supports firms in handling intellectual property rights.

Other programmes to facilitate international knowledge linkages and spur innovation in firms include the Go-International programme that encourages companies to do business abroad. It is the main export promotion programme of the Austrian Chamber of Commerce to encourage the internationalisation of innovative firms. One of the programme's 25 instruments is the Export Cheque (2015-19) that co-finances the activities of technology-oriented enterprises abroad. The COIN programme focuses on foreign companies that seek R&D partners and networking projects in Austria. The EUREKA programme is a thematically open programme for supporting internationally oriented R&D-performing SMEs. Overall, these programmes build strong linkages between Austria and other EU countries. However, they are offset by weak linkages and funding opportunities for collaboration with partners from countries outside of Europe (World Bank and OECD, 2018).

Austria's participation in Horizon 2020 programmes

Central to Austria's international collaborative efforts in the area of research and innovation is its participation in the European framework programmes. Success in the programmes reflects the quality and international relevance of the national research and innovation system. EU programmes are also an important arena for international networking and for building critical mass in research. The current Horizon 2020 programme (2014-20) provides EUR 7.9 billion per year. According to the most recent data, Austria's share of the total budget in Horizon 2020 amounted to 2.8%in September 2018 (FFG, 2018), compared to Germany (16.3%), the United Kingdom (13.6%) and France (10.9%).

Austria has been particularly successful in the pillar Industrial Leadership, where it secured a 3.1% share of funding, reflecting Austria's strengths in applied industrial R&D. In the Societal Challenges pillar Austria received 2.9% of the Horizon 2020 funds available in 2018. In this pillar, Austria is particularly successful in the areas of energy and transport, which account for more than 50% of the funds allocated to Austria within this pillar. In contrast, Austria's performance is average in the areas of food and water (22%), and below the level of leading innovation countries in the areas of climate change, health and ageing populations. Up to 2018, 232 European Research Council grants have been awarded to researchers at Austrian institutions (see above), indicating its high success rate in the Excellent Science pillar.

Austria in the forthcoming Horizon Europe programme

With regards to the upcoming European Framework Programme *Horizon Europe*, Austria participated in a foresight process that builds on the interim evaluation of Horizon 2020 (BMBWF, BMVIT and BMDW 2018). The preparatory process was part of the BOHEMIA project (2015) that supported the discussion about the future of European STI policy by providing a long-term view on the requirements and opportunities for research and innovation in Europe, and for the next framework programme in particular. The process aimed to summarise potential global and socio-economic environmental developments through 2040 that will likely shape future research and innovation agendas regarding societal challenges. The result of this scoping exercise provided preliminary input for missions and partnership areas for the next framework programme.

Austria's participation in providing input to identify potential research areas for Horizon Europe is an important exercise in the context of Austria's next RTI Strategy. The fact that Horizon Europe will have a strong mission-oriented research component means that better alignment and interoperability between Horizon Europe and Austria's national research programmes will improve synergies and effect a more efficient use of EU funding, particularly in the areas of societal challenges, as outlined above.

Internationalisation beyond Europe

To improve Austria's research co-operation beyond Europe and EU funding programmes, the Beyond Europe Strategy strengthens the commitment to the international positioning of Austria as a location for science and R&D, with third countries. The programme supports Austrian enterprises, research and higher education institutions, and other organisations to establish and expand co-operation with partners outside Europe.

The strategy aims to improve the co-ordination of relevant policies, international activities of ministries and stakeholders, and the implementation of a dedicated Austrian Foreign RTI Policy. This includes the development of recommendations for strategic actions to foster RTI co-operation with third countries, and a discussion of an Austrian position in European strategic fora (BMVIT et al., 2013). To internationalise STI in Austria, and strengthen collaboration outside the EU, the strategy was developed by an inter-ministerial working group including all major Austrian STI stakeholders and implemented from 2014 onward. Specific activities include the conclusion of new bilateral STI agreements with priority countries such as Brazil, the People's Republic of China (hereafter "China"), Israel and South Africa.

Co-operation with third countries is essential to build reliable long-term relations, particularly with countries catching-up with technology frontiers in certain areas. Considering the programme's ambitious objectives, it should be re-considered whether a budget of EUR 4.6 million for the programme's first call is sufficient to effectively support international research collaboration with third countries.

Other initiatives to promote internationalisation for Austrian firms and start-ups include international awareness campaigns, such as the US-Austrian Research and Innovation Talk 2017 in Austin, Texas, or the Austrian-Canadian Science and Innovation Days 2017 in Vienna (BMBWF, BMVIT and BMDW, 2018). In addition, a national platform for sharing information on international activities was launched in 2014 and meets on a regular basis, focusing on priority countries and regions defined in Beyond Europe.

Better co-operation with third countries is also a priority in Austria's input for implementation of Horizon Europe. According to BMWFW (2017), third-country co-operation "should also be an essential element of the EU's overall strategy". Third-country co-operation should build reliable long-term relations, including, bilateral co-funding mechanisms with international partners (BMWFW, 2017).

With a budget of more than EUR 60 million, and more than 200 employees, the OeAD (Österreichischer Austauschdienst) is the Austrian agency for international mobility and co-operation in education, science and research. The OeAD advises, promotes and supports international co-operation in education, science and research, and manages mobility and co-operation programmes for the BMBWF, such as the implementation of more than 20 scientific and technological co-operation agreements. These programmes provide funding for about 250-300 bilateral and multilateral co-operation projects annually, and are used to stimulate international STI co-operation activities of Austrian higher education and non-university research institutions. Based on the Beyond Europe Strategy, the BMBWF, in co-operation with the BMEIA, it has substantially expanded its system of co-operation programmes with international partner countries in recent years. New agreements for bilateral co-operation or the continuation of existing agreements have been signed recently with Argentina, Bosnia and Herzegovina, China, Israel, South Africa and Viet Nam and prepared with Brazil and Korea. Such bilateral co-operation programmes are also used for multilateral and regional activities in STI, for instance in the context of the EU Strategy for the Danube Region.

Improving support for international research co-operation

A recent evaluation of the FFG Department for European and International Programmes examined the support, monitoring and governance mechanisms for Austrian participation in international R&D collaborations (AIT et al., 2018). Particular emphasis was placed on the support services for participation in EU programmes. In general, the evaluation finds that research institutions involved in international collaborations are rather satisfied with the support, advice and information they receive. Overall, the support provided had a positive impact on the performance of Austrian STI actors in Horizon 2020.

Room for improvement has been identified with regards to the provision of more targeted advice and information to different user groups according to their focus on different aspects of European collaboration. Information about calls and new initiatives should be simplified and made more user friendly. In addition, efforts to empower and incentivise Austrian research organisations to develop their own capacities for EU framework programme-related strategies seem not to have been unambiguously successful, with a number of institutions still very much dependent on the services of the FFG Department for European and International Programmes. Efforts in this vein should be continued and reinforced.

Improving the linkages between national support through FFG and EU programmes would be beneficial. For instance, a system for redirecting highly rated but rejected proposals for EU programmes to relevant national funding mechanisms could be established, and the research focus between the national and the EU levels could be better aligned. To leverage synergies with international initiatives beyond EU programmes, it would be useful to create incentives for Austrian actors to participate in international research activities.

The governance and co-ordination of ERA policies and support seems to be well established, and effectively carried out by Department for European and International Programmes. However, there seems to be a need to strengthen the co-ordination of internationalisation and participation in EU programmes on the ministerial level. This is particularly important as the current and future European framework programmes focus increasingly on cross-sectoral issues, which will require closer alignment of funding mechanisms and funding bodies at the national level. Furthermore, if the current ERA Council Forum is merged with other advisory bodies, the co-ordinating role and function of this body will have to be compensated by strengthening the strategic forum for ERA policies on the ministerial level, for instance.

Evaluating policy for science and innovation – Data requirements and limitations

Robust evaluation of innovation policy is a critical element of policy development. The "Austrian research and technology report 2017" describes the development of evaluation practice in Austria over recent decades. The report's key observations include: evaluation competences and capacities, as well as the creation of responsibilities in ministerial departments and agencies, have expanded since the mid-1990s; there has been an important rise in RTI evaluation activities in the last 15 years; the Austrian Council for Research and Technology Development has helped strengthen the perception of the role and relevance of evaluations through its publications and recommendations; the Research and Technology Promotion Act has standardised evaluation principles; since its creation in 1996, Austria's research and technology policy evaluation platform has been instrumental in advancing evaluation practice. Members of the platform include ministries, agencies, research institutes and consultancy firms, and the platform offers discussion fora, develops publications, and implements training courses and workshops.

However, the same report notes that "quantitative methods, in particular those that can be applied to estimate causal effects, and experimental approaches, are used seldom." This situation is often due to the limited availability and quality of data. Current evaluation practice in Austria is significantly constrained by the Austrian Statistics Law, which restricts evaluators' and researchers' ability to access and match firm-level micro-data. This is at odds with international best practice, which increasingly allows access to anonymised firm-level micro-data within secure websites or online labs, thereby facilitating more cost-effective and timely policy monitoring and evaluation.

Access to firm-level micro-data is critical to developing a deep understanding of the factors which shape innovation outputs and links to growth and productivity. Individual firm-level data are also important in conducting robust evaluations of policy initiatives by enabling the construction of control groups, etc. (see, for example, Box 5.6, which illustrates the various methodological approaches available for evaluating R&D tax credits, including control-group approaches). Significant advances have also been made in recent years in understanding business processes by matching firm-level data. For example, matching data from innovation surveys with time-series data on business performance can help to identify the performance benefits of innovation and how these differ between sectors and firm size bands. Matching data from firms with that of their individual employees can also be very useful in investigating the impact of diversity or training on aspects of business performance. Alongside its value for improving evaluation and developing new insights for policy, the ability to match administrative data sources also has advantages for businesses in terms of reducing the survey burden.

Box 5.6. **Methodological approaches to the evaluation of R&D tax incentives**

Over past decades, R&D tax incentives have been evaluated in many countries using different methods (see Appelt et al., 2016; Castellacci and Lie, 2015; Hall and van Reenen, 2000; Laredo et al., 2016). The main goal of evaluations is usually to determine the effectiveness of R&D tax incentives in terms of input additionality, i.e. whether the tax incentive led to a causal increase in R&D expenditure of firms. Some evaluations also consider output additionality, i.e. the impact of the tax incentive on innovation or productivity. Commonly used evaluation methods include surveys of firms that use R&D tax incentives, econometric analysis of R&D expenditure of firms based on a control-group approach, estimations of the user cost of R&D (price elasticity), quasi-natural experiments which investigate changes in design features of R&D tax credits over time, and estimates of user costs of R&D based on structural models. Each method has advantages and disadvantages.

Surveys: Surveying beneficiaries of R&D tax credits on their perceived impacts of the tax credit is an easy method to implement that does not require external data (such as data on the amount of tax relief or time series data on the firms' R&D expenditure). A main weakness of this approach is that survey respondents (entrepreneurs or managers) might be unable to accurately assess the genuine impacts of the scheme and distinguish these from the many other possible determinants of R&D spending. Long-run effects might be ignored, especially if the survey is administered shortly after the commencement of the scheme. Respondents could also have strategic reasons for overstating or understating the impacts of R&D credits. Surveys may also be subject to biases if only an unrepresentative number of beneficiaries respond.

Box 5.6. **Methodological approaches to the evaluation of R&D tax incentives** (*continued*)

Econometric analysis of R&D expenditure based on a control-group approach: The main idea of this method is to compare the R&D expenditure of firms using a tax incentive with almost identical firms not using the tax incentive. It is usually implemented by using firm-level panel data on R&D expenditure for a group of firms subject to an R&D tax incentive and another group of firms not subject to the incentive. The econometric model includes a variable for the R&D tax incentive as well as variables that represent other relevant determinants of R&D expenditure. The method has been used both for firm-level data (e.g. comparing firms in a region that offers a tax incentive with firms from another region that does not, or analysing firms before and after the introduction of an R&D tax incentive scheme) and industry- and country-level data. The advantage of the method is its relative simplicity and, if conducted at the industry or country level, its low demand on data availability. The disadvantage is that the measurement is relatively imprecise and strongly depends on the availability of variables to represent all other determinants of R&D expenditure.

Estimating price elasticity of R&D: This approach attempts to estimate the response in firms' R&D expenditure to changes in the price of R&D. As R&D tax incentives reduce the price of conducting R&D, price elasticities can be used to determine the impact of R&D tax incentives on the level of R&D expenditures. There are, however, both data and modelling challenges. While estimating price elasticity of R&D can be done with firm-level data on R&D expenditure collected in R&D surveys, there is usually very limited information on the actual changes in input prices of R&D (R&D personnel, material used in R&D, etc.) and also a limited number of control variables for other determinants of R&D. Consequently, R&D price elasticities are often rough estimates. If an R&D tax incentive leads to relabelling of some non-R&D firm expenses as R&D, this method will overestimate the real price elasticity. In addition, the firm characteristics that determine to which extent a firm can benefit from an R&D tax incentive will also affect the level of the firm's R&D investment, making standard econometric methods inappropriate. More advanced econometric approaches such as instrumental variable techniques are very demanding in terms of data needs and may lead to a less precise estimation.

Box 5.6. **Methodological approaches to the evaluation of R&D tax incentives** (*continued*)

Structural models: This method is a further development of price elasticity estimations. It uses a theory-based model of a firm's optimal R&D stock (i.e. the accumulated R&D expenditures over time considering devaluation of knowledge) and considers the time dimension of the relationship of R&D to its user cost. A good example of this method is the work by Lokshin and Mohnen (2007; 2012; 2013) who evaluated the Dutch R&D tax incentive scheme WSBO, including a macroeconomic cost-benefit analysis of the scheme. They found that the cost to the government of a volume-based R&D tax credit grows faster than the additional firm R&D that such a programme stimulates. The deadweight loss of the programme is higher for large firms than for small and medium-sized enterprises. While this method allows cost-benefit analysis of R&D tax incentive schemes, both modelling efforts and data requirements are higher than for the other methods. In addition to time series data on the R&D expenditure of firms, information is required on the amount of R&D tax incentive received by each firm.

Quasi-natural experiments: This method exploits changes in design features of R&D tax incentive (e.g. change in the group of beneficiaries, change in the tax rate) or differences in the generosity of the tax incentive for different groups of firms (e.g. a higher rate at a certain size threshold, a ceiling on the amount of tax support a firm may receive, etc.). By comparing changes in R&D expenditure or other target variables prior to and after the change, or for firms below or above a certain threshold or ceiling, one can apply econometric methods such as regression discontinuity designs to identify causal impacts. Dechezleprêtre et al. (2017) performed such an evaluation for the United Kingdom's R&D tax allowance using an increase in the size threshold under which firms can access a more generous tax rate as well as an increase in the enhancement rate. They found significant positive impacts of the tax incentive, raising aggregate business R&D in the United Kingdom by about 10%. A precondition for conducting such an analysis is the availability of firm-level data on R&D expenditure before and after the change, while no data on the firms' actual R&D tax claims are needed. Data on the R&D expenditure of firms over time are collected through official R&D surveys.

Current legislation in Austria – notably the Austrian Statistics Law – means that access to individual firm-level data is tightly restricted, and the scope for matching individual data sources is limited. This constrains academic research on Austrian firms, any firm-level comparative analysis and the evaluation of business policy, and is a marked contrast to more open data policies in other European and OECD countries (see Box 5.7). Steps have been taken in Austria to improve data access, but changes in basic legislation are likely to be necessary to provide more open data access while maintaining individual and corporate confidentiality.[2] Consideration should be given to reform of the provisions (or potentially the application) of the Austrian Statistics Law, to allow researchers and evaluators direct access to anonymised business data for analysis and data matching. Matching best practice internationally here would require the development of a secure online service providing remote access.

Box 5.7. **Towards more open business data**

The Scandinavian countries – particularly Denmark – have perhaps the most open data policies, allowing researchers and policy analysts direct access to anonymised firm-level data, and the ability to match these data with information on related individuals. This type of employer-employee data access is not limited to Scandinavia, however. Estonia has also moved to enable firm-level data matching (performed by the Statistical Office, for a small fee). Central to this in Estonia is the Estonian Commercial Registry dataset of firms' annual reports, which includes income statement, balance sheet and ownership data. The registry provides annual data on all firms in Estonia since 1995. As in Denmark, Estonia also allows the creation of employer-employee datasets using the Estonian Commercial Registry, with data accessed using a Safe Centre at the premises of Statistical Office.

Different countries also adopt different approaches to allowing researchers and analysts access to firm-level survey and administrative data. In Ireland, legislation allows researchers to be made "officers of statistics", which then permits them to access specific Central Statistical Office datasets.[1] The United Kingdom, by contrast, has established a process for training so-called "accredited researchers", who are then permitted to access data in a series of secure "datalabs" in different locations and through a secure online service (the Secure Data Service). This enables academics and other accredited researchers to access a wide range of government (administrative) data sources via secure access from their own workplace. Other countries adopt an even more open approach to some survey data. For example, anonymised firm-level data on innovation from the Spanish and Chilean Community Innovation Surveys are freely available to download.

1. www.cso.ie/en/aboutus/dissemination/accesstomicrodatarulespoliciesandprocedures/policyonaccesstoresearchmicrodatafiles.

Notes

1. The Federal Organic Budget Act (Bundeshaushaltsgesetz, BHG 2013) and the Vorhabensverordnung are the legal basis for the decision on whether or not a budgetary approval is required.
2. http://ec.europa.eu/eurostat/documents/64157/4372828/2015-AT-improvement-actions/d390a3b1-9eb9-4ffa-b728-1a0710855efa.

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