Chapter 1.

Overall assessment and recommendations

This chapter presents an overall assessment of Luxembourg's innovation system and policy, reflecting key findings of the review. It reviews recommendations of the OECD Innovation Policy Review: Luxembourg 2007 *and their implementation and identifies strengths and weaknesses of the innovation system today. It sets out strategic tasks for innovation policy and develops specific policy recommendations for improving Luxembourg's research and innovation performance.*

1.1 Achievements and challenges – diversifying the economy and the role of innovation

Contributing to the great effort to overcome a long history of conflict on the European continent, Luxembourg has consistently played an active role in European political and economic integration. As a founding member of the Benelux group of countries, it has to this day helped advance and operate the institutions that constitute the European Union and the Economic and Monetary Union. The city of Luxembourg is the seat of several European institutions and agencies, including the European Court of Justice, the European Court of Auditors, and the Statistical Office of the European Communities (Eurostat). It also hosts the European Commission's Directorate-General for Translation and the Secretariat of the European Parliament. Luxembourg naturally participates in the Schengen group of countries, named after the Luxembourgish village of Schengen where the agreement facilitating free movement of citizens among member states was signed.

Over the course of the early 20th century, Luxembourg transitioned from a largely agrarian economy to an industrialised one with an important steel industry, which dominated in the aftermath of the Second World War until the oil and steel crises of the 1970s announced its secular decline. Even at the height of the steel industry, however, Luxembourg managed to attract a number of important multinational enterprises (MNEs) from other manufacturing areas. Beginning in the 1980s, the creation of new enterprises (supported by the newly established Société nationale de crédit et d'investissement), the development of industrial zones and other policies and initiatives mitigated the decline of the steel industry to some extent.

Luxembourg's second transformation, however – now towards a service economy – arose from the growth of its financial industry, clearly evidenced by the massive long-term shift in the structure of value added. Between 1970 and 2011, total industry's share in Luxembourg's value added declined from 47% to 8%, and that of steel from 28% to 2%. In parallel, the massive increase in the value added from the financial sector more than compensated for the decline of the steel industry. Financial-sector activity has been the main driver of economic growth in the past three decades. Luxembourg's banking sector is the largest in the European Union, accounting for roughly one-quarter of gross domestic product (GDP).

Luxembourg's development as a major global financial centre owes to a combination of a "first mover's" strategy in implementing international regulation, low taxation and strict banking secrecy rules. Luxembourg's financial sector comprises investment funds, insurance companies and banks. The country hosts the second-largest fund-administration industry globally. Most of the banks are foreign-owned subsidiaries that are weakly linked to the domestic economy through their operations. Numerous international companies are domiciled in Luxembourg.

Overall, Luxembourg's current macroeconomic situation remains favourable. The country enjoys the highest GDP per head[1] in the OECD, and its public finances are among the most solid. While real GDP growth remains well above the eurozone average, the unemployment rate has nearly doubled over the pre-crisis level. Reducing unemployment, especially among lower-skilled resident workers, is an important task. Reducing the economy's heavy dependence on the financial sector, which (as mentioned) has underpinned much of the growth of recent decades, is an overarching longer-term challenge.

The large financial sector has weathered the financial crisis relatively well, while posing challenges in aligning financial regulations with EU and international initiatives. Some fiscal and regulatory rules and practices that have provided Luxembourg with advantages in the past have come under scrutiny in the aftermath of the financial crisis. As many countries face tight budgetary constraints, international efforts to improve transparency (e.g. related to banking secrecy) have gained momentum, with some tax advantages being challenged or phased out. In such a context, diversifying its economy while maintaining a competitive financial sector has emerged more strongly as an important strategic issue for the future of Luxembourg.

1.2 The evolution of the innovation system: Following up on the *OECD Review of Innovation Policy: Luxembourg 2007*

The *OECD Review of Innovation Policy: Luxembourg 2007*, the first of its kind, found Luxembourg's innovation system in a state of significant transformation. Public research and development (R&D) expenditure had grown substantially in the years preceding the *Review* and (following an extended public debate) Luxembourg had just created its first university, the University of Luxembourg. The 2007 *Review* welcomed the Luxembourg government's objective of further strengthening and developing the public research base as a springboard for increased innovation-led growth. Specifically, it acknowledged the government's strong commitment to increase investment in R&D to bring the ratio of public R&D expenditure to GDP closer to the level of comparable OECD countries.

At the same time, the *Review* noted that the public institutions for funding, supporting and performing research and innovation – e.g. the National Research Fund (FNR), Luxinnovation, the public research centres (CRPs) and especially the University of Luxembourg – were all relatively young. It concluded that: "The innovation system is not yet fully developed. In some respects it is still unbalanced and needs to be adjusted to guarantee efficient use of an increase in public investment in R&D and innovation. At the same time there is great potential for future development, which is enhanced by a consensus among all relevant actors on the objectives and also the need for change in the institutional set-up and steering mechanisms". The *Review* further noted that the process of setting up the University of Luxembourg was obviously not complete and had proven more difficult than expected. It also found that the specialisation and division of labour between the CRPs, as well as their relation to the evolving university, had yet to be adequately defined.

Overall, the 2007 *Review* found that governance in the field of research and innovation was still rather weak, owing to a lack of objectives, strategies and state-of-the-art performance contracts to structure the governance of Luxembourg's public research centres (and other institutions). Consequently, major parts of the *Review* and the bulk of its recommendations focused on improving the steering and funding of CRPs and the new University, as well as lifting governance mechanisms to the level required by the increased scale of investment in R&D, the differentiation of the innovation system and the role innovation was expected to play in Luxembourg's future development – including in diversifying its economy.

The Luxembourg authorities decided to take on board all major recommendations made in the Overall Assessment and Recommendations of the 2007 *Review*. Table 1.1 summarises these recommendations and their subsequent implementation. This overview indicates that the commitment and responsiveness of the Luxembourgish government and

innovation actors turned the *Review* into an important step developing Luxembourg's innovation policy, with demonstrable and measurable impact on the design and performance of the innovation system.

After a period of rapid, largely government-financed expansion – especially in public research – and substantial reforms in the organisation and governance of the research and innovation system and its main institutional actors, Luxembourg has now entered a period of consolidation. This is the right time and opportunity to take stock of what has been achieved, and how to proceed further.

Table 1.1. **Recommendations of the 2007 Review and their implementation**

Summary of major 2007 recommendations	Implementation
– *Clarify the role of actors* in the research and innovation system by separating more clearly the policy formulation and implementation functions.	– Actors' roles were more clearly defined, particularly through the establishment and evaluation of performance contracts concluded with the public research performers and agencies. The creation of the Luxembourg Institute of Science and Technology (LIST) through the merger of CRP-Gabriel Lippmann and CRP-Henri Tudor and of a co-ordination mechanism among the research performers may contribute to this goal in the future.
– *Improve co-ordination among policy actors*, including among the major ministries in charge of R&D policies (Ministry of Higher Education and Research and Ministry of the Economy), and aim for better horizontal co-ordination of sectoral policies.	– The co-ordination between ministries (particularly the Ministry of Higher Education and Research and the Ministry of the Economy) has improved partly thanks to the new performance contracts. The previous formal Inter-ministerial Co-ordination Committee has become inactive.
– *Improve strategy formulation and management capabilities*, particularly at the ministries in charge – whose staffing should be increased – and rely more on external advice.	– The performance contracts, and their subsequent evaluations, reinforced strategy formulation and management capabilities of public innovation performers and agencies They have also been strengthened in the ministries, but staffing remains rather modest in view of an expanded and more complex innovation system.
– *Establish an Advisory Board on S&T Policy,* to be chaired either by the prime minister or one or several ministers. The Board's main task would be to monitor progress in implementing the government agenda for strengthening Luxembourg's research base, advising the government and initiating complementary studies and evaluations. The Board should comprise members with a strong background in business, science-and-innovation policy, including a sufficient number of non-residents.	– The Superior Committee for Research and Innovation was created in 2008 to support the development of national research and innovation policies and advise the government in implementing such policies. The Committee is co-chaired by the Minister of Higher Education and Research and the Minister of the Economy and Foreign Trade. Its other members are scientists, business people and civil-society representatives. The impact of the Committee has been limited.
– *Set science and technology priorities.* Building up the research base in Luxembourg requires a number of discretionary investment decisions that render a pure bottom-up approach insufficient. The ongoing Foresight Study should be used to derive priorities for such decisions. In the meantime, consultations with the end-users of research in preparation of the launch of Competence Centres could provide useful information for sharpening priorities for research at the University and the CRPs.	– The government has set six public research priorities based on the results of the 2006-07 Foresight Study. The priorities are addressed in the newly created CORE programme of the FNR and are part of the performance contracts of the CRPs and the Centre for Population, Poverty and Public Policy Studies (CEPS/INSTEAD). The University supports the priority-setting process through its own research priorities, which are partly in line with national-level priorities.
– *Steering of public research institutions.* Enhancing accountability and (ultimately) efficiency requires a clear mission statement for each CRP and agency; these mission statements should base themselves on strategic audits of the respective institutions. The current contractual arrangements between the government and public research institutions (e.g. the multi-annual programmes of CRPs) should be replaced by state-of-the-art performance contracts.	– The creation of performance contracts between the government and the CRPs, CEPS/INSTEAD, the agencies and the University of Luxembourg was a step change in improving governance. The contracts provide a framework for governance in the public research sector and are now in their third round. They enabled a shift to global budgets and multi-annual planning, with clear definitions of research priorities, goals and indicators, as well as evaluation and reporting schemes. The innovation performers and agencies perceive them as a useful instrument to structure and enhance governance while retaining institutional autonomy.

Table 1.1. **Recommendations of the 2007 Review and their implementation** (*continued*)

Summary of major 2007 recommendations	Implementation
– *A new role for Luxinnovation*. The agency plays an important role in Luxembourg's innovation system, especially by connecting business enterprises and public-sector research and ensuring greater participation of small firms in innovation. To maintain the quality of services in an environment of growing demand, the agency should streamline its current portfolio of activities and strengthen its organisational capabilities. It should play a key role in extending the reach of innovation policy to the service sector and other activities in which innovation does not directly rely on R&D.	– Luxinnovation's role has been adapted, but not fundamentally redefined. The introduction of performance contracts and external evaluation was an important change. The 2009 law on the promotion of research, development and innovation (RDI) highlights Luxinnovation's importance as a consulting and supporting institution. Its mission, objectives and portfolio have been refined accordingly. The appointment of a representative from the private sector as president may herald further reorientation.
– *Entrusting the FNR with all project and programme-based funding* of the CRPs and University of Luxembourg. The FNR has to fulfil an overly broad mandate mixing strategy and implementation.	– Much project and programme-based funding of CRPs and the University is now allocated by the FNR, with some notable exceptions, e.g. the significant funding channelled through the biomedical initiative.
– *Linking research to education*. This is a fundamental task of the University of Luxembourg, which should be facilitated by the establishment of research schools that can attract talented doctoral and post-doctoral students. However, the CRPs must complement the University's role by emphasising doctoral and post-doctoral training in their research units and ensuring the mobility of the highly skilled and trained workforce to the business sector.	– While the University of Luxembourg has a focus on research, much is performed in the two interdisciplinary centres, e.g. outside the teaching faculties. The University offers doctoral education through five doctoral schools (specialising in systems and molecular biomedicine; economics and finance; educational sciences; computer science and computer engineering; and law). The CRPs also host PhD students, though the majority are registered in foreign universities.
– *Promoting a coherent internationalisation strategy*. Internationalisation – in the "Grande Région" and beyond – is fundamental to the performance of Luxembourg research institutions and should be a key criterion for measuring the performance of CRPs. At the same time, performance contracts should ensure that the internationalisation strategy of CRPs is in line with their mission.	– While no formal overarching internationalisation strategy is in place, the University of Luxembourg, the CRPs, the CEPS and the innovation agencies have addressed many aspects of internationalisation. For example, the FNR operates the ATTRACT and PEARL programme to attract excellent researchers, as well as the INTER Mobility Programme promoting participation in international research projects, while Luxinnovation supports firms participating in European projects through Fit4Europe. Bilateral and multilateral co-operation agreements, as well as European RDI programmes, support internationalisation. The University of Luxembourg has entered into agreements with partner universities in Europe and worldwide and participates in a variety of EU programmes. The CRPs and CEPS are well connected to the international research community. Funding through European Framework Programmes was a recurrent issue in some evaluations, however. The FNR established co-operations with international peer organisations, e.g. the United States National Science Foundation. Luxembourg is a member of the European Space Agency and European Molecular Biology Laboratory, and participates in a variety of European Strategy Forum on Research Infrastructure projects.
– *Launching a Centres of Competence (CoC) programme* to promote sustainable long-term strategic linkages extending public-private interaction in research and innovation. CoCs are goal-oriented, long-term contractual arrangements between CRPs and firms, serving the needs of both sides. The rich international experience in this field could be used to design and implement a programme customised to Luxembourg's specific needs.	– A CoC programme has not been launched. However, the government has focused on public/private research collaboration and encourages establishing Centres of Excellence. The University's Interdisciplinary Centre for Security, Reliability and Trust (SnT) provides a platform for interaction and collaboration. Clusters promoted by Luxinnovation serve as networks of public and private stakeholders in the areas of space, materials, information communication technologies (ICTs), eco-innovation and biohealth. The Neobuild innovation cluster supported by the Ministry of the Economy is a private-sector initiative promoting R&D and innovation in sustainable construction. The FNR provides targeted support to public-private partnerships (P/PPs), e.g. in the CORE programme. The joint location of activities in the Cité des Sciences, de la recherche et de l'innovation (City of Sciences, Research and Innovation) in Belval is expected to result in synergies and facilitate P/PPs.

1.3 Main strengths and weaknesses of Luxembourg's innovation system today

Table 1.2 presents the results of strengths, weaknesses, opportunities, threats (SWOT) analysis of Luxembourg's innovation system.

Table 1.2. **SWOT analysis of the Luxembourg innovation system**

Strengths	Opportunities
– a high level of socio-economic development – an open economy, taking full advantage of its favourable location at the heart of Europe – a largely favourable regulatory environment and a responsive government – a dynamic and evolving research landscape – improved research system governance as a result of consolidation and well-designed performance contracts – a majority of firms routinely engaged in innovation – some strongly innovating MNEs – high-level recruitments that have boosted the research system's maturity and international visibility – strong research capabilities and links to socio-economic agendas in the University's interdisciplinary research centres – pockets of research strength in the CRPs, with good links to industry and professional practice – new research infrastructures, such as the Cité des Sciences in Belval, including teaching and research facilities and incubators.	– develop a national innovation strategy to improve direction-setting and coordination in the national innovation system – improve horizontal co-ordination (between the Ministry of Higher Education and Research, the Ministry of the Economy and the Ministry of Health) to promote policy effectiveness – improve contribution of public research organisations to innovation – provide stronger incentives for accumulating innovation capabilities within firms and extending their ambition – provide better support for business innovation through more professional implementation and a move towards project-level appraisal and instrument-level evaluation – enhance integration with high-potential international innovation networks, also beyond Europe – take full advantage of valorisation, e.g. by adopting a wider concept – see the Grande Région as an organising framework for policy initiatives that depend critically on proximity and critical mass (clusters, infrastructure, undergraduate programmes, etc.) – take advantage of the strong cluster emerging around the Biomedical Initiative and the SnT.
Weaknesses	**Threats**
– lack of a well-articulated strategy for directing innovation policy – occasional weak coherence and alignment between national priorities and those pursued by various actors – relatively low level of visibility and acknowledgement of Luxembourgish research actors at the global level – some weaknesses in accumulating further innovation capabilities and extending the reach and ambition of innovation in parts of the business sector – lack of critical mass of internationally excellent research, especially in CRPs – low levels of business R&D, concentrated in a limited number of big players – weak intensity of PP/Ps and collaborations, at least by other advanced-economy standards – relatively low participation in EU Framework Programmes compared to other advanced economies – lack of visibility of research performed in the University faculties – under-developed linkages between the University and CRPs.	– lack of progress in economic diversification – stagnation or decrease of business R&D investments – inability to further expand the system for the longer term owing to stagnating public financial resources – research actors disconnected from the rest of the economy – lack of public understanding of the benefits of local spillovers arising from public research actors – increasing difficulty in attracting and retaining highly skilled workers in the face of mounting global competition.

1.4 Strategic tasks

The overriding task of Luxembourg innovation policy is to strengthen innovation as a driver of sustainable growth and maintain and increase the population's high standards of living. Innovation policy can make important contributions to solving major strategic tasks the country's faces.

- *Achieving and maintaining adequate productivity growth.* Productivity is recognised as the main driver of economic development in the long term, and the major source of differences across countries in GDP per capita, notably for

high-income countries. Luxembourg's high living standards are supported by its high level of labour productivity. Multifactor productivity (MFP), e.g. the joint efficiency of the production inputs, labour and capital, growth is the most important driver of labour productivity growth. For the most developed countries, innovation tends to be the main driver of MFP growth. Thus, long-run economic performance depends on the level and quality of its innovation activities.

- *Diversifying the Luxembourg economy within the financial sector but also through the development of new high value-added economic activities* in non-financial services and manufacturing industries. This would help to reduce, over time, the economy's heavy reliance on the financial sector. In the aftermath of the crisis, it has become widely acknowledged that diversification could contribute to strengthening the resilience of the economy and mobilising new sources of growth, notably through innovation-driven economic activities. High-value-added activities tend to be technology and knowledge-intensive, and require investment in human resources R&D and innovation.

After a period of rapid, largely government-financed expansion of the research and innovation system – especially in public research – and substantial reforms in the organisation and governance of the research and innovation system and its main institutional actors, Luxembourg's innovation system is now entering a new phase. Major tasks to be addressed in this next phase include:

- to consolidate the progress Luxembourg made over the past decade, and advance further to become a widely recognised location for research and innovation in Europe
- to better link and orient more strategically the promising initiatives in the area of research and innovation that have been initiated and flourished during the recent period of rapid growth and change
- to improve governance and steer the innovation system in a way that:
  - enhances co-ordination across ministries and agencies
  - strengthens linkages between public research centres (the CRPs) and the University of Luxembourg
  - helps better target long-term funding to the most promising research areas and groups.

1.5 Key issues and recommendations

Taking due account of Luxembourg's innovation-related SWOT and the strategic tasks to be addressed by innovation policy, this report has identified a number of key issues leading to some policy recommendations.

Promoting critical mass, excellence and relevance in public research

Over the last decade, the Luxembourg government has accelerated its investment in public-sector research and made new investments in research infrastructure, notably the Cité des Sciences at Belval. The University of Luxembourg is now the largest public-sector research performer, followed by the CRPs. While the University has grown greatly over a short period, the CRPs have also expanded significantly. Bibliometric

analysis suggests that the public research sector's output has increased, with a generally positive trend in its international impact.

Government chiefly funds the University of Luxembourg and CRPs through block grants from the Ministry of Higher Education and Research and competitive funding from the FNR. The Ministry of Higher Education and Research block grant is governed by performance contracts with each of the CRPs and the University (see below). FNR funding – which has grown markedly – is directed through several schemes emphasising research excellence, notably the thematic programme CORE, the Aides à la formation-recherche (AFR) funding programme for PhD and post-doctoral research, and the INTER, ATTRACT and PEARL mobility programmes.

The University of Luxembourg

The University of Luxembourg conducts research in its three faculties – the Faculty of Science, Technology and Communication; the Faculty of Law, Economics and Finance; and the Faculty of Language and Literature, Humanities, Arts and Education – as well as in two semi-autonomous interdisciplinary centres founded in 2009 – the Interdisciplinary Centre for Security, Reliability and Trust (SnT) and the Luxembourg Centre for Systems Biomedicine (LCSB). In 2013, the University secured almost EUR 30 million in third-party funding for research, up from EUR 16 million in 2010. By the end of 2013, the University had a total staff of 1 460, 16% of whom are faculty members and 57% other scientific and research staff.

Reflecting its ambition to achieve international visibility in a few research areas, the University of Luxembourg has a limited number of research and teaching priorities. These are revisited every three or four years, with some continuity – but also some differences – with earlier articulations of priorities. The faculties include several research units whose activities may or may not be aligned with the University's strategic research priorities. For example, the Faculty of Science, Technology and Communication (which employed around 350 R&D personnel in 2013) features five research units – computer sciences and communications, engineering sciences, mathematics, physics and materials sciences, and life sciences; of these, only two are aligned with the University's current strategic research priorities on computation sciences, and physics and materials. The 2013 evaluation of the University of Luxembourg highlighted the lack of visibility of faculty research compared with research performed in the interdisciplinary centres covering the University's strategic research priorities. Still, the faculties continue to account for the largest part of the University's block grant.

The two interdisciplinary centres, LCSB and SnT, warrant special attention, as they have grown rapidly and are increasingly visible at the international level. The LCSB originated in the Luxembourg government's Health Sciences and Technologies Action Plan and was built through a partnership with leading US institutes specialising in systems biology (see below). Its aim is to carry out fundamental research in the field of systems biology and biomedicine and to analyse the mechanisms of disease pathogenesis, with a special focus on neurodegenerative diseases and more specifically on Parkinson's disease. By the end of 2013, the LCSB employed more than 140 R&D personnel, including only 7 faculty members; the remainder are supported by a mix of University priority funding, FNR studentships and fellowships, FNR research grants, EU Seventh Framework Programme/Horizon 2020 funding, and funding from other national sources. In 2013, the LCSB secured more than EUR 13 million in research grants. According to the scientific review panel associated with the 2013 evaluation of the University of

Luxembourg, the LCSB fills a niche that is not yet over-populated. The panel was impressed with its performance, judging it to be "very good" and firmly on track to become "excellent". At the same time, the panel raised concerns about inadequate facilities at Belval and the need to improve collaboration with other parts of the University, notably related research units in the Faculty of Science, Technology and Communication.

The SnT was created to take the lead on implementing the University's focus on information technology security and reliability. This priority is particularly pertinent for Luxembourg, which has for some time sought to position itself as a European centre of excellence for secure, reliable and trustworthy ICT systems and services. Like the LCSB, the SnT has experienced fast and steady growth in terms of staff members, PhD students, industry partners and public grants since its creation in 2009. By the end of 2013, it numbered 222 R&D personnel (including PhD students and interns), including 17 faculty members. A key defining feature of the SnT is its Partnership Programme, where key actors contribute know-how and resources to shape and build the SnT; 20 such partnerships involving a mix of public and private organisations already existed in 2013. That year, the SnT spent EUR 11.5 million on R&D; externally funded projects accounted for 69% of research revenues, mostly funded through various FNR schemes, but also through the Partnership Programme (16%). The Programme is notable for relying upon strategic mid- and long-term research partnerships with strongly committed industry or research players, rather than on short-term service-type projects that are more typical of the industry relationships permeating the more applied research-oriented CRPs. The SnT strategy holds that public funding for high-risk fundamental research should find an articulation with, and not be done separately from, more practice-oriented projects with partners. The scientific review panel associated with the 2013 evaluation of the University recommended expanding partnerships further afield – starting with stronger relationships with international institutes – to drive excellence. It also highlighted the unclear division of labour with the Faculty of Science, Technology and Communication and its focus on academic research.

The interdisciplinary centres have undoubtedly proven successful so far and have provided a major boost to the University's research profile. Their independent status lends them considerable agility and has allowed them, for example, to install swift recruitment procedures and expand very rapidly. At the same time, such autonomy risks disconnecting them from the faculties and weakening the links between research and teaching activities. Differences in contracts, distribution of workload and promotion tracks contribute to tensions between interdisciplinary centre staff and faculties. Tensions also arise over the University allocating the bulk of its block grant to the faculties, despite the interdisciplinary centres' strong research performance.

The 2013 evaluation of the University of Luxembourg highlighted the need for a common understanding of "research quality" and the means to monitor, improve and reward it, as well as clarity on the meaning and utility of research priorities. The evaluation recommended that the University's central administration develop, together with all parties concerned, a clear and balanced strategy on the relationship between faculties/research units, the interdisciplinary centres, and the University's overall priorities, also taking into account the relationships between research, teaching and valorisation. This strategy has yet to be developed; notwithstanding the pressures of the upcoming move to Belval, it should be articulated and implemented as soon as possible.

A further priority for the University of Luxembourg is establishing a School of Medicine. Currently, neighbouring countries accept medical students from Luxembourg, with the University providing the first year of medical training. Luxembourg would be less dependent on foreign medical education providers if it had its own medical school, adapted to its own health system and featuring strong links between teaching and research – particularly in the fields of biomedicine and translational research. Proceeding along these lines presents benefits, but also considerable constraints that need to be considered. First, establishing a medical school would be a very expensive endeavour, consuming a large part of the University's budget while providing training for just 25-50 students a year. Second, productive links between teaching and research are most likely to emerge in advanced and postgraduate studies rather than in the first years of medical teaching, so linking research and teaching might not prove as beneficial as expected. Finally, important complementary assets – such as the ready availability of medical doctors with extensive teaching experience – appear to be under-developed. The University and Ministry of Higher Education and Research have each commissioned studies to assess the advantages and disadvantages of creating a medical school in Luxembourg; they will report their results in 2015.

Recommendations

- *Articulate and implement an inclusive whole-of-university research strategy within the University*. Among other things, the strategy should aim to set University research priorities: define the meanings, relevance and implications of research excellence; delineate a fair reward system for research excellence and relevance among faculty research units and interdisciplinary centres; clarify the relationships between interdisciplinary centres and faculties; consider the merits of establishing further interdisciplinary centres; and define relationships with external actors, including the CRPs and international research partners.
- *Consider carefully the options for setting up a medical school at the University*. The many potential benefits of establishing such a school should be weighed against the very substantial costs involved.

Public research centres (CRPs)

The R&D law of 1987 established three major public research centres: CRP Gabriel Lippmann, CRP Henri Tudor and CRP Santé. Since 2015, CRP Gabriel Lippmann and CRP Henri Tudor have merged to become the Luxembourg Institute of Science and Technology (LIST), and CRP Santé has been renamed the Luxembourg Institute of Health (LIH). LIST research focuses on three main areas – environment, information technology and materials – while LIH focuses research on clinically-oriented biomedical research and public health. The Luxembourg Institute of Socio-Economic Research (LISER) (formerly CEPS/INSTEAD) performs both basic and applied research in areas such as population and employment, geography and development, and business and industrial organisation with the aim of informing social policy making in Luxembourg. All these centres are under the direct responsibility of the Ministry of Higher Education and Research.

The merger of the Gabriel Lippmann and Henri Tudor CRPs seems appropriate in light of the high degree of overlap and contemporary changes in the wider system, including the new infrastructures in Belval. It represents an opportunity that should be fully exploited to address past issues and seize future opportunities. A new CRP law (2014) cements the status of the CRPs as autonomous public legal entities with financial

and administrative autonomy, and alters the terms of their relationship with the Ministry of Higher Education and Research. The law also formally updates their missions to promote knowledge and technology transfer, training and lifelong-learning, and scientific co-operation at national and international levels; it also introduces more transparent and open recruiting procedures.

Although the CRPs were originally established to support service-oriented applied research to meet business-sector needs, they have increasingly focused over the past 25 years on more strategic applied – and occasionally basic – research. This shift derived from a significant increase in public investment in the CRPs and has led to hundreds of new researchers arriving in Luxembourg in recent years. While the block grant has increased continuously in absolute terms, its relative share in the budget of the CRPs has been declining. Performance indicators for the overall CRP sector reveal difficulties in attracting competitive and contractual research funding, especially from European sources. The CRPs received about 10% of European FP7 funding (up to August 2014) – approximately half of the funding received by the University of Luxembourg over the same period. The success of SnT in securing long-term industry funding through its Partnership Programme leads to questions about the difficulties of CRPs in meeting their targets for attracting contractual research funding. More positively, the CRPs have secured a sizeable number of the AFR doctoral and post-doctoral grants provided through the FNR. The CRPs have also benefited from the PEARL and ATTRACT programmes of the FNR to attract – though only to a minor extent – top international talent to Luxembourg.

According to recent evaluations, the CRPs and the University of Luxembourg could significantly enhance their interaction. For example, very few of the PhD students at the CRPs are enrolled at the University of Luxembourg, and joint staff appointments are extremely rare. Various institutional arrangements at the University that appear to hinder greater co-operation are currently under review or revision; co-location at Belval is likely to offer new opportunities for closer collaboration. Luxembourg could learn from experiences in many advanced European countries, where deep and extensive ties exist between universities and CRP-like public research institutes.

The roles of the CRPs continue to be contested – in the same vein as with similar institutions in other countries – not only owing due to the breadth of activities in which they engage, but also because of recent institutional changes in the wider innovation system. The CRPs serve considerably different functions than those of the University of Luxembourg. For instance, providing support to evidence-based policy features prominently in the mission of both LISER and LIST (which also has the explicit objective of strengthening business-innovation capacities). While their distinct missions are to some extent reflected in the performance contracts, the sorts of activities they engage in are notoriously difficult to measure and account for using rigorous performance indicators. The performance indicators on international scientific excellence are less questionable – and here, the CRPs are facing increasing pressure to improve their scientific output. The number of scientific outputs has grown for all CRPs; however, the impact and number of citations of these publications are not exhibiting similar growth, especially in the case of LISER and the former CRP Henri Tudor.

Recommendations

- *Promote further the international focus of the CRPs* by encouraging greater participation in EU funding programmes and greater co-operation with firms outside of Luxembourg. This could be a core part of efforts to improve

international scientific excellence in a framework of socio-economic relevance. The creation of LIST creates good conditions for a next step in this direction. Prepare this shift with a broad discussion on the level of ambition, geographical scope and further specialisation of public research actors.

- *Consider carefully the possibility of additional mergers in light of the experience of the merger of CRP Gabriel Lippmann and CRP Henri Tudor into LIST.* Merging LIH and LISER either with the University of Luxembourg or with LIST would require considerable time to prepare and should be carefully evaluated, taking into account the relative merits of grouping researchers, creating critical mass and reducing administrative costs.
- *Implement additional measures to extend and deepen collaboration between the CRPs and the University of Luxembourg*, such as joint staff appointments, specific provisions in the performance contracts or new co-ordination mechanisms that may now be feasible in light of the co-location at Belval. Joint senior staff appointments between the University of Luxembourg and CRPs in particular would help build and cement co-operation between the two, e.g. through joint PhD supervision and joint research projects.
- *Explore what lessons can be learnt from the approach taken by the SnT* to resolving tensions between academic and user-oriented research in the same institute, bearing in mind the somewhat different missions, histories and legacies of the CRPs.
- *Revisit the choice of performance indicators used for some of the core functions performed by the CRPs*, as they may be intrinsically difficult to compare systematically over time. Selecting complementary assessment methods, including evaluations by clients or other stakeholders, may be preferable when it comes to these functions.

Cité des Sciences infrastructure at Belval

The large-scale infrastructure development at the former industrial site of Belval is an important milestone in the continuing efforts to consolidate and upgrade the public research system. It is one of the largest and most ambitious current urban-renewal projects in Europe, with a budget close to EUR 1 billion. It is expected to house over 6 000 inhabitants, sustain over 20 000 new jobs, and become the studying and working place of about 7 000 students and 3 000 researchers and lecturers. The Cité des Sciences at Belval aims to assemble most of Luxembourg's public research organisations (including the University of Luxembourg) and most of the public research centres (including LIST and LISER) in one place. For historical reasons, the University of Luxembourg is currently located in four sites. This dispersion limits communication, synergies (e.g. interdisciplinary work and consolidation of common functions) and critical mass. Most of the University is expected to move during 2015-16.

Once complete, Belval should have numerous functionalities: it will co-locate the so-called "knowledge triangle" of research, teaching and innovation. It will also feature residential, commercial, industrial, sports and leisure facilities. Newly built facilities will also house private firms involved in research as well as support P/PPs, e.g. the Technoport and House of BioHealth (see below). Nevertheless, the conditions that make for a vibrant knowledge community are difficult to recreate. Concerns have been voiced about the site's apparent lack of space to house the research groups that are supposed to

move there over the next few years. This jeopardises Belval's original aim to co-locate researchers working in similar areas, independent of their organisational affiliation, and instead risks raising tensions about which group should get the most space. The quality of public transport links with Luxembourg City is also under question.

Recommendations

- *Ensure Belval has sufficient space and facilities to co-locate University of Luxembourg and CRP research groups as originally planned.* This may require further infrastructural investments so that the initiative may deliver on its aims of creating critical mass and excellence in chosen research areas.
- *Establish mechanisms to monitor the evolution of Belval* in light of its social and economic functions, *allow continuous learning* from international experience and *co-ordinate responses* to the challenges identified.
- *Acquire a better understanding of the implications of locating public research units within thematically organised "houses"*, shifting away from their current location around centres and faculties. Opportunities may arise in terms of interdisciplinarity, some institutions could be reconfigured once researchers start working in the same buildings, and previously unforeseen possibilities for co-operation may emerge.
- *Ensure Belval is appropriately branded and promoted internationally*, since the *Cité des Sciences* offers unique opportunities to raise the international visibility and attractiveness of research and innovation activities in Luxembourg.

Valorisation

The University's guidelines on valorisation define it as "all initiatives and activities undertaken with a view to increasing the value of research results and, more generally, enhancing knowledge". Academic engagement with industry involves multidirectional knowledge-related collaboration through formal (e.g. collaborative research, contract research and consulting) and informal activities (e.g. networking and exchanges at conferences and other forums). Although sometimes measured through patenting and licensing of inventions, as well as academic entrepreneurship (e.g. spin-offs), valorisation does not only occur at the end of a research project or programme. Instead, it is the result of interaction between a variety of research and innovation actors at different stages of research and innovation.

Considerable effort is under way in Luxembourg to improve the valorisation capabilities of public research actors and provide adapted institutional and physical infrastructures. The FNR seeks to promote knowledge transfer from public-sector research to the business sector through collaborative research programmes involving P/PPs. For example, its two largest programmes, CORE and AFR, support P/PPs. The FNR is regularly criticised for not doing more to support P/PPs, particularly with regard to its procedures for scientific excellence, and is currently rethinking its approach.

Luxinnovation also has several activities and programmes promoting knowledge transfer between firms and public-sector research organisations. It regularly organises networking events and actively helps businesses find the right research partners in the public research landscape. It also has a dedicated programme supporting innovative start-ups and assisting companies on intellectual property (IP) matters.

Many of the relevant infrastructures for promoting spin-offs and IP from public research are already or will be located in Belval. These include Technoport, the House of Biohealth and a new FNR-funded initiative in SnT. Co-location in Belval will provide an opportunity for researchers, academics and students to interact and benefit from local knowledge spillovers. Other structures promoting technology transfer and valorisation are hosted by the University of Luxembourg and the CRPs.

The performance contracts include valorisation indicators, e.g. the number of patents, spin-offs, prototypes, contract research and licensing income. These indicators do not indicate a clear trend, given their low numbers and a limited number of observations. Moreover, they do not capture the valorisation activities occurring through collaborative research, personnel exchanges, mobility programmes or other channels and forms of knowledge transfer that are equally important to innovation. Few internationally comparable indicators of the economic relevance of public research are available, but those that exist suggest weak valorisation. For example, industry financed just over 1% of higher education R&D in Luxembourg, compared with 6% on average across OECD countries. Further, Luxembourg's performance in terms of the number of patents filed by public research institutions stands well below that of most other OECD countries.

All in all, while these efforts appear to be bearing some fruit, the impact of valorisation activities seems low by most accounts. This is not surprising, given that valorisation-minded policy has only gained momentum over the past decade. It is even less surprising considering that the economic impact of most *measurable* traits of valorisation (e.g. spin-offs and patents) is weak even in advanced innovation systems, where valorisation mostly occurs in the form of unmeasurable spillovers from training, collaboration and human-resource mobility.

Recommendations

- *Adopt realistic expectations around valorisation*, learning from international experiences. This pragmatism relates closely to the government's ambition to diversify Luxembourg's economy, which should acknowledge the limits of "science-push" approaches. In this regard:
  - *Utilise a broad conceptualisation of valorisation in policy making*, acknowledging the important roles played by teaching, consulting, policy advice, etc., in knowledge transfer from public-sector research. Moreover, valorisation policy should not focus solely on research commercialisation, but also target public research's contribution to clinical practice, public regulation, etc.
  - *Learn from international good practice* on maximising the impacts of the commercialisation infrastructures at Belval. Many countries have more than two decades of experience in developing and maintaining such infrastructures, and have useful lessons to relay.
- *Broaden the appeal and openness of the FNR to P/PPs*. Including industry representatives and other users in all FNR panels (as is done in many other countries) is one means to this end; another is joint programming with the Ministry of the Economy targeting P/PPs in need of larger private-sector contributions.

Building a world-class human-resource base for science, technology and innovation (STI)

Luxembourg has a highly educated population. Its high share of tertiary-educated adults (40%, just behind Finland) almost doubled between 2000 and 2012. However, the quality of secondary education could be improved. In the 2012 OECD Programme for International Student Assessment (PISA) assessment of 15-year olds in mathematics, reading and science, Luxembourg had a mean performance just under the OECD average and below that of most other countries with advanced innovation systems (except for Norway).

Luxembourg features very high (inward and outward) workforce mobility. A large share of the workforce lives outside Luxembourg. Despite the establishment of the University of Luxembourg in 2003, most Luxembourgers still receive their tertiary education abroad. A small majority of University of Luxembourg students are non-nationals – many of whom, however, are long-term residents of Luxembourg. University of Luxembourg bachelor degree programmes have a compulsory mobility component that has seen increasing numbers of students study outside of the Grande Région. In the area of public R&D, more than 80% of researchers are non-Luxembourgers, but there are some indications that a number of research institutes favour nationals of neighbouring countries. Since science is a global endeavour, attracting talent from further afield will be important in the longer term.

Gender imbalance appears to be an issue. Just 24% of researchers (headcount) in Luxembourg are women. The situation is especially unbalanced in the business sector (11%) but better in the CRPs (36%) and the University of Luxembourg (39%). There are no programmes currently addressing this issue.

Almost 6 200 students enrolled at the University of Luxembourg in 2013/14 – a 20% increase over 2009/10. The most popular subject group is business and administration (24% of all students), followed by education (16%), humanities and arts (12%), science, mathematics and computing (12%), law (12%), and social and behavioural sciences (11%); engineering lags far behind, accounting for just 4% of students. However, dropout rates are relatively high and some courses are well under-subscribed. Most students (53%) are pursuing a bachelor's degree, 19% are studying towards a master's, 9% towards a PhD and 19% are enrolled in other programmes (e.g. diplomas and certificates). Postgraduate programmes have grown the most rapidly in recent years: master's enrolments soared from 259 in 2006/07 to 1 183 in 2013/14, while PhD enrolments rose from 148 in 2006/07 to 545 in 2013/14.

Policy has placed considerable emphasis on strengthening the human-resource base for research. In 2013, the FNR funded 99 AFR PhDs and 49 post-doctoral places for a total of EUR 29 million. The FNR PEARL programme aims to attract high-calibre researchers to Luxembourg by offering them five-year research grants; it selects an average of one or two candidates a year (for a total grant amount of EUR 3-4 million), to be recruited by either the University or the CRPs. The FNR ATTRACT programme operates in a similar fashion to PEARL, but is aimed at younger researchers. In 2011-13, the FNR funded 4 ATTRACT projects for a total of about EUR 6 million – below the total allocated budget. Its INTER Mobility Programme promotes scientific exchanges between research groups located in Luxembourg and abroad. It supports both researchers working in Luxembourg wishing to go abroad and researchers working abroad wishing to join public research groups in Luxembourg.

In addition to the instruments described above, the FNR runs several programmes to improve public understanding of science and promote science among students of all ages. These are focused particularly on increasing the attractiveness of research careers among Luxembourg's youth. The FNR has conceived a number of initiatives – including Go for Science (promoting joint activities between universities and schools), ProScience (focusing on awareness raising), the information website science.lu, the school contest GENIAL!, the Science Festival, Researcher's Days, and a variety of other children's programmes – to encourage young people to become scientists or engage in scientific activities at an early age.

Recommendations

- *Review the scale and scope of undergraduate teaching at the University of Luxembourg and its fit with local labour-market needs.* Some courses are under-subscribed and could perhaps be delivered in partnership with other institutes in the Grande Région.
- *Consider introducing a national initiative to promote more women in science in Luxembourg*. This could be led by the Ministry of Higher Education and Research and the Ministry of the Economy and would involve research performing organisations and the FNR taking steps to improve the gender balance of researchers.
- *Develop clear research career routes (including tenure tracks) to improve Luxembourg's attractiveness to the most promising researchers.* This will likely require developing a portfolio of schemes for different career stages, administered by research performing organisations and the FNR.

Improving public governance – steering and co-ordination

Setting national priorities

Luxembourg's small size means it is unable to pursue a wide range of research areas in the same manner as larger advanced economies. The areas pursued should have "critical mass", e.g. they should be of sufficient size and depth to produce very good or excellent research that is (for the most part) internationally visible. The government has also signalled through its funding approach that research should have high socio-economic relevance, and has designed and implemented a mix of action plans and research priorities to channel large portions of public spending towards research. For example, sectoral action plans exist for healthcare technologies (see below), eco-technologies and logistics; they are part of a "multi-specialisation" strategy that seeks to diversify Luxembourg's economy and reduce its dependence on the financial sector.

The FNR conducted a foresight exercise in 2006-07 and identified several "national" research priorities targeting a small number of thematic areas; these are organised into five broad categories, which have been used to concentrate funding in its largest funding scheme, the thematically oriented CORE programme. Some areas of existing research competence in Luxembourg are excluded, notably law and mathematics, where the University has strengths. The FNR recently introduced the OPEN programme, a modest new project-funding scheme aimed at researchers in the excluded areas.

There is considerable debate in Luxembourg on the merits, meaning and status of FNR national research priorities, which do not perfectly align with the sectoral action plans and clusters promoted by the MECE and Luxinnovation. This is understandable: not

all sectors and clusters necessarily have strong links to public research, and it would be unwise to try to force alignment along these lines. Nevertheless, where there is overlap, e.g. in biomedicine and smart materials, alignment and co-ordination would be expected.

There is also some misalignment with the research areas pursued in the University and CRPs. In some fields – e.g. biomedicine, ICTs and smart materials – emerging strong research capabilities in the University and CRPs indicate good alignment, but that is not the case in other fields (e.g. sustainable resources). Since the FNR accounts for just one-fifth of national public research funding in Luxembourg, it has limited leverage over the research areas pursued by the University and CRPs. The bulk of public funding to the University and CRPs is still channelled through Ministry of Higher Education and Research block grants, which they are free to allocate internally themselves. A more strategic alignment of University and CRP research profiles with national priorities would likely need incentivising. This could be done through "top-slicing" of block grants for specific priorities and/or by channelling a larger proportion of public research funding through FNR's thematic programmes. Some form of national research assessment exercise, including criteria on excellence, relevance and critical mass, could also be launched. While such mechanisms would encourage the University and CRPs to consolidate their research profiles, they have their pros and cons and are likely to be controversial. They would need to be carefully considered as part of a wider debate on steering the research system.

There is also discussion on the number and breadth of FNR national priorities. One argument holds that fewer and /or narrower research priorities could allow Luxembourg to develop the critical mass needed to be a major international research player in perhaps one or two chosen fields, and that these priorities should be selected based on their promise of sizeable economic returns in the near future. The action plans mentioned above have already taken this approach in many respects. However, given the uncertain nature of research, this overly specialised approach is too narrow for a national funding agency, which should maintain some variety in its support. While aiming for critical mass is also important, its meaning will vary considerably among fields – e.g. in terms of the size of research groups, the equipment they need, and the sorts of links they should have internationally and with socio-economic actors to realise their ambition. Debates on priorities also extend to the types of support measures that are most appropriate for building and maintaining critical mass in a small variety of research fields; the current FNR portfolio of support measures seems appropriate in this regard. There also appears to be flexibility to assign extra resources to a few chosen priority areas. For example, the FNR recently announced a new pilot scheme, the National Centres of Excellence (NCER) programme, to provide long-term funding to consortia of leading scientists to address ambitious scientific and socio-economic goals.

Overall, Luxembourg would benefit from regularly revisiting the issue of national priorities in terms of their necessity, formulation and implementation. For this purpose, most advanced OECD countries prepare dedicated national innovation strategies on a five- to ten-year cycle. Such an exercise should include a clear articulation of the rationales for prioritisation, as well as for the priorities chosen. National research priorities should be aligned with other national innovation-related priorities as appropriate. The government will need to pay special attention to implementation and perhaps make changes to the funding system, e.g. by providing incentives to the University of Luxembourg and CRPs to strategically consolidate their research profiles and step up their co-operation.

Recommendations

- *Implement a national innovation strategy* that articulates the links between research investments and their likely impacts on the government's economic diversification, social well-being, and sustainability goals. In this regard:
  - *Ensure the strategy process is inclusive, reflective, forward-looking and comparative*. It should lead to articulating clear statements on models, expectations of outcomes, priorities, objectives and the expected roles of the main innovation actors.
  - *Pay particular attention to implementation* and introduce as required funding and regulatory reforms to enact the strategy's objectives. All of the main actors of the innovation system – including government ministries, agencies and other intermediaries, and research performers – could also be asked to formulate and implement strategic organisational plans reflecting the national strategy's orientation and objectives.
  - *Learn from the experiences of other advanced OECD countries* in developing and implementing national innovation strategies.
- *In the context of a national strategy, review FNR funding priorities and measures:*
  - *Revisit the national FNR research priorities*, as they are now eight years old and the research landscape has radically transformed over the intervening years. This should involve a deliberative process including all the main stakeholders in Luxembourg, but should be lighter and considerably shorter than the foresight exercise carried out in 2006-07. Furthermore, while selecting national FNR research priorities should take into account the industry priorities set by the Ministry of the Economy and the institutional priorities of actors like the University of Luxembourg, they should not be fully aligned simply for the sake of neatness.
  - *Translate FNR national priorities into extra support for priority areas*. In this regard, the FNR should continue with the NCER programme to develop further centres of excellence in other priority areas. Doctoral training programmes and other measures related to human resources could also be usefully aligned towards national priorities.
  - *Maintain FNR funding measures for supporting research projects that fall outside of the priority themes.* Initiatives such as the OPEN programme should become an established part of the FNR measures mix.

The Health Sciences and Technologies Action Plan

The Health Sciences and Technologies Action Plan announced by the government in mid-2008 aims to position biomedicine as a key innovation driver to foster economic diversification. The action plan originated in the Ministry of the Economy, but is a joint initiative with the Ministry of Higher Education and Research and Ministry of Health. It is notable for the significant amounts of investment made and the fact that Luxembourg previously lacked substantial research and innovation capabilities in biomedicine. At the time of its launch, the government gave multiple rationales for the initiative, including the need to improve Luxembourgish research capabilities through partnerships with leading international research centres; reduce the costs of the health system through new

therapeutic approaches; and promote economic development by creating new firms and attracting existing ones from abroad.

The government selected molecular medicine as a niche, explaining that due to its small size, Luxembourg has to specialise and be selective in its research; patents are likely in this very recent and emerging field, allowing the country to be at the cutting-edge of scientific and technological development; and developing non-invasive medical devices and technologies promises to be quicker than producing conventional drugs. While these criteria seem well chosen and compelling, the limited number of related firms and pre-existing research capabilities in Luxembourg also makes the choice of biomedicine a rather risky initiative.

At the outset, the three pillars of the action plan (commonly referred to as the "biomedical initiative") in Luxembourg were the LCSB in the University of Luxembourg (see above), the Integrated Biobank of Luxembourg (integrated into the LIH in 2015) and the Lung Cancer demonstrator project hosted at CRP Santé. While the Lung Cancer demonstrator has since been subsumed into another initiative, both the LCSB and Integrated Biobank of Luxembourg are now well-established in the Luxembourg research landscape. The biomedical initiative revolved around a strategic collaboration with several leading US institutes, which received funding to advise and train researchers working in Luxembourg, thereby providing considerable "scientific capital". The initiative's objective of improving Luxembourgish capabilities appears to be well on track. However, the partnership reportedly cost tens of millions of euros, meaning that repeating such an expensive initiative in other fields would need to be carefully considered.

The economic and health benefits of the biomedical initiative have yet to be realised. It is not realistic to expect companies to be created or attracted at a fast clip. Furthermore, scholarly research suggests that only a small share of spin-offs ever become successful, in the sense that they become small and medium-sized enterprises (SMEs) rather than large firms and are more commonly targets for acquisition by other firms. "Failures" are part of the process. Similarly, realising health benefits takes time and requires close co-operation between researchers and clinicians. Luxembourg's own historical development suggests that a reasonable amount of time should elapse before any judgement on the initiative's "success", "failure", or "effects" can realistically be made.

At the same time, while the investments and institution-building required to develop leading-edge research capabilities are a necessary condition for pursuing the diversification policy, they cannot alone guarantee success. Several framework conditions typically required for success appear to be under-developed. First, Luxembourg's industrial base and attractiveness in the biomedicine area are still low. While new infrastructures, such as the House of BioHealth at Belval, could help attract firms, the government may need to offer other incentives to entice more firms to locate in Luxembourg. Second, too little attention appears to have been paid to the regulatory framework governing health technologies, e.g. genetic testing. Innovations in the life and health sciences are generally highly sensitive to ethical, legal and regulatory frameworks. The Ministry of Health needs to take the lead in this area, but so far has played a rather minor role in the initiative. Third, a lack of tradition and history in the field means that linkages between government, industry, clinical practice and research remain weakly developed, which will likely hamper health innovation and its adoption in clinical settings.

Recommendations

- *Given the novelty of the biomedical initiative, have realistic expectations on its returns on investment*. While research should be ambitious and aim to make socio-economic contributions, it bears noting that this takes time, and many contributions from such investments are indirect and difficult to measure.
- *Urgently implement a regulatory framework conducive to biomedical innovation*, in order to exploit opportunities stemming from the biomedical initiative. For this to happen, the Ministry of Health needs to become more actively involved in the initiative.
- *Further develop clinical research in Luxembourg hospitals*, with a view to providing new treatments to local patients and – ultimately – international markets. As part of these efforts, the Ministry of Health needs to co-operate with the Ministry of Higher Education and Research to develop new professional schemes (e.g. secondments, detachments and sabbaticals) between hospitals and research centres to improve knowledge transfer and co-operation.
- *Consider launching similar – but less costly – initiatives in a few other areas*, taking into account lessons from the biomedical experience. While repeating the biomedical initiative approach for other priority areas seems unlikely due to its costs, it can provide lessons for developing a less costly and more efficient approach targeting partnerships with "excellent" or "very good" international partners. Any such initiatives should be developed in a more open and transparent manner than in the past and should involve all of the principal stakeholders.

The use of performance contracts

Following a key recommendation of the *OECD Review of Innovation Policy: Luxembourg 2007*, Luxembourg instituted a comprehensive system of steering the country's public innovation actors through performance contracts (PCs) in 2007/08. Such contracts have been concluded between the Ministry of Higher Education and Research (and other principals) on the one side and the University of Luxembourg, CRPs, the FNR and Luxinnovation on the other side. These organisations are currently into the third cycle of four-year PCs, following two cycles of three years each (though the University's cycle was always four years). The PCs state the organisation's main objectives and thematic orientations, as well as a number of carefully selected and formulated performance indicators, and the budget trajectory for the relevant period. The PCs typically also contain a *future* performance agreement. The Luxembourgish contracts also feature indicator monitoring and – less strictly – evaluations. Failure to meet indicator-based targets can lead – and has actually led – to block funding cuts, negotiated through amendments (known as "*avenants*"). Luxembourg's PC system lacks a pronounced competitive element, and organisations do not receive extra financial rewards for performing better than foreseen. The targets and indicators themselves are realistic.

Overall, this system for steering (and to a lesser degree, funding) public research actors is well-designed and has a number of advantages. First, it provides a framework for forward-looking negotiations and is well adapted to the country's small size. Second, it facilitates learning and has resulted in continuous improvements of the PCs as an instrument. Third, it addresses elements of inter-organisational collaboration. Fourth, it couples contracts with evaluation and monitoring. Overall, Luxembourg has avoided the "small-system trap", characterised by a tendency towards micro-management and the use

of too many indicators and steering instruments. The 2016-17 cycle of institutional evaluations will be an important milestone for assessing the success of the system, preferably through benchmarking with successful international comparators. The evidence so far is encouraging, though there is still scope for improvement.

Recommendations

- *Retain the amendments ("*avenants*") as an adaptation instrument but ensure process transparency.* Such an important change, effected through renegotiation, should be transparent, adequately documented and follow a clear procedure.
- *Consider rewarding "overachievers".* The current PC system rightly allows for cuts in case of underachievement, but does not foresee extra funding to reward overachievement, e.g. winning top international grants or contracts. The Ministry of Higher Education and Research should consider designing such a mechanism for the next contract period.
- *Ensure thorough and timely preparation of the 2016-17 round of evaluations at the organisational and system level.* The 2014-17 PC of the FNR presents a systematic approach to coupling strategic objectives, criteria, measurement methods and indicators to support the international evaluation with the organisation's own exercises and studies. The Ministry of Higher Education and Research should examine whether such an approach could become a standard for other organisations' PCs.
- *Embed horizontal collaboration more strongly into the PC system.* The current PCs require a common strategic plan for all research organisations. This plan features a ten-year perspective for co-operation among Luxembourg's main performers, e.g. within the CRPs and with the University. This ambitious approach has yet to be put into practice, but points in the right direction.
- *Strengthen the international dimension of future PCs.* In the past, mostly national benchmarks were used to negotiate PCs and measure performance. However, being the best in Luxembourg is not enough. Future PCs should contain more incentives and internationally oriented indicators, e.g. winning international grants and contracts (such as Horizon2020 grants and related programmes), international attractiveness and additional indicators measuring international reputation. Correspondingly, the number and weight of nationally oriented indicators should be reduced.

Horizontal co-ordination across government

The task of ensuring efficient use of increased public investment in research and innovation, and managing and addressing the needs of an expanded, more differentiated and interlinked (and more efficient) innovation system, entails a continued need for horizontal co-ordination of actors across government. This especially applies to the major ministries in charge of R&D and innovation policies – e.g. the Ministry of Higher Education and Research and the Ministry of the Economy – while the Ministry of Health plays an important role in ensuring the success of research and innovation initiatives in its area of competence (e.g. the biomedical area). Other ministries are also highly relevant to the success of innovation in Luxembourg and should be included in order to achieve a better horizontal co-ordination of policies supporting and facilitating innovation.

The Superior Committee for Research and Innovation was created in 2008 and is co-chaired by the Minister of Higher Education and Research and the Minister of the Economy. The Committee's members comprise scientists, business people and representatives of civil society, typically with international experience. The Committee was given the task of contributing to formulating and developing a coherent and effective national research and innovation policy, and advising the government on its implementation. Its impact on policy development appears to have been limited, and its actual role is rather unclear in practice; it did not gain visibility by producing reports. Nevertheless, a high-level advisory committee could fulfil a useful function if given a more clearly defined role. If retained, a reconstructed Superior Committee for Research and Innovation could be entrusted with the task of monitoring the implementation of the national innovation strategy mentioned above.

The Inter-ministerial Co-ordination Committee aiming to co-ordinate the innovation policy and related activities of the Ministry of Higher Education and Research and Ministry of the Economy, is no longer active. The Committee lost its main purpose following the creation of the PCs with the innovation agencies and public research performers. The two ministries do, however, hold regular informal meetings and co-operation seems to have improved. A new co-ordination body is emerging in the form of a committee bringing together the heads of the CRPs, the University, the FNR and representatives from the Ministry of Higher Education and Research. The purpose of the committee is to advise the Ministry of Higher Education and Research on conceiving and implementing RDI policy and related activities (the committee would complement the current Superior Committee for Research and Innovation advising both the Ministry of Higher Education and Research and the Ministry of the Economy). The committee's role is augmented by the fact that the 2014-17 PCs oblige the CRPs and the University to come up with a common ten-year strategic co-operation plan. The research organisations' move to the new Belval site should also provide an opportunity for more inter-organisational collaboration.

The recent merger of the two departments in charge of higher education and research at the Ministry of Higher Education and Research is a welcome step towards increasing permeability between the research and higher education agendas, which in turn can help improve relationships in the innovation system – including between the CRPs and the University.

Recommendations

- *Reconsider the purpose of the Superior Committee for Research and Innovation.* If retained, the Committee should have a more defined role, and its activity should be structured and linked to the strategic policy agenda. The Committee could, for example, take a key role in implementing the national innovation strategy if its organisation and *modus operandi* were revised to allow it fulfil its new role effectively.
- *Consider strengthening incentives for inter-organisational collaboration between CRPs and the University in the next generation of PCs,* depending on the experience in the current round.

Fostering innovation in the business sector

Luxembourg is primarily a service economy, endowed with a strong financial services sector. SMEs account for the lion's share of value added and employment in the business sector. Their dominance is even greater than average in the European Union,

partly reflecting the high-value activities of small businesses linked to the financial sector and ancillary activities. Indigenous businesses are generally small.

Thanks to its geographic position, generally favourable framework conditions and proactive investment support (including through business regulation), Luxembourg is an attractive location for foreign investment. Many MNEs choose to locate parts of their global operations in Luxembourg, including headquarters, through holding companies. The tyre manufacturer Goodyear Luxembourg and materials manufacturer DuPont de Nemours are two examples of innovative MNEs with production sites in Luxembourg. Other MNEs with substantial operations in Luxembourg include steel manufacturer ArcelorMittal and international financial services firm Dexia. Major media companies (e.g. SES Global, SES Astra, Skype Technologies and RTL Group) also have their headquarters and part of their operations in Luxembourg. The country is also an important logistics hub.

Available evidence points to several innovation strengths. Evidence from the EU Community Innovation Survey suggests that a high share of Luxembourgish firms have introduced product, process, marketing or organisational innovations in recent years. A relatively high number also engage in multiple innovation modes (e.g. product and process, as well as marketing and organisational innovation). Nevertheless, business R&D expenditure is relatively low, and has declined over time.

The 2009 Law for the Promotion of Research, Development and Innovation – which updated and replaced the former 1993 Law on State Aid for Research, Development and Innovation – provides the legislative framework for public support of R&D and innovation in the business sector. The Law defines financial support for business innovation, which takes place through direct funding of R&D and innovation projects (approved grants amounted to EUR 30-40 million a year in 2011-12 and exceptionally up to EUR 75 million in 2013), collaborative projects with the CRPs and University of Luxembourg (about EUR 1 million in 2010, increased to almost EUR 9 million in 2013) and funding for process and organisational innovation in services (about EUR 3 million). The eligibility criteria match EU rules and include provisions for directing higher shares of co-funding to projects involving SMEs, fundamental research and cross-border collaboration. A number of specific programmes target SMEs and young innovative enterprises; the remaining interventions are meant to provide the institutional – and in some cases physical – infrastructure that can foster business-innovation capabilities. They take the form of support for clusters, incubators and business parks; innovation contests and awards; technology matchmaking; and advice on IP rights management. With the exception of Luxinnovation's sizeable budget (about EUR 11 million per year), they are much less resource-intensive.

The 2009 Law provided for new possibilities to develop policy measures that appear to have helped rebalance the policy mix. At the same time, several aspects of instrument design and implementation could be improved. First, the existing policy framework to promote innovation in the business sector lacks a clear strategic orientation and is lacking explicit rationales explaining the choice of specific instruments and the magnitude of the budgets. The instruments are not always aligned with government priorities (e.g. the sectoral action plans) and strategic goals: most of the programmes are open to all kinds of R&D and do not target specific sectors. The only exception is the Luxembourg Cluster Initiative, which mainly provides business-support services rather than implementing ambitious innovation projects. While neutral innovation support is certainly helpful to promote innovation in all sectors, a stronger alignment between business-innovation

programmes and national priorities could foster synergies between public research and business innovation and upgrade the business sector's absorptive capacity.

Furthermore, strengthening business-innovation performance in both existing and new companies requires using innovation policy instruments in ways that facilitate accumulating in-house innovation capabilities and progressively extending their ambition. Transitioning to a rigorous evaluation and selection of project proposals based on their commercial viability, as well as scientific and technological merit, would help induce behaviour that would not exist in the absence of policy. However, this transition would require increased administrative resources and capabilities, and may be difficult to bring about within current institutional arrangements. Delegating some implementation functions (notably funding) to an agency outside of the Ministry of the Economy would result in a division of labour, possibly leading to more sophisticated programming and implementation – as is already the case in many countries with advanced innovation systems.

Last but not least, the growing resources and increasing maturity of the system, together with the ambition to use innovation policy as an economic diversification tool, call for changes in the programming and delivery of innovation policy. Linking government intervention to specific instruments and (to the extent possible) measurable objectives can enhance the legitimacy of innovation policy and provide a common framework for discussion and policy development. While the existing policy mix is helpful to many firms, the lack of policy-impact evaluations makes it difficult to ascertain to what extent it is a good use of public resources. In countries with a long history of innovation policy (e.g. the Netherlands), programming and instrument design is typically informed by past evaluations and adjusted to evolving policy challenges. Ensuring the long-term efficiency and effectiveness of innovation policy would require introducing similar processes in Luxembourg. The imminent revision of the 2009 Law would provide a good opportunity for evaluation, possibly performed by mixed national and international expert teams.

Recommendations

As the innovation system matures and ambition and funding levels increase, business-innovation policy will need to become more discerning and target behavioural changes (e.g. to accumulate innovation capabilities, foster collaboration with the public research system and raise ambition). This highlights the need to:

- *Consider aligning some of the instruments promoting business-sector innovation as national sectoral and research priorities.* This would facilitate creating research and innovation P/PPs and further diversifying the national diversification strategy.
- *Make business R&D support more competitive and selective* and consider instituting competitive funding for larger, more strategic or collaborative projects in addition to a generic R&D funding instrument with low barriers. This would require applying a rigorous R&D project-appraisal process to select the best projects based on their scientific, technological and commercial potential.
- *Consider delegating some business-innovation policy implementation functions – notably project selection and funding – to benefit from professionalised agencies.* Possible scenarios include extending the capabilities and raising the ambition of Luxinnovation (in the same vein as the Finnish Tekes, collaborating with the FNR where required) or a possible delegation to the FNR and corresponding extension of its capabilities (like the Research Council of Norway).

- *Routinely evaluate programmes and instruments supporting business*. Evaluation can improve the effectiveness and efficiency of innovation policy, particularly with respect to longer-term goals (e.g. economic diversification and capability accumulation). Evaluating current innovation programmes would help strengthen the evidence base for future amendments of legislation on R&D and innovation, feeding back into policy design. Making evaluations public would create awareness and facilitate learning in the wider system.

Supporting international knowledge linkages

Like other advanced small OECD countries, Luxembourg has established strong international linkages that are also reflected in relevant STI indicators. Luxembourg's high degree of STI-related internationalisation is reflected in (among others) bibliometric indicators: over 70% of its top-cited scientific publications – the highest share among OECD countries – involve a foreign co-author. This owes in part to well-established collaborations, notably with neighbouring countries, and a high share of foreign R&D personnel: in 2003, almost 40% of internationally co-authored publications had a co-author from France, Germany or Belgium. This share decreased to 32% in 2012, mostly due to an increase in co-authorship with researchers from the United Kingdom and the United States.

Luxembourg's participation in the EU Framework Programme is low compared to leading European countries, where advanced small-sized economies tend to attract higher amounts of European funding per researcher. A small share of Luxembourgish Framework Programme participants (14%, compared with 28% in the United Kingdom, 20% in the Netherlands and 18% in Denmark and Belgium) played a co-ordinating role. As happens with scientific co-authorship, Luxembourg mainly collaborates on EU projects with organisations in neighbouring countries.

Over time, Luxembourg has strengthened its membership in European agencies and consortia (such as the European Space Agency, European Molecular Biology Laboratory or EUREKA). Luxinnovation acts as the official National Contact Point for EU research and innovation programmes and actively supports (private and public) research organisations in preparing applications. However, a 2010 evaluation of Luxinnovation shows that CRPs considered its technical support too generic to provide real value added to researchers. The same evaluation showed that the relatively low participation in European programmes is also explained by their more competitive nature compared with national funds, both for enterprises and researchers. Although the evaluation dates back to 2010 and Luxembourg's participation in EU programmes has improved since then, there is still considerable room for improvement.

FNR programmes cover multiple aspects related to the internationalisation of public research, including mobility programmes to recruit foreign senior and junior researchers and give Luxembourgish researchers the opportunity to spend part of their career abroad. The budgets allocated to this purpose are not entirely spent, yet another proof that attracting talent remains a challenge. At the same time, the current success of the two interdisciplinary centres at the University of Luxembourg owes much to the attraction of high-calibre researchers. Moreover, since the late 2000s, the FNR has signed bilateral and multilateral agreements with research funding agencies in leading European countries, including the United Kingdom, Germany and Switzerland. Additional agreements with partners in Europe and beyond are currently under negotiation.

A number of cross-border initiatives promoting science-and-innovation linkages within the Grande Région have been developed recently, including: i) the Université de la Grande

Région, an inter-university consortium comprising six universities in the cross-border area; ii) cross-border clusters, notably in the field of material sciences; and iii) business-support activities, e.g. matchmaking or networking events. Successful collaborations in science and research depend on finding the most suitable partners, irrespective of their location. However, for other types of collaboration (e.g. involving business development agencies, clusters, SMEs or services that need to be delivered by local actors, including undergraduate higher education), critical mass, agglomeration and proximity are decisive. The Grande Région is the suitable place for this type of policy intervention.

Recommendations

- Given its small size, Luxembourg compares particularly favourably on STI indicators related to internationalisation. However, *the quality and ambition of these international collaborations should be carefully assessed through both quantitative and qualitative STI indicators* to gain a better understanding of the nature of international partners, their location (e.g. proximate vs. global collaboration) and the (leading or supporting) role played by Luxembourgish actors. Policy promoting STI internationalisation should be designed and targeted accordingly.
- *Prioritise improving participation in, and the range of benefits derived from, European research programmes.*
  - *Consider establishing a common Office of Advisors* (serving both the University of Luxembourg and the CRPs) to assist researchers in building project consortia and drafting Horizon2020 research proposals.
  - *Improve co-ordination between Luxinnovation and the FNR.* Providing assistance to research-intensive actors, including both public and private organisations, would also help.
- *Continue the effort of the FNR to expand bilateral partnerships* as part of its internationalisation strategy, with a view to extending them to developed and emerging economies beyond Europe.
- *Focus research and innovation efforts targeting the Grande Région on areas where collaboration most benefits from critical mass and agglomeration,* e.g. physical research infrastructure (including access to laboratories or libraries), business coaching, job placement initiatives and support for technology transfer and incubators. The University could also consider jointly providing undergraduate courses with higher education institutions in the region in fields where it struggles to achieve critical mass.

Note

1. For many purposes, gross national income per head may be seen as a more relevant indicator for a (very) small open economy such as Luxembourg.