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ISSUES PAPER FOR THE STI OUTLOOK "FORWARD LOOK" CSTP/TIP WORKSHOP

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This document includes short background issues papers in support of the CSTP/TIP STI Outlook workshop of June 2015. The afternoon breakout group sessions of the workshop aimed to improve the "outlook" dimension of the 2016 STI Outlook edition. Delegates were invited to brainstorm and discuss future trends and policy implications 10-15 years into the future on topics related to ongoing TIP projects. These discussions should also help identify future TIP priorities of work.

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ISSUES PAPER FOR THE STI OUTLOOK "FORWARD LOOK" CSTP/TIP WORKSHOP

Background

The OECD STI Outlook (STIO) is a biennial flagship publication that provides policy makers with the latest information and data on recent and forthcoming trends in the global science, technology and innovation (STI) landscape and identifies potential implications for national policies. The STI Outlook is produced every two years by the OECD Directorate for Science, Technology and Innovation (DSTI), under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP). The next STI Outlook will be released second half of 2016.

The Secretariat aims to improve the "outlook" dimension of the 2016 STIO edition by enhancing its forward-looking perspective, i.e. by extending time horizons to 10-15 years into the future. For that purpose, the Secretariat will build on some basic trends analysis carried out in the 2014 STI Outlook (DSTI/STP(2015)7) and will capitalize on ongoing STI projects, such as the Next Production Revolution. The project will also be fed by desk analysis, telephone interviews and workshop discussions.

As a first exercise of this type, a workshop involving country Delegates has been organised on the 17th June in OECD headquarters (Paris), back-to-back with the 45th meeting of the Working Party of Innovation and Technology Policy (TIP). This CSTP/TIP workshop aimed to identify major milestones, actors and possible contributions by CSTP/TIP Delegates to new 'forward-looking' activities.

The afternoon session of the CSTP/TIP workshop was organised in the form of five parallel breakout groups, with each group focused on discussing a topic of interest to CSTP/TIP that will feature in the forward looking analysis. Selected topics were congruent with ongoing TIP and CSTP work, for example, around the Knowledge Triangle and Systems Innovation projects. This document includes short background issues papers in support of these workshop's breakout group sessions.

Contents

Breakout group n°1: The future of public Research and Technology Organisations[1]

Public research institutes play an important role in national innovation systems. Together with universities, they are the main public research actors and an important tool for governments seeking to promote research and innovation. A particular category of institute – Research and Technology Organisations (RTOs) – comprises applied research institutes that carry out user or problem-orientated research and provide a range of knowledge-related services. Large-scale examples include VTT in Finland, the Fraunhofer Society in Germany and TNO in the Netherlands. Their origins are often as testing laboratories, product and process developers for industry or branch-based research associations.

The types of activities in which RTOs engage are rather diverse, including basic and applied research, advanced and applications engineering, design and development, studies, training, measurements and tests, providing information and advice, producing prototypes and even occasionally short production runs. **These types of activities are notoriously difficult to measure** and account for using rigorous performance indicators. The lack of official statistics about research institutes is also an important problem. These information shortcomings hinder policy-making around RTOs.

A key argument for governments to subsidise RTOs is to reduce innovation risk, allowing firms to tackle innovation opportunities that would otherwise stretch them beyond their technical capabilities. In some cases this could be expected to trigger technological learning by the firms involved; in others, typically in areas like technical services, the RTOs provide access to tools and techniques that individual customers could not develop or acquire for themselves. Either way, reducing risk is expected to increase the rate of innovation and influence economic growth. In effect, **RTOs allow firms to take a step beyond what their own technological capabilities would allow and this enables them to do more innovation**.

RTO customers have grown increasingly sophisticated over time as production becomes more technology-intensive. This dynamic requires RTOs to increasingly move towards more demanding research, as some of their services become more commonplace and can be delivered by the private sector without subsidy. In principle, government "core funding" is primarily intended to pay for this more demanding research, allowing RTOs to develop knowledge and capabilities needed to support its industrial customers. This is the key thing that distinguishes an RTO from a (private sector) technical consultancy. **Public money is used to create the capabilities institutes need to take firms "one step beyond" what they could otherwise do, thereby providing social returns by de-risking innovation**.

There is a movement in the way governments fund RTOs to increase the proportion of competitive funding and reduce automatic core funding – as well as to make increasing demands (in terms of performance indicators) in relation to the use of core funds. At the same time, public research spending through RTOs (and public research institutes more broadly) is slowly declining, while that through universities has been rising. Where RTOs grow it tends to be through mergers rather than via organic growth. **RTOs normally win the greater part of their funds competitively** – through business contracts and competitive research funding from national research funding agencies and from abroad (especially in Europe, where Horizon2020 plays an important funding role). The increased use of **'open' innovation models and processes**, in which knowledge may not be freely available but where organisations increasingly seek and use knowledge generated by others, also provides opportunities for RTOs.

As core funding has declined, **governments have encouraged RTOs to work much more closely with universities in developing more advanced capabilities**. In many OECD countries, RTOs and universities are increasingly strongly linked, through joint projects, PhD training, co-publication, joint appointments, joint research centres and, in some cases, co-location. RTOs show a uniform trend towards

[1] This text is abridged from Arnold et al (2010a).

having a higher share of PhDs in their staffs and closer teaching and doctoral student links with universities. These help RTOs to develop and renew capabilities. At the same time, universities are under growing economic and policy pressure to adopt a ‘third mission’ of supporting society and the economy. As a result, they perform applied research and increasingly co-operate with the business sector. This leads to **significant overlaps between the missions and tasks of RTOs and universities**, with the potential of increasing both competition and co-operation between them.

Breakout group exercise

The breakout group will perform a future-oriented SWOT analysis of public RTOs, focusing on the following issues:

a. The main strengths and weaknesses of public RTOs today

b. The main drivers of change affecting the futures of public RTOs (time horizon 2030)

c. The main future opportunities and threats facing public RTOs (time horizon 2030)

The group facilitator will guide the discussion around a few main questions:

1. What are the main strengths of public RTOs in your country? What are their main weaknesses?

2. Looking to 2030, what are the key drivers of change affecting the futures of public RTOs?

3. What opportunities and threats might public RTOs face over the next 10-15 years in light of these key drivers of change?

4. In summary, what do we need to know about this issue that we don’t already know?

Further reading

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OECD (2011), *Public Research Institutions: Mapping Sector Trends*, OECD Publishing, available at http://dx.doi.org/10.1787/9789264119505-en

Breakout group n^{o}2: New technologies in production: economic, environmental and policy implications

Many innovations are set to radically affect key features of economic and social life, from how we work, travel and communicate, to what we buy and learn, to how we are medicated. The range of technologies that could significantly affect production and distribution is great. Production today is continuously expanding technological possibilities. Indeed, OECD (2013) highlighted that the business sector in OECD economies allocates a growing share of total investment to what is termed 'knowledge-based capital' (including assets such as computerised information, innovations protected by many types of intellectual property, and new forms of business organisation).

Technologies complement and amplify each other's possibilities in combinatorial ways. This implies that a mapping between today's known technologies and tomorrow's outcomes is tenuous (and becomes more tenuous as longer time periods are considered). Many potentially disruptive production technologies are on the horizon. A small sampling could include:

- Powerful data analytics, and large data sets, which increasingly permit machine functionalities that rival human performance in tasks, such as pattern recognition (Elliott, 2014). It appears that this process will increasingly allow machines to displace humans from complex and creative work in industry and knowledge-based services.

- Robots are set to become more intelligent, autonomous and agile. Micro-processors that mimic the brain might soon increase computers' awareness of events around them, possibly enabling more diverse robot behaviours.[2] Inexpensive drones could become ubiquitous in distribution and some aspects of production.

- Combined with an increased connectedness of parts, components and machines to the Internet, new digital technologies could raise the efficiency of production (for instance through novel optimisation and maintenance strategies).

- Synthetic biology, still in its infancy, could become transformative. Among other applications, synthetic biology could allow petroleum-based products to be manufactured from sugar-based microbes, thereby greening production processes.

- 3D printers are becoming cheaper and more sophisticated. Objects can now be printed (such as electric batteries) that embody multiple structures made from different materials. 3D printing might soon be performed with programmable matter, and could make manufacturing both more profitable in small batches and less damaging to the environment (Lipson and Kurman, 2013).

- Bottom-up intelligent construction and self-assembly of devices might become routine, based in part on greater understanding of the principles of biological self-construction. Indeed, systems and materials for micro-scale self-assembly of devices have already been developed using man-made viruses to guide the process.[3]

- Nanotechnology – which uses the properties of materials and systems below the 100 nanometre scale - could find many uses. Most benefits of nanotechnology arise from being able to engineer

2 MIT Technology Review 2014. Available at: http://www.technologyreview.com/featuredstory/526506/neuromorphic-chips/

3 See: http://spectrum.ieee.org/semiconductors/materials/germs-that-build-circuits

the structures of materials at the nano-scale to achieve specific properties. Materials can in this way be made stronger, lighter, more electrically conductive, and so on.

- Other developments in materials science will also yield materials with enhanced or novel characteristics of value to industry. An example is new forms of aerogel, a material consisting of more than 96 % air – and 4% silica matrix – with many new applications, such as in aerospace.

The precise economic implications of such near-term technologies are unknown. But they are likely to be large. McKinsey & Company (2013) seeks to estimate the economic impacts to 2025 of 12 major technologies (mobile Internet, automation of knowledge work, The Internet of Things, The Cloud, advanced robotics, autonomous vehicles, genomics, energy storage, 3D printing, advanced materials, advanced oil and gas exploration and recovery and renewable energy). The economic benefits will take the form of consumer surpluses and new revenue and GDP growth as technologies are commercialised. The estimation procedure used in the McKinsey study is subject to numerous caveats and uncertainties. Nevertheless, the authors conclude that, taken together, the 12 technologies have the potential to create economic impacts of USD 14 trillion to USD 33 trillion a year by 2025.

Furthermore, new production technologies are likely to significantly augment productivity. Research shows that firms that base significant decisions on data analytics have levels of output and productivity 5-6% higher than would be expected given their other investments and use of information technology (Brynjolfsson, Hitt and Kim, 2011). Another benefit of technological development in production could include increased environmental sustainability.

The development of new production technologies will be shaped by many forces

A range of technology, policy, institutional and broader conditions (or mega-trends) will shape the development of new production technologies. Some developments are likely to be continuations of past trends. For example, Moore's Law – which posits exponential shrinking of transistor sizes on integrated circuits– has held true since Gordon Moore first published on this phenomenon in 1965 (with concomitant reductions in price). The period over which Moore's Law will remain true is uncertain. Public policies towards science and technology will affect innovation, sometimes in hard-to-foresee ways. And, more broadly, environmental considerations and the growing scarcity of some raw materials will increase pressures for materials-, water- and energy-efficient production. Continued economic globalisation will augment competitive pressures that spur innovation. Demography will play important roles in determining which products are most demanded by consumers, and where production is located (many other factors could also influence location, from political instability in some parts of the world to weather patterns).

Risks will also attend technological change in production

Risks will arise with technological change in production. The various risks will have higher or lower probabilities and be more or less significant for different countries and population groups. For instance:

- The effects of technological change on earnings inequality is drawing increased attention from academics and policymakers. Senior policy figures and analysts have foreseen the loss to machines and computer code of occupations on which a large part of the workforce currently depends.[4] Indeed, OECD (2011) finds that skill-biased technological change is the single most important driver of rising inequalities in labour income.

4 For instance, in the July 7th 2014 edition of The Wall Street Journal Lawrence H. Summers argues that the defining upcoming economic challenge will be the limited availability of jobs.

- Policymakers in some countries fear the consequences of unpreparedness in the face of rapid technological change. Unpreparedness might take various forms, and have numerous consequences. For instance, rapid technological change can generate skills shortages. A recent example is the reported shortfall of managers and analysts with adequate understanding of the business uses of 'big data' (McKinsey & Company, 2011). Accordingly, policymakers in some countries are concerned that education and training systems might not be suited to realising the potential for innovation. Similarly, new technologies can require infrastructure needs, or new policy settings, which might not have been foreseen. Countries which fail to adequately prepare for innovations in production could lose income and growth opportunities to those that are prepared, and first-mover advantages in some sectors might be hard to reverse.

- As a corollary to the risk of widespread machine-driven labour displacement, automation might undermine labour-cost advantages on which many emerging economies rely. A precursor of this possibility could be the decision of Foxconn to invest massively in robots in its China-based factories.[5]

- As production systems become more complex and ICT-mediated, the risk and consequences of system fragility may grow. For example, critical interlinked ICT systems might behave in unpredictable and emergent ways (in fact, interacting algorithms contributed to the 'Flash Crash' of May 2010, when more than a trillion dollars in value were lost in minutes from global stock markets). Improved understanding of complex systems is essential if governments are to protect society from potentially serious disruptions (Nesse, 2014).

- Risks also exist that beneficial technologies might be held back by lack of public understanding or social acceptance. For instance, concerns over genetically-modified organisms (GMOs) have historically been much more of an issue in Europe than in other regions. Relevant social norms and ethical values can vary greatly between communities and countries. A case in point has been the diversity of attitudes towards embryonic stem cell research.

- Lastly, innovations might create new risks that need to be managed. For instance, ICTs allow ever more scientific information to be available to ever larger numbers of people, with some of this information being potentially dangerous. As biotechnology advances, for example, the understanding of how to deliberately make diseases worse will become more widespread.

Breakout group exercise

The breakout groups will focus on the following three issues:

a. The risks created by new production technologies.

b. The opportunities created by new technologies.

c. Policy priorities, including the need for policy reforms.

For the three issues, the group facilitator will guide the discussion around a few main questions, including the following: (1) What are the most important risks created by new production technologies, and what steps are your governments taking to prepare for these risks?

5 See http://www.extremetech.com/electronics/185960-foxconn-is-attempting-to-replace-its-human-workers-with-thousands-of-robots.

(2) What are the most important opportunities that could be created by new production technologies, and what steps are your governments taking to realise these?

(3) Which of today's policies is most likely to need reform, and in what ways?

(4) What do we need to know about this issue that we don't already know?

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Breakout group n°3: The future of science policy design and delivery[6]

Public research is carried out by research universities and public research institutions (PRIs) which are publicly owned, publicly operated or primarily funded with public money. **Public research plays a key role in innovation systems** by providing new knowledge and pushing the knowledge frontier. Universities and PRIs often undertake **longer-term, higher-risk research** and complement the research activities of the private sector (OECD, 2010). Although the volume of public R&D is less than 30% of total OECD R&D, universities and PRIs perform more than three-quarters of total basic research. Furthermore, public research meets specific needs of national interest such as defence, health and energy. It also involves research in areas where there are insufficient incentives to spur private investment such as those related to social and environmental challenges.

Funding arrangements between the central government, on the one hand, and universities and PRIs, on the other, are an important channel for delivering public research policy and a major driver of change in

6 This text is abridged from OECD (2014).

the public research landscape. Most countries combine, in different proportions, discretionary institutional core funding ("block grants") and competitive R&D project grants. Institutional funding provides stable funding over the long term and a certain degree of research autonomy, which is essential for basic research. Block grants are granted on the basis of various criteria (e.g. formulae, performance indicators, budget negotiations). Competitive R&D project grants put more emphasis on research outcomes in the shorter run and provide governments more scope to steer research towards certain fields or issues. Overall, **there is a clear global trend towards more competitive funding** with the introduction of performance-based elements in core institutional funding and a move towards more contractual arrangements. Still, scientific research requires robust **research infrastructure**. This includes large and expensive research infrastructures but also libraries and information archives, both of which need to be renewed as they wear out or become outdated.

In recent years, **public R&D budgets have levelled off in real terms** in many countries and have started to decrease in others. The current budgetary outlook puts pressure on public R&D spending and has encouraged governments to adjust the design and governance of public research policy. OECD R&D expenditure by the higher education and government sectors has stagnated as a percentage of GDP since 2010 in a context of weak GDP performance. In this context, governments have put greater emphasis on efficiency, prioritisation and concentration of resources. The search for greater efficiency has led to a restructuring of research activities: an increase in mergers and in the size of institutes, better co-ordination across research units, and the **introduction of new public management approaches in universities and PRIs to reinforce autonomy, accountability and business-like operational models**.

The target and focus of public research have evolved in recent years as missions and mandates change to **respond to wider economic and political developments** (e.g. green growth, societal issues, etc.) and to strengthen the contribution of public research to innovation. In particular, multidisciplinary sciences have drawn increasing attention. Some countries have reinforced an interdisciplinary approach to public research governance, evaluation and funding arrangements to address "**grand challenges**" such as climate change, ageing societies and development; furthermore, the **convergence of key technologies** and interdisciplinary research is seen to create opportunities that may be difficult to seize in discipline-based and "silo"-type public research systems.

While scientific research remains at some distance from commercial uses, it is no longer considered cut off from applications and users (OECD, 2010). Universities and PRIs are increasingly expected to **fulfil a "third mission"**, that of transferring knowledge to industry, and to **adapt their governance arrangements, incentive frameworks and academic culture to this new context**. In fact, public research has been the source of many of today's innovations, sometimes as a by-product of basic research and sometimes without any prospect of a direct business application. Knowledge and research generated by the public research system diffuses through a variety of channels – mobility of academic staff, scientific publications, conferences, contract research with industry, and licensing of university inventions – though much policy attention in OECD countries has centred on promoting knowledge transfers through publications, the patenting and licensing of academic inventions, and the promotion of academic start-ups.

Recent data show a slowdown in the main commercialisation indicators in many OECD countries. This raises concerns among policy makers and practitioners about the effectiveness of existing approaches to technology transfer and commercialisation. But **many governments and institutions have focused excessively on patenting and licensing as a channel for commercialisation**. This has led to a rise in the number of patents filed and a narrow emphasis on exclusive licensing of inventions. Many institutions have also focused on the role of professors in commercialisation and less on student entrepreneurs. Many countries are now diversifying their commercialisation policies and promoting two-way flows between industry and science through public-private partnerships, joint research initiatives/centres, outward and inward licensing of IP by universities and PRIs, and incentives for the mobility of entrepreneurial academics.

In line with economic globalisation, **research co-operation and academic mobility have internationalised sharply in recent decades**. R&D and innovation are characterised by pronounced economies of scale and scope. In areas such as the increasingly transnational “grand challenges” (demographics, environment, energy), but also in some S&T disciplines (notably aerospace, some areas of physics), fixed costs exceed levels that could be covered by any one nation alone. **Financing from abroad has become a more important part of the research funding of many institutions**. While internationalisation has increased opportunities for co-operation, it has also increased the competitive pressures on research and higher education, as universities are now being ranked on a worldwide basis. Countries have long used international agreements to encourage the internationalisation of public research, and institutions often establish their own cross-border research agreements and projects. International research centres also encourage the internationalisation of public research through formal or informal joint research partnerships. **Researcher and student mobility is closely linked to growing international co-operation** in higher education and is another important aspect of the internationalisation of public research. Attracting scientific talent from abroad can boost domestic research efforts, while researchers who travel abroad develop new knowledge, perspectives and professional contacts. Recognising these benefits, most OECD and partner countries promote researcher and student mobility. Many countries recognise the potential benefits from outflows of students and researchers as well as those from student inflows. Outward mobility can allow researchers to develop new skills and acquire new knowledge, and a number of countries support outward mobility through funding. To benefit from researcher mobility while avoiding the possible **negative effects of brain drain**, many countries encourage researchers based abroad to return to their home country.

Information and communication technologies (ICTs), new data storage infrastructure and large-scale computing are modifying the way science is conducted and the way the results of research are disseminated. They offer new opportunities to organise and publish the inputs and outputs of research, whether scientific publications or large datasets, to make it available for free, or at extremely low marginal cost, to other scientists and researchers and potential users in the business community and society. Furthermore, even though fields such as physics and medicine have long been data-intensive, ICTs make it possible to collect large amounts of data that can be the basis of scientific experiments and research and help make science more data-driven. This **transformation of science into a more open and data-driven enterprise** is often known as open science. It is enabled by public policies that encourage greater access to the results of publicly funded research, including publications and data. The increased access to scientific research results has the potential to make the research system more effective and productive by reducing duplication and the costs of creating, transferring and re-using data; by allowing the same data to generate more research; and by multiplying opportunities for domestic and global participation in the research process.

A particular issue has been the **poor reproducibility of much science,** which may be driven in part by the rush to publish, which is in turn driven by academic recognition criteria and the personal stakes now associated with ‘breakthrough science’.

Breakout group exercise

The breakout group will perform a future-oriented SWOT-type analysis of public research systems and their public policy support, focusing on the following issues:

a. The main strengths and weaknesses of public research systems today

b. The key drivers of change affecting the future of public research systems (time horizon 2030)

c. The main future challenges facing public research systems (time horizon 2030)

The group facilitator will guide the discussion around a few main questions:

(1) What are the main strengths of the public research system in your country? What are its main weaknesses?

(2) Looking to 2030, what are the key drivers of change affecting the future of public research systems?

(3) In light of these key drivers of change, what are the main challenges facing public research systems in the next 10-15 years?

(4) In summary, what do we need to know about this issue that we don't already know?

Further reading

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Breakout group n°4: The future of innovation policy design and delivery

Today's innovation policy challenges are increasingly multifaceted, interconnected and difficult to outline. With the growing profusion of policy objectives, targets and instruments for public action, innovation policies have reached an unprecedented level of complexity and uncertainty that call for the design of new or revised policy frameworks and toolkits. For instance, recent interest in "systems innovation" illustrates a shift in the policy paradigm towards large-scale socio-economic transformations that challenge existing governance structures and would require governments to build new ones.

Innovation is high on the policy agenda and innovation policy mission is broader than ever.

The search for new sources of growth and the challenges brought by environmental and societal issues have introduced new expectations from technology and innovation and raised the status of innovation and R&D in policy agendas.

The scope of innovation policy has simultaneously broadened to embrace a larger range of public goals. Public intervention in the field has been increasingly geared to go beyond its traditional economic mission, with a view to green socio-economic activities, assist the living of ageing populations, or ensure a more inclusive development etc. Recent developments on new metrics for national prosperity (beyond GDP) illustrate changing attitudes and social norms vis-à-vis classical concepts of well-being and progress.

How are these trends expected to evolve? What are the limits of these trends? What are the policy implications? How are countries' STI policy systems prepared for these changes?

- In a context of high complexity and limited financial resources, could technology and innovation policies face multiple challenges? Is there a risk of diluting public action and resources by trying to meet too many expectations? Could governments afford ignoring some pressing challenges?

- Is a more responsible innovation policy desirable and implementable? What would such responsible policies imply in terms of agenda design, risk research and management and adjustments in governance capacity?

The governance of innovation policy is increasingly decentralised, deliberative and data-driven.

New STI governance arrangements have emerged and new ones are still needed. Two models prevail across countries: a networked model based on different public service providers and other public or private intermediaries (eventually private intermediaries under contract), and a one-stop shop model, typically based on a central innovation agency. The "agencification" of policy delivery is a major feature of the last two decades. Autonomous and professionalised agencies have been increasingly responsible for the funding, management and evaluation of innovation programmes. National STI strategies have been relayed to the operational level through regional strategies, implementation plans or performance agreements. This stresses the separation between decision-making and policy execution that aims to allow for more flexibility, independence and responsiveness to changing socio-economic needs.

Consequently, the circle of actors involved in STI policy design and delivery has enlarged reflecting a more horizontal "whole-of-government" approach in governance and a vertical segmentation of STI policy activities. In addition, as they intended to deliver more efficient and suitable public services, policy makers have looked for preferences of a greater variety of actors in the private sector and civil society. The top-down approaches to policy planning have given way to more consensus building, new partnerships and further knowledge sharing.

Technologies have been instrumental in that respect. The spread of ICTs and the Internet, the deployment of e-government and new IT-based platforms for public services delivery have supported new forms of public intervention and helped gather unprecedented amount of information. The post-crisis requirements for fiscal consolidation also gave the impetus to more monitoring and evaluation of innovation policies, programmes and institutions. Greater attention is paid to assessing the impact of public investments and building a knowledge base on STI policy.

Greater international coordination or a partial transfer of authority to intergovernmental organisations would also be needed to meet grand challenges and benefit from transnational externalities.

How are these trends expected to evolve? What are the limits of these trends? What are the policy implications? How are countries' policy systems prepared for these changes?

- Have the current STI governance structures kept pace with this growing complexity? How do they currently respond to increasing needs for accountability mechanisms, cross-border governance arrangements, multiple stakeholders' involvement etc. ? How could governments reap the benefits of big data and analytics? How could governments cope with the risks raised by cyber threats? What role should governments play in balancing transparency and privacy?

- Which future models of governance are needed? Which governance capacities would be required to implement these new models of governance? In a context of tightening public budgets, how are the agencies activities and capacities expected to evolve?

Governments have put greater emphasis on targeted strategic areas and on building supportive ecosystems around.

The changing context of innovation and policy intervention has called for changes in national strategies. Global value chains (GVCS) have introduced a dimension to innovation policy design beyond the scope of national policies. Building attractive national STI ecosystems around high-quality education supply, world-class public research infrastructures and sound framework conditions for business innovation have become an imperative. Besides general purpose technologies, many countries have emphasised support in strategic technologies and sectors. The resurgence of industrial policies and the spread of smart specialisation strategies signal efforts by governments to integrate global knowledge networks and high value-added segments in GVCs.

How are these trends expected to evolve? What are the limits of these trends? What are the policy implications? How are countries' policy systems prepared for these changes?

- Do targeted innovation policies, including industrial policies, raise the risk of overreliance on a particular technology or a particular industry and the risk of exposure to economic shocks or technological twist? Are innovation ecosystems flexible enough to reallocate resources and capacities rapidly in case of technology shifts or industrial disruption? How could targeted policy approach support emerging technological niches and help them gain momentum?

- Do governments have capacity for technology assessment?

A broad mix of policies to support business R&D and innovation is now commonplace in OECD and beyond.

Overall public support to business R&D has substantially increased over the past decade in most OECD countries and emerging economies. Direct funding through grants, public contracts and other subsidies has been awarded through more competitive tools. Increased emphasis has been given to debt and equity financing and support to venture capital industry. Public funding schemes have been streamlined with a view to ease access. Tax incentives on R&D have been made more generous and more accessible to a larger number. As 2000s WTO agreements limit the volume of State aid granted to the private sector, R&D tax concessions have become a popular policy instrument to finance domestic firms' R&D efforts and reinforce the attractiveness of national STI ecosystems. However, issues around the cost-efficiency and performance of tax systems and administrations remain. There is a lack of evidence on the interaction between different STI policy instruments and their additionnality effect. Recent developments around the "patent box" have also put in evidence a risk of tax base erosion due to profit-shifting strategies of multinationals at a time when governments need to secure tax revenues and consolidate public budgets.

Governments have also focused attention on a range of demand-side innovation policies to "pull" innovation. In a context of fiscal consolidation, there is an interest to leverage demand for innovation without creating new public spending. Standards and regulations could for instance facilitate the transition to new markets and system innovation. There are however risks, notably with public procurement, to favour large firms over small firms or lead to technology lock-in.

How are these trends expected to evolve? What are the limits of these trends? What are the policy implications? How are countries' policy systems prepared for these changes?

Breakout group exercise

This session will focus on policies in support of business R&D and innovation. This theme follows on the recent OECD Innovation Strategy 2.0 and relates to current impacts assessment work in TIP, NESTI, GSF and BNCT. The breakout group will perform a future-oriented SWOT analysis of innovation policy systems, focusing on the following issues:

a. The main strengths and weaknesses of national innovation policy systems today

b. The main drivers of change affecting the futures of national innovation policy systems (time horizon 2030)

c. The main future opportunities and threats facing national innovation policy systems (time horizon 2030)

The group facilitator will guide the discussion around a few main questions:

(1) What are the main strengths of the national innovation policy system in your country? What are its main weaknesses?

(2) Looking to 2030, what are the key drivers of change affecting the futures of national innovation policy systems?

(3) What opportunities and threats might national innovation policy systems face over the next 10-15 years in light of these key drivers of change?

(4) In summary, what do we need to know about this issue that we don't already know?

(5) What are the policy implications, for example, in terms of objectives pursued, policy instruments used, information needs (incl. statistics), etc.?

Further reading

Flanagan, K., E. Uyarra and M. Laranja (2010), *The Policy Mix' for Innovation: Re-thinking Innovation Policy in a Multi-level, Multi-actor Context*, Manchester Institute of Innovation Research Working Paper Series, University of Manchester.

OECD (2010), "The Innovation Policy Mix", in *OECD Science, Technology and Industry Outlook* 2010, OECD Publishing. http://dx.doi.org/10.1787/sti_outlook-2010-48-en

OECD (2014), *Science, Technology and Industry Outlook 2014*, OECD Publishing, Paris, http://dx.doi.org/10.1787/sti_outlook-2014-en.

OECD (2015, forthcoming), OECD Innovation Strategy 2015, OECD Publishing, Paris.

Breakout group n^{o}5: Future research careers[7]

As the core producers of new knowledge and main agents in its transfer and exploitation, researchers and the institutions in which they perform research create the necessary knowledge base for economic growth. A full understanding of the research profession in its complexity is therefore crucial for sound decision and policy-making.

Stock of researchers and their education and training: Many countries have a range of measures aimed at ensuring they train enough researchers to meet their national R&D targets. These include both regulatory and quasi-regulatory measures, such as national action plans and programmes, and new or updated legislation. They also include ‘soft’ measures, such as awareness-raising schemes about research careers, and improvements to the quality and relevance of doctoral training or incentives in the form of special awards. The last two decades have seen large increases in the numbers of new PhDs, including in STEM topics. There are concerns, however, that the pool of PhDs and post-docs is far larger than the opportunities available in the research profession. Many are pushed out of research careers, which raises questions over the return to public investment in their costly training. The duration of PhD training is still quite long in a number of countries and means the social and private costs of producing new graduates is high; it also reduces the speed at which the system can respond to changes in demand. Some countries lack guidelines for PhD supervision and mentoring. This could be an area for policy action at the institution or government level, insofar as enhanced supervision can help steer candidates to areas where there are opportunities or demand. Given many PhDs leave the research profession, they should receive quality training aimed at providing transferable skills and exposure to industry and other employment sectors.

Open, transparent and merit-based recruitment procedures: Recruitment based on merit and academic excellence from the very earliest stages and throughout a research career are a prerequisite for research excellence and optimising research talent. In a number of countries, national authorities and/or research institutions report having taken steps to make the process more transparent. Nevertheless, many researchers’ perception is that there is still a long way to go. They believe that protectionism and nepotism are still widespread in a number of countries, and that institutions do not have sufficiently open and transparent recruitment practices. Furthermore, despite the growing importance of the commercialisation of research, new researchers are rarely recruited based on their performance in non-scientific areas (e.g. patenting, technology transfer, fund raising).

Working conditions: Attractive working conditions and career prospects are a key driver for attracting young people into a researcher career and ensuring top-quality research results in public research institutions. However, research careers present a particular challenge during doctoral training and in the early career stages when many researchers are on short, fixed-term contracts or indeed have no contract at all. In such cases, they are often not covered by social security provisions or the provisions are not on a par in terms of health, and in particular parental, unemployment and old-age benefits, with what is available to those on permanent contracts. Thus career paths appear uncertain and years of pension contributions may be lost.

Significant barriers exist to “permanent” or tenured employment and several countries report delays or increases in the age at which researchers obtain tenured employment or “permanent” status. In many countries, universities, and to a lesser extent PRIs, rely on temporary positions to recruit new entrants or specialists in the face of strong rigidities in the labour market for established researchers. Yet, most academic employment systems were not designed to accommodate the growing number of mobile researchers recruited with soft money at centres of excellence or on competitively-funded research projects. A “dual labour market” has subsequently emerged in the public research sector. Established

[7] This text is abridged from Kergroach and Cervantes (2006) and Deloitte (2014).

researchers often have access to civil servant and public employee contracts – and hence a greater degree of employment protection. Temporary staff generally works under private employment law contracts. Part-time employment for researchers is possible in most countries but is viewed as a transitional measure (in response to family or personal reasons) rather than a career path model.

These problems can be compounded by poor remuneration, although there are wide differences across countries. Researcher salaries, especially for mid-level and senior staff tend to be attractive, but salaries for early-stage researchers are rather low in many countries relative to per capita GDP. Compensation systems are based on fixed wage scales negotiated through collective agreement with little room for individual bargaining, except for private law employees or temporary staff in a few countries. Some countries have adopted variable pay mechanisms at the margin – often determined by seniority and or research outputs. Only a few countries promote researchers primarily based on performance. A mix of seniority and performance predominates in most other countries.

At the same time, researchers are facing an increase in their workload, partly as a result of the massification of higher education, and a decrease in the amount of support staff available to researchers and faculty. Questions can be raised as to how this could affect working conditions and the quality and productivity of researchers.

Gender imbalances: Women still face a glass ceiling in the research profession. They outnumber men at the first two levels of tertiary education, but are considerably less likely to occupy a senior academic position, or to sit on decision-making bodies – they are even less likely to head a university or public research institute. This situation has improved slightly over the last few decades, but progress is slow, despite policy attention.

Collaboration between academia and industry: Moving out of public sector research into the private sector for a short period during doctoral studies or thereafter is still very much the exception, even though it is perceived as potentially beneficial for a researcher's career, access to funding and the exploitation of research results. Researchers appear to be held back by lack of preparation in areas such as intellectual property and knowledge transfer. Many countries acknowledge the problem and are promoting partnerships between universities, PRIs and private companies, and measures to improve the skills of doctoral researchers in areas such as technology transfer and intellectual property. Other measures include the implementation of joint projects, exploitation programmes, research traineeships in companies, inter-sectoral mobility programmes, industrial PhD programmes, and the possibility to combine teaching and private sector research. Still, in many countries, there is scope for matching PhD training closer to market needs and diversifying career paths through internships, as well as allowing the portability of PhD fellowships to industry.

International mobility: This is often associated with excellence, the creation of dynamic networks, improved scientific performance, improved knowledge and technology transfer, improved productivity, and ultimately enhanced economic and social welfare. The academic labour market is relatively open to foreign researchers who first undertake PhD or post-doctorate training in the host country. However, for those coming from abroad there are higher barriers to entry. Work visas are a common cause for concern. Another important obstacle to mobility relates to social security issues, in particular pension rights.

Breakout group exercise

The breakout group will perform a future-oriented SWOT-type analysis of the research profession, focusing on the following issues:

a. The main strengths and weaknesses of the research profession today

b. The key drivers of change affecting the future of the research profession (time horizon 2030)

c. The main future challenges facing the research profession (time horizon 2030)

The group facilitator will guide the discussion around a few main questions: (1) What are the main strengths of the research profession in your country? What are its main weaknesses? (2) Looking to 2030, what are the key drivers of change affecting the future of the research profession? (3) In light of these key drivers of change, what are the main challenges facing the research profession in the next 10-15 years? (4) In summary, what do we need to know about this issue that we don't already know?

Further reading

Deloitte (2014), *Researchers Report 2014: Final Report*, DG Research and Innovation, available at http://ec.europa.eu/euraxess/pdf/research_policies/Researchers%20Report%202014_FINAL%20REPORT.pdf

European Commission – Directorate General for Research and Innovation (2012), *Excellence, Equality and Entrepreneurialism Building Sustainable Research Careers in the European Research Area*, report by the Expert Group on the Research Profession, available at http://ec.europa.eu/euraxess/pdf/research_policies/ExpertGrouponResearchProfession.pdf

Kergroach, S. and M. Cervantes (2006), *Complete Results of the SFRI Questionnaire on the Working Conditions of Researchers in the Universities and Public Research Organisations*, OECD report, DSTI/STP/SFRI(2006)1.

OECD (2011), *Skills for Innovation and Research*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264097490-en*.