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THE IMPORTANCE OF FOSTERING INCREMENTAL INNOVATION

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INCREMENTAL INNOVATION

The importance of fostering incremental innovation

This briefing paper discusses the fundamental relevance of incremental innovation and the role that patent protection plays in this regard.

The text begins by elaborating on the importance of innovation in general before focusing on the particular significance of incremental advances in technology. Subsequently, it introduces the patent mechanism, including the underlying economic rationale and the key characteristics of this form of intellectual property protection. Finally, the paper presents specific challenges that relate to the patentability of incremental innovation.

Introduction

Today, innovation performance is widely recognised as a crucial determinant of economic growth and a means to address global challenges, such as climate change, food security and public health. As noted in the G20 Blueprint on Innovative Growth,[1] technological progress will be key to achieving the Sustainable Development Goals (SDGs) of the United Nations.[2]

Based upon the degree to which the innovation presents an advancement of the state of the art, economists distinguish between incremental and radical innovation. Incremental innovation involves refinements and relatively small extensions of existing technologies. By contrast, radical innovation produces considerable technological advancements that have the potential of completely substituting products and industries by new ones. However, in practice, any radical improvement of a technology invariably draws on a series of incremental changes.

Successful innovation rests on a number of enabling factors, including access to finance, a skilled workforce, and a predictable legal environment that includes enforceable intellectual property rights (IPRs). As a particular type of IPR, the patent assumes a significant role in stimulating technological progress. It gives the inventor the right, for a specified duration, to prevent others from using, making, selling, offering for sale or importing the patented invention without his or her authorisation. Thus, he or she can enjoy market power and earn profits for a limited period of time. As a consequence, the patent system encourages companies and other organisations to engage in research and development (R&D). The granting of a patent necessitates the satisfaction of several internationally agreed criteria, namely, subject matter eligibility, utility, novelty, non-obviousness and sufficiency of disclosure. For patent policy reasons, each of the requirements for patentability needs to be applied rigorously when patenting inventions of all types.

Drawing on recent economic literature, the first section elaborates on the importance of innovation in general and identifies a range of enabling factors. The second section presents the relevance of incremental innovation, including for developing countries. The third section introduces the patent mechanism, outlining in particular the economic rationale behind this form of intellectual property protection. The fourth section discusses specific challenges that relate to the patentability of incremental innovation.

Innovation as the driver of economic growth

It is only recently that economists have attempted to elucidate the pivotal influence that innovation exerts on growth. According to the so-called neoclassical theory, which dominated economic thought until the early 1990s, increases in output in the short run result from the accumulation of capital and labour (Solow 1957; Swan 1956). Since, under this approach, capital stock rises at the same rate as the population in the long run, growth ultimately depends on gains in productivity—and thus on technological progress. However, in the neoclassical perspective,

1 G20 Blueprint on Innovative Growth, September 2016

2 Adopted in September 2015 by 193 countries, the 17 SDGs constitute the most ambitious global agenda ever developed for the social, economic and environmental advancement of the world. They include the objectives to end poverty, abolish hunger, accomplish gender equality, foster equitable economic growth, reduce inequality and address climate change—by 2030 or earlier. However, significant gaps towards achieving these goals persist in all, but especially in the developing, countries.

technological change is exogenous in that it draws on a scientific process which takes place independently from the forces of the economy. Put differently, neoclassical theory does not account for the relationship between the actions of economic agents and public policies, on the one hand, and technological progress and the rate of long-term growth, on the other.

Empirical evidence is clearly at odds with neoclassical predictions.[3] In reality, it is essentially productivity, rather than the stocks of capital and labour, that explains the majority of income differences across countries (Easterly & Levine 2001). For instance, since the mid-1990s, the United States (US) has been consistently growing faster than Europe which nevertheless displays higher saving rates and capital-to-labour ratios (Aghion & Howitt 2006). Similarly, the spectacular growth performance of the "Eastern Tigers" (Singapore, Hong Kong, Taiwan, Republic of Korea) in the period 1960-1990 did not derive from capital accumulation—but was essentially due to an increase in productivity (Hsieh 2002).

Contrary to the neoclassical school, the "new", or endogenous, growth theory emphasises the role of innovations in bringing about rise in output (Aghion & Howitt 1992; Griffith *et al.* 2004; Romer 1990). These innovations occur in the form of novel products and processes, which to a considerable extent result from purposeful economic activities by profit-seeking businesses that invest in R&D. In other words, economic factors impact on the rate of technological progress and hence the long-run rate of economic growth.

By focusing on the pivotal role of innovation, the endogenous growth theory permits the identification of plausible policy interventions at two levels. First, for most businesses and other organisations engaging in R&D, the primary motivation is to seek or secure competitive advantages through innovation. The availability of sound and enforceable IPRs play generally an important role in determining whether such advantages can materialise. Second, the way to grow rapidly is not to save a large fraction of output but to devote a significant part thereof to innovative activities. This requirement refers to private and public investments in R&D, as well as to the design of relevant tax schemes.

The endogenous growth theory also accounts for technology transfer whereby innovations in one country enhance the productivity in other countries. The three most relevant channels for technology transfer are international trade, foreign direct investment (FDI), and licensing. For example, a study based on data from 22 countries over the period 1971-1990 shows the effect of trade: the positive impact on productivity from foreign R&D stock—a proxy for successful technological transfer—is larger in economies that are more open to international commerce (Coe & Helpman 1995). Therefore, policies to promote technology transfer should be designed to encourage FDI, licensing to domestic entities and integration into global trade and value chains.

In addition, it is crucial that the recipient country display an adequate degree of absorptive capacity, *i.e.*, the ability to do basic or applied research, to understand, implement and adapt technologies (Cohen & Levinthal 1989; Griffith *et al.* 2004). Absorptive capacity, in turn, depends on the macroeconomic and governance environment as well as on education systems. Moreover, the effectiveness of policies to promote technology transfer differs according to the recipient country's distance from the technological frontier. Human capital formation is key for developing countries

3 Even in his seminal paper, Solow (1957) could only account for 13 per cent of variation in output through capital and labour, leaving the remaining 87 per cent—the so-called "Solow residual"—unexplained.

far from the technological frontier, whereas investing in R&D becomes more relevant for advanced countries (Benhabib & Spiegel 1994).

To sum up, novel technologies generally result from private and public R&D expenditures and diffuse only in the presence of certain factors. By affecting the private costs pertaining to technology development and diffusion, economic policies with respect to trade, education, taxes and IPRs can influence the rate of innovation and the broad availability of new solutions.

Incremental innovation

While academia has provided a great variety of definitions of the term "innovation", the concept basically designates changes to existing products or production processes that enhance their commercial value (Baregheh *et al.* 2009; O'Sullivan & Dooley 2008). Moreover, economists have identified a range of different types of innovation. The most important of these distinctions concerns the degree to which the innovation presents an advancement of the state of the art. It has given rise to two broad categories: radical innovations and incremental innovations (Utterback & Abernathy 1975; Tushman & Rosenkopf 1992; Henderson 1993; Hill & Rothaermel 2003).[4]

Incremental innovation produces relatively small improvements, refinements and extensions of existing technologies. By contrast, radical innovation involves considerable technological advancements that can completely replace old products and industries with new ones, *e.g.* oil lamps with electric ones (Schumpeter 2010). Premised on the Schumpeterian idea of "creative destruction", innovation cycles tend to be viewed as disruptive technologies effectively rendering existing solutions obsolete. Recent examples include the mobile Internet, cloud computing, the Internet of Things, 3-D printing and autonomous vehicles.

However, it is important to underline that the distinction between radical and incremental innovation primarily serves analytical purposes. What is termed "radical innovation" largely results from the accumulation and integration of existing technologies. In fact, it takes generally a host of "incremental improvements" to spawn any "radical improvement" in technology. Moreover, a series of further incremental improvements are needed to produce most of the economic value attributable to such "radical" innovation. While being often more spectacular, radical innovations are not only rare but also unpredictable. They usually necessitate large expenditures on R&D for a highly uncertain return on investment. In fact, the degree to which an innovation is radical negatively correlates with the predictability of its technical and commercial success (Globerman 2014).

Incremental innovation can produce a range of important benefits, for instance, cost-efficiency or better performance under specific conditions (Box 1). It can give rise to substantial price reductions, as well as functional improvements, such as higher user friendliness, enhanced reliability and capacity, and marginal additions to applications (Box 2) (Dosi 1982; Banbury & Mitchell 1995). For instance, in the pharmaceutical sector, incremental modifications can provide great value for both physicians and patients (Box 3).

4 The term is partly synonymous with the concepts "disruptive innovation" and "breakthrough innovation".

BOX 1: The role of incremental innovation in the development of wind turbines

In 2016, more than 54 gigawatt of clean renewable wind power was installed across the global market, which now includes more than 90 countries. Worldwide wind power penetration levels continue to rise, led by Denmark (some 40%), followed by Uruguay, Portugal and Ireland (22%), Spain and Cyprus (20%), Germany (16%), Canada (6%), the US (5,5%), and the People's Republic of China (4%).

A key mitigation technology to address the global challenge of greenhouse gas emissions, modern wind turbines comprise the following four groups of components: (i) the rotor, (ii) the power train, (iii) the mounting and the encapsulation, and (iv) the grid connection and the storage. The rotor, which consists of the blades and the hub, serves the conversion of wind energy into rotational energy. The power train transmits the rotational energy to the generator that converts it into electrical energy. The mounting and encapsulation typically include the foundation, the tower, and the nacelle, that aim to ensure the load carrying, machinery enclosure, to support the machinery at a designated height, and to transfer the load to the ground. The grid-connection consists in transferring the electrical energy to the grid; in the case of off-grid generation, the storage serves the stocking of electrical power.

Since the early 1980s, the price of wind turbines per watt of electric capacity has declined from USD 3.5 to 1.9, while turbine capacity has increased more than 20-fold. Numerous incremental innovations have contributed to refining and scaling up the overarching turbine design, namely, a horizontal axis rotor with airfoil-shaped blades that use the lift forces of the wind.

First, the tower's average height has risen by more than factor 4, so that higher wind turbines can capture the stronger winds that prevail higher off of the ground. Second, wind turbines have slowly evolved to enhance mechanical efficiency, especially by eliminating unnecessary gearing and friction, with many recent models having no gearboxes at all. Third, turbines have increasingly been adapted to specific local conditions. For instance, lower wind conditions necessitate larger blades and smaller generators. Fourth, improvements in the design of blades, such as changes to their length, facilitate the accommodation of different relative air speeds between tip and hub, generating more aerodynamic lift. Fifth, optimised maintenance of specific wind turbines in specific conditions ensures that they maintain the optimal balance, lubrication and uptime. Partly as a result of these improvements, the availability factor, that is, the percentage of time that a wind turbine is available to produce electricity, amounts to 98 per cent. Sixth, their increased robustness due the constant refinement of materials means better tolerance for high-winds, icing, and other realities of exposed structures. In addition, advanced coatings that deteriorate far more slowly on blades (especially the leading edge) increase laminar flow, while maintaining aerodynamic efficiency for longer. Seventh, advances in wind modelling allow the right wind turbines to be selected and sited to maximise use of the wind resource in a specific location. Eight, ICT-based applications that are connected to wind farm managers and grid operators allow immediate adjustment to enhance power output in different wind conditions and to minimise downtime.

Source: Huenteler et al. *2016; The Economist (2015)*

BOX 2: An innovative guiding system for automated guided vehicles

Based in Malaysia, DF Automation and Robotics is a company that designs, manufactures, markets, and maintains Automated Guided Vehicles (AGV) for various kinds of industrial and commercial use. An AGV is a programmable mobile robot that uses sensors to guide its direction to automatically transport materials from one location to another, for instance, in a manufacturing facility or warehouse in the automotive, textile, food and beverage sectors.

Various guiding systems have been developed to allow control of AGVs. One patented method involves numerous radio frequency tags provided along the path over which the vehicle travels. One drawback of this system is that the movement depends on the specific tag setup and that any path modifications require changes of the tags, which necessitate expenses and time. Under another patented approach, the actual position and direction of the vehicle is pre-determined and programmed in a computer. However, this limits the operation of the vehicle since each change on the map requires time-consuming changes to the entire affected operation mode. Moreover, not many employees are able to do the complex programming.

In 2017, DF Automation and Robotics filed a patent for an innovative navigation system that avoids the aforementioned shortcomings. The system represents an improvement on existing navigation systems by allowing AGVs to travel along a network of guide tracks comprising a database, several servers linked to the vehicle via a communication network and an interface unit linked to the server for facilitating interaction between a user and the server. Moreover, the server includes a mapping module based on an innovative software—NavWiz. Protected by trademark registration, the software deploys a simple and easy-to-use drop flow chart. The invention has two key advantages. First, it enables the non-specialist user to rapidly configure a map of the network of tracks via computer-implementable instructions. Second, the link to the communication network allows the AGVs to be integrated into the Internet of Things, or Industry 4.0. This furthers the international expansion of the Malaysian company, which has already a customer base in Singapore, Thailand, Philippines, Indonesia, Vietnam and Mexico.

Source: Interview with Dr Yeong Che Fai, Director of DF Automation and Robotics, September 2017

BOX 3: Incremental innovation in the pharmaceutical industry

Incremental pharmaceutical innovation provides a range of important benefits for the individual patient as well as for public health in general, both in terms of improved treatments and reduced costs.

Therapeutic value: Being rarely optimal, the "breakthrough drugs" require in general further refinements. For instance, some 63 per cent of the drugs on the World Health Organization's Essential Drug List are follow-on drugs.

Therapeutic alternatives: If there are increased therapeutic options, physicians can treat patients according to their individual needs.

Enhanced compliance: Patients are more likely to comply with their treatment regimen if they can select their treatment according to simplified administration or minimised side effects.

Supplemental indications: Follow-on studies can reveal physiological interactions of known substances, as well as important therapeutic uses, frequently for indications unrelated to the initial disease condition.

Greater supply security: The availability of therapeutic alternatives enhances supply security, which is especially important in the case of market withdrawals, shortages and regulatory action.

Increased price competition: The existence of valuable alternatives increases price competition in the pharmaceutical market.

Reduced period of market exclusivity: The speed of entry following the launch of an innovation has increased dramatically over time. According to a recent study analysing 72 drug classes in which the first-in-class compound was improved in the period 1960-1998, 235 follow-on drugs were approved through 2003.

Financial necessity: Because of the rarity and the unpredictability of radical innovation, incremental progress sustains the industry financially since no mature industry can do so from income derived from breakthrough innovation alone.

Source: Lybecker (2014)

On the whole, the spillover benefits of incremental innovations—which represent the vast majority of innovations—are at least as large as those of the relatively small number of breakthrough innovations (Globerman 2014). First, incremental innovations at one stage in the value chain generally induce innovations in other stages. Second, in the long run, they allow both business and household consumers to benefit from access to better products as well as standard products that become gradually less expensive. Thus, in economic terms, this type of innovation increases consumer welfare.

Third, incremental innovations contribute to making it easier for radical innovations to be adopted by a greater number of potential users. As noted, the realisation of economic benefits from radical innovations necessitates numerous incremental innovations. Radical innovations appear in a relatively primitive condition so that they need to undergo a lengthy process of technical improvement and cost reduction (Rosenberg 2006). Most of today's electronic devices, like TV sets, mobile phones, computers, are typical examples (Box 4). When first introduced, their commercial use was limited while production costs were high. Widespread distribution of those products has been made possible by a series of incremental innovations (UNIDO 2016).

BOX 4: Incremental innovation as a means to further the diffusion of new technologies in the computer industry

Numerous businesses have failed despite their ability to come up with radical innovations, or survived essentially because of incremental innovations. A case in point is Apple Inc. Over two decades, the company released several radical innovations in the electronics and computing sector, such as the first PC with graphical interface, the first mouse, the first laptop, and the first digital assistant. Yet, Apple did not succeed in achieving a significant market share for any of these ground-breaking products. For example, in 1983 it launched Lisa, the first PC with a graphical user interface (GUI) which deploys common objects as interface metaphors (*e.g.* desktop, folders, files), as opposed to a command line interface where the user interacts with the computer through text commands. However, the technological benefits that Lisa introduced turned out to be unsuited to the computer's target market. Aimed at office applications like word processing and worksheets, GUI provided only a relatively small advancement over the same software based on a command line interface. If a radical innovation is ill-targeted, competitors may pose a considerable threat to the first mover if they can incrementally improve the technology at issue, thereby more effectively accessing the market. Once the interface and its concept had been revealed, GUI became extremely easy to imitate. In the years following its launch, Lisa saw its potential market share decline drastically as other companies released products with a similar graphical interface, including Unix systems in 1984, Microsoft Amiga and Atari in 1985, IBM in 1987, and Hewlett-Packard in 1989.

In 1998, many market observers expected Apple's bankruptcy to be imminent. Remarkably enough, in the very same year, the salvation for the company came from a product that did not contain any radical innovation: the iMac. Although all technologies used for the iMac were industry standards by then (*e.g.* USB, ethernet ports, modem port), the computer was highly innovative in combining and introducing incremental improvements to existing technologies. A very user-friendly device, the iMac was very easy to install, set up and use. Moreover, with its new product, Apple had pushed its "all-in-one" concept forward. For instance, the computer comprised a handle so that it could be carried around. Its cables and ports were concealed beneath a trap. In addition, Apple created a computer suitable for the living environment. Unlike the producers of other desktop computers, the company focused on the appearance of the product. Within only a few months, the iMac became the best-selling computer in the United States. It not only restored Apple's image and reputation but led to fundamental changes in the industry as well as in other sectors, including consumer expectations concerning personal computers.

Source: Rayna & Striukova (2009)

Fourth, through learning-by-doing, incremental innovation can also further radical innovation. In particular, innovation draws upon earlier innovations which, in turn, stimulates and guides future technological change. Technological learning-by-doing, especially experience as to how to produce, exerts an important influence on what innovators learn in the future. A case in point is the invention of the incandescent lamp: while there is no doubt that Edison introduced a new technical product, he deliberately patterned many of his practices upon those of the old gas industry (Globerman 2014).

In advanced economies, incremental innovation is often crucial where competition is intense and where many firms are already producing on the production possibilities frontier, which designates the maximum quantity of output that can be efficiently produced for a given input level. In developing countries that are in the process of catching up, incremental innovation may be even more important (Naudé & Szirmai 2013). In the context of technology transfer, it allows the adaption of existing solutions to the local context. What is more, incremental innovation is the prevalent, if not the only possible, mode of technological advancement in the frequent case of low technological capacity.

By making an existing innovation more suitable for the context into which it is introduced (*e.g.* a particular country, industry, firm, farm), incremental innovation ensures that the solution is more likely to be adopted or that it performs better in that new environment. For example, a recent study analyses adaptive innovations that have been made to mobile phone handsets being sold in Kenya (Foster & Heeks 2013). Especially, it examines the innovation responses of Chinese mobile handset firms to suggestions on the part of Kenyan intermediaries working close to low-income consumers for modifications to handsets. Their innovations comprised dual SIM card phones (allowing users to choose the lower-cost network to phone particular contacts), translation of the phone interface into Swahili, and the addition of a single-button-enabled new interface for the popular M-Pesa mobile money service.

IP and innovation in general

Innovation amounts to the creation of knowledge (Arrow 1962; Foray 2004; Nordhaus 1969; Romer 1990). From an economics perspective, knowledge constitutes a public good, *i.e.*, it is both non-rivalrous and non-excludable. Non-rivalry implies that the quantity of knowledge does not decline when others use it. Put differently, unlike a physical good, knowledge can be replicated virtually without additional costs. Non-excludability refers to the fact that, once knowledge has become public, others cannot be prevented from benefiting from it: anyone can copy an innovation once it has been made publicly available. In light of these two characteristics, innovators are not able to recover their investments in R&D under conditions of perfect competition. In other words, it is impossible to organise the production and distribution of knowledge through the free workings of a decentralised market system (Pollock 2008). Therefore, public intervention is needed to ensure the production of socially valuable knowledge by supplying tools that can be used by innovators to recuperate their R&D investments upon success in the marketplace.

As one form of IP, patents address the market failure that arises from the imperfect appropriability of knowledge. Based on a number of specified criteria (Box 5), they encourage investment in R&D by giving the inventor the right to prevent others from using, making, selling, offering for sale or importing his or her invention without authorisation during a limited period of time (Greenhalgh & Rogers 2007). In exchange, the patentee must disclose his or her invention.

BOX 5: Patentability criteria under the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS)

Under the TRIPS Agreement, the four internationally accepted patentability criteria are **subject matter eligibility**, utility, novelty, non-obviousness,[5] as well as sufficiency of disclosure.[6]

As regards subject matter eligibility, States are expected to provide patent protection to inventions whether products or processes, in all fields of technology and to make patent rights enjoyable without discrimination as to the place of invention, the field of technology and whether products are imported or locally produced. At the same time, the TRIPS Agreement allows States to exclude certain fields of technology from the scope of patentable subject matter.[7] In some countries, the statutes explicitly indicate the categories that are eligible for patent protection,[8] while case law defines those that are not. In other jurisdictions, the laws set out which categories are not patentable.[9]

Utility, or **industrial applicability**,[10] aims to restrict patent protection to applied technology, as opposed to abstract knowledge. It is a means of avoiding prematurely granted patents, which could impede further research without having delivered any noteworthy benefit. Throughout the world, the threshold is relatively low. Utility requires the invention neither to be commercially viable nor an improvement over the prevailing state of art. Therefore, even an inconsequential, trivial, or simply ludicrous invention may satisfy this criterion (Bagley *et al.* 2013).

Novelty represents arguably the most fundamental limitation on access to the patent system. An invention lacks novelty—and hence is not patentable—if all its features can be found in a single prior art reference. Without this criterion, the patent would exclude the public from the use of technologies to which it already has access. Put in economic terms, granting exclusive rights for known technologies would entail the social costs associated with increased market power but fail to produce the benefits of promoting R&D and introducing welfare-enhancing inventions (Bagley *et al.* 2013).

5 Article 27.1 TRIPS

6 Article 29.1 TRIPS

7 Pursuant to Article 27.3 TRIPS and Article 52.2 of the European Patent Convention (EPC), subject matter which may be or is excluded from patentability includes discoveries of materials or substances already existing in nature; scientific theories or mathematical methods; plants and animals other than microorganisms, and essentially biological processes for the production of plants and animals, other than non-biological and microbiological processes; schemes, rules or methods, such as those for doing business, performing purely mental acts or playing games; and methods of treatment for humans or animals, or diagnostic methods practiced on humans or animals (but not products for use in such methods).

8 Cf. US Patent Act 101.

9 Cf. Article 25 of the Patent Law of the People's Republic of China, which excludes, inter alia, "scientific discoveries", "rules and methods for intellectual activities" and "substances obtained by means of nuclear transformation", or Article 52(2) of the European Patent Convention, which excludes, among others, "discoveries, scientific theories and mathematical methods", "aesthetic creations" and "presentations of information".

10 In US patent law, the term "utility" is used, whereas other jurisdictions, such as the Member States of the European Patent Convention and India, deploy the expression "industrial application".

Non-obviousness, or **inventive step**,[11] means that the invention is not apparent to a person having ordinary skill in the art (PHOSITA).[12] This standard allows the unpatentable work of the "ordinary mechanic" to be distinguished from the patentable advances of more insightful inventors. That is, modifications that are within easy reach of those working in the field, as opposed to non-obvious advances that necessitate efforts beyond routine work (Eisenberg 2004).

Under the **sufficiency of disclosure** requirement, a patent application must disclose a claimed invention in sufficient detail for the PHOSITA to carry out that claimed invention. In general, the disclosure consists of two components: the specification and the claims. The specification must include a written description of the invention. It must conclude with one or more claims particularly pointing out and distinctly claiming the subject matter that the applicant regards as his or her invention.

Source: Saxenian (1994)

The patent system provides a number of specific advantages. First, being relatively decentralised, it leaves key responsibilities with the innovators, especially the management of IP rights within collaborations, and the recovery of R&D investments. In general, individual actors have better information on the costs, risks and benefits related to the innovation process. Second, patents assign the costs to the users rather than to tax payers (Encaoua *et al.* 2006). Third, patents allow patentees to recoup investments through licensing or selling the inventions to those who appreciate its value thereby creating a direct link between the attractiveness of a product to consumers and the reward to inventors (Kremer & Williams 2010). Fourth, patents can significantly reduce asymmetric information problems that impose transaction costs on technology transfer. They allow inventors to fully reveal the characteristics of an innovation to the market without risking misappropriation (Anton & Yao 2002). Fifth, venture capitalists are more likely to fund projects that have patent protection. Sixth, firms may invest more in R&D using profits gained from IPRs through licensing and other patenting strategies. Seventh and finally, the disclosure requirement of patents fosters the diffusion of technological knowledge (Encaoua *et al.* 2006; Greenhalgh & Rogers 2007).

However, patents also entail different types of costs for society. To begin with, they bring about the systemic cost of processing, enforcing, and maintaining patent rights. This necessitates appropriate institutions, such as national IP offices, and resources to address IP-related disputes. What is more, the patent system has been criticised as potentially increasing the costs of cumulative innovation that draws on patented technologies. Even if the follow-up inventor can afford to pay for the permission to use the invention at issue, he or she may face transaction costs that arise from the necessity to negotiate with a multitude of previous researchers (Blair & Cotter 2005).

Notwithstanding these shortcomings, according to an extensive literature review on the economics of knowledge, there is no coherent theory that can convincingly demonstrate the superiority of non-proprietary knowledge production over an approach based upon IPRs (Pollock 2008).

11 While the expression "non-obviousness" is deployed in the US, other jurisdictions, including the Member States of the European Patent Convention, use the term "inventive step".

12 A legal fiction, a PHOSITA is a person that has normal skills and knowledge in a particular field of technology.

It is important to note that other forms of IPRs supplement the patent system. Rather than focusing on one particular type of protection, companies frequently resort to hybrid strategies in which they combine a range of different measures to protect their inventions (Friesike 2011). Protecting information as trade secrets, for instance, can safeguard knowledge which inventors and businesses choose not to patent, which is non-codifiable, or which does not meet the patentability criteria. Finally, reward-based instruments such as pre-invention grants, subsidies, and tax deductions can support the existing IP-based innovation framework.

IP and incremental innovation in particular

As shown earlier in this paper, relatively small changes to foundational technologies are an intrinsic feature of technological progress. These incremental technological improvements give companies a competitive edge which they try to maintain through a variety of strategies, including by protecting such improvements through patents (Box 6).

Despite the fundamental role of incremental technological advances in the innovative process, certain jurisdictions have introduced—in addition to the aforementioned TRIPS standards—other criteria that could prevent patent protection of incremental innovations (Box 7). What is more, some critics argue that the patenting of "minor" improvements permits companies to unduly extend the period of market exclusivity and thus prevents the introduction of innovative or less expensive products. According to them, especially pharmaceutical companies use this strategy of "evergreening" patents to block generic competition, thereby delaying the entry into the market of medicines at a lower cost (Correa 2011).

However, in reality, once the patent for a foundational technology expires, that technology is no longer subject to patent protection. It falls into the public domain and therefore can be produced, used, or sold by anyone (Darrow 2010; Ganguli 2016). The subsequent patent exclusively covers the new and non-obvious technology that the inventor has specifically and sufficiently disclosed in the application. It does not prolong the life of the patent pertaining to the foundational technology. What is more, the effective utilisation of the patent for economic gains is frequently less than 20 years, partly due to the lag between the moment of patent filing—at which the exclusivity period begins to run—and the moment of product commercialisation (Grabowski & Kyle 2007).

The patentability criteria of novelty and inventive step are the only benchmarks for assessing the value of an invention in terms of its differentiation with regard to prior art. Accordingly, the sufficiency of disclosure requirement restricts the scope of claims. It thus acts as a safeguard against overbroad patents, which could stifle competition. In fact, the requirement provides that valid claims must be limited to the increment found to be non-obvious. As a consequence, it stimulates the process of "designing around" whereby a competitor invests in the creation of a new technology that represents an unpatented improvement to what has been previously patented.

An effective innovation policy needs to protect small changes to foundational technologies by applying the same patentability criteria to all types of inventions. Additional hurdles for incremental innovations are unnecessary since the proper application of the well-established standards of novelty and non-obviousness already prevent non-deserving improvements from obtaining patent protection.

BOX 6: Incremental innovation to enhance the performance of solar power systems

A key tool to mitigate global climate change, solar power refers to the conversion of energy from sunlight into electricity. One of its main enabling technologies is photovoltaics (PV). A PV cell consists of two or more layers of semi-conducting material. When the material is exposed to light, electrical charges are generated and conducted away by metal contacts as direct current. The electrical output from a single cell being relatively small, multiple cells are connected together and encapsulated to form a module or panel.

While the use of crystalline-silicon wafers still dominates the market, the so-called thin-film technologies are commonly seen to be the most promising candidates for significantly improving the performance of commercial solar power systems over the long term. A thin-film PV cell is made by depositing one or more thin layers of photovoltaic material (*e.g.* cadmium telluride) on a substrate, such as glass. Film thickness varies from a few nanometres to tens of micrometres, much thinner than the silicon solar cell. This allows thin-film cells to be more flexible, and lower in weight. What is more, they not only can be manufactured at lower cost than crystalline-silicon technologies, but—due to numerous incremental innovations— also allow increasingly for higher module efficiencies.

Magnolia Solar Inc., a US-based business specialised in thin-film technologies, has achieved a number of advancements in this area. Its patent-protected inventions increase the power output of the cells as they overcome a certain number of disadvantages of the prior art. For instance, new materials broaden the range of solar spectrum captured by the solar cell, enhancing cell performance and providing power even in hazy atmospheric conditions harnessing UV/IR Spectrum. Further incremental improvements include nanostructure-based anti-reflection coatings that minimise reflection losses at the air/glass interface, as well as a transparent, highly conductive, and an anti-reflective middle coating which acts as an absorber in one direction and as a reflector in the opposite direction to increase capture of energy. Now a subsidiary of Ecoark Holdings Inc., the company is the assignee of seven US Patents, while it has filed 16 additional patent applications that are at various stages of review at the US Patent Office.

Sources: U.S. Patent No 9,590,133

BOX 7: Challenges for patenting incremental innovations in India and Argentina

In several countries, companies face challenges in effectively managing intellectual assets related to certain forms of incremental innovation.

In India, statutory changes made in 2005 restrict the patentability of certain inventions in the pharmaceutical and chemical field. Specifically, under Section 3 (d) of the Patents Act, certain variants of chemical compounds do not satisfy the novelty requirement unless they "differ significantly in properties with regard to efficacy". The listed variants comprise salts, esters, ethers, polymorphs, metabolites, isomers, mixtures of isomers, complexes, combinations and other derivatives of known substances.[13] However, such variations to molecular or structural compositions can decisively affect the characteristics of a substance and enhance its therapeutic value (*e.g.* by increasing stability and bioavailability). Improvements of this kind, especially with regard to delivery, storage or administration of medicines, often represent significant innovations in themselves. According to data from the Indian patent office, Section 3 (d) was a ground of rejection for about two thirds of rejected pharma patent applications during the 2013-15 period, leading a commentator to describe the provision at issue as "one of the most formidable hurdles to pharmaceutical patent applications".[14] The current law narrows the scope of innovations for which enforceable patent rights can be secured, while causing uncertainty for innovative businesses.

In Argentina, guidelines for patent examiners similarly impact the patentability of certain inventions in the above-mentioned industries. Under the guidelines adopted in 2012, certain variants of chemical compounds no longer constitute patentable subject matter. They comprise so-called polymorphs and pseudo polymorphs (*i.e.*, hydrates and solvates), as well as enantiomers of known compounds.[15] In addition, salts, esters and other derivatives, such as amides, of known substances are not patentable since they are considered to be the same substance.[16] However, as noted above, even minute modifications to the molecular structure can decisively affect the characteristics of a substance and thus its therapeutic value. Therefore, the guidelines could adversely influence innovation and technology transfer in the relevant sectors in Argentina.

13 Under the Patents (Amendment) Act of 2005, the recited variants of known substance are "considered to be the same substance" and hence not novel.

14 "India rejects 955 pharma patent applications in last 3 years", The Economic Times, July 25, 2016 https://economictimes.indiatimes.com/industry/healthcare/biotech/pharmaceuticals/india-rejects-955-pharma-patent-applications-in-last-three-years/articleshow/53383273.cms (March 8, 2018);
"It's Official—Section 3(D) is the Most Formidable Hurdle for Pharmaceutical Patent Applications in India", InvnTree, September 16, 2016
http://www.invntree.com/blogs/its-official-section-3d-is-the-most-formidable-hurdle-for-pharmaceutical-patent-applications-in-india (March 8, 2018)

15 Enantiomers are chiral molecules that are non-superimposable mirror images of one another.

16 Joint Resolutions 118/2012, 546/2012 and 107/2012 by the Ministry of Industry, Ministry of Health and National Industrial Property Institute

Conclusion

The essential objective of the patent system is to ensure that the market produces technological knowledge at adequate levels. In line with the underlying economic rationale, the availability of temporary exclusive rights over intellectual property furthers innovation. Without such rights, the incentives to invent (*i.e.*, to invest in R&D) and to innovate (*i.e.*, to exploit commercial opportunities that a new invention entails) may be insufficient because others cannot be prevented from appropriating the benefits without sharing the costs. In addition, patents have further effects, which in turn can stimulate domestic innovation. These include attracting foreign direct investment, as well as fostering technology transfer and dissemination. Empirical evidence on the impact of IPRs reforms undertaken in the context of the TRIPS Agreement shows that patents can effectively contribute to the realisation of the aforementioned objectives (Lippoldt 2011). However, they can fulfil this role only in conjunction with other enabling factors, such as overall legal security, absorptive capacity, public R&D investment, and openness to international trade.

As confirmed by TRIPS, the internationally accepted patentability requirements are utility, novelty, non-obviousness, and sufficiency of disclosure. Their definition is related to the patent-specific trade-off between fostering innovation and temporarily increased market power. At the same time, their implementation must reflect the characteristics of the innovation process. In particular, given that innovation essentially consists of incremental changes to existing technologies, additional patentability requirements that neglect this reality could impede technological progress and ultimately hamper economic growth. Moreover, as noted in the UN report on collaborative R&D to address global climate change,[17] incremental innovation is especially important for technology deployment and development in emerging economies.

17 United Nations (2010) Framework Convention on Climate Change. Report on options to facilitate collaborative technology research and development. FCCC /SBSTA/2010/INF.11

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