ENABLING THE NEXT PRODUCTION REVOLUTION

CSTP, 23-25 March 2015
CIIE, 26-27 March 2015

Delegates will find attached for their comment a discussion document prepared by the Secretariat for Session 3.2 of the 2015 OECD Ministerial Council Meeting (session on "Investment in Innovation to Foster Productivity"). It draws together several areas of DSTI's existing and future work, and aims to provoke substantive discussion among Ministers about policy action to enable the next production revolution.

Following discussion at the CSTP and CIIE meetings, the document will be submitted to the OECD Executive Committee and Council, before being submitted for discussion at the MCM on 3-4 June.

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ENABLING THE NEXT PRODUCTION REVOLUTION

Executive Summary

The spread of global value chains, the increasing importance and mainstreaming of knowledge-based capital and the rise of the digital economy are dovetailing to open the door to what is referred to as the “next production revolution”. Countries need to seize this opportunity to harness innovation to boost economic growth and spur job creation, but enabling the next production revolution requires tackling a number of policy challenges. While opportunities abound from scientific and technological change, and the greater use of data and digital competencies, these come with concerns about facilitating structural change, including impacts on jobs and inequality, questions on how to better enable dynamism amongst firms, demands for investment in infrastructure and education, and pressures to ensure cyber-security, privacy, intellectual property and other relevant regulatory systems are fit for purpose.

In 2015-16, the OECD will be undertaking a project on the next production revolution, which aims to provide a view of possible science and technology-driven developments driving changes in production over the next 10-15 years, and to explore the risks, opportunities and policy settings required for countries to seize the benefits. This paper invites Ministers to consider the backdrop and challenges for countries to enable the next production revolution as a key path to economic growth.

1. The recent productivity slowdown has sparked interest among academics and policymakers alike, with the debate centring on the extent to which the slowdown is temporary, or a sign of more permanent things to come. Productivity (principally labour productivity) drives the large differences in income per capita currently observed across countries and it is expected to be the main influence on economic growth and well-being over the next 50 years (Braconier et al., 2014). Investments in innovation and knowledge-based capital (KBC), which represents a bundle of investments including R&D, software, data, intellectual property and organisational know-how, will make an important contribution to future productivity growth. As Paul Krugman (1994) once noted, “productivity isn’t everything, but in the long run it is almost everything”.

2. Countries must harness innovation and KBC to secure their economic futures, but the path is not easy. Opportunities abound, with some key trends – the spread of global value chains, the increasing importance and mainstreaming of KBC and the rise of the digital economy – now dovetailing to open the door to what is referred to as the “next production revolution”. At the same time, innovation can be disruptive and lead to, or indeed require, the creative destruction of established businesses and markets, even as it acts as an essential engine of long term economic growth. The natural churn spurred by technological change contributes to dynamism across the business cycle, although it can be further sped up during recessions; many of today’s leading firms – think Microsoft, for instance – were born or transformed during the creative destruction of economic downturns.

3. Managing creative destruction is challenging for both firms and governments. Firms’ pursuit of (short-term) profits may result in reluctance to change or an exclusive focus on the short term, while governments must address social issues arising as labour markets shift. But the inability to adapt to evolving business models (such as in the case of Kodak) may lead to loss of market shares and eventually
the end of the business, as disruptive innovation is introduced by competitors. And in the long run, it is better for governments to assist transition towards growing activities, than to perpetuate declining ones.

4. In the current context of weak global recovery, business and policy leaders need to take advantage of the process of creative destruction to accelerate structural shifts towards a stronger and more sustainable economic future that creates jobs and opportunities. In the context of the OECD’s 2015-16 project on the next production revolution, this paper lays out the backdrop and challenges for countries to enable this revolution as a key path to economic growth.

The productivity dilemma

5. As discussed in a new OECD study on the future of productivity, there are two polar views on likely future trends in productivity, and uncovering which is closer to the truth is essential if policymakers are to understand how to support drivers of future productivity via policy settings. The more pessimistic (such as Gordon, 2012) hold that the recent slowdown is a permanent phenomenon and that the types of innovations that took place in the first half of the 20th century (e.g. electrification, internal combustion) are far more significant that anything that has taken place since then (e.g. Information and Communication Technologies – ICTs), or indeed, likely to transpire in the future. This is compounded by a number of headwinds related to demography, education, inequality, globalisation, environment and the debt overhang. By contrast, technological optimists (such as Brynjolfsson and McAfee, 2011) argue that the underlying rate of technological progress has not slowed and that the ICT and subsequent revolutions will continue to dramatically transform the global economy. In support of this view, it has been argued (e.g. Mokyr) that science and technology’s main function in history is to make taller and taller ladders to get to the higher-hanging fruit and to plant new and possibly improved trees (see OECD, 2014a).

6. One could question the judgement of the optimists in light of recent low average productivity growth. But in fact, as it turns out, polarisation is also a good description of recent productivity performance amongst firms. Despite the slowing in aggregate productivity over the 2000s, new OECD evidence shows productivity growth for firms at the “global productivity frontier” has remained relatively robust. Figure 1 charts the evolution of labour productivity in the manufacturing and service sectors for firms at the global frontier (GF), non-frontier firms, and all firms. It shows those firms situated at the GF became relatively more productive over the course of the 2000s, with productivity increasing at an average annual rate of 3.5 per cent in the manufacturing sector, compared to an average growth in labour productivity of just 0.5 per cent for non-frontier firms. The contrast was even greater for firms in the services sector.

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1 This joint work between the OECD’s Directorate for Science, Technology and Innovation and Economics Department comprises an overview of the future of productivity (Adalet McGowan, Andrews and Criscuolo, 2015) and supporting evidence (see Adalet McGowan & Andrews 2015a, 2015b; Andrews, Bartelsman & Criscuolo 2015; Andrews, Criscuolo & Gal 2015; and Andrews & Saia 2015). This discussion of “the productivity dilemma” draws heavily on this work.

2 These “global frontier” firms are defined the 100 most productive firms in each industry each year, i.e. the results are not driven by a small sample of high-technology IT firms. The identity of the GF firms may change each year.
Figure 1. Solid growth at the global productivity frontier but spillovers have slowed down

Labour productivity; index 2001=0

<table>
<thead>
<tr>
<th>Manufacturing Sector</th>
<th>Services Sector</th>
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<tbody>
<tr>
<td>Frontier firms</td>
<td>Frontier firms</td>
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<tr>
<td>(2.5% per annum)</td>
<td>(1.0% per annum)</td>
</tr>
<tr>
<td>All firms</td>
<td>Non-frontier firms</td>
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<tr>
<td>(0.7% per annum)</td>
<td>(0.3% per annum)</td>
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Note: “Frontier firms” corresponds to the average labour productivity of the 100 globally most productive firms in each 2-digit sector in ORBIS. “Non-frontier firms” is the average of all other firms. “All firms” is the sector total from the OECD STAN database.


7. This new evidence raises several interlinked questions. What has been driving the stand-out performance of the GF firms? To what extent will these trends continue? Why haven’t laggard firms learned from the GF firms’ example?

8. Taking the first of these, firms at the GF are typically larger, more profitable, and more likely to patent, than other firms. Moreover, they are on average younger, consistent with the idea that young firms possess a comparative advantage in commercialising more radical innovations. They also tend to be large trans-national corporations. These features hint strongly at the importance for these firms of investing in KBC and of harnessing competencies across the globe into their value chains. However, the average age of firms at the global frontier is increasing, bringing into doubt whether these trends will continue. The ageing trend may foreshadow a future slowing in global frontier firms’ growth rates, bringing into sharp focus the policy factors that shape their performance, such as investment in basic research, intellectual property regimes and other policies that shape technology diffusion.

9. Perhaps more important though, is the rising gap in productivity growth between firms at the global frontier and other firms. Why are technologies and production processes not diffusing to all other firms in the global economy? This has two dimensions: i) the extent to which the most productive firms in different countries are able to benefit from advances of those firms at the global frontier; and ii) the extent to which lagging firms within all countries are able to benefit from the advances of frontier firms within their domestic economy. In policy terms, the first dimension is largely a function of openness, with exposure to international trade and foreign direct investment and integration in global value chains (GVCs) being key factors allowing firms to benefit from the global frontier. However, this is complicated by the importance of tacit knowledge, which may be less easily absorbed through trade and investment flows. The second dimension is determined in large part by the capacity and incentives for the most dynamic firms in an economy to upscale, and the ease with which resources are reallocated away from less productive firms.

KBC and GVCs – the “secret of success”?

10. As suggested, global frontier firms seem to be leveraging KBC to boost their performance. OECD work has shown how KBC increasingly constitutes an integral part of companies’ business models.
Sustained competitive advantage is more and more based on innovation, which in turn is driven by investments in R&D and design, as well as organisational capital, employee skills, branding and marketing, and other intangible assets (OECD, 2013a). Only a subset of the created knowledge is codified in software code or IPR filings while the remainder, such as the ability to analyse vast amounts of data or to devise an organisational structure adapted to GVCs, are largely tacit and firm-specific in nature and hence difficult to transfer. Generating higher value-added largely hinges on the (continuous) development of superior capabilities and firm-specific “resources”, which are often intangible, tacit, non-tradable and difficult to replicate.

11. But it is perhaps the interaction of KBC and GVCs that has crucially created opportunities (and pressures) for frontier firms (which are frequently multinationals) to create new production methods and new business approaches. KBC has become an important driver of success in GVCs. The value created by economic activities is unevenly distributed along value chains, with much of the value creation often found in upstream activities, such as the development of a new concept, R&D or the manufacturing of key parts and components, or in downstream activities, such as marketing, branding or customer service. OECD countries today increasingly specialise in the production of ideas, concepts and services, and less so in the production of physical goods. As pure production activities have increasingly relocated to emerging economies, manufacturers in OECD countries rely more on complementary non-production functions to create value, using KBC to develop sophisticated and hard-to-imitate products and services.

12. KBC also allows companies to shape the architecture of a GVC in order to capture a larger share of the value created. Superior capabilities allow firms to innovate and compete in their own market segment, but also to change the competitive conditions of the whole value chain. Firms are often able to manage linkages with other firms within a GVC so as to make themselves less replaceable while making other firms more dependent on them. Because the latter have to co-operate with them to create value, such firms can leverage their position in GVCs and capture more value.

13. As industries and products become more fragmented and decentralised, economic competencies in terms of system integration skills can leverage companies’ innovation activities in GVCs. Lead firms integrate the different stages of the value chain and make the different elements work together. The example of Apple shows that its strong design capabilities enabled it to take the lead in integrating the different components and services into its different products. Lead firms in electronic GVCs have used standards not only to transfer knowledge to their suppliers but also to lower barriers to entry in the corresponding segment of the GVC and thus increase competition among suppliers.

The “Digital Economy” as a supercharger

14. Important though they are, KBC and GVCs would not have provided the opportunities they have without the emergence of the “digital economy”. In fact, several aspects of KBC (software and data) are a core component of the digital economy. Information communication technologies (ICTs) and the Internet have triggered deep changes in economies and societies and have underpinned the forces driving productivity gains. Indeed, the innovation of container shipping, complemented by a technology-induced fall in the cost of communication that enabled more efficient management and tracking of intermodal movement, contributed more to the growth of trade than liberalisation through free trade agreements or as a member of GATT (Bernhofen et al., 2013). And ICTs have enabled the emergence of micro-multinationals (small firms with a global reach), as even tiny firms now have the ability to tap a global market via e-commerce and other ICT tools enabled by broadband.

15. The ICT sector itself plays a strong role in innovation, with its R&D intensity well above that of the all-industry average. This is particularly so for the ICT manufacturing sector, which invests 27% of its value added in R&D (Figure 2). The information economy sector’s share of total business expenditure on
R&D is also substantial – 17% for ICT manufacturing and 13.5% for information and communication services, for example. And importantly, these inputs have translated into innovative outputs. For instance, ICT-related patents are typically more radical than the average patent application (where radicalness means that the patent is citing previous patents from a wide variety of patent classes outside its own – implying “newness”). In general, patents in ICT technology make up around one-third of applications to main patent offices.

**Figure 2. R&D intensity and contribution to total BERD by industry in the OECD, 2011**

R&D expenditure as a percentage of value added and of total BERD

Source: OECD (2014b), http://dx.doi.org/10.1787/888933147838

But it is not just the ICT-producing sector making a difference – the Internet and ICTs are now ubiquitous and intertwined with economic activity in all sectors. In fact, making a distinction between the “digital economy” and the overall economy is increasingly meaningless. The innovations spurred by the ICT sector hold huge potential for boosting new growth trajectories and driving societal improvements, with the biggest impact coming with the application of ICTs across the economy and society, including in public administration, health, education and research. ICTs contribute not just to innovation in products, but also in processes and organisational arrangements, as Figure 3 below shows.
17. For example, the rise of large volumes of data ("big data") from ubiquitous and interconnected applications and increasingly from smart devices embedded in the Internet of Things, is signalling a new wave of (data-driven) innovation and productivity gains. The analysis of this data (including in real time) opens new opportunities for value creation and fostering new products, processes and markets, as well as for empowering autonomous machines and systems that can learn and make decisions independently of human involvement. For instance:

- Linking clinical, biological, and other data with the massive amounts of health system transactional data can create a tremendous new resource for accelerating innovation and for better prevention and care for people with dementia and other age-related diseases. Already, second generation sequencing techniques with embedded data-mining algorithms have spurred a plunge in the costs of genome sequencing, from around USD 1 million in 2011 to less than USD 5 000 in early 2014.

- TomTom, a leading provider of navigation hardware and software, now has more than nine trillion data points collected from its navigation devices and other sources, describing time, location, direction, and speed of travel of individual anonymised users, and it adds six billion measurement points every day (TomTom, 2014). The results of the data analysis are fed back to navigation devices to inform drivers about the current and predicted state of the traffic.

- In manufacturing, autonomous machines, including robots, provide an opportunity to increase productivity to such a point that it may become profitable to bring back certain manufacturing activities to countries with higher labour costs. Some modern factories, such as the Philips shaver factory in Drachten, the Netherlands, are almost fully robotic today, employing only one-tenth of the workforce employed in its factory in China that makes the same shavers (Markoff, 2012). Available estimates for Japan suggest that the use of ICTs, in particular data analytics, in manufacturing could lead to maintenance cost savings worth almost JPY 5 trillion (more than 15% of sales in 2010) (MIC, 2013).
Heading for the Next Production Revolution

18. Investments in KBC, the opportunities provided through participation in GVCs, and the diffusion of digital technologies are dovetailing to create the conditions for the “next production revolution” – a potential step-change in the way goods and services are produced and distributed at the global level. Technologies are mixing and amplifying each other’s possibilities in combinatorial ways. Many potentially disruptive production technologies are on the horizon or already starting to have an impact:

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

- 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. And human interaction with automated systems is set to be enlarged as sensors and (intuitive) interfaces evolve and computers respond to ordinary-language instructions.

- 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. Developments in synthetic biology could also bring the life sciences closer to engineering and thus entail the need for standardisation of procedures, parts and assembly (all essential to manufacturing).

- 3D printers are becoming cheaper and more sophisticated. Objects can now be printed (such as an electric battery) 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.

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

- Cloud technology is already giving rise to new business models and enabling the rapid growth of Internet-based services (McKinsey & Company, 2013).

19. The precise economic implications of these – and other – near-term technologies are unknown. But they are likely to be large. McKinsey & Company (2013) sought 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). Their results are subject
to numerous uncertainties, but the authors concluded 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.

20. New production technologies are likely to significantly boost productivity, particularly if they can be diffused beyond the global frontier firms. The fact that nano-and bio-technologies, and ICTs, are general purpose technologies makes them well placed to generate long-term productivity increases and thus economic growth. Such possibilities are foreshadowed, for instance, in firm-level research showing 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).

21. New production technologies also hold the promise of cleaner production and of an array of new products that could help meet global challenges. For instance, facilities producing bio-based chemicals or plastics could help to address environmental and waste issues and generate new jobs. Books that adapt content in multiple languages to the needs of readers could help advance education. And nano-particles coated with DNA could help identify bacteria in a person’s bloodstream, indicating when and what type of infection is present.

22. However, there are several potential barriers to maximising the potential of the next production revolution for productivity, growth and jobs. For one thing, there is still a low level of ICT adoption in most businesses, preventing the realisation of the full potential of ICTs and the Internet. Advanced ICT applications such as enterprise resource planning (ERP) software applications, cloud computing, and Radio Frequency Identification (RFID) are used to a much lower degree than the high level of broadband connectivity and website adoption might suggest (Figure 4). In general, larger enterprises are more likely to use advanced ICT applications; this may be because of the higher complexity of internal business processes in larger organisations, but it may also signal some barriers to the adoption of ICTs in smaller firms. These might include a lack of awareness of, and skills in, ICTs for business process re-engineering, and higher financial pressures that reduce the scope for spending time dealing with the teething issues that inevitably come with new technologies.

**Figure 4. The diffusion of selected ICT tools and activities in enterprises, 2013**

Percentage of enterprises with ten or more persons employed

![Graph showing the diffusion of selected ICT tools and activities in enterprises, 2013](source: OECD (2014b), [http://dx.doi.org/10.1787/888933148510](http://dx.doi.org/10.1787/888933148510))

23. Enabling the next production revolution is also not only about technological change; benefiting from new technology also rests on the ability of firms, workers and society to adjust to this change.
Organisational change, workplace innovation, management and skills are some of the areas where firms will need to invest to support rapid technological change. And across firms, enabling resources to flow to the most productive and innovative firms will also be essential.

24. Another potential barrier is the willingness of society to allow the intensive sharing and use of personal data and, more broadly, to accept the outcomes enabled by application of digital technologies. Discrimination enabled by data and analytics may result in greater efficiencies, but also reinforce stereotypes, limiting individuals’ freedom but also potentially creating financial harm. The whole functioning of the digital economy relies on trust and adequate security for people transacting in the digital sphere, making this a critical policy issue. Moreover, many areas of science and research have been transformed by the application of ICTs; biotechnology and nanotechnology researchers, for instance, can use powerful computational capabilities to undertake studies that were not previously possible. Although their results should be interpreted with caution, surveys of public perceptions suggest a significant fraction of the population may have mixed or critical opinions as regards the balance of beneficial and harmful effects of scientific research (see Figure 5 below), highlighting the key issue of trust in harnessing science and technology in the economy.

**Figure 5. Public perception of scientific research benefits, 2010**

"Have the benefits of scientific research outweighed the harmful results?"

![Graph showing public perception of scientific research benefits, 2010](http://dx.doi.org/10.1787/888932890542)

25. The question then, is how to transition to this new future?

**Key policy issues**

26. Enabling the next production revolution and harnessing innovation for stronger economic growth requires tackling a number of policy challenges. While opportunities abound from scientific and technological change, and the greater use of data and digital competencies, these come with concerns about facilitating structural change, questions on how to better enable dynamism amongst firms, demands for investment in infrastructure and education, and pressures to ensure cyber-security, privacy, intellectual property and other relevant regulatory systems are fit for purpose.

27. The more governments understand how the next production revolution might proceed, the better placed they will be to prepare for the risks, shape appropriate policies, and reap the benefits. The OECD is
therefore undertaking work over 2015-16, focused on the possible developments in production
technologies and their risks and opportunities, to help policy makers solve the following policy challenges:

Reallocating resources to support innovative firms

28. Innovative firms must be able to attract the tangible resources (capital, labour, skills and research
effort) required to implement and commercialise new ideas. Here, the OECD already has significant policy
learning that countries can draw from (e.g. Andrews and Criscuolo, 2013). To begin with, incentives for
the reallocation of resources to their most productive use via well-functioning product, labour and risk-
capital markets, as well as through the implementation of policies that enable resources to be “released”
from inefficient firms, are essential. This includes efficient judicial systems and bankruptcy laws that do
not excessively penalise failure. Competition underpins these policy directions. Greater domestic and
international competition can facilitate the diffusion of existing technologies to laggards, which determines
their capacity to catch-up to more innovative firms.

29. Enabling start-ups and economic renewal is a key part of the resource reallocation process. In
order to emerge and grow, firms need to constantly experiment with new products, processes and business
models. In this way, they can introduce not only incremental but also disruptive innovations. The
innovation process is inherently uncertain with success and failure often going hand in hand – even the
savviest venture capital investors are unable to predict success and growth of innovation, as shown by the
highly skewed nature of the returns on investments (Kerr et al., 2014). Thus, policy needs to enable
investors and firms to experiment, assess and commercialise many different projects and terminate the
unsuccessful ones quickly. While advances in ICT technologies have significantly lowered the cost of
experimentation for frontier firms, policies that can reduce the costs of experimentation on entry (e.g.
regulations affecting product and financial markets) and exit margins (e.g. excessive employment
protection legislation and bankruptcy law), are important (Adalet McGowan and Andrews, 2015b).

Meeting the infrastructure challenges

30. High-speed networks and services are critical to unleash the potential for the next production
revolution to spur economic growth, productivity and social welfare. Moreover, if countries do not address
infrastructure challenges, they can become a bottleneck that hampers current and future development.
Governments play a key role in infrastructure investment and management, and getting policy right in this
area will have long-lasting impacts.

31. Infrastructure for the digital economy is particularly important to benefit from the next
production revolution. Countries are still in the process of deploying their broadband infrastructure, both
fixed and mobile. Most OECD countries are developing national broadband plans and many have
established broadband connectivity targets (speed and coverage), which generally include measures such as
cost-reduction initiatives for broadband infrastructure deployment, public funding schemes, or measures to
promote competition. In the area of wireless broadband, spectrum is a vital resource for supporting high-
performing and seamless wireless networks. Most OECD countries have completed the first “digital
dividend” (i.e. releasing analogue TV spectrum for use in mobile communications, especially mobile
broadband) and are currently examining options to meet future demand for spectrum. Finally, IPv6 (i.e.
Internet addresses) and machine-to-machine communications (M2M) will play a fundamental role in the
next production revolution. The transition to IPv6 is now more urgent than ever as available Internet
addresses are rapidly running out, jeopardising the further expansion of the Internet.
Building the skills for the next production revolution

32. Production in a “next production revolution world” will be highly innovation-intensive and will thus require innovation-related skills. But these are not simple to define – many disciplines and levels of skill contribute to innovation and there is no skills-related ‘silver bullet’. Simply augmenting the supply of workers with high-quality training in a specific field – be it mathematics, mechanics, genetic or software engineering, data science or biology, and so on – will not be enough. (Indeed, future mathematicians, engineers and others will not necessarily be attracted to production jobs – some may perceive such work as “dirty and hard”, although others may see future production processes using high-tech IT in a more favourable light.) And while some generic skills, such as creativity, problem solving and communication, are clearly particularly important to innovation, consensus does not yet exist on how education systems should systematically develop and test them (although education systems increasingly include such skills in their educational objectives).

33. A number of education and training policy issues thus loom particularly large in the innovation arena, including: promoting strong generic skills throughout the population, both because of their inherent value and because they allow specific technical skills to be more readily acquired; establishing incentives for institutions to provide high-quality and relevant teaching; supporting firm-level training and life-long learning; ensuring the attractiveness of careers in academic research; making sure that barriers to women’s participation in science, entrepreneurship and innovation are removed; and facilitating the development of enduring linkages and networks among researchers across countries. Governments, therefore, must ensure the presence of well-functioning institutions and well-designed policies, such that all of these needs are fully addressed.

34. But in addition, attention must also be paid to the disruptive effect on labour markets of the next production revolution. The reallocation of resources to innovative firms also implies the reallocation of labour, since the availability of skilled workers underpins the creativity and growth of innovative firms. Evidence indicates that the rate of skill mismatch – one potential metric of skill misallocation – is relatively high in some OECD economies (Adalet McGowan and Andrews, 2015a,b). Framework policies that improve the efficiency of matching in labour markets can improve productivity performance by reducing skill mismatch. But there will also be those for whom a “match” becomes increasingly difficult, as technological change obviates the need for some jobs. 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. The OECD (2011) has already found skill-biased technological change is the single most important driver of rising inequalities in labour income, even if the evolution of skills demand is a more complex process than technology-focused headlines often suggest. These policy issues will become more pressing.

Ensuring an enabling regulatory regime

35. Governments have a role to play in establishing the conditions that will enable data-driven innovation and the production revolution to take place. This implies something of a regulatory balancing act, weighing opportunities with risks. At the broadest level, maintaining an open and trustworthy Internet for the continued expansion of the digital economy is crucial. Regarding more specific issues, the example of M2M deployment was alluded to above, and is a good illustration of the type of decisions governments must make. The regulatory challenges here are related to opening access to mobile wholesale markets to firms not providing public telecommunication services (e.g. a car company or a health service provider) and issues of spectrum allocation and assignment of numbers to telecommunication services. The practical problem is that only mobile network providers can own SIM cards that sit inside devices (say, a car or an item of medical equipment), meaning that not only are device makers locked into contracts for the life of the device, but also that the end-user of the device is charged costly roaming rates whenever crossing a
geographic border. There are many technological and business model innovations that a large-scale M2M user might want to introduce, but they are currently stifled. Removing regulatory barriers to entry for non-telecom operators in this mobile market would create competition, yielding potential billion dollar savings on mobile connectivity and revenue from new services.

36. Competition policy in fact faces new challenges in industries founded on KBC, particularly in the digital economy. Never before have leading firms grown so large so quickly and, often, this scale comes without “mass”, as measured by employment. Furthermore, the nature of competition often differs in some respects from other sectors. Some experts have observed, for example, that unlike traditional manufacturing sectors, the digital economy’s most meaningful competition takes place at the level of business models. And the economics of data favours market concentration and dominance, posing risks of “winner take all” situations and exacerbation of inequality. Competition policy needs to account for the changing nature of competition, promote contestable markets, and enforce the protection and encouragement of innovation. But governments also face challenges to adequately assess market concentration and consumer detriment (including privacy issues) in this new environment.

37. Ensuring that regulations enable the renewal of the economy is also important. Subsidies to incumbents and other policy measures that delay the exit of less productive firms might stifle competition and slow the reallocation of resources from less to more productive firms. Examples include regulations which are less stringent for incumbents (e.g. fiscal measures which favour well-established firms – such as R&D tax credits which do not have carry forward provisions). Policies which (unwittingly) constrain the growth of firms should be assessed with particular care. Examples include both “sticks” (i.e. regulations which only affect firms above a certain size) and “carrots” (i.e. support mechanisms for which only smaller firms are eligible).

38. In some situations, the opportunity-risk calculation will be of strategic and/or societal importance. For instance, as production systems become more complex and ICT-mediated, the risk and consequences of system fragility may increase. Critical interlinked ICT systems might behave in unpredictable and emergent ways (in fact, interacting algorithms caused 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. As another example, innovations might create new hazards that need to be countered. 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 (e.g. as biotechnology advances, the understanding of how to deliberately make diseases worse will become more widespread). Here too, governments will need to play a role in shaping the conditions under which innovation and production take place.

Ensuring intellectual property regimes are fit for the digital age

39. IP supports innovation by making it a more worthwhile investment and encouraging knowledge diffusion. The economic rationale for IP rights is that it is in everyone’s long-term interest for people and businesses that create knowledge to have well-defined, enforceable rights to exclude third parties from appropriating their ideas, or the expression of their ideas, without permission. Failing to put restrictions on appropriating others’ inventions and creations would dilute the rewards for investing in innovation, thereby reducing the incentives for making such investments. In addition, both i) disclosure requirements and time limits for exclusivity that are built into IP laws; and ii) IP rights’ facilitation of licensing and other knowledge transfers, contribute to knowledge diffusion and thus to innovation.

40. The context in which IP operates has been changing substantially, with the growth of the Internet, digitisation, and globalisation all having an impact. This has created both new challenges for IP, including
the facilitation of piracy and industrial espionage, and new opportunities for it to stimulate inventions and creativity as well as to distribute knowledge. In the context of copyright, for instance, several governments consider that the time is now right to assess their copyright laws to make sure they remain fit for the digital age. Several countries have already done or are now doing so with the aim of ensuring that their legal frameworks strike a good balance between protection for right-holders as an incentive for creation and the need to adapt certain aspects of the copyright regimes to the 21st century. Some stakeholders assert that current national copyright regimes emanating from international treaties and conventions provide sufficient flexibility and do not impede new business models, while others argue that those models and tools are hindered by outdated copyright frameworks. Policy makers must also consider whether IP systems are adequately designed to cope with the increased use of IP bundles, where firms rely on joint use of patents, trademarks and industrial designs.

**Earning public acceptance**

41. Trust plays a central, if not vital, role for social and economic interactions and institutions. Ensuring trust and public acceptance as economies transition to the next production revolution is key to success and requires action on numerous fronts.

42. At a general level, potentially beneficial technological advances might be held back by a 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. Building a culture of trust via openness, transparency and accountability of government and business activities is essential.

43. More specifically, the increasing use of data (and personal data in particular) for innovation can pose important challenges to societies’ notions of privacy and consumer rights. There are a number of means to address individuals’ concerns, including enhancing the participation of individuals and the transparency of data processing; promoting the responsible usage of personal data and the effectiveness of privacy enforcement; and encouraging privacy risk management. The most difficult policy prescription is the definition of boundaries within which responsible use and decision automation should be limited as these boundaries may also limit innovation.

44. Moreover, as organisations increasingly rely on KBCs, digital security incidents can undermine their competitiveness, productivity, and reputation. For example, trade secrets can be stolen through sophisticated intrusions in key information systems, production processes can be altered or sabotaged by distributed denial of service attacks, data breaches can expose employees, customers, or partners’ personal data, damaging the organisation’s image and leading to legal proceedings. It is impossible to eliminate digital security risk without at the same time eliminating the interconnectedness, openness and interoperability on which data-driven innovation relies. Some level of digital security risk must be accepted for organisations to take full advantage of the digital environment for innovation and growth. Thus leaders and decision makers in organisations whose production processes rely on the digital environment and KBCs should include digital security risk management as part of their broader risk management frameworks.

**Tailoring innovation policies**

45. The uncertainty inherent to innovation highlights the dangers for governments using industrial policies to promote national champions. But governments are certainly faced with making strategic choices, given budget constraints and the understandable motivation for effective spending. Advocates of “new industrial policy”, which shifts away from a sector focus towards a focus on certain technologies and activities, see it as putting emphasis on building networks, fostering public-private partnerships and
improving co-ordination, with less reliance on direct support. The “smart specialisation” approach is one application of new industrial policy, aimed at helping entrepreneurs identify their knowledge-based strengths at the regional level. Key to this is increased use of diagnostic and indicator-based tools, to monitor and evaluate performance and policies, so that efforts can be more quickly redirected when outcomes are below expectations.

46. Uncertainty also provides a strong caution to governments that they should not add to inherent “innovation” uncertainty with policy uncertainty by unnecessarily tinkering with fiscal incentives and other features of the policy environment. OECD research shows improvements in public funding and the organisation of basic research, which provide the right incentives for researchers, are crucial for moving the global frontier and to compensate for inherent underinvestment in basic research (Adalet McGowan and Andrews, 2015b). Beyond this, it is important to design innovation policies, including R&D fiscal incentives, collaboration between firms and universities, and IPR protection, so that they do not excessively favour applied over basic research, or incumbents over young firms (the latter who are often the drivers of employment and productivity growth). Demand-side policies, such as innovation-oriented public procurement, regulation and standards, can also play a role, even though to-date most governments still focus on supply-side instruments. Governments have the capacity to take a longer-term view, beyond the profit cycles of most businesses, and thus have a responsibility to ensure that public policy is incentivising creativity and risk-taking by researchers and entrepreneurs.

47. The nature of global frontier firms (often large trans-national corporations) poses additional policy issues for governments, particularly with respect to international policy co-ordination in areas such as investment in basic research and related policies (e.g. R&D tax incentives, corporate taxation and intellectual property rights regimes) (Adalet McGowan and Andrews, 2015b). While difficult, this is clearly an area where the OECD offers a forum for countries to explore options for better global outcomes.

How to approach transition when economies are fragile

48. Finally, resource reallocation, by its nature, implies winners and losers. This is undoubtedly easier to deal with in an economy that is robust and growing, than in an economy struggling to re-establish its growth trajectory. In the wake of the global economic crisis, many OECD governments face severe constraints on public spending. Such constraints are set to continue as populations age. Policymakers must thus be concerned with identifying the most cost-effective policies and institutions to enable new production possibilities and cope with the associated risks.

49. Some elements of the required institutional-policy context can be highly capital intensive but others need not entail significant outlays in fiscal terms (such as modifications to intellectual property rules, to the incentives facing educational institutions, or to rules governing privacy and the use of data for the creation of economic value). Indeed, some necessary developments could be fiscally positive overall. For instance, policy interest in biofuels is great (and algal biofuels may soon afford a disruptive technological breakthrough). The supportive policy regimes for biofuels in many countries are not in place for bio-based chemicals or plastics. And yet, some bio-based products are much closer to market, at scale, than are the latest biofuels, while also promising greater job creation and value-added.

50. Certain policy instruments may also be particularly cost-effective. For instance, public-private partnerships, if well designed, could entail small public expenditures but be significant in inducing important private investments (such as in integrated bio-refining). But understanding of policy cost-effectiveness often needs to be improved. An example is technology prizes, which are being used increasingly and which have been central to the emergence of some significant breakthroughs (such as autonomous vehicles).
A main task, then, is for governments to develop detailed quantitative understanding of the cost-benefit relationship for the key policy instruments in question. For each country, this understanding must go hand-in-hand with an appreciation of which constraints most significantly impinge on new production possibilities and the likely impacts – positive and negative – if these possibilities are realised.
REFERENCES AND FURTHER READING


