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Government policy and technological innovation—a suggested typology

Wilfred Dolfsma *, DongBack Seo **

Faculty of Economics and Business, University of Groningen, Nettelbosje 2, 9747 AE Groningen, The Netherlands

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ABSTRACT

Reports on the effects of government's role in stimulating technological development provide a mixed picture. Some policies have had the expected, stimulating effect and other policies have not. We suggest that specific characteristics of technologies that government has sought to stimulate have not been taken into account when governments formulated and implemented innovation policies. While technologies can be characterized according to more dimensions, we focus on two highly relevant characteristics. Technologies either develop in a discrete manner, independent of what specific knowledge has been developed in the past, or develop cumulatively. In addition, network effects may be present or absent in the market anticipated for the products for which a technology is used. A 2×2 typology of technological development ensues. We suggest that governments should consider developing policies to stimulate technological change keeping these characteristics in mind.

1. Introduction

Technological development can be beneficial for private business and for the economy and society at large (Jones and Williams, 1998). Governments have realized that the social benefits can be higher than the private ones, due to the high levels of uncertainty related to investments in technological development (Hall, 2002), giving rise to a situation of market failure (e.g. Nelson, 1959), and so have developed a number of different policies to stimulate technological innovations. These policies have sometimes had the expected effects, but in many cases they have not had the effects hoped for. This brief note suggests that government policies could consider some characteristics of the technologies that their policies sought to stimulate. In a 2×2 matrix (Table 1), we suggest two characteristics (nature of technology and network effect in a market), while acknowledging that considering other characteristics of technology might lead to fruitful insights as well.

Two important ways in which to characterize technologies may indicate which policies might be expected to offer the results aimed for. First, some technologies develop in a cumulative manner, while others develop in a more discrete manner where specific, previously developed knowledge (rather than the more general capabilities that people involved need) is not a basis for further development. Second, while market demand is ultimately needed for all technologies that are developed, in the market for products based on some technologies, network effects play a substantial role, whereas they do not in other markets. Markets for products based on technologies in which network effects play a role are those where the consumption by consumers is affected by how many and what other users consume. In markets where network effects are important, an emerging dominant (technological) design can significantly influence technological developments and market dynamics.

These characteristics usefully help classify technologies and suggest that policies to stimulate technological development should align with these characteristics. The 2×2 classification in Table 1 suggests that some policies may be expected to have effect on some technologies but not on others, and it suggests that some policies may not have the effects that are expected (Flanagan et al., 2011).

We first briefly discuss some current policy aiming to stimulate innovation and technological development. We do not claim to be exhaustive, providing a full review of innovation policy, but merely to suggest that the outcomes of these policies are mixed. We suggest that the outcomes may be mixed due to the fact that characteristics of the technologies targeted have not been taken into account enough. In this paper, we focus on two characteristics to classify technologies in a 2×2 matrix (Table 1). The extent to which technologies develop in a cumulative manner on one hand, and the extent to which market demand for the products in which technologies are used on the other hand, differ. We thus suggest, in a subsequent section, that innovation policy could be differentiated accordingly.

2. Innovation policy

Government policy to stimulate innovation and technological development is different from policy it might have to stimulate particular types of firms, such as Small and Medium sized Enterprises (SMEs), or certain industries. While certain industries may be expected to be more innovative than others (cf. Pavitt, 1984), the extent to

* Corresponding author. Tel.: +31 50 363 2789.
** Corresponding author. Tel.: +31 50 363 2931.
E-mail addresses: w.a.dolfsma@rug.nl (W. Dolfsma), d.seo@rug.nl (D. Seo).

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Table 1
A classification of technological development.

		Nature of technology	
		Discrete	**Cumulative**
Network effect in market	**Low**	**Romanticism** [e.g. pharmaceutical, chemical technology, internal combustion engine; electrophotography; nanotechnology; photovoltaic cell].	**Standing on the shoulders of giants** [e.g., software; nuclear energy; laser-printing technology; semiconducting].
	High	**Schumpeter mark I** [e.g., automobile, telegraphy; telephony; railways; CDMA; Internet Protocol (IP) technology; electronic grid].	**Schumpeter mark II** [e.g., WCDMA; IP-TV, voice over IP; ICT—hardware, electronics; high-speed train; air- and space technology; electronic vehicle].

which this is true can differ over time. In part, the change in the extent an industry is innovative can relate to the phase in the Industry Life Cycle it is in, and it can relate to the specific technologies used in the products firms in it produce (Dolfsma and Van der Velde, 2012; Malerba and Orsenigo, 1997; Mueller and Tilton, 1969). In such a situation when seeking to stimulate technological development by targeting specific industries, a government would conceivably have to change its policy whenever an industry or (set of) technologies underlying the products produced were to change. Policy would also become dependent on strategically motivated actions and decisions by players in the industry, including by foreign firms beyond its jurisdiction. In addition, a government's policy to stimulate innovation by focusing on particular players in an industry could become industry policy under a different guise. The current paper thus takes a more narrow view compared to, for instance, Schoen et al. (2011).

Governments have been involved in stimulating technological innovation for quite some time now. A diverse set of policies has been developed (Aschhoff and Sofka, 2009; Edler and Georghiou, 2007). Flanagan et al. (2011) emphasized the complexity faced when developing innovation policies, involving a mix of actors, instruments, institutions, and inter-actions between them. Classifications have been proposed to help understand the nature of the policies and the effects to be expected. A commonly used distinction is between policies that push the supply of innovations on one hand, and policies that stimulate the demand for innovations (demand pull) on the other hand (cf. Edler and Georghiou, 2007).

There is conflicting evidence about what type of public policy successfully encourages technological innovation. In a recent study, Blind (2012) showed how different types of policies are found to influence innovation, but is exasperated by the fact that still little progress is made in our understanding of what brings about the effects of regulation. Aschhoff and Sofka (2009) underlined the importance of public procurement and knowledge spillover from publicly funded universities (cf. Edler and Georghiou, 2007). Goldfarb (2008) shows how such policies are not likely to stimulate high-quality technological research. Jones and Williams (1998), and more recently Nemet (2009), argued that government-encouraged demand-pull policy did not promote innovation. Peters et al. (2012) found that innovation effects of domestic demand-pull and technology-push policies had categorically different effects. While demand-pull policies prompt innovative output in a country as well as beyond its borders, domestic technology-push policies do not cultivate innovative output outside of national borders (Peters et al., 2012), which plays into mercantilist considerations. Mowery and Rosenberg (1989) warn against a mercantilist inclination to favor the latter over the former in a situation where technological development is increasingly global. Technology-push policies, also, are sometimes found to be more effective in stimulating non-incremental innovations (Dosi, 1988) as these rely on input from sources beyond national borders. In addition, technology-push and demand-pull may often work in conjunction, particularly for radical innovations (cf. Van den Ende and Dolfsma, 2005).

The inconclusive or mixed findings about the effects of government policies to stimulate innovation and technological development, in combination with a liberal inclination to have markets take on a larger responsibility and for governments not to favor some market players over others, seem to have led to two suggestions. The first suggestion is to develop broad set of policies aimed at appropriately changing the national system of innovation so that technological innovation may be stimulated. Government policies to stimulate technological development from a national innovation systems point of view tend to be "messy", however, dealing with a "complex, multi-level, multi-actor reality" (Flanagan et al., 2011, p. 702). At best, the "sheer complexity of the policy process" and policy instruments precludes an assessment of effectiveness of the innovation policies implemented (Flanagan 2011, p.709). At the very least, results from a simulation model suggests that a number of government instruments, drawing on a "strategy characterized by symmetry in its objectives", should be used in a "sustained effort" to then only expect improvement in the long term (Samara et al., 2012, p.637). While providing practical guidance (cf. Klein Woolthuis et al., 2005), policy recommendations ensuing from a system of innovation perspective are also highly idiosyncratic with respect to a specific national innovation system (Samara et al., 2012). In particular the multi-level dynamics that can differ between innovation systems (Flanagan, 2011; Blind, 2012) might affect transferability of insights. This is not very encouraging in terms of understanding and further enhancing the positive effects of innovation policy.

Governments may also develop rather generic policies, such as providing tax incentives. Tax incentives may actually have negative effects (David et al., 2000). Stimulating public research facilities to patent their findings and so stimulate invention to be commercially exploited as innovations, possibly by third parties, another generic policy, is a presumably straightforward measure to stimulate innovation, but has not had the expected effects as well (Rafferty, 2008). A final generic suggestion is that governments should develop policies to stimulate innovation at all. Blind (2012) implicitly suggests that policies not specifically meant to affect innovation may nevertheless impact efforts at and outcomes of innovation, however. It thus seems preferable to have an understanding of the effects of government policy on technological development.

In this contribution we suggest that the effects of innovation policy can be better understood, and that some of the puzzling and conflicting findings in the literature can be resolved, by considering how the impact of innovation policies might differ by the nature of the technology targeted. We suggest two dimensions by which to characterize technologies, and now elaborate on these.

3. A typology for technological innovations

Technology may be defined as a coherent bundle of (scientific) knowledge that is specific to a particular domain of application.

Table 2
Technology characteristics and government policies to promote technological development.

		Nature of technology	
		Discrete	**Cumulative**
Network effect in market	**Low**	***Romanticism*** 1. Funding and tax credits for R&D. 2. Supporting universities and research centers. 3. Assisting companies to commercialize innovative technology. 4. Innovation vouchers. 5. Stimulate innovative entrepreneurship.	***Standing on the shoulders of giants*** 1. Promote regional clustering. 2. Encouraging technology upgrades through subsidies and tax credits. 3. Procurement policies. 4. Innovation brokerage.
	High	***Schumpeter mark I*** 1. Easy access to intellectual property by third parties. 2. Promoting harmonized standards or requiring compatibility among technologies.	***Schumpeter mark II*** 1. Activating antitrust law to prevent lock-in. 2. Deregulate industries. 3. Liberalize markets. 4. Standard setting/enforcing. 5. Flexible IPR regime.

Technologies do not tend to change in a random manner, but develop along trajectories (Dosi, 1982). Yet, some technologies develop in a cumulative fashion, while other specific developments in technology do not rely on previously developed knowledge, or much less so (Scotchmer, 1991). On the other hand, while products based on technologies will need to find a market, characteristics of (an anticipated) market demand for products based on a technology are important to understand a technology's development. For consumers of products on some markets it matters which specific others have purchased a good, and especially how many others have done so (cf. Dolfsma and Leydesdorff, 2009). In such cases, network effects play a role, probably apparent from a dominant design being important in that market.

We suggest that these two dimensions are important to understand important aspects of the nature of technological development, and that they may be combined into a 2×2 matrix (Table 1). They can thus be used to classify technologies, and can also help explain what effects we might expect of government policies to stimulate technological innovations (Table 2). Other dimensions of a technology may be important too, and their use might shed additional light on the issue of what government policy is appropriate under which conditions. Some might suggest the distinction between radical and incremental innovation. We submit, however, that the distinction of radical versus incremental innovation (cf. Aschhoff and Sofka, 2009; Edler and Georghiou, 2007; Nemet, 2009) may not be useful for this purpose, if only because innovations may be classified ex post as radical or incremental (cf. Levinthal, 1998; Van den Ende and Dolfma, 2005). We will briefly discuss the typology for technological innovations based on the two dimensions we suggest, to proceed in a next section by arguing that government policy can take note of these differences when it develops and implements instruments to stimulate technological innovation.

In characterizing each type of technology, and providing examples, we acknowledge that classification can be ambiguous in some instances. The purpose is not to provide a definitive classification, however, but to offer ideas for government policy to take into consideration.

Some technologies can develop based on a breakthrough idea without much of an explicit and necessarily acknowledged basis in previous technological knowledge. In contrast to discrete technology, cumulatively developing technologies necessarily are the results of combining many new as well as existing ideas. For example, the Internet Protocol itself was developed based on a discrete technology, while IP-TV was developed based on the combination of IP and Television (TV) technologies. Code Division Multiple Access (CDMA) is one of radio communications technologies based on a particular channel access method, while Wideband Code Division Multiple Access (W-CDMA) has been developed on the existing knowledge of CDMA and Frequency-Division Duplexing (FDD).

When filing for a patent, there will be many previously granted patents that are typically cited in case of a development in a cumulative technology. There can be intense litigation in sectors where technology develops cumulatively. Due to the fact that the gains are relatively large if a patented technology becomes a part of the dominant design in such sectors, there is also, at the same time a need for collaboration, for example, being involved in a patent pool or technology alliance (cf. Dittrich and Duysters, 2007). In anticipation of this, patenting will be more rife than elsewhere, or than otherwise would be the case. Discrete technologies may be developed by the quintessential entrepreneur that has a brilliant idea and does not need to take account of the presence and ownership of previously developed knowledge by existing companies. Where knowledge develops cumulatively, relatively large organizations that have developed ownership of the knowledge that they have developed may tend to prevail over time.

Each user of a good developed on the basis of underlying technological knowledge may or may not value the good depending on the type and number of other users who own it. If such effects are substantial, network effects are said to be present in a market (Katz and Shapiro, 1994). The more people who have a mobile telephone, for example, the higher value the telephone has to any specific owner, because she has more people to call. In an industry based on a technology where network effects are strong, firms must rely on substantial investments in production capacity and complementary assets (Teece, 1986), and are also likely to have to rely on an alliance network of partners to offer complementary goods and services (David and Greenstein, 1990; Colombo et al., 2006). For instance, a smartphone is valuable to a consumer only when it is connected to a network with those of other users. Users of a smartphone also expect a number of complementary services in the form of software applications. In the case of these examples, properly negotiated, defined and guarded interfaces must be in place. This obviously derives from an anticipated situation in the market. Expected network effects may thus influence the way in which technologies develop (Suarez, 2004). When the network effects in a market for products based on a technology are low or non-existing, a single possibly small company can innovate, develop, and release a technology to a market. For example, companies have innovated and released clocks and watches by themselves without coordinating with others for a long time (Foster, 1986).

Technologies that can develop discretely and are not subject to expected network effects in a market can, however, be a part of a product that is driven mostly by other technologies that do develop cumulatively and where network effects do play a role. There can be cases, needless to say, where unambiguous classification is difficult; some technological subfields, for instance in Information and Communications Technologies, are to be classified as technologies where network effects are important while for other ICT technologies such as encryption network effects play a limited role only.

When technological knowledge develops in a discrete manner and network effects are non-existing, an individual inventor is more likely to be found and be successful. This situation is the ***romantic view*** that many have of innovation in general, but it is a view that only relates to part of the scene. In cases where network effects are strong(-er), a formally organized company of some size is needed not just to develop a technology but also to bring a product to a market. Involving more individuals in a somewhat larger organization will bring a larger diversity of ideas to the innovation table, and a company that involves more than single individual can also better organize the commercialization efforts. Specialization is possible here as well. This view is in line with the early view of Schumpeter, sometimes referred to as ***Schumpeter Mark I***.

When a technological development is cumulative, but network effects are absent, technology develops by ***Standing on the Shoulders of Giants***, without a need to take anticipated non-technical considerations into account such as IP portfolios, the need for investments in production capacity and the need to secure complementary goods. If a technology develops both cumulatively, and strong network effects are in place, large, resource-rich firms will dominate in the market for the goods that are based on it. The latter is a view of technological development that Schumpeter later on in his academic career emphasized and has sometimes been labeled ***Schumpeter Mark II*** (cf. Malerba, 2002).

4. Targeting innovation policy

The typology of technological development suggested above indicates, it seems to us, under what conditions specific government policies to stimulate innovation may (not) hope to achieve their goals, or, alternatively formulated, it suggests how policies may need to be formulated to achieve specific goals. Implicitly, the typology suggests why some innovation policies may have failed, perhaps because inappropriate goals were aimed for (see Table 2). Rather than discussing each of the many different policy instrument that have been developed over the years in terms of the suggested typology at length, by discussing a limited number of policies, suggesting for which technology in which quadrant they would work and where they might not work, we expect the reader to understand the suggested logic and apply that to other policies. We understand both that more research is required to develop this line of work as well as that some policies might not unambiguously fit in a particular cell. Future research could therefore seek to widen the scope of the current paper. Our suggestion for policy-makers to take into account the two characteristics, when developing innovation policies, differ from, but, we believe, are compatible with much advice others have provided.

4.1. Romanticism

The view of the individual inventor is an appealing and also a romantic one. It is a view that broad swathes of the population have in mind when they conceive of innovation, and one to which the media likes to cater, if only implicitly. When technological development is independent of previously developed specific knowledge, and the products that are based on the technologies are exchanged in markets where no network effects play a role, individuals as inventors can be expected to thrive (cf. Lettl et al., 2009; Nooteboom, 1994). Products based on newly developed technological knowledge can then result and be brought to a market quickly. Such a market does not have to be large for the products to be relatively successful. Although strong competition is expected, inventors do not need to fear other players, for instance in term of infringing intellectual property rights and having problems accessing complementary assets, because of the discrete nature of technologies and an absence of network effects in a market (cf. Lanjouw and Schankermann, 2004; Teece, 1986).

Government policy that stimulates spin-offs from university by individual scientists employed at universities, as an important technology transfer mechanism, caters to this romantic view of technological innovation (Grimaldi et al., 2011). Government policy can focus on stimulating individual entrepreneurs for instance by creating circumstances that facilitate them. For some technological fields, these kinds of inventors are more prevalent than for others (cf. Table 1) – failing to align technological circumstances with expectations about policy can give rise to disappointment (cf. Massa and Testa, 2008). A government may stimulate technologies of the kind that are characterized by their discrete development and absence of network effects in a number of different ways, as the US government has done for technologies related to satellite and radar from 1945 until the early 1980s (Fuchs, 2010). Support for research centers and universities to develop more technological knowledge for which applications are foreseeable may be suggested. Support for individuals to obtain the required background capabilities to see opportunities, and to stimulate an entrepreneurial spirit in them is another option. A technology-transfer center may help diffuse an innovation.

If a government formulates a policy for a technology that develops cumulatively and/or that is subject to network effects, but that targets individual inventors, the policy may not be successful. A government policy that does not take into account that a firm will need to commit substantial resources in such cases, for instance by offering adjacent measures, the firm may not be successful and the policy may be expected to fail to lead to commercial success for individual inventors.

4.2. Schumpeter mark I

When a technology develops in a discrete manner, relying relatively little on specific, previously developed knowledge, but when network effects in the anticipated market for products in which the new knowledge is used are more pronounced, then some extent of organization is needed to be successful at technological development as a firm. Marketing and strategic capabilities and investments are now needed as well, for instance. Still, however, relatively small firms can develop technology to cause what Schumpeter would refer to as a 'gale of creative destruction'. These circumstances are thus favorable for innovation of the Schumpeter Mark I kind, as suggested by Malerba (2002).

The Korean government, for instance, played an important role in encouraging innovations for 2 G mobile technology in Korea. It did not select the same 2 G technological standard in the 1990s as other governments did, but considered other available options as well: Global System for Mobile Communications (GSM), Digital Advanced Mobile Phone System (D-AMPS), Personal Digital Cellular (PDC) and Code Division Multiple Access (CDMA). A small innovator, Qualcomm, based in the US, had developed CDMA as a second-generation mobile telecommunications technology in the 1990s (Lee, 2001). The nature of the technology, then, allowed such a relatively small player nonetheless to possibly play a key role. Qualcomm had difficulties to commercialize the technology: no operator committed to adopt its technology. GSM, D-AMPS and PDC could easily be chosen by the Korean government because they were already available and used in other markets, but the selection of one of these three technologies would not have stimulated Korean firms to develop complementary mobile telecommunications technologies and related services. The decision to adopt CDMA as the national standard could encourage Korean electronics manufacturers to successfully start offering commercial services on the basis of the CDMA technology. The Korean government also intervened for the Korean manufacturers to access necessary intellectual property from Qualcomm to manufacture CDMA systems. The government made sure that its national manufacturers received the best deal for the licensing agreement. In the end, end-users were able to enjoy various mobile communications services at lower prices, which i gnited a rapid diffusion of mobile communications technology (see Seo, 2010).

In contrast to the above case, the United States government handed over the role of making a choice with regard to technological standard to the telecommunications industry itself. Thus, large, incumbent firms with an established position in the market and IP portfolio preventing entry into the industry by others. In effect, the US government adopted a policy more in line with a Schumpeter Mark II situation (see below) than with a Schumpeter Mark I situation. The United States government also allowed multiple standards to co-exist, fragmenting the market, which delayed introduction of new technological innovations, such as Short Message Service (SMS). SMS was finally widely adopted in the market when a non-government organization, the Cellular Telecommunications Industry Association (CTIA), adopted the Short Message Peer to Peer (SMPP) interoperability protocol. This development gave US consumers a valued service that others had enjoyed for some time already.

4.3. *Standing on the shoulders of giants*

Technologies may develop in a highly cumulative manner (Scotchmer, 1991), where technological knowledge developed earlier, possibly by others, needs to be relied on to a significant degree. Players in such technological domains must necessarily stand on the shoulders of giants (Merton, 1965). When network effects to be expected in a market for the products that can be developed based on the technological knowledge do not play a large role, the technological considerations are the major ones to take account of. One field one may consider is software development, including encryption technology (Giarratana, 2004) and games (Ozcan and Eisenhardt, 2009; Rietveld, 2011). Technology is likely to have become quite specialized, relying on highly field-specific knowledge, which means that individuals or small firms with generic skills are not likely to make a contribution. To make a contribution, knowledge of different kinds must be combined. Depending on the number of different specialists required and the concomitant investment, (somewhat) larger firms will be found in the domain, possibly co-existing with smaller firms that these firms collaborate closely with.

This type of technology is most likely to develop when exchange of ideas between players is relatively easy. Since the technology develops cumulatively, possibly using a number of different knowledge sources, and since the expected network effects in the related market(s) are weak, players are not likely to perceive of each other as competitive threats. A government can create a regional cluster, or actively broker technological knowledge in some other way, so that companies can actively share knowledge or more passively hope for knowledge to spill over. Clustering is not a policy that is required for technologies that develop in a discrete manner, and is not likely to work for technologies that feature in products for which network effects are substantial since competition considerations are too pervasive. Silicon Valley remains an exception for this reason.

In circumstances of cumulative technological development and an absence of network effects, a government can also stimulate technological development through subsidies and tax credits to encourage existing companies to innovate based on the existing knowledge and innovation skills. Stimulating entrepreneurship is not likely to work when technologies develop cumulatively, however, as resource requirements can be daunting. A government as a buyer can demand better performing technologies through its procurement policies or regulation (cf. Dolfsma and Leydesdorff, 2009). A government is more likely to be adept at this than the general audience since it may be in a better information position about a technological field, and can better solicit the knowledge from third parties such as universities.

4.4. *Schumpeter mark II*

For some technologies, network effects in the market for products that draw on these technologies may be expected, while these technologies develop in a highly cumulative manner as well. Successful commercialization will require scale or collaboration among a large number of players, both to develop the technology and to be able to offer complementary products. This is likely only to be feasible for (very) large firms. These are circumstances that are most akin to the argument that Schumpeter has made in later phases of his academic career, now referred to as the Schumpeter Mark II position (Malerba, 2002).

If and when the network effect relates to a (technical) dominant design emerging in a market with limited interoperability, customers may end up in a situation where they may not be able to switch to an alternative product or only at high cost. A government worried about customers having sufficient choice, about not being locked-in as a customer itself, or about keeping a diversity of current technological developments alive as a source for future technological development, may want to restrict the consolidating tendencies in these circumstances. Restricting consolidating tendencies, for instance through tighter or more strenuously enforced anti-trust policies, is compatible with policies of deregulation and standard setting. A more intrusive policy of using antitrust law, especially in order to protect small players active in a field of technology (Lanjouw and Schankerman, 2004), increases competition. Deregulation allows for entry into a market by outside parties, increasing competition as well. Competition between firms sponsoring different technologies could be encouraged by opening up a market for competition from adjacent markets where products that offer similar services to consumers have developed based on other technologies. Developing a number of different policies to stimulate the use of vehicles using electricity as a source of energy, rather than the combustion engine running on fossil fuels, enhances the dynamics of the market for automobiles, for instance. Setting appropriate technical standards ensures compatibility between technological standards and can thereby allow others to offer competing or complementary products thus increasing competition (Funk, 2009). A more flexible IPR regime may prevent firms from using their IP position to deter entry or even actively seek to exclude existing players from a market. Even though the policies suggested in the lower right cell of Table 2 can conflict in some circumstances, they mostly are compatible. A government can also restrict consolidation by preventing information about actual market shares from becoming known to players in the market (Dolfsma and Leydesdorff, 2009).

These policies might not work for other types of circumstances. Markets for products based on technologies that develop in a discrete manner, or where network effects are low, for instance, are likely to have a high competitive pressure already since they are more likely to be contestable markets where outside firms can easily enter (cf. Baumol, 1982). Increasing that competitive pressure further can mean that the resources to cover the cost of research are no longer available to the same degree.

Establishing a system of Intellectual Property Rights (IPRs) is a policy that governments have chosen to pursue on a large scale. Many believe that IPRs will stimulate technological development per se, but empirically the effects are unclear and the system has particularly been hotly discussed off late (cf. Dolfsma, 2009). Some have suggested changes to the system, for instance by adding more flexibility (Lerner and Schankerman, 2010). The nature of a technological advance for which a patent is granted has not been a consideration in this discussion, however. Particularly when a technology develops in a cumulative way, new players can be deterred from innovating when incumbents have a strong (patent) position already: Research and Development (R&D) can then in particular be a barrier that prevents entry into technological domains and industries (Mueller and Tilton, 1969). Both when a single incumbent will have many of the patents and when a large number of players have used their patents as a basis for inclusion into a technology alliance, negotiations about the terms for the use by newcomers or outsiders of the knowledge protected by these patents can be cumbersome (Kingston, 2001). In cases when the public interest is fundamentally involved, actively pushing to establish a patent pool for knowledge that all involved players can use under specified and possibly relatively favorable conditions can be considered (cf. Bittlingmayer, 1988).

5. Conclusion

We argue in this brief note that technological development differs by technological domain, so governments and policy makers might consider to employ existing and develop new policies corresponding to the type of technological innovation targeted. Rather than providing an exhaustive discussion, we suggest two dimensions to characterize the technological development in an area: extent to which technological development is discreet or cumulative on the one hand, and extent to which network effects in the market for products that draw on the newly developed technological knowledge are in place on the other hand. The two dimensions are combined into a 2×2 matrix (Table 1). For each of the four alternative ways in which technology develops that can be distinguished, matching policy instruments can be expected to lead to the technological development aimed for (Table 2). In case of a mismatch between the government policy developed and the characteristics of a technology, we submit, the expected outcomes of the policy may not materialize. Alternatively, keeping the suggestions we provide in mind should be beneficial when developing and implementing innovation policies (cf. Kapsali, 2011).

References

Aschhoff, B., Sofka, W., 2009. Innovation on demand—can public procurement drive market success of innovations? Research Policy 38 (8), 1235–1247.
Baumol, W.J., 1982. Contestable markets: an uprising in the theory of industry structure. American Economic Review 72 (1), 1–15.
Bittlingmayer, G., 1988. Property rights, progress, and the aircraft patent agreement. Journal of Law and Economics 31 (1), 227–248.
Blind, K., 2012. The influence of regulations on innovation: a quantitative assessment for OECD countries. Research Policy 41 (2), 391–400.
Colombo, M.G., Grilli, L., Piva, E., 2006. In search of complementary assets: the determinants of alliance formation of high-tech start-ups. Research Policy 35 (8), 1166–1199.
David, P.A., Greenstein, S., 1990. The economics of compatibility standards: an introduction to recent research. Economics of Innovation and New Technology 1 (12), 3–41.
David, P.A., Hall, B.H., Toole, A.A., 2000. Is public R&D a complement or substitute for private R&D? A review of the econometric evidence.. Research Policy 29, 497–529.
Dittrich, K., Duysters, G.M., 2007. Networking as a means to strategy change. The case of open innovation in mobile telephony. The Journal of Product Innovation Management *24* (6), 510–521.
Dolfsma, W., 2009. Knowledge Economies. Routledge, London and New York.
Dolfsma, W., Leydesdorff, L., 2009. Lock-in and break-out from technological trajectories. Technological Forecasting and Social Change 76 (7), 932–941.
Dolfsma, W., Van der Velde, G., 2012. Innovation, firm size, and entrepreneurship: schumpeter mark III. Mimeo.
Dosi, G., 1982. Technological paradigms and technological trajectories. A suggested interpretation of the determinants and directions of technical change. Research Policy 11 (3), 147–162.
Dosi, G., 1988. Sources, procedures, and microeconomic effects of innovation. Journal of Economic Literature 26 (3), 1120–1171.
Edler, J., Georghiou, L., 2007. Public procurement and innovation—resurrecting the demand side. Research Policy 36 (7), 949–963.
Flanagan, K., Uyarra, E., Laranja, M., 2011. Reconceptualising the 'policy mix' for innovation. Research Policy 40 (5), 702–713.
Foster, R.N., 1986. Innovation: The Attacker's Advantage. Simon and Schuster, New York.
Fuchs, E., 2010. Rethinking the role of the state in technology development: DARPA and the case for embedded network governance. Research Policy, 39; 1133–1147.
Funk, J.L., 2009. The co-evolution of technology and methods of standard setting: the case of the mobile phone industry. Journal of Evolutionary Economics 19 (1), 73–93.
Giarratana, M.S., 2004. The birth of a new industry: entry by start-ups and the drivers of firm growth: the case of encryption software. Research Policy 33 (5), 787–806.
Goldfarb, B., 2008. The effect of government contracting on academic research: does the source of funding affect scientific output? Research Policy 37, 41–58.
Grimaldi, R., Kenney, M., Siegel, D.S., Wright, M., 2011. 30 years after Bayh–Dole: reassessing academic entrepreneurship. Research Policy, 40; 1045–1057.
Hall, B.H., 2002. The financing of research and development. Oxford Review of Economic Policy 18 (1), 35–51.
Jones, C., Williams, J., 1998. Measuring the social return to R&D. Quarterly Journal of Economics 113 (4), 1119–1135.
Kapsali, M., 2011. How to implement innovation policy through projects successfully. Technovation 31, 615–626.
Katz, M.L., Shapiro, C., 1994. Systems competition and network effects. Journal of Economic Perspectives 8 (2), 93–115.
Kingston, W., 2001. Innovation needs patents reform. Research Policy 30 (3), 403–423.
Klein Woolthuis, R., Lankhuizen, M., Gilsing, V., 2005. A systems failure framework for innovation policy design. Technovation 25, 609–619.
Lanjouw, J.O., Schankermann, M., 2004. Protecting intellectual property rights: are small firms handicapped? Journal of Law and Economics 47 (1), 45–74.
Lee, W., 2001. Lee's Essentials of Wireless Communications. McGraw-Hill, New York.
Lerner, J., Schankerman, M., 2010. The Comingled Code: Open Source and Economic Development. The MIT Press, Boston, MA.
Lettl, C., Rost, K., von Wartburg, I., 2009. Why are some independent inventors 'heroes' and others 'hobbyists'? The moderating role of technological diversity and specialization. Research Policy 38 (2), 243–254.
Levinthal, D.A., 1998. The slow pace of rapid technological change: gradualism and punctuation in technological change. Industrial and Corporate Change 7 (2), 217–247.
Malerba, F., 2002. Sectoral systems of innovation and production. Research Policy 31 (2), 247–264.
Malerba, F., Orsenigo, L., 1997. Technological regimes and sectoral patterns of innovative activities. Industrial and Corporate Change 6, 83–117.
Massa, S., Testa, S., 2008. Innovation and SMEs: misalligned perspectives and goals among entrepreneurs, academics, and policy makers. Resaerch Policy 28, 393–407.
Merton, R.K., 1965. On the Shoulders of Giants. The Free Press, New York.
Mowery, D.C., Rosenberg, N., 1989. New developments in US technology policy: implications for competitiveness and international trade policy. California Management Review 32 (1), 107–124.
Mueller, D.C., Tilton, J.E., 1969. Research and development costs as a barrier to entry. Canadian Journal of Economics 2 (4), 570–579.
Nelson, R.R., 1959. The simple economics of basic scientific research. Journal of Political Economy 67, 297–306.
Nemet, G., 2009. Demand-pull, Technology-push, and government-led incentives for non-incremental technical change. Research Policy 38 (5), 700–709.
Nooteboom, B., 1994. Innovation and diffusion in small firms: theory and evidence. Small Business Economics 6 (5), 327–347.
Ozcan, P., Eisenhardt, K.M., 2009. Origin of alliance portfolios: entrepreneurs, network strategies, and firm performance. Academy of Management Journal 52 (2), 246–279.
Pavitt, K., 1984. Sectoral Patterns of technical change: towards a taxonomy and a theory. Research Policy 13, 343–373.
Peters, M., Schneider, M., Griesshaber, T., Hoffmann, V.H., 2012. The impact of technology-push and demand-pull policies on technical change—does the locus of policies matter? Research Policy, Forthcoming.

Rafferty, M., 2008. The Bayh-Dole act and university research and development. Research Policy 37, 29–40.
Rietveld, G.J., 2011. Profiting from digitally distributed cultural products: the case of content producers in the video games industry. In: Dolfsma, W., McCarthy, K., Fiolet, M. (Eds.), The Nature of the New Firm. Edward Elgar, Cheltenham, pp. 100–120.
Schoen, A., Könnölä, T., Warnke, P., Barré, R., Kuhlmann, S., 2011. Tailoring Foresight to field specificities. Futures 43 (3), 232–242.
Scotchmer, S., 1991. Standing on the shoulders of giants: cumulative research and the patent law. The Journal of Economic Perspectives 5 (1), 29–41.
Seo, D., 2010. The significance of the role of government in standardization: the case of the wireless communications industry. Journal of Cases on Information Technology 12 (1), 63–73.
Suarez, F.F., 2004. Battles for technological dominance. Research Policy 33 (2), 271–286.
Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy 15 (6), 285–305.
Van den Ende, J., Dolfsma, W., 2005. Technology-push, demand-pull, and the shaping of technological paradigms—patterns in the development of computing technology. Journal of Evolutionary Economics 15 (1), 83–99.