Executive Summary

Economic growth has been a powerful force for reducing poverty, creating jobs and improving general living standards. However, it cannot be taken for granted. Before the 18th century the world economy saw little growth. Poverty was widespread and any substantial improvement in living standards for more than the privileged few was beyond imagining. Since then, the world economy has grown at an unprecedented pace – greatly improving the quality of life and generating widespread material prosperity. Even so, some national economies have seen faster and more sustained growth than others, leaving wide disparities in the prosperity of nations today.

One central insight from scholarly research is that lasting economic growth relies on continuous technological progress. Indeed, the last three centuries have seen a series of innovative breakthroughs in different fields of technology that have profoundly transformed productive activity and spurred the growth of new industries. How did these breakthrough innovations come about and how did they increase economic output? Answers to these questions are important, as policymakers continuously strive to improve the enabling environment for future growth. Indeed, as the world economy still reels some seven years on from the global financial crisis, there is serious debate as to whether innovation can continue to deliver rates of growth matching those before the crisis.

This report endeavors to provide an analytical input into that debate. It explores the channels through which innovation promotes growth, and the ecosystems in which innovation flourishes. In so doing, the report pays special attention to the role of the intellectual property (IP) system, which at its heart seeks to support innovative activity.

In addition to reviewing historical patterns of growth and conceptualizing the linkages between innovation and growth, the report's main analytical contribution consists of six case studies of breakthrough innovations. In particular, it focuses on three historical innovations and three innovations which currently hold breakthrough potential (see table 1). Through case studies, one can take account of the different nature of innovative breakthroughs and the evolving context in which innovation takes place. In addition, even though many conclusions are specific to the six cases and may not be generalizable, the commonalities and differences presented by the cases offer food for thought on which policy approaches work best in alternative circumstances.

Table 1: Breakthrough innovations studied in this report

Historical innovations	Current innovations
Airplanes – from hobbyists gliding in the 19th century to a reliable mode of transportation in the first half of the 20th century	*3D printing* – the creation of 3D objects through successive layering of material, aided by digital technology
Antibiotics – from the discovery of sulfa drugs in the 1930s to the birth of the modern pharmaceutical industry	*Nanotechnology* –technology at the scale of one-billionth of a meter, with applications in electronics, health, materials, and other fields
Semiconductors – from amplifying radio waves for better communication in the early 20th century to ever-more potent computer chips driving the ICT revolution	*Robotics* – from the first robots spurring industrial automation to today's autonomous machines with artificial intelligence

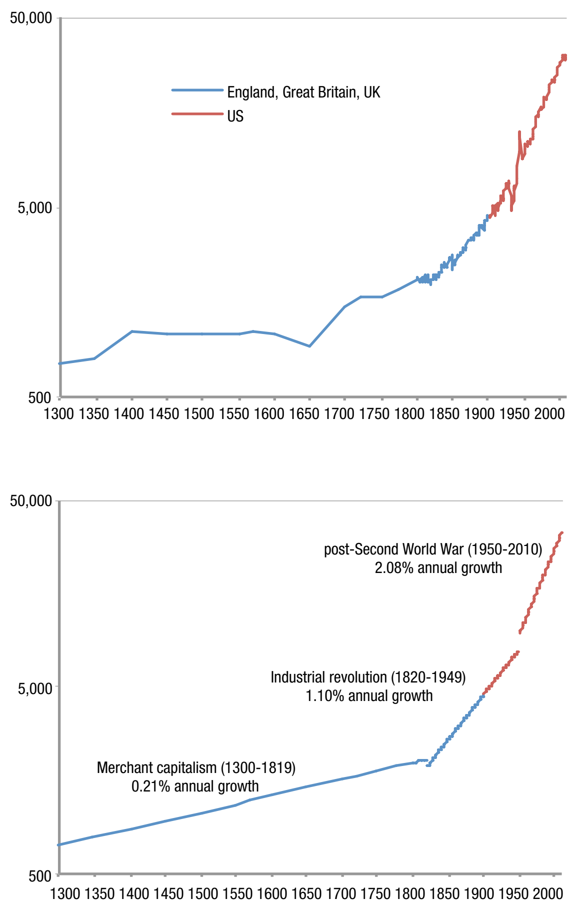
Economic growth throughout history

Growth at the frontier took off in the early 19th century and accelerated in the post-Second World War era

Relying on the most comprehensive set of historical estimates available, figure 1 depicts the evolution of GDP per capita at the frontier since 1300. The frontier here means the economy showing the highest economic output per capita at a given point in time. For the purpose of figure 1, these are taken to be England, Great Britain and the United Kingdom (UK) up to 1900, and the United States (US) thereafter.

Figure 1: Growth at the frontier over seven centuries

Real GDP per capita, 1300-2000, logarithmic scale



See figure 1.1

The figure's lower panel divides the seven centuries into three growth periods. The first period, up to the early 19th century, saw only little and sporadic growth, averaging around 0.2 percent per year. The onset of the industrial revolution then led to a sharp increase in the annual rate of growth, to 1.1 percent. Finally, in the post-Second World War era, growth accelerated further to 2.1 percent per year – implying a doubling of income every 34 years. In light of centuries of history, the growth performance since 1950 thus emerges as both spectacular and exceptional.

Diverging growth paths have increased the gap between the poorest and richest countries…

Outside the group of frontier economies, growth performance has been mixed. While selected once-poor economies – notably in East Asia – were able to catch up with the frontier group, no general process of converging per capita incomes has taken place. As a result, the inequality in the prosperity of nations has widened since the 19th century.

…even if fast growth in China and India has been an equalizing force in the world's income distribution and has caused absolute poverty to decline

Widening income inequality across economies does not necessarily imply that the world has become a more unequal place. The distribution of income among citizens worldwide – which takes into account the population size of different countries as well as income inequality within countries – offers a more optimistic picture. Studies focused on the last several decades have shown that the fast growth of populous and initially poor Asian economies, notably China and India, has been an equalizing force in the world's income distribution. In addition, using different poverty thresholds, these studies uniformly document a substantial reduction in absolute poverty levels.

How innovation drives economic growth

Decades of scholarly research in economics have established the central role that innovation plays in driving long term growth. Yet quantifying the innovation contribution – which innovations have accounted for how much growth during which time period – is challenging. The infographic at the end of this report depicts some of the most important innovative breakthroughs over the past 200 years against the background of the frontier growth path shown in figure 1. It is meant as an illustration, and the selection of technologies is subjective.

Despite the quantification challenge, the channels through which innovation spurs growth are well understood conceptually.

Innovation prompts capital deepening...

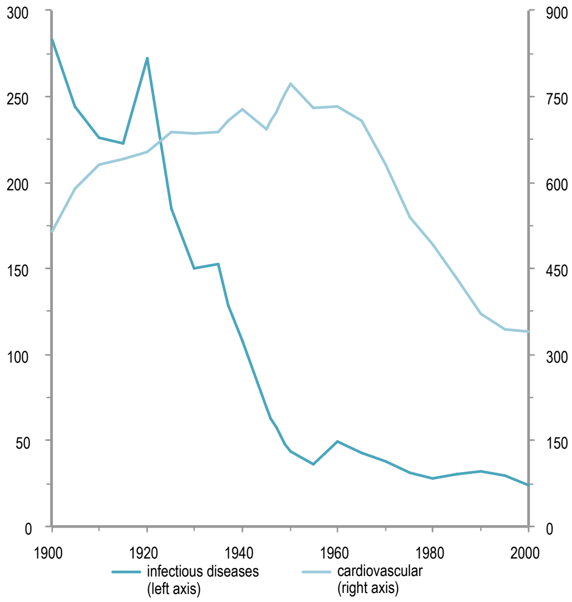
Firms invest in new capital equipment based on the future income they expect those investments to generate. The introduction of new technologies can raise investment returns and lead firms to undertake new investments. Historically, the introduction of major breakthrough technologies has often unleashed investment booms, driving expansions in economic output. The semiconductor case study, for example, discusses evidence that shows that as ICTs took off in the 1990s, firms throughout the US economy rapidly increased their ICT capital stock, especially when compared with other fixed capital assets. In addition, intangible asset investments – the establishment of new business processes, databases and other knowledge-based activities – have become an important component of overall investments and are also linked to the introduction of new technologies.

...supports a growing, healthier and better-educated labor force...

Innovation has been a key force behind the expansion of the workforce. Advances in health technology have prompted a dramatic increase in life expectancy. In 1800, average life expectancy at birth was below 40 years in all developed economies; by 2011 it had risen above 75 years, with Japan seeing the highest average of 83 years. Figure 2 – drawn from the antibiotics case study – illustrates the dramatic reduction in mortality since the arrival of the first antibiotic medicines in the 1930s.

Figure 2: Antibiotics had a profound effect on human health

Mortality due to infectious and cardiovascular diseases, deaths per 100,000 inhabitants, 1900-2000



See figure 2.4

Innovation has also been instrumental in facilitating greater adult participation in the workforce. For example, the arrival of speedy mass transportation has reduced geographical barriers in the labor market. It has similarly promoted access to education. Advances in educational technology, in turn, have widened and deepened educational achievements, leading to a better-educated labor force.

...raises the productivity of firms...

Innovation can affect the productivity of firms through a variety of channels. *Process and organizational innovations* can increase the efficiency with which inputs – especially labor – are converted into output. The resulting productivity enhancements free up resources that can be used to expand output – in the same firm, in the same sector, or elsewhere in the economy.

Product innovation can also have an important effect on firm productivity, especially if it takes the form of powerful new or improved intermediate inputs. The case studies in this report offer numerous examples of radical new products and services that have changed the face of productive activity – including air transport, computers, industrial robots and 3D printers.

...and transforms economic structures

Innovation is often at the root of profound structural transformation. In the medium to long term, such structural transformation affects an economy's productivity through a variety of channels:

- Innovation can change the face of industries, leading to the exit of some firms and the entry of others. In many cases, these changes prompt growth-enhancing efficiency gains and redeployment of production factors.
- Breakthrough innovations typically unleash a reorganization of supply chains, with firms developing unique expertise and specializing in producing goods and services that serve a variety of companies, within and across industries. Technological innovation has also driven the globalization of supply chains – amplifying gains associated with greater specialization.
- As technological innovation gives rise to new economic activity, it prompts the decline of older activity. In the short and medium term, such technological disruption may create hardship for workers whose tasks have become redundant. However, in the long run, the redeployment of workers in growing sectors of the economy represents one of the most important ways through which innovation can generate output growth. In practice, technological progress has prompted a substantial shift away from agriculture and industry toward the service sector. This has largely reflected substantially faster historical rates of productivity growth in agriculture and industry, compared with labor-intensive services.

The diffusion of innovations matters...

For technological breakthroughs to spur economic growth, they need to diffuse widely throughout the economy. Firms need to learn how to use a new technology, undertake capital investments, reorganize business operations and train workers. Indeed, the arrival of new technologies typically spurs complementary organizational and business model innovations that, in themselves, are responsible for major productivity gains. Competitive dynamics, access to finance, standard-setting and technical regulations, among other determinants, can shape the technology diffusion path in important ways.

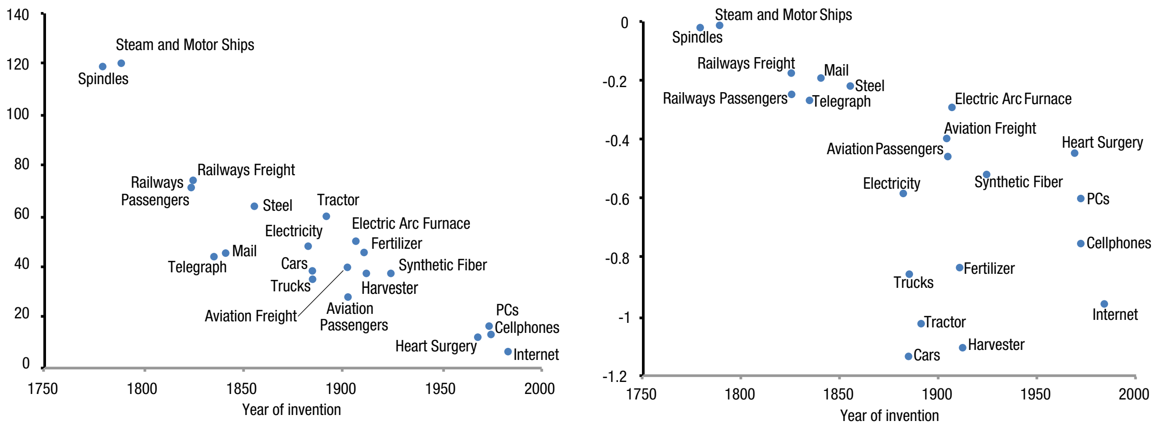
...and differs greatly across technologies and recipient countries

How easily does technology diffuse across economies, especially to less developed ones? This question is important. Given the significance of innovation in driving long-run growth, imperfect technology diffusion might be one explanation for diverging levels of economic prosperity.

Recent evidence on technology diffusion patterns points to a mixed picture. On the one hand, it suggests that more recent technological innovations have diffused more rapidly to low- and middle-income countries (see left panel in figure 3). On the other hand, it also suggests that more recent innovations have seen a greater gap in how intensively economies use technology (see right panel in figure 3).

Figure 3: Faster but less pervasive technology diffusion

Adoption lag since first invention, in years | **Difference in penetration rates, in logs**



See figure 1.8

For economies to make productive use of technologies developed abroad, they need to possess sufficient *absorptive capacity* – including the human capital able to understand and apply technology, organizational and managerial know-how, and institutions that coordinate and mobilize resources for technology adoption. In many cases, absorptive capacity also entails the ability to undertake incremental technological and organizational innovation in order to adapt technology to local needs.

Ecosystems giving rise to breakthrough innovation

What kind of ecosystem best supports the flourishing of innovation and the adoption of new technologies? The six case studies included in this report point to a number of well-known elements of success:

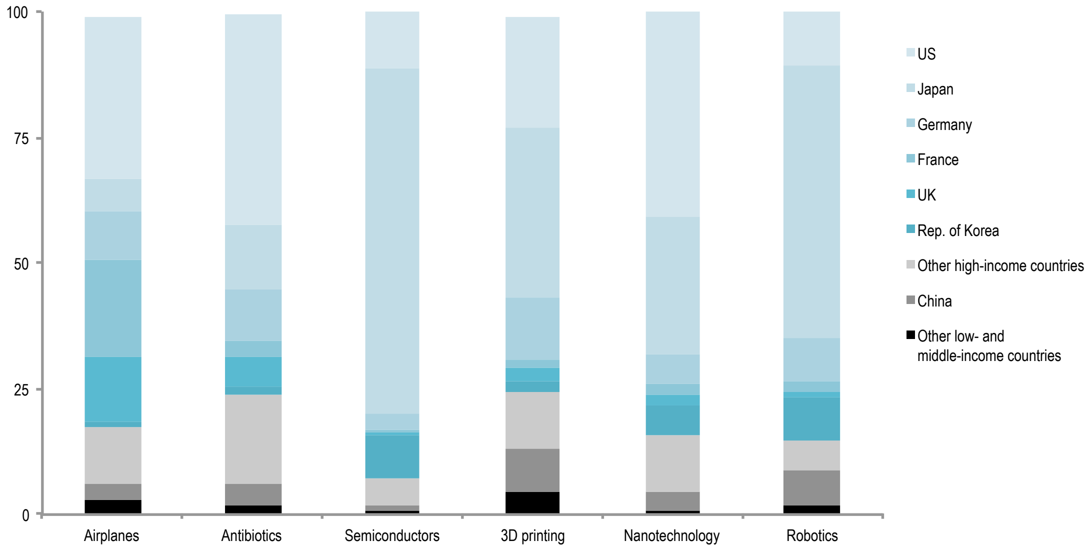
- Governments have been the main source of funding for scientific research that was often instrumental in inventive breakthroughs. In many cases, governments have also played a crucial role in initially moving promising technology from the laboratory to the production stage – often motivated by national defense and industrial policy interests.
- Competitive market forces and efforts on the part of firms were equally crucial, especially in commercializing promising ideas and engaging in follow-on innovation that facilitated scaled-up production, cost reductions and wide-scale adoption of new technologies.
- Linkages between the various innovation actors mattered. They ranged from informal knowledge exchanges, professional networks and worker movements to formal university–industry licensing frameworks and R&D collaborations. They promoted the sharing of knowledge among researchers and connected the upstream and downstream activities that helped transform promising ideas into commercial technologies.

Patenting activity associated with the six breakthrough innovations has been geographically concentrated...

The case studies identify the patents filed around the world that are associated with each of the six breakthrough innovations. While not offering a perfect mirror of the innovation landscape, the resulting patent mappings offer rich information on the geographical and institutional origin of inventions – especially those with commercial potential. They show that across all six case studies, patenting activity has been geographically concentrated (see figures 4 and 5 as well as table 2). High-income countries account for more than 80 percent of filings in all six cases. Even within high income countries, patent filings are concentrated, with the US, Japan, Germany, France, the UK and the Republic of Korea accounting for 75 percent or more of first filings worldwide.

Figure 4: Patenting activity has been geographically concentrated

Share of first patent filings in world total

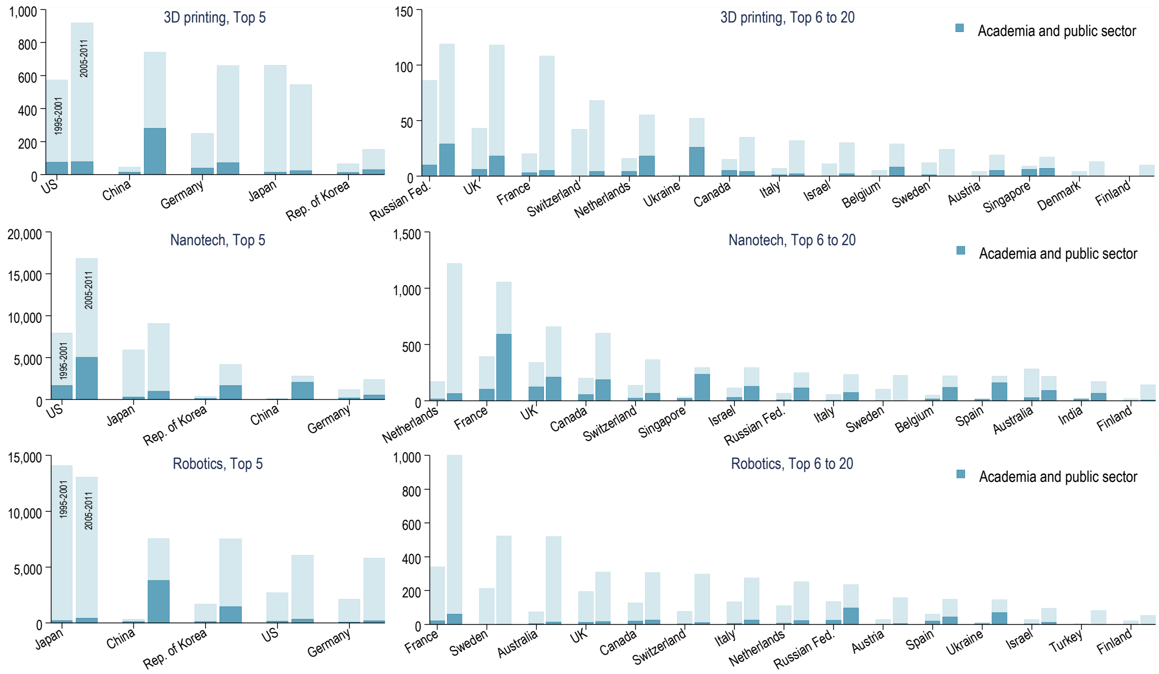


Notes: This figure is a summary of figures 2.3, 2.5, 2.8, 3.2, 3.7 and 3.12, covering the same time periods as the ones shown in those figures. Note that the bars do not exactly sum up to 100 percent, reflecting unknown origins in less than 1 percent of first patent filings.

Source: WIPO based on PATSTAT database (see technical notes).

Figure 5: Which countries drive patenting in 3D printing, nanotechnology and robotics?

Top 20 origins in first patent filings, 1995-2001 and 2005-2011



Source: WIPO based on PATSTAT database (see technical notes).

Table 2: Five countries between them account for the top 10 patent applicants

Top 10 patent applicants in 3D printing, nanotechnology and robotics since 1995

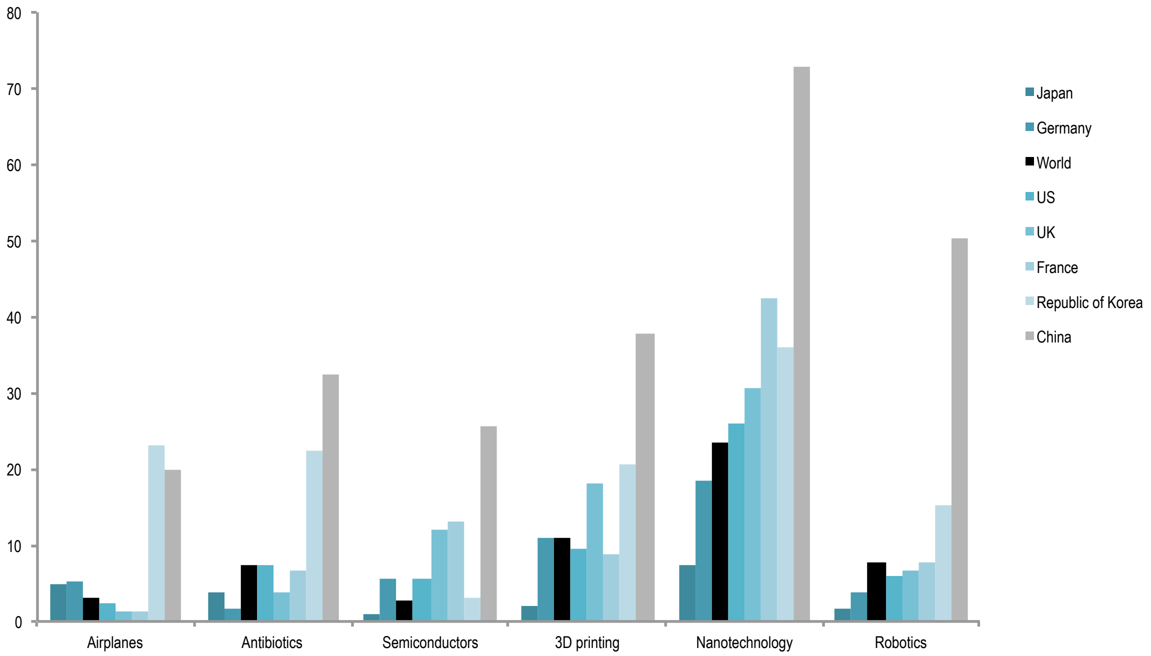
3D printing			Nanotechnology			Robotics		
Applicant	Origin	First filings	Applicant	Origin	First filings	Applicant	Origin	First filings
3D Systems	US	200	Samsung Electr.	KR	2,578	Toyota	JP	4,189
Stratasys	US	164	Nippon Steel	JP	1,490	Samsung	KR	3,085
Siemens	DE	145	IBM	US	1,360	Honda	JP	2,231
General Electric	US	131	Toshiba	JP	1,298	Nissan	JP	1,910
Mitsubishi	JP	127	Canon	JP	1,162	Bosch	DE	1,710
Hitachi	JP	117	Hitachi	JP	1,100	Denso	JP	1,646
MTU Aero Engines	DE	104	Univ. of California	US	1,055	Hitachi	JP	1,546
Toshiba	JP	103	Panasonic	JP	1,047	Panasonic	JP	1,315
EOS	DE	102	Hewlett Packard	US	880	Yaskawa	JP	1,124
United Technologies	US	101	TDK	JP	839	Sony	JP	1,057

Notes: CN = China, DE = Germany, JP = Japan, KR = Republic of Korea, US = United States

See tables 3.3, 3.7 and 3.10

Figure 6: The share of academic patenting is higher for today's innovations

Share of university and PRO applicants in first patent filings, in percent



Note: This figure covers the same time periods as the ones shown in figures 2.3, 2.5, 2.8, 3.2, 3.7 and 3.12.

Source: WIPO based on PATSTAT database (see technical notes).

...although China has emerged as an important origin of patenting activity in more recent history

If one looks at more recent history, China emerges as an important origin of patents in 3D printing, nanotechnology and robotics. In particular, looking at first patent applications filed since 2005, Chinese applicants account for more than a quarter of first filings worldwide in the case of 3D printing and robotics – the highest share among all countries. In the case of nanotechnology patent filings since 2005, Chinese applicants make up close to 15 percent of fillings worldwide – the third largest origin of patents.

Innovation today appears to be more closely connected to science than in the past...

Another notable finding from the patent mapping is that the science system and formal linkages between scientific institutions and companies appear to be more important today than in the past. Figure 6 depicts the share of applicants from universities and public research organizations (PROs) for the six innovations studied in the report. It shows higher shares of academic patents for 3D printing, nanotechnology and robotics, compared with the three historical cases. Nanotechnology stands out, with academic applicants accounting for around a quarter of patenting worldwide. Interestingly, the academic patenting share has increased in most countries since nanotechnology took off in the 1980s, suggesting that the scientific base of nanotechnology innovation has become even more important in more recent history.

The greater prominence of universities and PROs in patent landscapes may partly reflect policy efforts to better harness the results of scientific research for commercial development. However, those policy efforts arguably recognize the critical role that upstream research plays in downstream technological progress.

...while the share of academic patents differs markedly across countries

While academic patenting has become more prominent across most of the major patenting origins, there are also notable differences. In the case of Japan, universities and PROs never account for more than 10 percent of total first filings. By contrast, China generally shows the highest shares of academic patenting, exceeding 70 percent for nanotechnology and 50 percent for robotics. On the one hand, this may suggest more limited R&D capacity in Chinese firms in the relevant technology fields, which may imply a lower rate of technology commercialization. On the other hand, as the historical case studies illustrate, a strong scientific base may, in the long term, spawn new firms and industries once technological breakthroughs occur.

The evolving role of IP

IP incentivizes innovation...

As the patent mappings illustrate, innovators in all six cases relied on the patent system to protect the fruits of their innovative activities. In some cases – especially semiconductors – they did so extensively. Their motivations for doing so varied, but available evidence suggests that IP protection contributed at least partially to R&D appropriation – thus indicating that IP rights mattered for innovation incentives.

...and enables technology markets

Equally important, the six case studies document how innovation flourished as a result of implicit or explicit knowledge-sharing arrangements. For example, the first clubs of amateur airplane inventors in the 19th century operated not unlike the open-source communities which today contribute to 3D printing and robotics research. In the case of semiconductors, cross-licensing agreements were important for the commercialization of new technologies and follow-on innovation. Today, many firms engaging in 3D printing, nanotechnology and robotics research have embraced open innovation approaches. They recognize that they may be better innovators by collaborating with others even if that involves some sharing of proprietary knowledge.

In many cases, the IP system has facilitated the sharing of knowledge, by encouraging disclosure and providing a flexible tool for innovators to decide which technologies to share, with whom and on what terms. However, the cases studies also illustrate the importance of social norms in supporting knowledge sharing and the role of government intervention to encourage knowledge sharing when it is in the public interest.

While technology markets were already important for the development of airplanes in the early 20th century, they are bound to be more important today. Pushing the technology frontier requires increasingly complex technological challenges to be overcome. The more prominent role of upstream scientific research is one response to this challenge (see above). In addition, the case studies suggest that firms increasingly specialize, realizing that they may be both more innovative and more efficient by focusing on selected research, development, manufacturing, or marketing tasks. By providing a flexible basis for licensing, IP enables specialization and is at the heart of modern technology markets.

One possible concern about today's innovation ecosystems is the large number of patent filings, which may give rise to patent thickets that could stifle rather than enable technology markets. In addition, there are concerns that widespread patenting might inhibit knowledge sharing. However, the evidence presented in the 3D printing, nanotechnology and robotics case studies suggests that so far, patent thicket concerns have not materialized and the IP system appears to have accommodated different knowledge-sharing mechanisms. It is important to keep in mind, however, that many of the technologies discussed in these case studies are still at a relatively early stage of development and some have yet to see any commercialization. There may well be greater conflicts surrounding IP in the future.

Patent applicants mainly seek protection in high-income markets

The patent mappings carried out for the six case studies uniformly suggest that innovators have overwhelmingly sought patent protection for their inventions in high-income countries plus China (see table 3 for the three current innovation fields). This likely reflects the large size of these countries' markets, as well as the presence of competitors with frontier technological capabilities.

Table 3: Patent applicants mainly seek protection in high-income markets

Share of patent families worldwide for which applicants have sought protection in a given country

	3D printing	Nanotechnology	Robotics
US	46.6	84.6	36.5
Japan	33.6	52.1	38.7
Germany	37.7	39.8	28.6
France	32.4	36.9	21.9
UK	32.9	37.6	21.3
Republic of Korea	11.8	25.2	19.2
Other high-income countries	16.4	20.5	9.5
China	38.3	31.8	36.6
Other low- and middle-income countries	2.8	2.7	1.4

Notes: This table is a summary of figures 3.5, 3.10 and 3.14, covering patents first filed in 1995 or later and for which at least one patent office issued a grant. Values for "other high-income countries" and "other low- and middle-income countries" are GDP-weighted averages (unweighted averages are similar in magnitude).

Source: WIPO based on PATSTAT database (see technical notes).

Only a small share of first patent filings in the relevant technological fields had equivalent patents in low- and middle-income countries other than China. This suggests that patents have been neither helpful for technology dissemination to those countries when it has occurred, nor harmful for dissemination when it has not happened. It rather points to the presence or lack of absorptive capacity as the main factor explaining the extent of technology dissemination. It is important to keep in mind, however, that this conclusion is based on aggregate patent filing patterns; given the highly skewed distribution of patent values, some individual patents may well exert disproportionate influence in certain technology fields. In addition, the conclusion is specific to the six technologies at hand.

Technology itself is shaping the evolution of the IP system

Throughout history, newly emerging technology raised difficult issues for IP policymaking. Patent offices and courts sometimes faced difficult questions about the patentability of founding inventions. In addition, the historical case studies document how court decisions, new laws and targeted government interventions led to a continuous adaptation and calibration of IP policy. This evolution is bound to continue. The case studies of today's breakthrough innovations have brought to light several new considerations that will inevitably shape IP policy in the future:

- Copyright is becoming increasingly relevant for technological innovation. This first happened with the inclusion of software within the domain of copyrightable subject matter. As software has become an integral feature of many new technologies – including 3D printers and robots – so has the role of copyright widened. In addition, copyright can protect any kind of digital expression, including 3D object designs and the design of computer chips. It is yet unclear whether this trend just signifies a shift in the use of different IP forms, or whether it raises fundamentally new policy challenges.
- The emergence of low-cost 3D printing has the potential to enable the easy reproduction of any object that may be protected by industrial design and possibly other IP rights. A natural question is whether this development will render the enforcement of those rights more difficult – similar to the challenge that digital technology has posed in relation to books, music, movies and other creative expressions protected by copyright. Such a

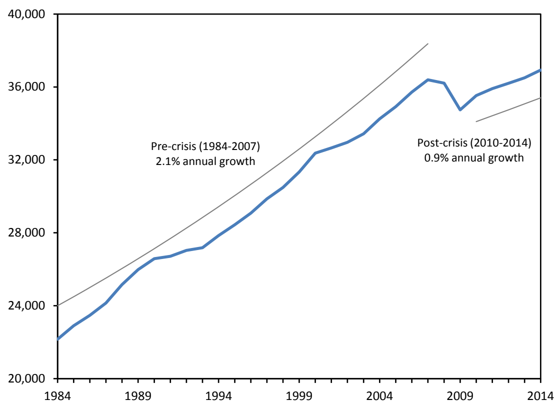
scenario may still be far off and there are important differences between 3D printing and digital content copying. Nonetheless, the experience from the digital content industry may well hold valuable lessons on how to best manage such a scenario.
- Trade secrets have always been an important – if not highly visible – form of IP protection. Even though the three case studies offer only suggestive evidence, there are reasons to believe that trade secret policy has become more important. The main reason is that the mobility of knowledge workers has increased. Despite the easy availability of codified knowledge, people remain crucial to put such knowledge to effective use. Trade secret laws regulate how knowledge can flow with people, and thus shape both innovation and technology dissemination outcomes.

Future prospects for innovation-driven growth

As pointed out above, historical data on GDP per capita at the frontier points to spectacular and exceptional growth in the post-Second World war period. Yet growth since the onset of the global financial crisis in 2008 appears anything but spectacular. Figure 7 depicts the evolution of per capita GDP in high-income countries since the mid-1980s. Before the crisis, growth averaged 2.1 percent per year. Not only did the crisis prompt a sharp decline in economic output, average annual growth since 2010 has fallen to 0.9 percent.

Figure 7: The end of spectacular post-Second World War growth?

Real GDP per capita in high-income OECD countries, 1984-2014



See figure 1.9

Optimists reckon that faster growth will resume...

Does the financial crisis mark the beginning of a new era of lower growth? Has the innovation-driven growth engine lost steam? Optimists contend that the world economy is still suffering from a post-financial crisis debt overhang. Eventually, market forces should lead economic growth to return to its long-term path determined by economies' fundamental productive capacities. In addition, looking at the potential for innovation to continuously sustain future growth, there are reasons to be optimistic:

- Never before has the world invested so many resources in pushing the global knowledge frontier. While the financial crisis has left a mark in some countries, R&D spending was far less affected than economic output. Moreover, the emergence of China as an innovator – along with the rapid growth of R&D expenditure in the Republic of Korea – has increased the diversity of the global innovation landscape.
- There still appears to be significant potential for innovation to generate productivity gains and transform economic structures. ICTs have already made important contributions to growth. However, if history is any guide, there is more to come. The growth contributions of major technological breakthroughs have only occurred with decades-long delays. The next generation of ICT innovations – centered on artificial intelligence – holds plenty of promise.
- There are numerous other fields of innovation that hold potential to spur future growth. These include the three fields discussed in this report. For example, the growing use of 3D printers and intelligent robots may well prompt the reorganization of supply chains in many sectors, with possibly sizeable growth effects. Other innovation fields showing significant promise include genetic engineering, new materials and various forms of renewable energy. New technologies have also dramatically improved the research tools that drive the process of scientific discovery. In particular, ICT-driven techniques such as big data analysis and complex simulations have opened new doors for research advances across many areas of technology. For optimists, the interplay between science and technology generates a self-reinforcing dynamic that seems unbounded.

...but doubts persist

Contrasting these optimistic perspectives, some economists have expressed doubt as to whether growth at the frontier in the coming decades will match the post-Second World War record. They put forward several arguments:

- Demographic shifts and other factors have pushed advanced economies into a state of "secular stagnation", whereby economies' realized growth persistently falls short of its potential. While innovation still contributes to future growth, persistently weak growth performance may become self-fulfilling: firms may shun investment opportunities created by new technology, long spells of unemployment may mean that workers lose skills or never acquire them, and fewer firm startups and "scale-ups" may slow the structural transformation of the economy.
- Estimates of economies' productivity growth show a decline that started well before the onset of the crisis. Chiefly, the US economy saw a marked pick-up of productivity growth from 1995 to 2003, mainly attributed to ICTs; however, productivity growth since then has been significantly slower. More generally, research shows that the growth potential of advanced economies started to decline in the early 2000s, mainly accounted for by a drop in productivity growth.
- Pessimists argue that the growth contribution of ICTs has been largely realized and there is no innovation of comparable significance on the horizon. Matching the achievements of earlier innovations in relation to speed of travel, life expectancy and long-distance communication may well be challenging. In addition, there is much less scope for innovation to increase labor force participation; if anything, demographic shifts in developed economies will lead to declining participation. One may also question the productivity of future innovative activity. Pushing the knowledge frontier is becoming progressively more difficult as the "low-hanging fruit" is plucked.

Finally, some economists wonder whether today's GDP measurement framework misses the true impact of new technology. This argument comes in two forms. One is that the tools of statisticians increasingly fall short of capturing quality improvements and new forms of economic output. The other is that the very concept of GDP is ill-suited to capture the societal welfare gains associated with today's innovation. In particular, many new technologies are highly expensive to develop but, once developed, relatively cheap to produce or can even be replicated for free. As such, they contribute little to economic output but may raise welfare disproportionately. However, other economists argue that under-measurement of GDP is not a new phenomenon and there is no convincing evidence that it is worse today than it was in the past.

Conclusion

Only time will reveal how future frontier growth compares with its post-Second World War path. However, continuously investing in innovation will remain imperative for policymakers and business alike. The report's cases studies document the long time it takes to turn promising ideas into workable technologies, for those technologies to be refined, and for companies and consumers to embrace them. Successful innovation, whether at the level of the firm or the economy as a whole, requires perseverance – not least in periods of low growth when innovation budgets come under pressure.

Policymakers will also need to ensure that the IP system contributes to an ecosystem conducive to innovative breakthroughs. Since the onset of the industrial revolution, the IP system has continuously adapted to the demands and challenges of newly emerging technology. This trend is bound to continue, and is best guided by careful consideration of available evidence and openness to the direction of technological change.