OECD Reviews of Innovation Policy: Austria 2018

Overall Assessment and Recommendations

December 2018

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.