Chapter 2

Strengthening innovation

The US innovation system has many strengths, including world class research universities and firms that thrive in innovation-intensive sectors. However, fissures have begun to appear, notably in the areas of human capital development, the patent system and manufacturing activity, while public investments in R&D and research universities are at risk of being curtailed by budget cuts. Revitalizing the dynamism of innovation has become a priority for US policymakers. To this end, it is important that federal and state governments sustain financial support for knowledge creation. The US workforce's skills will need to be upgraded, especially in STEM fields, and measures taken to provide more favourable framework conditions for developing advanced manufacturing in the United States. While the recent patent reform is a big step in the right direction, patent reform needs to be taken further by ensuring that the legal standards for granting injunctive relief and damages awards for patent infringement reflect realistic business practices and the relative contributions of patented components of complex technologies.

The US innovation system has many strengths, led by world-class research universities and world-leading businesses in various innovation-intensive sectors such as ICT, biotechnology, energy and agriculture. In addition, it has competitive product markets and flexible labour markets, facilitating the reallocation of resources triggered by innovation to more efficient products and processes. However there is continued weakness in K-12 education performance, especially in science, technology, engineering and mathematics (STEM); emerging countries are increasingly attracting research centres with high-skilled personnel; the patent system needs adjustment to ensure that it drives innovation in all sectors to which it applies; and there has been a reduction in entrepreneurial activity. In addition, government support for R&D will be reduced if the funding cuts in the Budget Control Act of 2011 are implemented.

This chapter discusses measures to foster innovation by US firms. After briefly reviewing innovation performance, the chapter discusses the importance for innovation and economic growth of limiting reductions in the federal R&D budget as far as possible. The next section discusses reforms to patent protection to increase the likelihood that it promotes innovation in all sectors to which it applies. Reforms to strengthen innovation in the manufacturing sector, which has a disproportionate impact on national innovation performance, are discussed in the following section. This is followed by a discussion of reforms to the education system to equip workers with the analytical skills they need to adapt to technological change, especially through having better skills in Science, Technology, Engineering and Mathematics (STEM). Policies to counter the decline in entrepreneurship and new firm creation in recent decades are discussed in the next section. The chapter concludes with a call to establish a national innovation agency to sustain an evidence-based focus on innovation policy and strategy.

Innovation performance is high but showing signs of faltering

Innovation is the "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD and Eurostat, 2005). While business enterprises or government agencies implement these improvements, they build on the flow of new knowledge from universities and research laboratories, most of which is funded by the Federal government. The intensity with which firms innovate depends on the incentives they face, which in turn are influenced by framework conditions such as competitiveness of product markets, flexibility of labour markets, protection of intellectual (and other) property rights, development of financial markets, supply of skilled labour and strength of public research capabilities that are subject to public policy influence. Some of these factors also influence the intensity with which government agencies innovate. Framework conditions are generally strong in the United States although, as noted in Chapter 1, there are concerns about the supply of skilled labour.

One longstanding approach to measuring innovation performance is to infer it from Multifactor Productivity (MFP) growth (see for example US Department of Commerce, 2012; White House, 2012). MFP is a residual that contains many things, but innovation is thought to be the primary source of long-run increases in MFP (Grossman and Helpman, 1991); another source is improvements in infrastructure, as occurred, for example, in the late 19th century when the railway network was developed and in the post World War II years when the national highway network was built (Box 2.1). If so, the decline in MFP growth rates in business cycles (tough-to-trough, as identified by the National Bureau of Economic Research (NBER)) since the 1970s suggests that there has been some long-run deterioration in innovation performance (Figure 2.1). Based on unofficial estimates of MFP growth before 1947, it is the period since 1970s that is unusual, not the post World War II years before the 1970s (Field, 2003, 2007 and 2009). While MFP growth picked up in the late 1990s and early 2000s as the diffusion of ICT pushed up productivity growth, especially in the distribution sector, these high rates have not been sustained. Kahn and Rich (2007 and 2012) estimate that there is a high probability that productivity growth has fallen back to the lower rate recorded over most of the period since the 1970s. Although MFP growth may have slowed, it still compares favourably with that in many other

Box 2.1. **The economic benefits of transportation infrastructure investment***

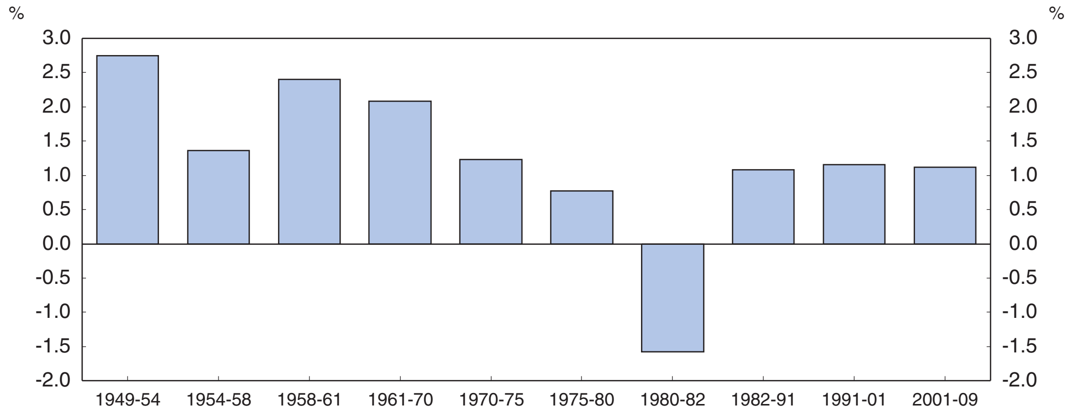
Investments in transportation infrastructure can significantly improve an economy's long-run economic performance, with the investments in the rail in the 19th century and the national highway system in the 20th century being outstanding examples (Field 2003, 2007, and 2009). Investments that create, maintain, or expand transportation networks are likely to enhance efficiency, productivity and economic activity (Department of Treasury and Council of Economic Advisers, 2010; and Gramlich, 1993). Despite high expected returns from such investments, the United States has been under investing for many years. Infrastructure investments have been running at around 2% of GDP in the United States compared with 5% in Europe. The American Society of Civil Engineers estimates that the United States needs to spend approximately USD 2.2 trillion on infrastructure over the next five years, with around half of this amount needed to make up for deferred maintenance.

Against this background, the Administration has proposed USD 50 billion in immediate investments in transportation infrastructure as part of the American Jobs Act. The proposal includes investments: to make highways safer and more efficient; to repair and modernize public transit systems; to improve intercity passenger rail service and develop high-speed rail corridors; to improve airports and modernize the air traffic system; and to support innovative multi-modal transportation programmes. The Administration is also championing a USD 10 billion proposal to capitalize an independent National Infrastructure Bank, which would both increase investment in infrastructure by attracting private capital to co-invest in specific projects and help to improve the efficiency of infrastructure investment by relying on a merit-based selection process for projects.

Expected returns from such projects at this time are likely to be unusually high owing to high levels of economic slack: competing demands for capital from the private sector are currently low and unemployment is high, notably amongst former construction workers.

* This Box draws heavily on White House (2011).

Figure 2.1. **Multifactor productivity growth has slowed since the 1970s**[1]



1. Non-farm business sector. Annual average growth rate. Periods correspond to business cycles (trough to trough) identified by the National Bureau of Economic Research (NBER).

Source: US Bureau of Labor Statistics and OECD calculations.

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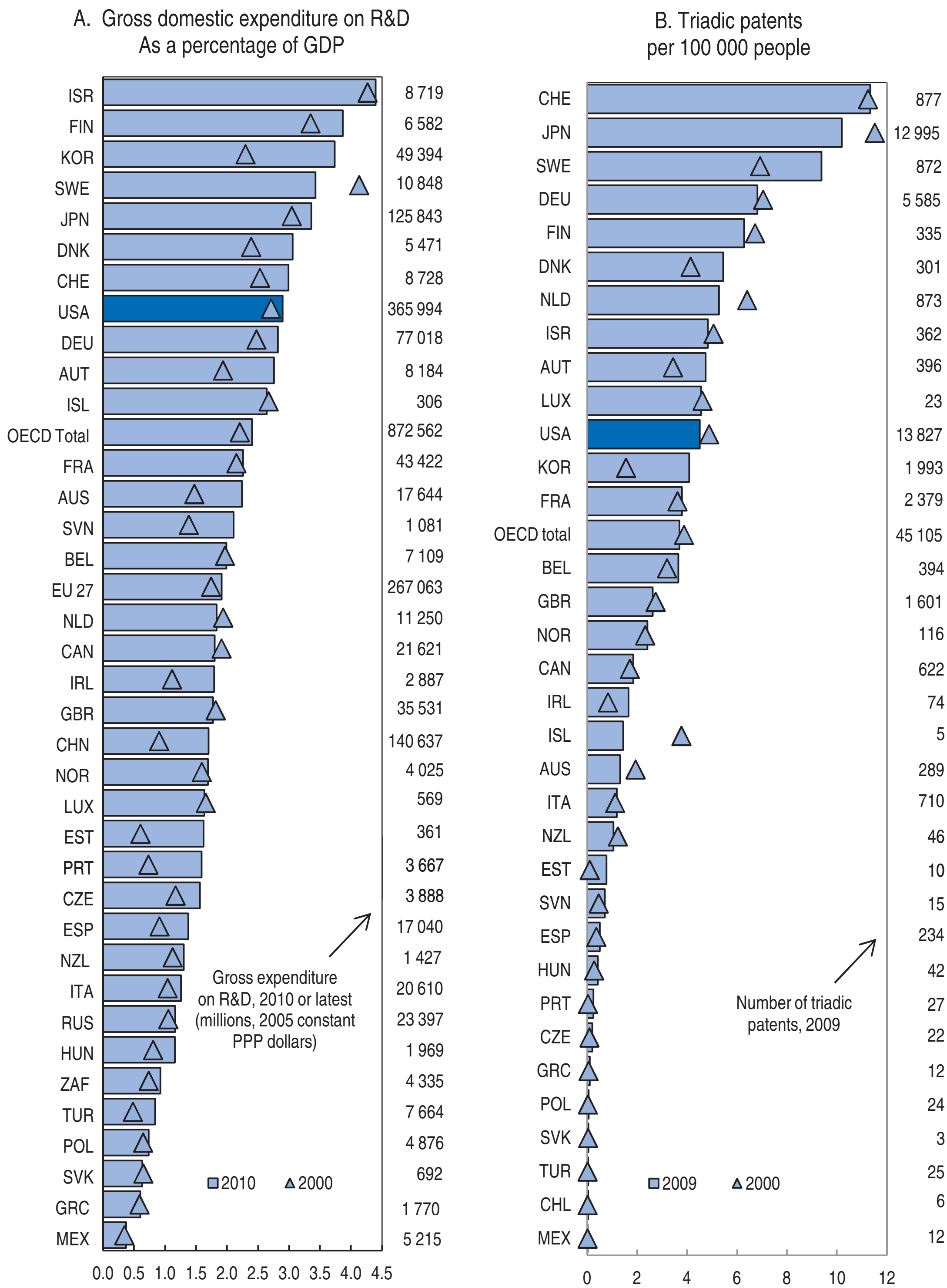
OECD countries, suggesting that the United States still has some advantages, most likely in the effective use of information technology to support changes in business practices (Brynjolfsson and Saunders, 2010).

This long-run decline in performance may well reflect the increasing difficulty of achieving transformational innovation now that the "low-hanging fruit have been picked" (Cowen, 2010). A related explanation is that the number of researchers and education attainment – factors that can explain most long-run MFP growth (Jones, 2002) – are no longer growing off a low base. In these circumstances, greater innovation investments than in the past would be required to counter the long-run decline in performance.

A more direct approach to measuring innovation performance is to conduct surveys of innovation outputs. For the time being, such data are quite limited in the United States, precluding comparisons over time and making them difficult across countries. The most important source of such information in the United States is the National Science Foundation's (NSF's) 2008 Business R&D and Innovation Survey (BRDIS), which has recently been modified to collect such data. For manufacturing firms, it shows that 22% introduced a new or significantly improved product during 2006-08 and the same proportion introduced a new or significantly improved process (NSF, 2010). For non-manufacturing firms, these proportions fall to 8%. Allowing for differences in design and coverage (notably non-manufacturing in BRDIS but services in the European Community Innovation Survey (CIS)), these rates may be around the OECD average (rates for other countries are available in OECD (2011a)). Improving these data sources should be a priority for the US authorities as this would allow policymakers to make better informed innovation-policy decisions.

The other main approach to measuring innovation performance is the proxy method, where indicators such as patents or R&D spending are tracked as a proxy for the level or rate of change of innovation, although these measures too are necessarily imperfect (US Department of Commerce, 2012; White House, 2012). Innovation surveys show that firms that make R&D investments are much more likely to innovate, such as by introducing a new product or process, than are other firms (NSF, 2010; OECD, 2011a). R&D spending as a share of GDP and per capita applications for triadic patents[1] (Figure 2.2) by US residents

Figure 2.2. **R&D spending and patent activity are slipping in global rankings but remain high**[1]



1. In panel A, 2001 and 2010 for Sweden, Denmark and Norway, 2000 and 2009 for Japan, USA, China and OECD Total, 2000 and 2008 for Australia, Iceland and Switzerland, 2001 and 2007 for Greece, 2000 and 2007 for Mexico and 2001 and 2008 for South Africa.

Source: OECD, *Main Science and Technology Indicators Database*.

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are relatively high by international comparison but are rising less quickly than in some other countries, with the result that the United States is slowly slipping down the global rankings . Similarly, composite indicators such as INSEAD's Global Innovation Index (Dutta, 2011), which combines these and many other indicators considered to be relevant for innovation activity, suggest that US innovation performance is relatively good but not exceptional. The United States is ranked seventh out of 125 countries and fifth among OECD countries in 2011. This assessment concords with the findings in *The Atlantic Century* (Atkinson and Andes, 2011), which further finds that the US score stagnated over the past decade, resulting in its ranking slipping from first to fourth.

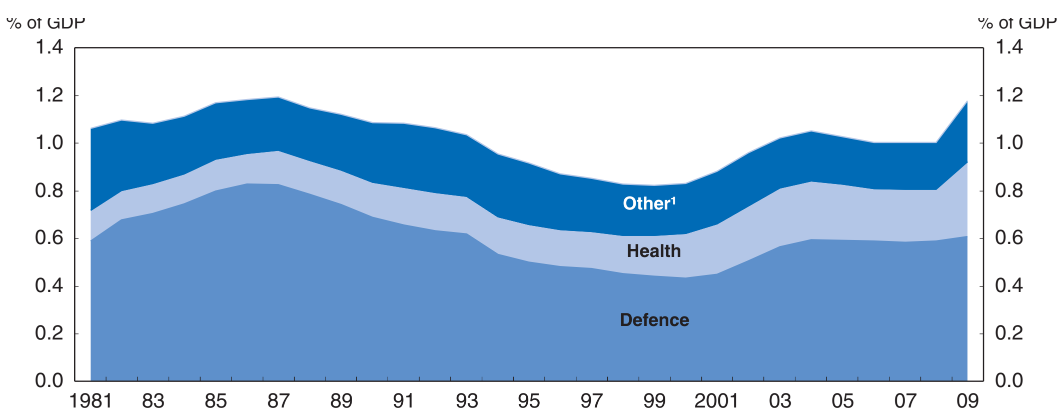
Strengthening government support for R&D investments

The government plans to increase federally-funded R&D

R&D investments are an important input to innovation. As noted above, firms that make R&D investments are much more likely to innovate. Yet firms under-invest in R&D because they are unable to capture fully the social returns on their investments owing to the public-good nature of knowledge. Much of the social return on R&D investments accrues to competing firms, downstream firms that purchase the innovating firms' products or consumers (Griliches, 1992). Empirical evidence suggests that social rates of return to R&D are substantially higher than private rates of return (Griliches, 1992), an indication that R&D investment is too low. In the absence of government involvement, the shortfall in fundamental research, which aims to expand scientific knowledge and thus does not have immediate commercial applications, is even greater as firms do not invest in such research. Yet it is an important foundation for private R&D investments. To increase R&D investments closer to the socially optimal level, the government finances most fundamental research and provides financial support to business R&D.

Federally-funded R&D budget allocations have fluctuated over the past three decades (Figure 2.3). The fluctuations have mainly occurred in defence, which declined with the

Figure 2.3. **US government budget allocations for R&D have fluctuated in recent decades**



1. The category 'Other' includes: Exploration and exploitation of space and earth; Transport, telecommunications and other infrastructure; Industrial production and technology; Agriculture; Energy; and General advancement of knowledge (R&D financed from other sources than general university funding (GUF)).

Source: OECD – Research and Development Statistics – Government Budget Appropriations or Outlays for R&D (GBAORD) Database 2011.

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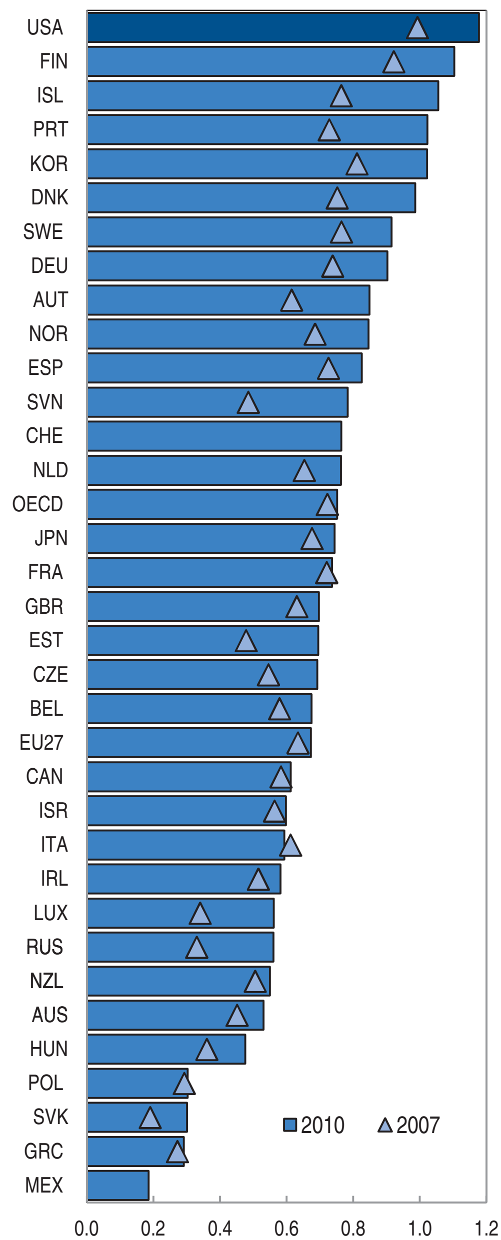
end of cold war but rose again following the 2001 terrorist attacks. Federal R&D spending received a sharp boost from the Recovery Act of 2009, temporarily pushing up such spending to 1.2% of GDP, the highest in the OECD (Figure 2.4). This increase was part of the

Figure 2.4. **US government R&D spending is high by international comparison**[1, 2, 3]

As a percentage of GDP



1. For Mexico, the latest data available are from 2006. For Switzerland, France, EU27, Canada, New Zealand, Poland and Greece, the latest data available are from 2008. For the USA, Israel, Sweden, Spain, Slovenia, the United Kingdom, Estonia and Russia, the latest available data are from 2009.
2. In the United States, general support for universities is the responsibility of state governments; therefore general university funds (GUF) is not included in total Government Budget Appropriations or Outlays for R&D (GBAORD).
3. For Israel, defence is excluded.

Source: OECD, *Main Science and Technology Indicators Database*, June 2011.

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Administration's effort to reach the goal that the President set in April 2009 of devoting more than 3% of GDP to R&D, both public and private.

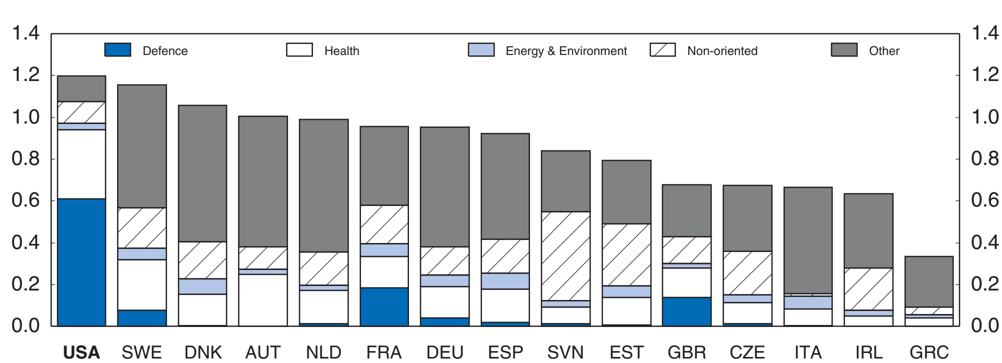
However, federal R&D spending will fall sharply if the expenditure reductions required by the Budget Control Act of 2011 are implemented. In view of the high social rates of return on R&D and the need for stable funding for R&D to be most productive, reductions in the federal R&D budget should be as limited as possible. It would be preferable to cut non-R&D expenditures (including tax expenditures) for legacy or incumbent sectors as this would facilitate the flow of resources to more productive uses. Ideally, Congress would go further by appropriating the funds approved in the 2007 America COMPETES Act, which called for doubling the funding of three key basic research agencies – the National Science Foundation (NSF), the Office of Science in the Department of Energy, and the National Institute of Standards and Technology (NIST) – within a decade. To date, Congress has only appropriated the first instalment towards realising this goal.

Policymakers need to be better informed about expected outcomes of R&D budget allocations

It may be possible to improve the allocation of the federal R&D budget by providing policymakers with better information about expected outcomes. The NSF's Science of Science and Innovation Policy (SciSIP) programme, which funds "... research that develops, improves and expands models, analytical tools, data and metrics that can be applied in the science policy decision making process", will contribute to making such information available. The results could be helpful to the President and Congress in determining R&D budget allocations, which are currently heavily weighted towards defence (mostly weapons development rather than research) and health in comparison with other countries (Figure 2.5), although judgements of experts in the various fields of science and technology are likely to remain important for such decisions. As regards non-defence, non-health government R&D budget allocations, the United States comes in lower than other OECD comparator countries.

Figure 2.5. **The shares of defence and health in government R&D budget allocations are high in the United States, 2010**

As a percentage of GDP



1. Health includes direct health government budget appropriations or outlays for R&D (GBAORD), advancement of knowledge (medical sciences) plus other funding.
2. Data for Greece refer to 2007. Data for France and the United Kingdom refer to 2008. Data for the Czech Republic, Estonia, Sweden, Spain, Slovenia, Ireland and the USA refer to 2009.

Source: OECD, *Research and Development Statistics Database.*

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Reforms to increase the impact on business R&D

Most governments support business R&D with the aim of correcting or alleviating two main market failures: difficulties of firms to fully appropriate the returns on their R&D investments, as discussed above; and difficulties in finding external finance, particularly for small innovation-based start-up firms. These market failures are manifest in a large gap between social and private returns on business R&D investment (Table 2.1). Government support is intended to raise business R&D closer to the socially optimal level.

Table 2.1. **Social rates of return on business R&D are far higher than private rates of return**

Researcher	Private	Social
Mansfield *et al.*, (1977)	25	56
Sveikauskas (1981)	7-25	50
Scherer (1982, 1984)	29-43	64-147
Bernstein-Nadiri (1991)	15-28	20-110

Source: Center for Strategic and International Studies, "Global Innovation/National Competitiveness", Washington, DC: CSIS, 1996.

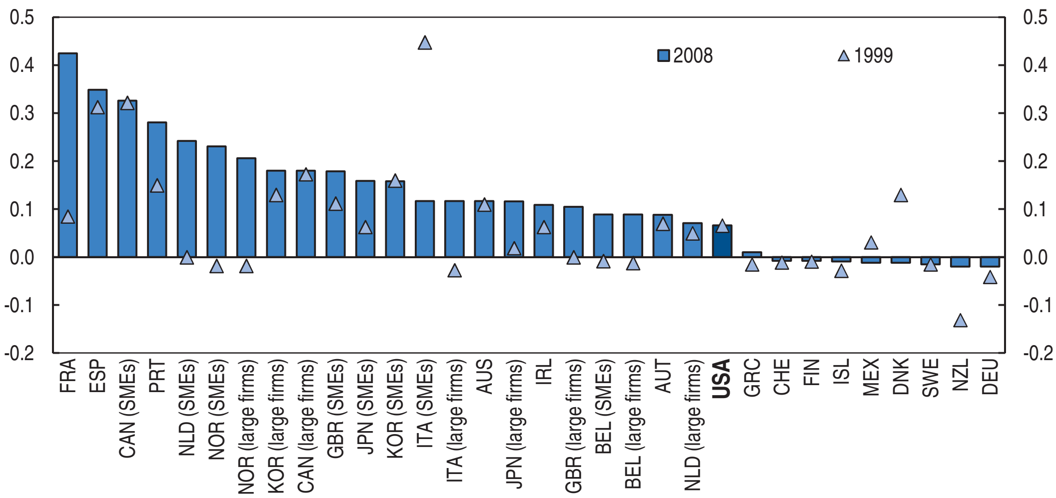
Such support typically takes the form of subsidies or tax incentives. In the United States, subsidies are provided to businesses for early-stage exploration of new technical concepts, to assist small businesses in doing R&D, for certain high-potential sectors such as nanotechnology, and to help create new technology-based industrial clusters. Subsidies are often considered to have the advantage that they can be directed to high-impact areas. This can, however, be a disadvantage if policymakers are not able to identify such areas. In this case, tax incentives are preferable as they are a market-based tool that aims at reducing the marginal cost to firms of R&D activities in a neutral way, leaving firms to decide on which R&D projects to fund. A disadvantage of tax incentives, however, is that unless carefully constructed, they reward companies for doing R&D that they would have done anyway. To minimize this kind of wasteful subsidy, the US Research and Experimentation (R&E) tax credit is made available only for increases in R&D spending over a base amount.

Government also contracts with businesses to carry out R&D to help accomplish specific government missions such as national and homeland security, environmental protection and public health. In the United States, most government budget outlays to finance R&D in the business sector are in pursuit of such public missions, while a relatively small part is intended to offset the market failures noted above. Moreover, the tax subsidy for business R&D is relatively low in the United States by international comparison (Figure 2.6). Consequently, the combined support of business R&D through subsidies and tax incentives is relatively low in the United States by international comparison.

The Small Business Innovation Research Program (SBIR), which is worth over USD 2 billion annually is aimed at encouraging innovation-based start-ups. SBIR funds are designed as a first step on the procurement ladder. Awards are linked to public sector customer requirements and the details of the topic, the recipient and the agency making the award are published. The programme requires government agencies with a certain level of external R&D budget (mainly Department of Defence, National Institute of Health,

Figure 2.6. **The tax subsidy for business R&D is low in the United States by international comparison**[1]

Tax subsidy to R&D (calculated as 1 minus B-index)[2]



1. 2009 for Mexico.
2. The B ratio shows the minimum benefit to cost ratio at which a R&D investment becomes profitable given a jurisdiction's income tax treatment for firms performing R&D. The difference between unity (when the benefits and cost of R&D are the same) and the B ratio is the tax-subsidy ratio. For example, in France, 1 unit of R&D expenditure results in 0.425 unit of tax relief, making R&D investment profitable at a B ratio of 0.575.

Source: OECD, *OECD Science, Technology and Industry Outlook 2010*.

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NASA, National Science Foundation and Department of Energy) to set aside 2.6% of their funds for the programme, which offers competition-based awards in three phases:

- Phase 1 (6 months), up to USD 100 000 for a feasibility study allowing small firms to test the scientific and technical value of their R&D effort and its feasibility;
- Phase 2 (2 years), up to USD 750 000 for a full R&D effort;
- Phase 3, the firm pursues – with non-SBIR funds – the commercialisation objectives resulting from Phases 1 and 2. Phase 3 follow-on projects can benefit from US government R&D funding; awards are then funded from mainstream budget lines.

Evaluation of the SBIR programme, however, has been mixed. Data showed that SBIR awards did not lead to an increase in employment in firms and appeared to crowd out private money that companies previously spent on R&D (Wallsten, 2000). Analysis also pointed to an inherent incoherence in the selection process of award-winners: SBIR managers aim at selecting firms with a likelihood of commercial success (pick winners) as they are looking for success stories. Research has shown that SBIR project performance is highest for those projects in industrial segments which themselves receive the highest level of venture capital financing (Gans and Stern, 2003). This means that if the programme administrators are given a strong incentive to identify projects with the highest performance, SBIR funding may precisely focus on those segments which least need financial support. Instead, SBIR managers should fund proposals that are not likely to receive funds from private sources (Wallsten, 1998 and 2000) but that might yield great social returns. On the other hand, some evaluations of the SBIR programme show that awards have caused the creation of new firms, with positive benefits in employment and growth for the local economy (NRC, 2000). Quantitative analysis has stressed that award recipients grew significantly faster in terms of employment and growth (over a ten years period) and were more likely to attract venture financing than comparable firms (Lerner, 1999).

All of these studies concur on the need for a continuous effort to carefully evaluate the SBIR programme to assess its real economic impact, to improve programme performance and spread best practice. They point to the fact that the efficiency of the programme could be increased through a regular internal/external assessment to inform agency management about programme outcomes (*e.g.* tangible results from firms' previous R&D awards should be examined more closely). Improved project management, notably by examining the track record of the firms receiving awards in order to help better identify multiple unproductive award-winners (NRC, 2008), would also raise the programme's impact.

Federal R&D support programmes should recognize the changing nature of innovation and adapt accordingly

Four important changes in the nature of industrial innovation should be taken into account in the design, implementation and funding of federal R&D programmes: *i)* open innovation; *ii)* service sector innovation; *iii)* globalization of innovation; and *iv)* basing innovation on the integration of technology with design, cultures, and business practices. These are each reviewed in turn.

Open innovation

Over the past two decades, many businesses have made radical changes in their innovation strategies. Whereas large firms once sought to invent and commercialize new technologies using their own resources, they now turn to external sources for ideas and technologies, including customers, suppliers, competitors, universities, government laboratories, and even the general public. This shift has reinforced the importance of collaboration in R&D, both among competitors and along supply chains, and it has made it imperative that all of the institutions are adequately supported and rewarded and that the interfaces between institutions operate as smoothly as possible. Policies that support R&D collaboration, that encourage technology transfer, and that take advantage of the virtues of clustering of capabilities are all steps in the right direction.

Service sector innovation

Innovation in the service sector has assumed substantially greater importance. The fact that the service sector now accounts for 80% of US economic activity means that continued growth in productivity and improvement in living standards depend heavily on service sector innovation. In the early 1960s, when much of present-day R&D policy was developed and programmes implemented, the service sector accounted for only a very small share of business R&D. Today, it accounts for 30%. With the exception of software, however, federal R&D programmes place relatively little emphasis on R&D in services. The National Science Foundation (NSF) and other agencies should aggressively explore opportunities to support fundamental research that is of value to the service sector, in part by encouraging researchers to acquire the background and skills needed to make contributions in the service industries.

Globalisation of innovation

Both R&D and innovation are increasingly conducted by global networks of complementary expertise and enterprises. Publications with co-authors from two or more countries are fast becoming the norm in science. Companies are increasingly engaged in developing new technologies along supply chains that span the globe and a rapidly increasing share of research and related publications are being carried out in countries other than the United States. Both academics and companies face barriers to more effective participation in global R&D. For example, academics find it difficult to use federal R&D funds to participate aggressively in global R&D networks owing to rigid rules governing the use of US funds to support research partners elsewhere. Federal programmes that encourage industrial R&D and technology commercialization often incorporate rules limiting the location of application of the results of such activities to the United States. These barriers made some limited sense when the United States was the unequivocal leader in R&D and innovation world-wide. Now, however, they are widely seen as problems for effective participation of US entities in global R&D and innovation networks. Federal policymakers should re-examine them with an eye to reform.

Integrating technology

It is widely recognized that a significant proportion of contemporary industrial innovation is based, not just on exploitation of new technologies resulting from advances in basic science, but on the integration of new technologies with new business practices, on the careful integration of technologies with design, and on the development of technologies that mirror and challenge contemporary cultures. This new world of innovation has been called the "Post-Scientific Society" (Hill, 2007). Firms operating successfully in the Post-Scientific Society need engineers, designers and marketing professionals who individually integrate understandings across the several disciplines mentioned above. However, little in the university curriculums in these disciplines or in the programmes of support to research and innovation recognizes these new realities.

One interesting educational model is Aalto University in Finland, which integrates three pre-existing institutions devoted to engineering, business, and the arts. Some have called for the extension of the STEM concept discussed below to embrace the "STEAM" framework (Science, Technology, Engineering, the Arts and Mathematics) as a way to move this topic to the current agenda of educational reform (see for example Rhode Island School of Design [2011]). Attention should be paid in both federal research and educational programmes to broadening the agendas of inquiry and pedagogy to develop a more systematic basis of fundamental understanding of how best to integrate technology, design, business and culture and to develop new curricula that prepare graduates for success in this new world.

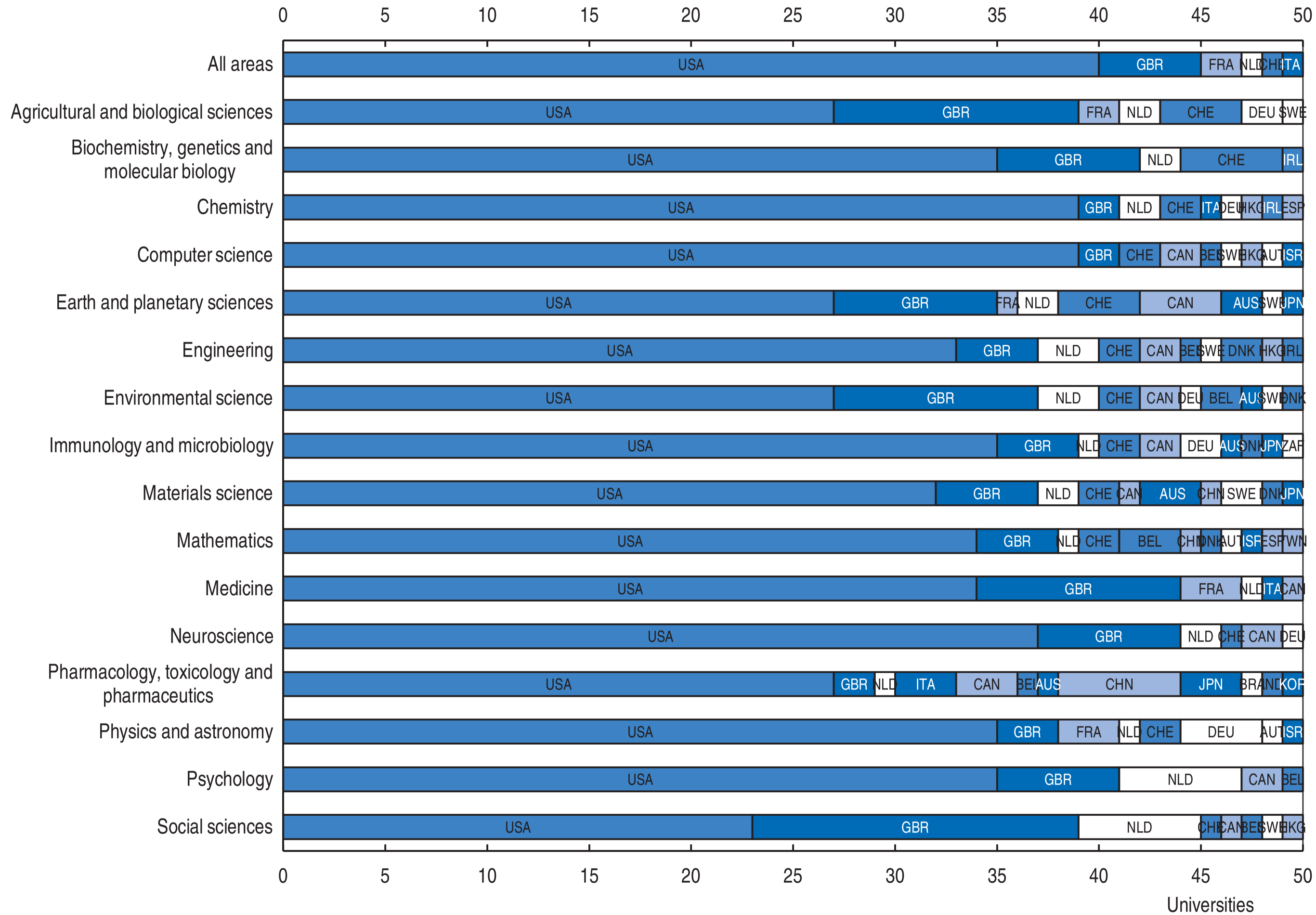
States should shield their research universities from budget cuts

State universities are the backbone of the US network of research universities, which are among the best in the world (Figure 2.7). Public universities and colleges account for 68% of university and college R&D in the United States (NSF NCSES website). They represent a key strategic advantage for innovation.

However, states have recently sharply reduced university budgets in the context of fiscal consolidation (College Board Advocacy and Policy Center, 2011). These actions follow

Figure 2.7. **US research universities are world leaders in most research fields**[1, 2]

Location of top-50 universities by main subject areas



1. The publication threshold set for the institutions is at least 100 documents in 2009.
2. The normalised impact is the ratio between the average number of citations received by a specific unit and the world average of citations in the same time period, document type and subject area, *i.e.* the normalisation is done at the level of the individual article. If an article belongs to several subject areas, a mean value of the areas is calculated.

Source: OECD, *OECD, Science, Technology and Industry Scoreboard 2011.*

StatLink http://dx.doi.org/10.1787/888932638564

declines in state support for universities in recent decades in the face of competing demands on state budgets from health-care costs and the costs of incarceration. As a consequence, universities have had to cut back on faculty salaries (or at least on their growth) and have no longer been able to afford "start up packages"[2] that new STEM faculty staff expect. Non-faculty staff have been cut and building maintenance and repairs have been deferred. The other main source of budget pressure is from the cap on the administrative share of indirect costs of federal research funds (the main source of public universities' research funds). This cap, which has been held at 26% for some years, is widely considered to be too low (United States Government Accountability Office, 2010; Association of American Universities, 2010). Universities have to make up the shortfall in funds for indirect costs of research from appropriated or other unrestricted funds. Consequently, when states cut back funding and students resist tuition hikes (and states put pressure on universities to hold down tuition fees) public universities have to cut costs everywhere they can, including in support of research. The resources invested in research have also been reduced by universities asking faculty to teach more courses with more students in each when state funds are cut. In view of the importance of these universities to state innovation systems, states would do well to shield them from budget pressures.

Taking patent reform further

One of the main ways in which government aims to encourage R&D investments is patent protection. Patents give time- and scope-limited exclusive rights over the use of a new product or process, rewarding the patent holder and helping to address a possible market failure in the supply of technology and knowledge. However, concerns have been voiced about the functioning of the US patent system, most notably in thirty days of hearings held by the Federal Trade Commission (FTC) and the Department of Justice in 2002. These hearings were followed by a report with recommendations from the FTC (2003) and a study by a specially constituted committee under the National Academy of Sciences (National Research Council, 2004). Reform legislation was introduced in Congress in 2005, although passage was achieved only with the America Invents Act of 2011. Several academic books critical of the US patent system also appeared during this time: see Adam Jaffe and Josh Lerner, Innovation and Its Discontents, 2004 (institutional critique); James Bessen and Michael Meurer, Patent Failure, 2008 (problem of indeterminate boundaries and poor notice; showing extreme variation in benefits and costs across industries); and Dan Burk and Mark Lemley, The Patent Crisis and How the Courts Can Solve It, 2009 (emphasizing industry differences and the judicial tools available for addressing differences).

A principal target of criticism was the Court of Appeals for the Federal Circuit, which was established in 1982 to hear all appeals from the district courts and the United States Patent and Trademark Office (USPTO). By 1999, the Federal Circuit had reshaped patent law to make patents more widely available and more difficult to invalidate, including opening up the United States to software and business method patents. Contemporaneous with the introduction of reform legislation, the US Supreme Court, which had previously deferred to the Federal Circuit on patent matters, began accepting major cases for review. In *KSR International v. Teleflex*, 550 US 398 (2007), the Court raised the threshold of inventiveness demanded of patent applicants by striking down the Federal Circuit's standard for obviousness. In *eBay v. MercExchange*, 547 US 388 (2006), the Court abolished the Federal Circuit's rule of automatic injunctive relief for infringement, a rule that gave patent owners powerful leverage over complex products. However, these landmark decisions do not appear to have had a discernible impact on the high volume of applications. Nor has the *KSR* decision reduced the number of patents issued. In fact, issuances have jumped significantly in the last two years.

Passed in 2011, the America Invents Act aims to increase patent quality by providing for new procedures for challenging patent validity, analogous to opposition proceedings in other systems, that may allow patent disputes to be resolved more quickly and at lower cost. It also allows the USPTO to prioritize certain applications, gives it some freedom to set fees and some assurance that fee income will not be diverted to other government purposes, and increases resources to reduce the backlog of patent applications and improve the quality of patent awards. The Act also replaces the first-to-invent rule, which had become a US anomaly, by a first-to-file rule with prior user rights in line with international practice. This eliminates costly interference proceedings that were sometimes needed to determine who had reduced the invention to practice first. At the same time, unlike many other jurisdictions, US law retains a 12-month grace period that gives patent priority to the first inventor to publish within a year to filing. This grace period may promote earlier disclosure of new scientific knowledge, helping to foster a more rapid rate of cumulative innovation.

Efforts to reform the calculation of damages to reflect the relative contribution of the patented technology met with resistance outside of the ICT sector and were abandoned. In line with the FTC's recent analysis (Federal Trade Commission, 2011), damages awarded for patent infringement should reflect the relative contribution of the patented function relative to the product as a whole based on what a willing licensee would have paid had they known about the patent ahead of time. While there is evidence that courts appear to be embracing a more disciplined approach to awarding "reasonable royalties" (*e.g.*, *Uniloc v. Microsoft*, Fed. Cir. 2011, 632 F.3d 1292), there remains a long way to go to get a consistent standard.

The division between complex and discrete technology perspectives was also evident in controversy over the timing of the various administrative invalidation procedures, especially the new post-grant review proceeding, which was limited to the nine-month period following issuance of the patent. The ICT sector wanted an alternative for contesting patents when litigation was threatened since the high volume of ICT patenting makes it impractically costly to monitor and evaluate patents as they issue, especially since most patents will never be asserted.[3] Evaluating patents is extremely expensive; the 2011 American Intellectual Property Law Association Report of the Economic Survey shows an average cost of USD 13 712 for an opinion on patent validity.

While the Supreme Court's *eBay* decision reduced awards of injunctive relief by about one-quarter, patent owners have taken to filing before the International Trade Commission, which still provides virtually automatic exclusionary orders for imported products that are found to infringe.[4] Since most information technology is imported, the remedy is very potent and can essentially bar an entire product line from the US market, regardless of the relative significance of the infringed patent. However, in recent high-profile cases the Commission has allowed defendants a period of time to design around or remove the patented function.

Nevertheless, non-producing patent assertion entities retain considerable ability to hold up producing companies, while at the same time having no exposure to the patents that producing companies have in their arsenals. This has recently led large producing companies to spin off portions of their portfolios to patent assertion entities that can maximise payoffs from the patents and raise rivals' costs – a practice known as "privateering". The net effect is to impose growing costs and risks on companies engaged in innovation. To counter these effects, patent reform needs to be taken further by ensuring that the legal standards for granting injunctive relief and damages awards for patent infringement reflect realistic business practices and the relative contributions of patented components of complex products.

Although the Act allows the USPTO to tailor patent fee schedules to better recover its costs, it only allows recovering the costs of its internal operations. This limits the extent to which the USPTO can set patent fees at levels that would account for the potential externalities of patenting activity, such as the search burden imposed on other innovators who wish to avoid infringing (Menell and Meurer, 2012). Again, this is a burden that may be insignificant for discrete products where notice is effective and competitors are naturally aware of each other's patents, but overwhelming for complex products where innovation is cumulative and patents are voluminous. In short, some sectors observe patents and others ignore them (Lemley, 2008).

The USPTO's recently proposed fee structure provides for more sharply rising maintenance (renewal) fees consistent with the principle that information about technology value emerges over time and with the desirability of reducing clutter from patents of marginal value (de Saint-Georges and Van Pottelsberghe, 2011). However, despite legislatively mandated reduced fees for small and "micro" entities as an explicit subsidy, the fee structure continues a front-end subsidy on the grounds that more patents are better.[5] Clearly, there are industry and professional differences about this. While China clearly embraces this view, albeit in a different manner, the European Patent Office (EPO) has taken a more conservative approach. An implicit subsidy for marginal patents will inevitably lower average patent quality and increase information asymmetries and strategic behaviour in the patent marketplace. Moreover, under-pricing the front-end fees provides patent offices with an incentive to grant patents, since they receive nothing for applications denied, and the repercussions of wrongly issued patents are experienced only indirectly at some future time. This is especially likely in times of chronic budget shortfalls (Frakes and Wasserman, forthcoming 2013). While the United States is not alone in subsidizing applications and examination, patent quality is generally considered to be more problematic for the USPTO than the EPO and the Japanese Patent Office, the other two "trilateral" offices (European Patent Office (2011); Quillen and Webster (2006); de Saint-Georges and Van Pottelsberghe [2011]).

The interplay between patent administration and market behaviour is beyond the scope of this report. However, there is growing concern in OECD economies over the implications of the activities of patent assertion entities and aggregators.[6] There is renewed concern about strategic behaviour ("privateering") by some large producing companies, which now collaborate with patent assertion entities in ways that raise costs for rivals and consumers without contributing meaningfully to innovation (Ewing and Feldman, 2012; Ewing, 2012).

To date, only the FTC has been active in analysing patent markets. Following the lead of the European Patent Office in 2004, the USPTO hired a chief economist in 2010, but an effort is needed to understand the dynamics of patent practice beyond the walls of the

USPTO. This should lead to better understanding of patent practice, more informed patent policy, and better integration with US innovation policy. However, it is clear that given the state-created nature of patent rights and the growing strategic state intervention in patent markets, the functioning of patent markets must be addressed from an international perspective. Given the historic prominence of the US system and the US origins of emerging and controversial practices, the USTPO and the FTC should play a leading role in international analysis and debate.

Government action to increase green innovation[7]

Innovation can help to make economic growth "green" by contributing to decoupling it from depletion of the natural resources and environmental services. Firms under-invest in green innovation because they are unable to capture the full social returns on their investments owing to the public-good nature of knowledge, as for other forms of innovation. In addition, the presence of dominant designs, technologies and systems in key sectors such as energy and transport can create entry barriers for new technologies and competitors owing to, for example, the high fixed costs of developing new infrastructures.

The starting point for increasing green innovation is to price environmental externalities in a clear and stable way. This increases households' and firms' incentives to develop and adopt green technologies, leading to the establishment of markets for green innovation. The United States has had a very favourable experience with pricing sulphur dioxide (SO_2) emissions (which cause acid rain) in the electric power sector, but Congress failed to pass legislation in 2010 to price Greenhouse Gas (GHG) emissions. Given the Supreme Court ruling that GHG emissions are a form of pollution and that consequently the US Environmental Protection Agency (EPA) is obliged to limit them, the EPA has recently proposed to introduce regulations to limit carbon dioxide (CO_2) emissions from new power stations, which would effectively render new coal-fired power stations uneconomic. This is an important sector because it accounts for a large share of US CO_2 emissions; indeed, this is one of the two sectors – the other is transportation – that account for such high per capita emissions in the United States relative to European countries (Carey, 2010).

In the area of transportation, the EPA and the Department of Transportation (DOT) have issued new joint regulations to reduce GHG emissions and increase fuel economy of new passenger cars and light trucks sold in model years 2012 through 2016. The EPA projects that CO_2 emissions per mile of the average new light-duty vehicle will be 23% lower by 2016 than in 2011 and that fuel savings associated with the more efficient GHG technologies will far outweigh the higher initial vehicle costs by 2020 (US Environmental Protection Agency, 2010). EPA and DOT have also issued a joint proposal – due to be finalized this summer – extending this programme to reduce further GHG emissions and improve fuel economy for model years 2017 through 2025. It is projected by EPA to save approximately 4 billion barrels of oil and 2 billion metric tons of GHG emissions over the lifetimes of those light duty vehicles sold in model years 2017-25. In addition, the Administration has finalized the first-ever national fuel efficiency and GHG emission standards for heavy-duty trucks, vans and buses spanning model years 2014-18. Given that greater fuel economy is likely to encourage more vehicle use, these measures should be complemented by an increase in gasoline taxes, which are exceptionally low by international comparison (Carey, 2010), until GHG emissions are priced.

Increased government investment in basic- and long-term research is also required. Such investment, which is not undertaken by private firms as it has no immediate commercial applications, helps address fundamental scientific challenges and fosters technologies that are considered to be too risky, uncertain or long-gestating for the private sector. Such research should increasingly be based on multi-disciplinary and inter-disciplinary approaches and should target generic technologies as opposed to highly specific technologies (*e.g.*, target energy storage devices instead of lithium-ion batteries), as innovations may emerge from a wide range of fields. As noted above, the American Recovery and Reinvestment Act (ARRA) of 2009 gave a large temporary boost to federal R&D expenditures. The ARRA included USD 400 million of funding for the Department of Energy's (DOE's) Advanced Research Projects Agency – Energy (ARPA – E), which promotes and funds work on advanced energy technologies that might not otherwise occur because of a high risk of failure. The doubling of the research budgets for three key scientific agencies discussed above would be very helpful in boosting fundamental research.

While these budget increases go in the right direction, still larger increases are likely to be required to enable backstop technologies to emerge and hence substantially reduce GHG abatement costs. Assuming a world carbon price scenario that targets a GHG concentration of 550 ppm, OECD (2009a) estimates that global energy R&D investments would need to rise approximately six-fold initially, to 0.12% of global GDP, to enable backstop technologies to emerge.[8] By 2050, abatement costs and GDP costs could be one half of the levels without such technologies; these results accord with those in other studies (Edmonds *et al.*, 2007; Manne and Richels, 1992; and Clarke *et al.*, 2006).

This greater research effort would also benefit from enhanced international cooperation to share the costs of public investment, improve access to knowledge and foster the transfer of technologies across countries. In this regard, the United States cooperates with other members of the Major Economies Forum on Energy and Climate (MEF) to promote innovation, deployment and information sharing in low GHG-emissions technologies, as well as through the Clean Energy Ministerial (CEM). The CEM, announced by MEF leaders in 2009, is a high-level global forum that promotes policies and programmes to advance clean energy technology, share lessons learned and best practices, and encourage the transition to a global clean energy economy. Action plans have been developed in the technologies considered to be the most important for reducing emissions. The United States is leading the action plans on energy efficiency in the buildings sector and industrial sector.[9] The US government has also substantially increased its assistance to developing countries to help them with abatement and adaptation measures (Carey, 2010).

To overcome specific market failures associated with green innovation, support for private investment in innovation, notably R&D, and for the commercialisation of green innovations is needed. Such support may be required because green innovation faces additional barriers in some markets, such as barriers to entry in the electricity sector. The ARRA included a considerable boost to funding to improve the electric grid so that it is better adapted to receiving and managing renewable energy and an additional USD 6.0 billion of loan guarantees offered through the Innovative Technology Loan Guarantee Program. These measures complement those taken by twenty-five states and the District of Columbia to establish renewable (energy) portfolio standards (RPS) (IEA, 2008). Unfortunately, these standards use different design principles and goals, increasing the cost by limiting cross-border trade in renewable energy. The federal government should establish a federal electricity RPS, covering those parts of the country in which cross-border trade in electricity is feasible, to overcome these problems.

The Renewable Fuels Standard (RFS), which mandates a progressive increase in the bio-fuel content of gasoline sold in the United States, highlights the dangers of favouring specific technologies and of lobbies shaping the programme to their advantage. In its initial incarnation in *The Energy Policy Act* of 2005, the OECD (2008) estimated that abatement costs under the RFS were high (at least USD 1 000 per tonne of CO_2). Moreover, the programme had also taken land out of production of food, pushing up prices. The revisions to the RFS in *The Energy Independence and Security Act* of 2007 (EISA) give increased weight to bio-fuels that are more effective in reducing GHG emissions, allowing for direct emissions and significant indirect emissions (such as from indirect land use changes), represent a substantial improvement. The cost effectiveness of the programme increased further when the import tariff on sugarcane-based ethanol and subsidies for corn-based ethanol expired at the end of 2011.

One possible approach to overcoming market failures more prevalent in green- than other technologies while avoiding the problems arising from targeted support for specific innovations is to support sustainable infrastructure (such as the smart electric grid discussed above) or basic conditions for a wide range of alternative technologies, *e.g.*, as noted above, energy storage technologies that are needed for a wide range of technologies, or general purpose technologies such as ICT that have a wide range of applications. This approach is widely followed in the federal R&D budget. In addition to support for research in ICT, the budget also provides considerable support to research in industrial biotechnology and nanotechnology, areas that are likely to be important for green innovation.

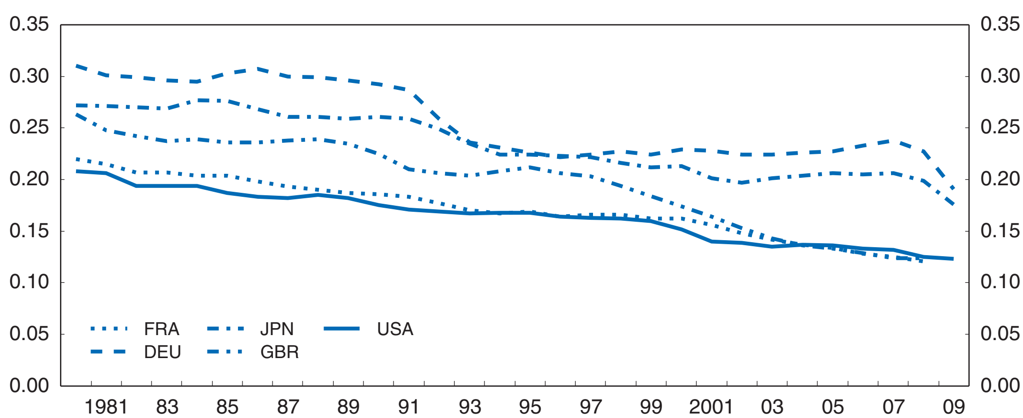
Measures to strengthen innovation in manufacturing

Manufacturing firms play a key role in innovation. They perform 70% of all privately-funded business R&D[10] and a significant proportion of industrial R&D performed in non-manufacturing sectors is done in close collaboration with or in direct service of manufacturing. This preponderant role in R&D makes them important players in innovation because, as noted above, firms that invest in R&D are much more likely to innovate (by introducing a new product or process) than are other firms (NSF, 2010; OECD, 2011a). In addition, important service sectors, such as information and health care, depend directly on manufacturing firms for the continued flow of new products that they embed or use in their services, such as network servers and routers for the information services industry and pharmaceuticals, instrumentation and medical devices for the health services industries. Because minimizing the time to market is important to the competitive success of leading service sector firms, it is to their advantage to be located close to associated R&D and early-stage manufacturing centres for the new devices they depend on.

Small firms – especially new, technology-based firms – are particularly important to innovation in advanced manufacturing sectors such as pharmaceuticals (Kaitin, 2010) and optical materials (St John and Pouder, 2007). Sustained innovation by established small and medium sized manufacturing firms is also critical to enabling innovation in the larger firms that are their customers for new materials, parts, components and subassemblies that become part of higher level system innovations made by the larger firms. Put another way, manufacturing innovation increasingly takes place, not in single large firms, but along supply chains and supply networks of firms of diverse sizes that collaborate to produce complex and innovative new systems (Dyer, 2000; Paasi *et al.*, 2010).

As in most other economically advanced countries, the share of manufacturing in total value added declined steadily in the United States over the last decades of the 20th century before falling sharply over the past decade (Figure 2.8). The employment share of manufacturing has declined even more, reflecting relatively high productivity growth in this sector. This has been underpinned by the applications of more efficient technologies in manufacturing, the continuing closure of large numbers of older, less efficient manufacturing facilities, and the shift to production of higher-valued goods.[11] Manufacturing productivity has also been boosted by firms focusing on their core competencies, where productivity is generally high, while outsourcing labour-intensive functions such as financial and accounting services, logistics services, maintenance, legal services, medical services, and food services, where productivity is often lower, to service sector companies.

Figure 2.8. **The share of manufacturing in total value added has been declining in the United States and other OECD countries**



Note: For Germany, data from 1980 to 1991 refer to West Germany.

Source: OECD, *STAN Database*.

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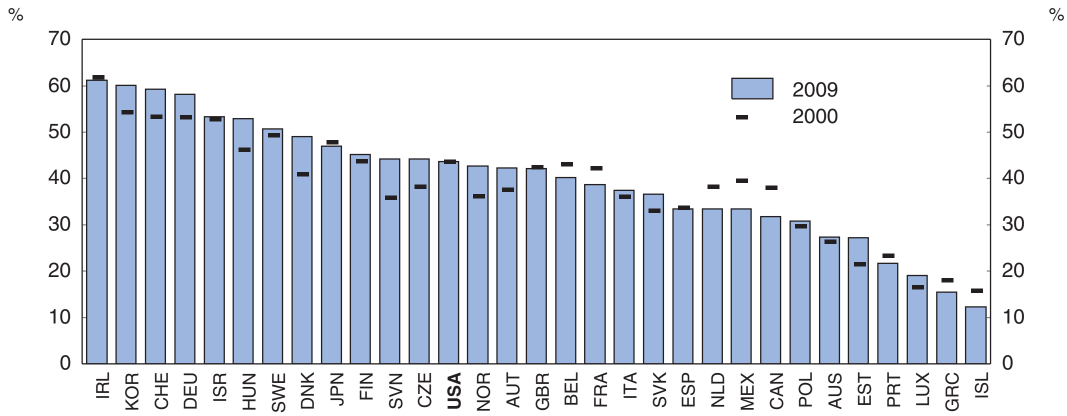
Value added in high- and medium-high tech manufacturing, which is particularly innovation-intensive, has only grown at the same rate as manufacturing value added in the United States over the past decade, in contrast to some other OECD countries such as Germany and Switzerland (Figure 2.9). The US share of such manufacturing in the total is middle ranking among OECD countries. The increasingly negative US balance of trade in advanced technology products may also be an indication of competiveness problems for US manufacturers in technology-intensive product categories (Figure 2.10).

Only a few of the large, integrated flagship industrial R&D laboratories that were established by major manufacturers in the decades before and after World War II have survived, leaving serious questions about where the capabilities reside to create the next generations of radical and transformative manufacturing innovations like those of the past such as the transistor, the semiconductor chip, optical fibres, carbon-fibre reinforced plastics, jet engines, and the like. In addition, US-based multinational firms have

Figure 2.9. **The share of high- and medium-to-high tech manufacturing in total manufacturing value added in the United States ranks around the middle of OECD countries' shares**



Note: Data for Germany, Switzerland, Israel and France refer to 2008. Data for Norway, the United Kingdom and Poland refer to 2007. Data for Portugal refer to 2006. Data for Australia refer to 2005.

Source: OECD, *STAN Database*.

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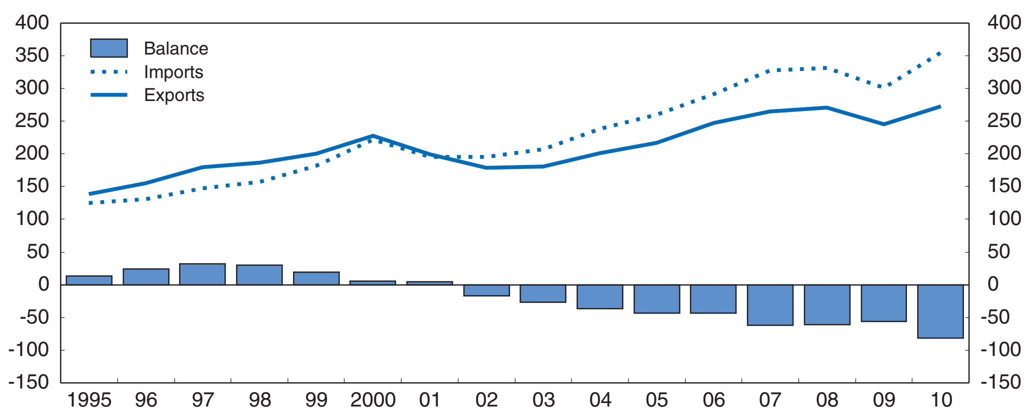
Figure 2.10. **The US trade balance in advanced technology products has deteriorated over the past decade**

USD (billions)



Source: National Science Board, *Science and Engineering Indicators 2012*.

StatLink http://dx.doi.org/10.1787/888932638621

increasingly located important elements of their R&D and innovative activities in other countries, responding to market opportunities there, as well as to the apparently greater availability of appropriately skilled and priced workforces, and to the demands of some host countries. The share of US-based multinational corporations' R&D performed overseas increased from 12% in 1999 to 16% in 2008 (National Science Board, 2012). US firms have also reduced their commitment to funding basic research (National Science Board, 2008). Small, entrepreneurial, technology-based firms have emerged to pick up some of the slack; and federal laboratories and universities have been enlisted in the past three decades to assist industry in its innovation work, enabled by the 1980 Bayh-Dole Act and the Stevenson-Wydler Technology Innovation Act of 1980 as amended by the Federal

Technology Transfer Act of 1986 and other amendments. These acts created both the authorities and the means by which universities and government laboratories could work with industry and transfer technology to industry with appropriate intellectual property protections in place. Innovation clusters, made up of several firms in similar lines of business, academic institutions, and suppliers of critical inputs and services, are increasingly seen as important mechanisms for aggregating the resources of people, knowledge, experience, and capabilities needed to make major new advances in focused areas of technology (Porter, 1998).

Economic studies show that there are agglomeration- (Greenstone, Hornbeck and Moretti, 2008) and knowledge (Keller, 2010; Branstetter, 2001) spillover benefits from manufacturing activity that benefit locations that have such activity. In light of these spillovers, measures to promote innovation in manufacturing are warranted. To this end (and/or to encourage US firms to conduct more of their manufacturing activities in the United States), the Administration has recently taken a number of steps to better focus existing resources on assisting manufacturers and it has proposed additional actions that would require congressional action for their realization. For example, in June 2011 the President announced the Advanced Manufacturing Partnership to focus approximately USD 500 million of existing programme funds on improving manufacturing performance for national security needs, reducing the time to develop and deploy advanced materials, develop next generation robotics and develop new energy-efficient manufacturing processes, as well as other activities. In December 2011, new co-chairs of the White House Office of Manufacturing Policy were appointed to coordinate "the execution of manufacturing programmes and the development of manufacturing policy". In January 2012, the President proposed that Congress consider changes in the federal tax code to encourage manufacturers to produce in the United States.

The President has also proposed warranted reforms to the US international tax system that address the current distortion that favours outward FDI over domestic investment. These reforms would make shifting profits offshore less attractive by: imposing minimum tax on foreign income of foreign subsidiaries located in no or low tax jurisdictions; taxing on a current basis excess profits associated with shifting intangibles to low-tax jurisdictions; and requiring that deductions for interest expense attributable to outward FDI be delayed until the related income is taxed in the United States.

To strengthen manufacturing innovation in the United States, especially in large firms, the existing Research and Experimentation (R&E) tax credit also should be reformed. Consideration should be given to increasing the tax credit, which is relatively low by international comparison (see Figure 2.6), as it is likely to be effective at increasing business R&D (OECD, 2011b). In addition, the R&E tax credit should be made permanent, as proposed in the President's FY 2013 budget, to strengthen its impact on R&D investments (Guellec and van Pottelsberge de la Potterie, 1997). The proposal in the President's FY 2013 budget to simplify the tax credit, which has become increasingly complex, also should be implemented to facilitate use of the credit.

Strengthening innovation in small- and medium-sized US manufacturing firms will require a broader and more sustained investment in regionally-based programmes of direct technological and operational assistance, organized around clusters of manufacturing firms in similar sectors where appropriate. The *Fraunhofer* Institutes in Germany[12] provide an interesting model for what could be done in the United States, although some adjustments to the *Fraunhofer* model would be needed for them to fit US circumstances. The much greater size of the United States along with greater dispersion of industrial activity in specific sectors suggests that duplication of *Fraunhofer*-type centres would be appropriate. In addition, experience with programmes like the Manufacturing Extension Partnership at the National Institute of Standards and Technology (NIST) suggests that the scope of centre activity might effectively incorporate assistance to firms on business practices and in employee training. The Administration's new National Network for Manufacturing Innovation (NNMI) is to be structured very much along these lines (*www.whitehouse.gov/the-press-office/2012/03/09/president-obama-announce-new-efforts-support-manufacturing-innovation-en*). The NNMI will be funded initially from existing programmes in the Departments of Defence, Commerce and Energy and NSF on an interagency basis. In his FY 2013 budget proposal, the President has asked Congress to appropriate USD 1 billion to NIST to set up the national network.

Further investments in upgrading American workers' skills

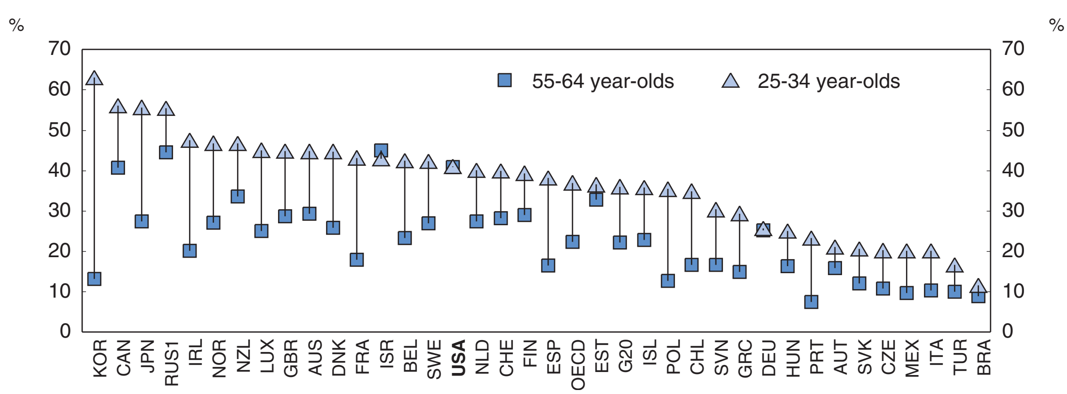
Increasing tertiary education attainment rates

Human capital policies influence the extent to which workers acquire the analytical skills required to adapt to technological change. The greater these skills, the more easily resources can flow to their most productive uses, thereby promoting investments in intangible assets (such as R&D) and innovation.

A major concern in this regard is that tertiary attainment rates in the United States have not been increasing in recent decades, in contrast to most other OECD countries, and for the younger generation, are now exceeded in many other countries (Figure 2.11). The lead that the United States had throughout the post-World War II period in the share of its workforce with tertiary education attainment rates is gradually being eroded as the younger cohorts replace the older ones in the labour force.

Figure 2.11. **US tertiary education attainment rates have stagnated in recent decades**

Population that has attained tertiary education



Note: Countries are ranked in descending order of the percentage of the 25-34 year-olds who have attained tertiary education.

1. Year of reference 2002.

Source: OECD, *Education at a Glance 2011*.

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At the same time, there has been a very large increase in the college wage premium since 1980, from which it can be inferred that the relative demand for college educated workers grew more rapidly than the relative supply over this period (Box 2.2). Indeed, the increase in the college wage premium since 1980 reversed the decline that had occurred since 1915, restoring the college wage premium to approximately its 1915 level (Figure 2.12). Goldin and Katz (2008) estimate that the college wage premium has increased by 24 percentage points since 1980 to 60% in 2005.

Box 2.2. **Growth in the relative supply of college graduates was lower than growth in the relative demand over 1980-2005, fully reversing the declines in the college wage premium that had occurred since 1915**

Growth in the demand for skills can be derived from growth in their supply and in skill earnings premiums. Goldin and Katz (2008) estimate that the average annual growth rate in the relative supply of college-equivalent educated workers (college graduates plus half of those with some college) to high-school equivalent workers (those with 12 years or fewer of schooling plus half of those with some college) was only a little more than half as much over 1980-2005 as over 1960-80 (Table 2.2). The college/high school wage premium, on the other hand grew markedly over 1980-2005 after having stagnated over 1960-80. Assuming an elasticity of substitution between skilled and unskilled workers of 1.64, Goldin and Katz estimate that the annual average growth rate in the relative demand for college educated workers slowed slightly in 1980-2005 from 1960-80; assuming other plausible values for the elasticity of substitution between the two groups of workers does not materially alter this conclusion. Thus, the increase in the college wage premium over 1980-2005 reflects a slowing in the growth of the relative supply of college graduates, not an acceleration in the growth in relative demand for college skills. These authors estimate that growth in the relative demand for college-educated workers has been steady over most of the 20th century. During 1915-60, the relative supply of college-educated workers grew more quickly than demand, driving down the college wage premium. For the period 1915-2005, growth in the relative supply and demand for college educated workers was in balance, leaving the college premium the same at the end of the period as at the beginning.

The "relative wage" shown in Table 2.2 is the log (college/high school) wage differential, which is the college wage premium. The relative supply and demand measures are for college equivalents (college graduates plus half of those with some college) relative to high school equivalents (those with 12 or fewer years of schooling and half of those with some college). The log relative supply measure is given by the log relative wage bill share of college equivalents minus the log relative wage series:

$$\log\left(\frac{S}{U}\right) = \log\left(\frac{w_s S}{w_u U}\right) - \log\left(\frac{w_s}{w_u}\right)$$

where S is efficiency units of employed skilled labour (college equivalents), U is efficiency units of employed unskilled labour (high school equivalents), and w_s and w_u are the (composition-adjusted) wages of skilled and unskilled labour. The log relative wage bill is based on the series for the wage bill share of college equivalents in Appendix Table D.1. of Goldin and Katz (2008). The relative demand measure $\log(D_{su})$ depends on σ_{SU} and follows from equation (3) in the text:

$$\log(D_{SU}) = \log\left(\frac{S}{U}\right) + \sigma_{SU}\log\left(\frac{w_3}{w_u}\right)$$

Box 2.2. **Growth in the relative supply of college graduates was lower than growth in the relative demand over 1980-2005, fully reversing the declines in the college wage premium that had occurred since 1915** *(cont.)*

To maximize data consistency across samples in the measurement of education, changes from 1980 to 1990 use the Current Population Survey (CPS), changes from 1990 to 2000 use the census, and changes from 2000 to 2005 use the CPS. The changes for 1915 to 1940 are for Iowa. See Autor, Katz and Kreuger (1998) for details on the methodology for measuring relative skill supply and demand changes.

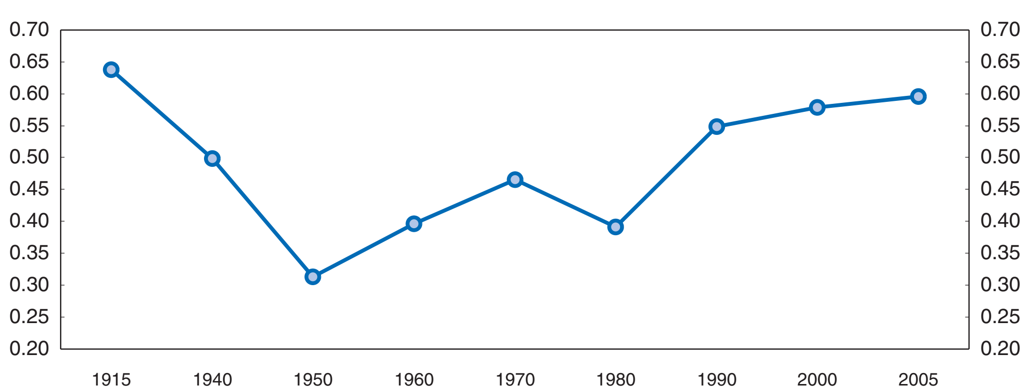
Table 2.2. **Changes in the college wage premium and the supply and demand for college educated workers: 1915 to 2005 (100 * Annual log changes)**

	Relative Wage	Relative Supply	Relative Demand (σ_{SU} = 1.4)	Relative Demand (σ_{SU} = 1.64)	Relative Demand (σ_{SU} = 1.84)
1915-40	–0.56	3.19	2.41	2.27	2.16
1940-50	–1.86	2.35	–0.25	–0.69	–1.06
1950-60	0.83	2.91	4.08	4.28	4.45
1960-70	0.69	2.55	3.52	3.69	3.83
1970-80	–0.74	4.99	3.95	3.77	3.62
1980-90	1.51	2.53	4.65	5.01	5.32
1990-2000	0.58	2.03	2.84	2.98	3.09
1990-2005	0.50	1.65	2.34	2.46	2.56
1940-60	–0.51	2.63	1.92	1.79	1.69
1960-80	–0.02	3.77	3.74	3.73	3.73
1980-2005	0.90	2.00	3.27	3.48	3.66
1915-2005	–0.02	2.87	2.83	2.83	2.82

Goldin and Katz (2009), Table 8.1.

Figure 2.12. **The college/high school wage premium has increased sharply since 1980, reversing earlier declines**[1]

College graduate wage premium (log wage differential, college/high school)



1. 1915 Iowa State Census; 1940 to 2000 US Census IPUMS; 1980, 1990, 2000, and 2005 CPS MORG samples; and February 1990 CPS.

Source: Goldin, C. and L.F. Katz, *The Race Between Education and Technology*, The Belknap Press of Harvard University Press (2008).

StatLink http://dx.doi.org/10.1787/888932638659

An important route for increasing tertiary attainment rates is to increase degree completion rates, which are relatively low. Measures such as those discussed in Chapter 1 to increase completion rates should be implemented. These include making pathways to graduation shorter and more rapid, helping part-time students to reconcile work and study schedules, alleviating liquidity pressures on students and their families, and improving secondary education so that more students are college ready.

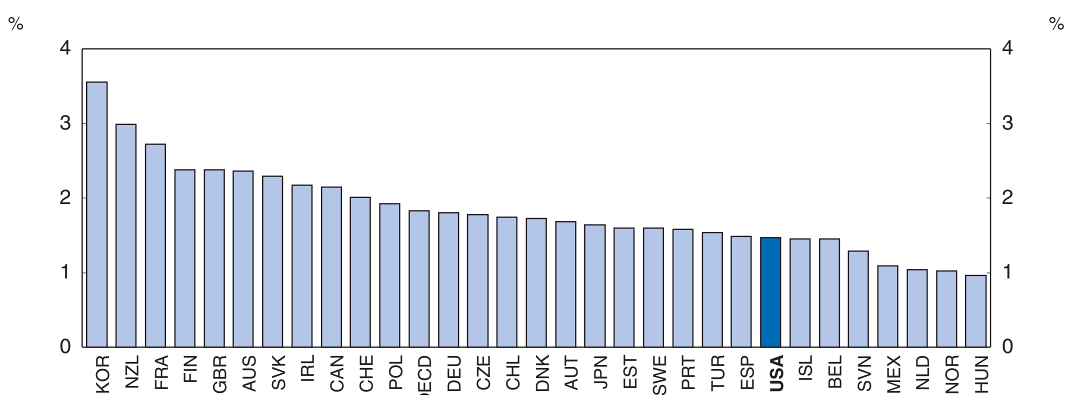
Reducing barriers to graduating in STEM disciplines[13]

STEM graduates are a key input into innovation. However, they represent a relatively low share of persons aged 25-34 years in employment in the United States (Figure 2.13). Moreover, the share of STEM in total graduations has not increased over the past decade except at the PhD level (Table 2.3), despite wage data pointing to persistent and, at lower qualification levels, worsening shortages of STEM workers (Figure 2.14). Langdon *et al.* (2011) estimate that the STEM-earnings premium increased from 18% in 1994 to 26% in 2010. They further estimate that all STEM degree holders receive an earnings premium relative to other college graduates, whether or not they work in a STEM job, although the premium is greater if they do.

Many students enter college intending to major in a STEM field but fewer than 40% of them complete a STEM degree (President's Council of Advisors on Science and Technology, 2012). A major problem is that many students are not well prepared for STEM tertiary studies (OECD, 2009b). The Administration has launched a variety of initiatives to improve secondary-school student achievement in STEM fields. They focus on improving science and mathematics teachers' subject knowledge, pedagogical skills and compensation as well as their evaluation and professional development. Efforts should also be made to increase female achievement, which lags further behind male achievement in these subjects than in most other countries, and achievement of other under-represented groups

Figure 2.13. **The number of STEM graduates in relation to total employment of persons aged 25-34 is relatively low in the United States (2009)**[1]

Number of graduates (science and engineering) divided by the total number of 25-34 year-olds in employment, per cent



Note: Science-related fields include life sciences; physical sciences, mathematics and statistics, computing; engineering and engineering trades, manufacturing and processing, architecture and building.

1. Data for Australia and Canada refer to 2008.

Source: OECD, *Education at a Glance 2011*.

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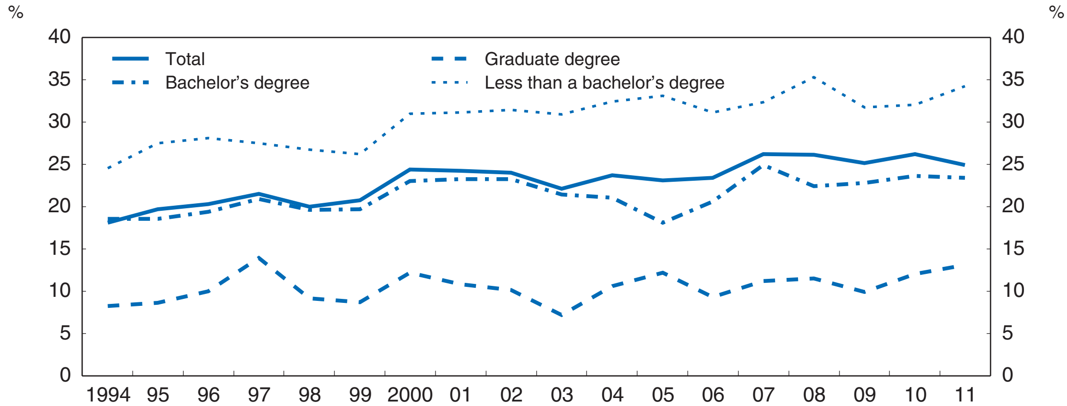
Figure 2.14. **STEM workers receive a significant earnings premium over other workers with the same level of education**[1]

Private wage and salary, workers aged 25 and over



1. Regression-based hourly earnings premiums for STEM workers over non-STEM workers with the same level of education 1994-2010. These earnings regressions (log earnings is the dependent variable) control for age (up to a fourth degree polynomial of age), gender, marital status, race and Hispanic origin, nativity and citizenship, educational attainment, metropolitan area, region, union representation, major industry, STEM occupation, time, and STEM occupation interacted with time (Langdon *et al.*, 2011). The regressions use Current Population Survey public use micro-data files of annual merged outgoing rotation groups from the National Bureau of Economic Research for 1994-2010.

Source: Langdon *et al.* (2011).

StatLink http://dx.doi.org/10.1787/888932638697

Table 2.3. **STEM degrees have grown more slowly than non-STEM degrees, except at the doctoral level**

2000-09

Per cent

	Annual average growth rate		STEM share of all degrees	
	STEM[1]	non-STEM	2000	2009
Doctoral				
All citizenships	5.7	1.5	62.0	66.6
Males	3.5	0.5	67.9	71.3
Females	9.5	2.5	54.5	62.0
US citizen/permanent resident	5.9	1.2	56.9	61.6
Males	3.1	–0.1	61.5	64.3
Females	9.9	1.9	52.0	59.5
Master's				
All	3.0	4.0	21.0	20.0
Males	3.4	3.6	28.3	27.9
Females	3.4	4.7	15.6	15.2
Bachelor's				
All	2.0	3.1	31.8	31.2
Males	2.2	3.1	36.9	36.3
Females	1.8	3.0	28.0	27.5
Associate's[2]				
All	2.9	3.8	5.4	5.0
Males	5.3	2.8	7.8	9.5
Female	–1.5	4.3	3.8	2.3

1. Excludes social scientists.
2. Associate's degrees are the degrees earned from two-year programmes offered by community colleges.

Source: National Science Foundation (2012), *Science and Engineering Indicators*; OECD Secretariat calculations.

(Cook and Kongcharoen, 2010). In the 2009 PISA study, girls' mean score in mathematics lagged that for boys by 20 points, compared with an OECD average of 12 points. In science the mean score was 12 points lower for girls than for boys compared with no gender difference on average across OECD countries (OECD, 2009b). Improving achievement of females and other under-represented groups in mathematics and science would help to narrow gender- and minority gaps in STEM graduation rates and hence, increase the supply of STEM graduates. There may also be a role for public information campaigns to encourage girls and minorities to consider STEM career opportunities.

State governments should also encourage tertiary institutions to take measures to increase STEM completion rates. They should take greater responsibility for bringing first-year students up to the required level. To this end, remedial programmes need to be made more effective (Complete College America, 2011). For engineering, where some 50% of freshmen do not complete the programme, universities should consider introducing an intermediate year so that only students likely to be able to cope are accepted into engineering school. Moreover, engineering programmes should include more applied content and team work in the early years as this has been shown to increase completion rates.

Expanding professional STEM master's programmes may also help to relieve pressure in the market for personnel with advanced STEM qualifications. Many employers claim that graduates of such programmes are better suited to their requirements than PhD graduates and returns on investing in such programmes appear to be high (Science magazine, 30 March 2012, *http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2012_03_30/caredit.a1200036*).

Enhancing opportunities for STEM qualified personnel from overseas to remain in the United States after graduation

Another challenge facing the United States is to ensure an adequate supply of STEM graduates at the PhD level going forward. At the PhD level, one third of STEM graduates are not US citizens or permanent residents (rising to almost 60% in engineering) (National Science Foundation, 2012). There is a risk that fewer such students will in the future come to the United States and that more of those that do will choose not to remain after graduating as universities and economic opportunities improve in their home countries.

In addition to the measures discussed above to increase STEM graduation rates, action is needed on visas to make it easier for graduates of US PhD STEM programmes to gain permanent residence. Most of these students currently plan to stay in the United States after graduating (NSF, 2012). Yet, they often encounter considerable difficulties as few visas per capita are available for citizens of large countries – only 20% of US visas are employment based and there is a cap of 7% on the share of such visas that may be allocated to citizens of any one country (*i.e.,* the limit is the same for a big country as for a small country). Consequently, there are very few visas available to students from China and India who comprise a large share of STEM PhD graduates relative to demand. The share of US visas that are employment based should be increased and the limits per country should be removed.

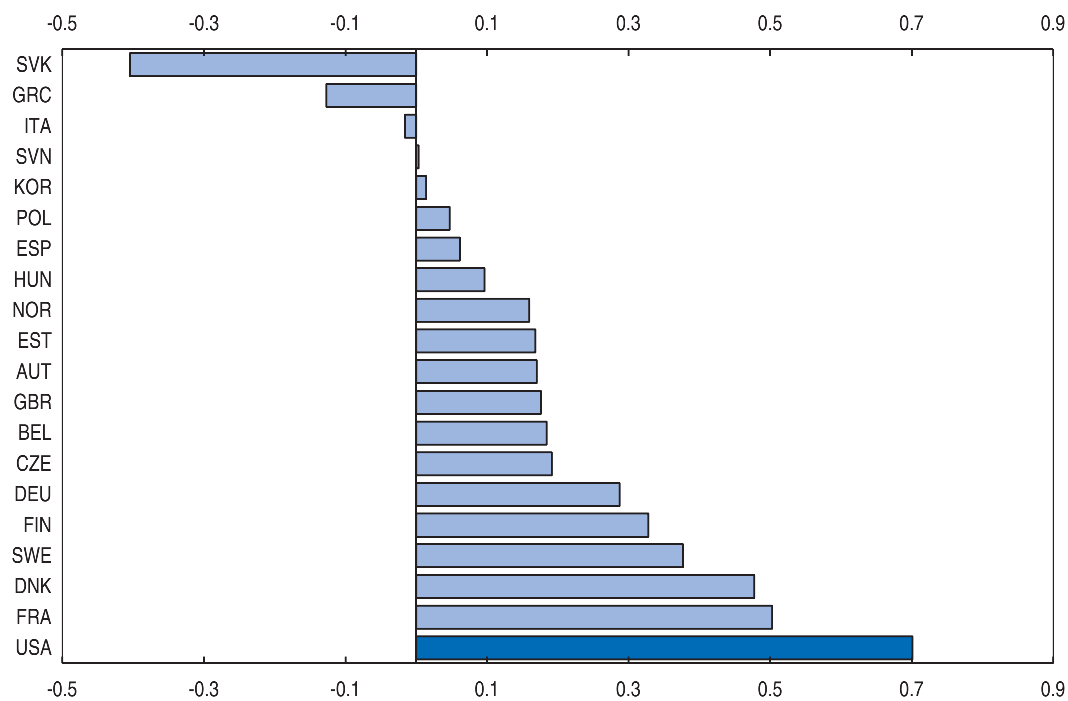
Encouraging entrepreneurship and firm start-ups

For innovations to increase productivity, resources must be transferred to new, more efficient products and processes from less efficient ones. The more easily that resources can be transferred, the greater will be productivity growth and incentives to innovate, leading to still more resource reallocation and productivity growth. An indicator of the degree to which resources are allocated to their most efficient uses is the extent to which *ceteris paribus* the most productive firms hold the largest market shares (Olley and Pakes, 1996). Estimates using a similar metric indicate that the United States is the world leader in allocating resources to their most efficient uses – firms with higher than average labour productivity have a higher share of employment than in any other OECD country (Figure 2.15).

Nevertheless, business start-up employment as a share of total employment has declined in the past decade, raising concerns about the rate at which would-be entrepreneurs are turning new ideas into new businesses (Figure 2.16). One factor that may have contributed to this decline is that access to the high-risk capital on which innovation-based entrepreneurial firms depend has diminished (Figure 2.17). Following the "dot-com"

Figure 2.15. **The contribution of the allocation of employment across firms to aggregate labour productivity is higher in the United States than in other OECD countries**

Log points; selected OECD Countries in 2006



Notes: The estimates show the extent to which the firms with higher than average labour productivity have larger employment shares, based on the Olley and Pakes (1996) decomposition of the log level of labour productivity. In most countries, the covariance between productivity and employment shares is positive, suggesting that the actual allocation of employment boosts aggregate labour productivity, compared to a situation where resources were allocated randomly across firms (this metric would equal zero if labour was allocated randomly). Labour is allocated relatively efficiently in the United States and some large Continental and Northern European countries – *e.g.* aggregate productivity in the United States is boosted by over 50% due to the rational allocation of resources – while there is considerable scope to improve resource allocation in most southern and eastern European countries. The sample excludes firms with one employee as well as firms in the top and bottom 1% of the productivity distribution. To enhance representativeness, re-sampling weights based on the OECD Structural and Demographic Business Statistics are applied.

Source: Andrews and De Serres (forthcoming 2012).

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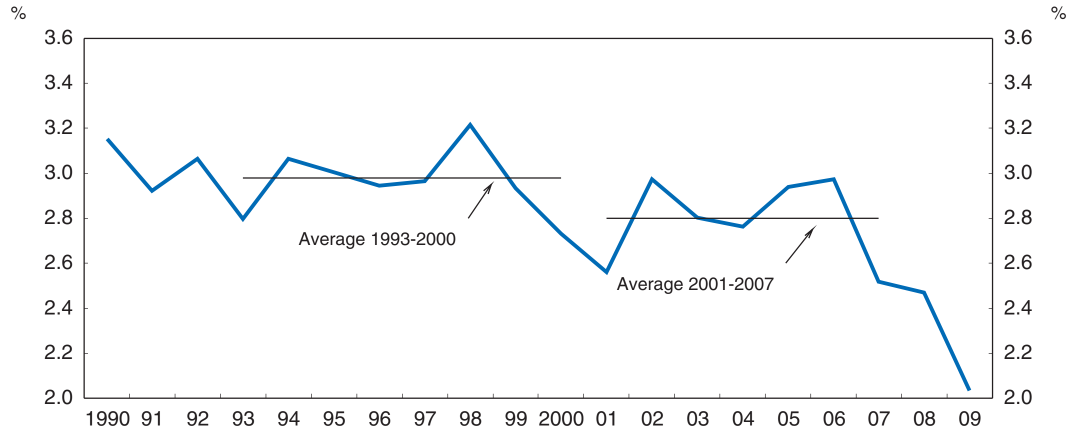
Figure 2.16. **Start-up employment has declined as a share of total employment**

Start-up job creation out of total business employment, in percentage

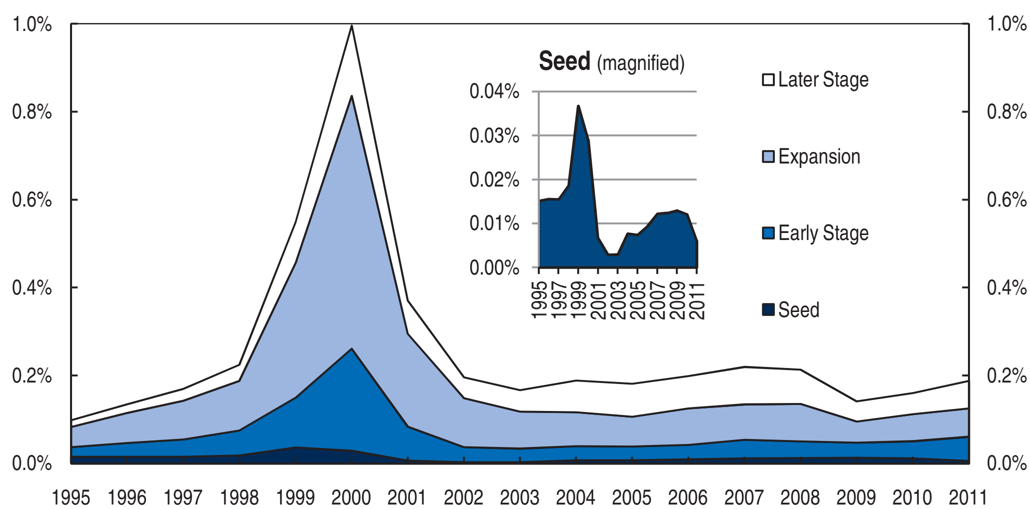


Source: US Census Bureau, Business Dynamics Statistics, *Longitudinal Business Database*.

StatLink http://dx.doi.org/10.1787/888932638735

Figure 2.17. **Seed/start-up financing has diminished**

Per cent of GDP



Note: Seed/Start-up stage: the initial stage. The company has a concept or product under development, but is probably not fully operational. Usually in existence less than 18 months. Early stage: The company has a product or service in testing or pilot production. In some cases, the product may be commercially available. May or may not be generating revenues. Usually in business less than three years. Expansion stage: Product or service is in production and commercially available. The company demonstrates significant revenue growth, but may or may not be showing a profit. Usually in business more than three years. Later stage: Product or service is widely available. Company is generating on-going revenue; probably positive cash flow. More likely to be, but not necessarily profitable. May include spin-offs of operating divisions of existing private companies and established private companies.

Source: PricewaterhouseCoopers/National Venture Capital Association MoneyTree™ Report, Data: Thomson Reuters.

StatLink http://dx.doi.org/10.1787/888932638754

bust of a decade ago, and reinforced by the economic downturn of the past three years, a greater share of high-risk capital is invested in later stage of development innovative firms, which tend to be less risky than start-ups, than before.

A variety of approaches to alleviate these pressures are being publicly discussed and, in some cases, experimented. These include: federal R&D agencies to finance very early-stage companies through add-ons to existing grants to support taking spin-offs to market; creation of a new federal programme to provide competitive funding to support proof-of-concept research at universities (the NSF is experimenting with this kind of funding programme through its Innovation Corp programme); "crowd funding", under which entrepreneurs with ideas seeking financing use the Internet to advertise their ideas and seek investments in small amounts from many small investors, as authorized in the Jumpstart Our Business Startups Act (JOBS Act); and providing matching funds and various forms of non-financial assistance to entrepreneurs with good ideas that are worthy of financing but are at too early a stage, and therefore, too risky to attract private capital. Following careful analysis and evaluation, the federal government should implement the most promising of these approaches.

These proposals fall within the scope of the Startup America initiative launched by the Administration in 2011 to improve the environment for high-growth entrepreneurship. They could usefully be complemented by the other main aspects of this initiative: creating mentorship and educational opportunities for entrepreneurs; reducing regulatory barriers; and driving a nationwide effort to engage potential new opportunities in industries like healthcare, clean energy, and learning technologies (US Department of Commerce, 2012). The federal government also runs a number of programmes to promote high-growth potential entrepreneurship at the regional level, including through the development of innovation clusters.

Entrepreneurial activity could be further enhanced by limiting clauses in employment contracts that expressly prohibit individuals from competing with their former employers (known as non-compete covenants). It has been found that stricter enforcement of such contracts is associated with lower rates of entrepreneurial start-ups, innovation and employment growth (Samila and Sorenson, 2011; Marx *et al.*, 2010).

Building a better social safety net would also encourage firm start-ups by reducing the potential costs of failure for entrepreneurs and their families. The Health Care Act of 2010 makes an important contribution to improving the safety net for entrepreneurs and making small firms more attractive to work for by reducing the costs of individual or small group policies. Similarly, the reforms proposed in the FY 2013 budget to encourage small firms to offer for the first time qualified employee retirement plans will help to make working for small firms more attractive.

Establish a national innovation agency to enhance coherence, continuity and coordination in innovation policy development and implementation

In contrast to other advanced economies, the United States does not have an agency responsible for national innovation policy. Instead, innovation policy (or strategy) is developed by the White House (usually by the National Economic Council and the Office of Science and Technology Policy) with help from the Secretary of Commerce and various agencies within the Department of Commerce (notably USPTO, NIST and the Economics and Statistics Administration [ESA]). While there have been efforts to provide line agency support for technology policy, such as the former Office of Technology Policy, they have lacked the scale and stature needed to sustain a disciplined evidence-based focus on innovation policy and strategy from one administration to the next. To address this problem, a line agency should be given responsibility and capacity for sustaining policy analysis and development across the government and serving as a point of coordination for other agencies' activities. The agency could be housed conspicuously within National

Institute of Standards and Technology, along with the proposed National Network for Manufacturing Innovation. This would fit with the remit of the Under Secretary for Standards and Technology and the fact that there is a programme office in the NIST director's office that is already well-regarded for its analytic work on technology policy. Alternatively, if the President's proposal to reorganize federal trade-related and small-business agencies is adopted, the agency could provide a high-level focus on the innovation agenda within the Department of Commerce, drawing on the Economic Development Administration, the Patent and Trademark Office, ESA, NIST and other innovation-related elements of the Department of Commerce. Either way, the resource would provide permanent capacity to address the changing technological, market, and geopolitical environment, *i.e.,* expertise and institutional memory that carries forward across administrations and congresses, strengthen collaboration, analysis and implementation across the government and serve as a regular interface with experts in industry, state and local governments, think-tanks, academia, and other national governments.

Box 2.3. **Recommendations for strengthening innovation**

Key recommendations:

- Given the importance of R&D for innovation and economic growth, reductions in the federal R&D budget should be as limited as possible. Ideally, funds would be appropriated to continue on the path approved in the 2007 America COMPETES Act of doubling the budgets for three key science agencies within a decade.
- Patent reform (America Invents Act) needs to be taken further by ensuring that the legal standards for granting injunctive relief and damages awards for patent infringement reflect realistic business practices and the relative contributions of patented components of complex products.
- Tertiary education attainment in STEM fields needs to be increased. An important step in doing so is improving access to quality secondary education so that students are better prepared for STEM tertiary studies.

Other recommendations:

- Complement an increase in funding for basic and long-term research that can reduce pollution abatement costs by pricing environmental externalities. Until Greenhouse Gas (GHG) emissions are priced, impose higher gasoline taxes.
- Implement the measures proposed by the Administration to strengthen manufacturing competitiveness, including lowering corporate tax rates and discouraging corporations from shifting profits offshore, making the R&E tax credit permanent and less complicated, investing in transport infrastructure, creating a fund for community colleges to partner with businesses to train workers for advanced manufacturing, increasing support for basic research and creating a network of manufacturing institutes to facilitate the transfer of new technology from invention to product development to manufacturing at scale.
- Raise tertiary graduation rates by taking measures to increase degree completion rates, including by improving secondary achievement so that students are more college ready. In STEM disciplines, state governments should encourage universities to take measures

Box 2.3. **Recommendations for strengthening innovation** *(cont.)*

to increase completion rates by improving remedial programmes and mentoring especially women and other under-represented groups and, in engineering, also by including more applied and team work in the early years.

- To increase the retention rate of foreign STEM PhD graduates, the share of visas that are employment based should be increased and the restrictions on country of origin should be removed.
- Encourage innovation-based entrepreneurship by increasing access to capital that supports young firms and by limiting non-compete covenants in employment contracts.
- Establish a national innovation office to increase coherence, continuity and coordination in innovation policy development and implementation.

Notes

1. Triadic patent families are defined as those patents applied for at the European Patent Office (EPO), the Japan Patent Office (JPO) and the US Patent and Trademark Office (USPTO) to protect a same invention. Triadic patents are typically of higher value and eliminate biases arising from home advantage and the influence of geographical location (OECD, 2011a).
2. A "start-up package" is the collection of benefits, other than direct compensation and personal benefits like health insurance, that is offered to prospective new faculty members to entice them to accept a job offer. For science, engineering and medical faculty members start-up packages might include things like:
   - a budget for purchase of experimental equipment and for its operation and maintenance;
   - a budget for the salary of specialized technicians if they are needed to operate especially sophisticated equipment;
   - a budget to pay the salary and associated running costs for one or more graduate assistants and/or post-doctoral associates;
   - a budget to pay for travel to professional meetings;
   - guaranteed access to be able to use equipment already purchased for other faculty members on a shared basis; and
   - less commonly, an opportunity to serve, for pay, on the board of a company that is supportive of the university or to be a consultant to such a company. Usually, funds in support of these packages are intended to be spent in the first two to five years of a faculty member's appointment to help establish him or her more or less immediately as an active researcher. Universities compete for top talent based in part on the size of these packages.
3. Lawsuits by non-producing patent-assertion entities (popularly known as "trolls") are only filed on average eight years after the patent has been issued (Bessen *et al.*, 2012).
4. The "domestic industry" requirement for filing before the ITC has been interpreted liberally to include any domestic company with a patent licensing programme. In many cases, patent holders sue in district court as well, since the ITC cannot award damages.
5. "Lower front-end fees encourage innovation, publication of new ideas, and knowledge sharing. This is good for the economy by encouraging research and development and promoting competition" (USPTO, 2012).
6. While aggregators may assert patents, they are distinguished from assertion specialists by virtue of acquiring substantial portfolios that are licensed on a nonexclusive basis to investors, members, or other insiders. The patents held by aggregators may be sold for use in counter assertions, perhaps with buyback arrangements. Or they may be asserted against outsiders, either directly, through shells, or simply through sales to assertion specialists.
7. This section draws heavily on OECD (2011c).

8. This estimate comes from the WITCH-model, which incorporates a detailed representation of the energy sector into an inter-temporal growth model of the economy and, in contrast to most of the literature, does not assume that backstop technologies emerge without dedicated investments. The way in which the impacts of R&D (and learning-by-doing) on the costs of these "backstop" technologies are incorporated into the model relies partly on past experience with solar, wind and nuclear power.
9. The other action plans are: advanced vehicles (led by Canada); bio-energy (led by Brazil and Italy); carbon capture, use and storage (led by Australia and the United Kingdom); high-efficiency-low-emissions coal (led by India and Japan); marine energy (led by France); smart grids (led by Italy and Korea); solar energy (led by Germany and Spain); and wind energy (led by Germany, Spain, and Denmark).
10. OECD calculations based on data in Table 1 of Raymond M. Wolfe, Business R&D Performed in the United States Cost USD 291 billion in 2008 and USD 282 billion in 2009, US National Science Foundation, NSF 12-309, March 2012. On line at: *http://nsf.gov/statistics/infbrief/nsf12309/*.
11. Growth in real output and labour productivity in manufacturing, however, may have been overstated during the past two decades owing to errors in the way that growth in imported inputs to manufacturing has been allocated to prices (overestimated) and volumes (underestimated) (Houseman *et al.,* 2011; Mandel, 2011).
12. Homepage Fraunhofer-Gesellschaft : *www.fraunhofer.de/en.html*. The *Fraunhofer* is a network of some 80 applied research institutes in Germany. It also supports institutes in other countries, including eight in the United States. The individual institutes carry out research of interest to industry, with each institute focused on a particular technical area. About 70% of the *Fraunhofer* budget comes from industrial contracts and 30% from public authorities in Germany.
13. While standard practice in the United States is to include the social and behavioral sciences in the "STEM" disciplines, in this report, we systematically exclude those fields from the STEM totals.

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