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Patent Rights and Cumulative Innovation: Causal Evidence and Policy Implications

Ensuring effective innovation incentives is a central element of innovation policy, and property rights in the form of patents is one of the main policy instruments to achieve this. Empirical evidence shows that patent protection can also discourage follow-on innovation by downstream firms if bargaining between upstream patent holders and potential downstream licensees breaks down. For the vast majority of patents, the evidence indicates that patents do not impede downstream innovation. However, blocking occurs in complex technology areas where later innovators need many different patents to conduct research (e.g., information technology and electronics), but not in other important sectors like pharmaceuticals and chemicals. Blocking appears to be concentrated in cases where large firms with patents interact with small downstream innovators. The finding that the impact of patent rights on cumulative innovation is localized rather than pervasive calls for more targeted policies rather than a general restriction in patent rights.

Moving to the Innovation Frontier

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Contents

5 Patent Rights and Cumulative Innovation: Causal Evidence and Policy Implications

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5.1 Introduction

Cumulative research is a dominant feature of modern innovation. New genetically modified crops, computers, memory chips, medical instruments and many other modern innovations are typically improvements on prior generations of related technologies. Of course, cumulative innovation is not new. Economic historians have emphasised the role of path dependence in the development of technology, documenting how past successes and failures serve as 'focusing devices' that guide the direction of later technological inquiry (Rosenberg, 1976). However, the increasing importance of basic science in shaping the direction of technological development has intensified this process.

Cumulative innovation is underpinned by knowledge spillovers, as later innovators build on earlier research. This process lies at the heart of the recent macroeconomic literature on innovation and growth – so-called 'endogenous growth' models (Grossman and Helpman, 1991; Aghion and Howitt, 1992; Acemoglu and Akcigit, 2012). At the same time, there is a large body of evidence showing that R&D creates positive 'knowledge spillovers' that increase productivity growth and subsequent innovation (e.g. Bloom et al., 2013). This consensus on the centrality of knowledge spillovers to innovation, and innovation to productivity growth, is the primary justification for government policies to support R&D.

There has been an intensifying academic and public policy debate over the role of patents in stimulating innovation and growth. The debate has been driven by several factors. The first is the recognition that modern economies are increasingly based on intangible knowledge assets, and that this is no longer limited to particular sectors. As a consequence, an effective growth strategy requires policies and institutions that promote the generation and diffusion of innovation. The patent system is one of the main instruments governments use to increase research and development incentives, while at the same time promoting follow-on innovation. However, there is growing concern among academic scholars and policymakers that patent rights are themselves becoming an impediment to innovation, rather than the incentive they were originally intended to be. The increasing proliferation of patents and the fragmentation of ownership rights among firms are believed to raise transaction costs, constrain the freedom of action to conduct research and development, and expose firms to ex post holdup through patent litigation (Heller and Eisenberg, 1998). In the extreme case where bargaining failure in patent licensing occurs, follow-on innovation can be blocked entirely.

These issues are thought to be particularly acute in 'complex technology' industries where innovation is highly cumulative and requires the input of a large number of patented components held by diverse firms – leading examples are information technology, software and biotechnology. On top of that, critics claim that (large) firms strategically accumulate patents to use them to resolve disputes through cross-licensing, and this puts small firms, without such patent 'chits' to trade, at a disadvantage in enforcing their patent rights. These dangers have been prominently voiced in public debates on patent policy in the United States (National Research Council, 2004, Federal Trade Commission, 2011) and recent decisions by the Supreme Court (e.g. eBay Inc. v. MercExchange, 547 U.S. 338, 2006). Similar concerns have also been raised in European policy discussions on the implementation of a unitary European Patent (European Commission, 2011).

In order to design evidence-based government policies that effectively address this potential problem, it is first important to quantify the extent to which patent rights *do* in fact impede follow-on innovation, and to identify whether their impact is pervasive or instead is localised in particular types of technology fields and transacting firms. Broad reforms of the patent system may be required if this blocking effect is widespread and has a substantial blocking effect on follow-on innovation by firms across different technology areas. On the other hand, more targeted policies may be preferable if patents appear to block innovation only in very specific environments.

To date, most of the economic research on the impact of patent rights on cumulative innovation has been primarily theoretical. The main conclusion from these studies is that anything can happen – patent rights may impede, have no effect on, or even facilitate subsequent technological development. It depends critically on assumptions about the bargaining environment and contracting efficiency between different generations of innovators. In an early contribution, Kitch (1977) argues that patents enable an upstream inventor to coordinate investment in follow-on innovation more efficiently and to mitigate the dissipation of profit from downstream competition that can lead to underinvestment. By allowing the upstream innovator to serve as the gatekeeper to coordinate downstream investments, patent rights can facilitate cumulative innovation. In contrast, Green and Scotchmer (1995) show that upstream patent rights will not impede follow-on innovation that increases total value (joint profit) as long as bargaining between the parties is efficient, i.e. if there are no transaction costs and perfect information. While these assumptions are not likely to hold perfectly in most environments, this work is important because it focuses our attention on bargaining failure as the source of any blocking effect patent rights might create. The question, then, is in what kind of environments is bargaining failure more likely?

Finally, a number of papers have shown how patent rights can block innovation when bargaining failure occurs. This can arise from two main sources. First, asymmetric information about the value of the initial or follow-on innovation can lead to the parties failing to agree on a license even though there is joint profit that could be shared (Bessen and Maskin, 2009). Second, bargaining failure can occur when downstream innovators need to license multiple (complementary) upstream patents that are held by distinct patent holders. Not only does this increase transaction costs but, since bargaining is typically done bilaterally rather than coordinated across the different licensors, this creates the 'complements (or royalty stacking) problem' – value maximisation requires coordinated resolution, which is ignored by independent claimants (Shapiro, 2001; Galasso and Schankerman, 2010).

This diversity of theoretical models highlights the need for empirical research. It is important not only to establish whether patent rights block subsequent innovation, but also to identify how this effect depends on the characteristics of the bargaining environment and the transacting parties. Who exactly is blocking whom, and in what settings? Understanding these issues is essential in order to design appropriate policy remedies.

In order to provide a solid foundation for formulating policy in this (and other) areas, we need credible evidence of the *causal relationship* (not just correlations) between patents and later innovation. Given the importance of the issue, there is surprisingly little econometric evidence on this link. In two influential papers, Murray and Stern (2007) and Williams (2013) provide the first causal evidence that patent rights block later research in the biomedical field. Murray and Stern exploit patent-paper pairs to study how citations of scientific papers are affected when a patent is granted on the associated invention. They show that citations of scientific publications fall (by about 15%) when a patent is granted on the innovation associated with that publication. Williams studies the impact of contract-based intellectual property (not patents) on specific genes on subsequent human genome research and a measure of medical diagnostic tests developed on the basis of the specific genes. Interestingly, both papers find roughly similar magnitudes – property rights appear to cause roughly a 15-30% reduction in follow-on research. These important studies focus on very specific (albeit significant) innovations in human genome and biomedical research, and it is hard to know whether their conclusions generalise to other industries.

In this chapter, we report on recent evidence of how patent rights affect the process of cumulative innovation, based on Galasso and Schankerman (2015). This research adopts a novel identification strategy to estimate the causal effect of patents on cumulative innovation. We use the decisions to invalidate patents by the U.S. Court of Appeals for the Federal Circuit, which has exclusive jurisdiction in appellate cases involving patents. Because patents constitute prior art, later applicants are still required to cite patents when relevant even if they have been invalidated and thus put into the public domain. This allows us to trace how the loss of the patent right affects the rate of subsequent citations to that patent, relative to those patents that are upheld by the Court.

The main concern is that unobserved factors might be affecting both the decision to invalidate a patent and the follow-on innovation, leading us to conclude wrongly that the loss of the patent causes the later change in innovation (this is called the 'endogeneity' problem). We are able to avoid this potential problem by exploiting the fortunate institutional fact that Federal Circuit judges are assigned to patent cases through a computer programme that randomly generates three-judge panels, with decisions governed by majority rule. This random allocation of judges allows us to pin down the causal relationship between the loss of the patent right and later innovation by other firms.

There are three main empirical findings. First, the loss of patent rights causes about a 50% increase in subsequent citations of the focal patent, on average, and this finding stands up to a wide variety of tests for robustness. Second, this average impact is misleading because there is a huge amount of variation in the effect of patent invalidation on later innovation. For most patents, there is no statistically significant effect; the positive (unblocking) effect of invalidation on citations is concentrated on a small subset of patents which have unobservable characteristics that are associated with a lower probability of invalidity (i.e. stronger patents).

There is also large variation across broad technology fields in the impact of patent invalidation, and the effect is concentrated in fields that are characterised by two features: complex technology and high fragmentation of patent ownership. This finding is consistent with predictions of the theoretical models that emphasise bargaining failure in licensing as the source of blockage. Patent invalidation has a significant impact on cumulative innovation only in the fields of computers and communications, electronics and medical instruments (including biotechnology). We find no effect for drugs, chemicals or mechanical technologies. Importantly, we also are able to confirm these results using measures of later innovation that do not rely on patent citations. In two technology fields – pharmaceuticals and medical instruments – we use data on new product developments (available because of government registration requirements) and in both fields our findings are the same as with citations – patents have no blocking effect in drugs, but do in medical instruments.

Lastly, we show that the effect of patent rights on later innovation depends critically on the characteristics of the transacting parties. The impact is entirely driven by the invalidation of patents owned by large firms, which increases the number of small innovators subsequently citing the focal patent. We find no statistically significant effect of patent rights on later citations when the invalidated patents are owned by small or medium-sized firms. This result suggests that bargaining failure between upstream and downstream innovators is not widespread, but is concentrated in cases involving large patentees and small downstream innovators.

Taken together, our findings indicate that patent rights block cumulative innovation only in *very specific* environments, and this suggests that government policies should be targeted at facilitating more efficient licensing in those environments. Since innovation is the key to sustained productivity growth, policies that improve the market for licensing will make an important contribution to promoting economic growth over the long term.

5.2 Strategy for identifying the causal effect of patent rights on innovation

There are two main challenges in studying the impact of patent rights on cumulative innovation. The first is that we need to identify comparable technologies with and without patent protection. The second is that follow-on innovation is difficult to measure.

In our analysis, we exploit patent invalidation decisions by the U.S. Court of Appeals for the Federal Circuit, established in 1982. We use comprehensive data on 1357 Federal Circuit decisions from 1983 to 2008, and record whether each patent was invalidated. About 40% of the decisions in our sample lead to a loss of patent protection for the technology. We use the number of citations by subsequent patents of the 'focal' patent as a measure of cumulative innovation. Patent applicants are required to disclose known prior art that might affect the patentability of any claim and any wilful violation of this duty can render the patent unenforceable. Importantly for our purposes, the expiration or invalidation of a patent has no impact on its prior art status, so the requirement to cite it remains in place. Citations have been widely used in the economics of innovation literature as a proxy for follow-on research (Griliches, 1992), and are the only practical measure of cumulative innovation for studies such as ours that cover a wide range of technology fields. We also show that our results are robust to non-patent measures of cumulative innovation that we are able to construct for two technology fields: pharmaceuticals and medical instruments.

To estimate the effect of patent rights on follow-on innovation, we compare the number of citations received by patents that are invalidated to those that are upheld by the Federal Circuit Court, in a five-year window following the decision. A fundamental challenge with this approach is that invalidated patents may differ from those that are upheld in a variety of dimensions that may affect patent citations. For example, patents covering technologies with greater commercial potential are both more likely to be an attractive target for follow-on innovation and to induce the patentee to invest heavily in the case to avoid invalidation. It is crucial to address this 'endogeneity' issue in order to estimate the true causal impact of patent protection on cumulative innovation. We show that failure to do this leads to misleading and incorrect findings.

As mentioned earlier, our empirical strategy exploits the fact that judges are assigned to patent cases through a computer programme that randomly generates three-judge panels, with decisions governed by majority rule. We show that judges on the Federal Circuit Court exhibited very different 'propensities to invalidate' in their tenure at the Court – some voted for invalidation much more often than others (varying from about 25% to 75%). The random allocation of judges to cases, together with this variation in their propensity to invalidate patents, essentially means that invalidation of patents is a randomised outcome and thus can be used to identify the true causal impact of removing patent protection (econometrically, we implement this approach using instrumental variables). In conducting this exercise, we control for a number of patent characteristics such as the age of the patent, the technology field, the number of patent claims, and the number of citations received before the Federal Circuit decision. This approach allows us to identify the *causal impact of removing patent rights on later innovation.*

5.3 What does the evidence show?

5.3.1 The 'average effect' of patents

The baseline finding, using our instrumental variable identification strategy, is that the removal of patent protection on a patent leads to about a 50% increase in subsequent citations to that patent, on average. This evidence shows that, at least on average, patents block cumulative innovation, and we emphasise that this is evidence of a causal relationship. It is critically important to use an appropriate identification strategy to pin down causal effects here, especially if one wants to make policy recommendations on the basis of the evidence. If we instead use a simple (OLS) regression that fails to account for the fact that the patent invalidation decision is endogenous, the results indicate that there is no effect on subsequent citations. But this is a false result, since formal statistical tests confirm that patent invalidation is in fact endogenous (i.e. influenced by unobserved factors that also affect subsequent citations). This highlights the importance of using an appropriate identification strategy, and the dangers of drawing policy conclusions from evidence that is not causal.

As additional checks on this key finding, we examine other possible explanations. First, we show that the jump in later citations following the invalidation of a patent is not simply due to a 'publicity effect' from the court's decision – where subsequent innovators become more aware of the patent and thus cite it. The impact begins only after about two years following the court decision, which is consistent with the onset on follow-on innovation rather than simply being a media effect from press coverage associated with the court decision. Morevoer, when we introduce a measure of the actual press publicity around the case, the results are the same – on average, patents block later innovation. Second, we examine whether part of the jump in later citations that we observe might reflect greater use of the invention covered by the invalidated patent by later innovators, because it is now cheaper to use when no longer protected by the patent. There is some evidence of this kind of 'substitution', but it can only account for a small part (about 15%) of the overall blocking effect we find.

While the average blocking effect of patents is large, we also find that the impact of patent invalidation on subsequent innovation is highly heterogeneous. This means that the average effect is misleading, and should not form the basis for policy prescriptions. There is a lot of variation across patents – there is essentially *no significant blocking effect for most patents, but a strong effect for a minority of patents*. From a policy perspective, it is very important to understand when patents block, and when they do not so that appropriate, targeted policy remedies can be designed. In our research, we show that the blocking effect depends critically on key features of the technology area and the contracting environment, as we summarise in the next section.

5.3.2 Unbundling the impact: When do patents block?

In which technology fields does blocking occur?

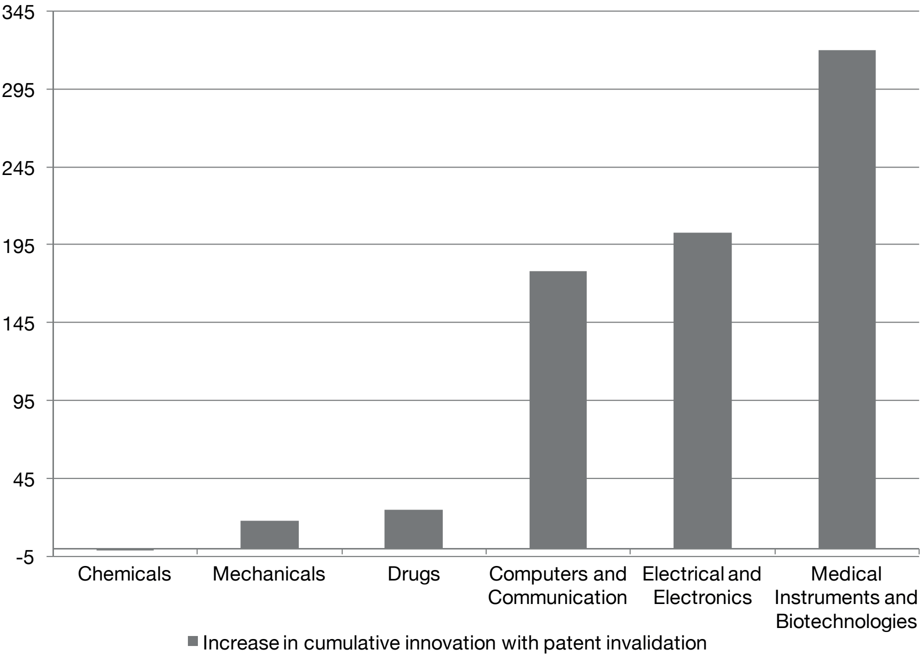
Previous empirical studies emphasise two features of the innovation environment that affect bargaining between upstream and downstream firms, and thus the incentives to invest in follow-on innovation. The first is the *fragmentation of patent ownership* in the technology field (Zeidonis, 2004). When patent ownership is fragmented rather than concentrated in a few hands, downstream innovators need to engage in multiple negotiations, which exacerbates the risks of bargaining failure and thus make it more likely that patents end up blocking later innovation. The second feature is the *'complexity' of the technology field*. In complex fields, new products – such as mobile telephones or medical instruments – embody numerous patentable elements, as contrasted with 'discrete' technology areas where products build only on few patents, such as pharmaceuticals or chemicals. When products typically incorporate many patented inputs, and they are held by different owners, licensees need to engage in multiple negotiations and the risk of bargaining failure is higher. Thus we expect the impact of patent rights on cumulative innovation to be more pronounced in complex technology fields.

To test these ideas, we construct two variables. The first is a measure of how concentrated patenting is in the technology field of the litigated patent – we use the share of patenting accounted for by the four largest patent owners in that technology subcategory during the five years preceding the Federal Circuit Court decision. The second is a control variable that identifies which technology fields are complex and which are not, building on earlier survey research by Levin et. al. (1987) and Cohen et al. (2000). Complex technology fields include electronics, computers and communication, medical instruments and biotechnology. Non-complex fields include pharmaceuticals, chemicals and mechanical technologies.

The evidence strongly confirms these hypotheses. We find that the 'blocking effect' of patents is much stronger when patent ownership is fragmented (i.e. where concentration is low) and in complex technology fields. The results indicate that the effect of invalidation is more than twice as large in complex technology areas as compared to the non-complex technology fields, and the blocking effect is much weaker when concentration of patent ownership is greater. Increasing the level of concentration by one standard deviation reduces the blocking effect of patents by about 32% in complex technology fields.

We can use these econometric estimates of the effect of concentration and complexity to compute the implied effect of patent invalidation on citations for each of the technology fields, based on the observed values of concentration and complexity that correspond to each field. The results are summarised in Figure 5.1, and they are striking. Patent rights have no statistically significant effect on cumulative innovation in the pharmaceuticals, chemicals and mechanical technology fields. By contrast, the effect is large and statistically significant in the fields which are complex and where patent ownership is more fragmented: patent invalidation raises citations by 320% in medical instruments/biotechnology, 203% in electronics and 178% in computers and communications.

Figure 5.1 Impact of patent invalidation on follow-on innovation



We want to emphasise that these key findings continue to hold when we use alternative measures of cumulative innovation that do not rely on patent citations. We are able to construct more direct measures of follow-on innovation for two of our technology fields – pharmaceuticals and medical instruments – thanks to government regulation that requires registration of new product developments. These two fields encompass both a 'complex' technology area (medical instruments) where we found a strong blocking effect, and a non-complex technology field (drugs) in which we found no blocking effect using the citations measure.

We begin with the medical instruments technology field. The Food and Drug Administration (FDA) in the United States has primary authority to regulate medical devices sold in the country. These products are subject to a regulatory process that requires detailed product information and evidence of safety from clinical trials. The FDA releases data on approvals requested for medical instruments. To use these FDA approval requests as a measure of follow-on innovation, we link them to the medical instrument patents in our sample using two different approaches (for details, see Galasso and Schankerman, 2015). Using these FDA approval requests of new medical devices as the measure of follow-on innovation in our empirical model, we find again that patent invalidation increases cumulative innovation by about the same magnitude as when we use patent citations to measure follow-on innovation. This analysis confirms our conclusion that patent invalidation has a significant impact on cumulative innovation in the complex technology field of medical instruments.

We were also able to do something similar for the pharmaceuticals technology field, again made feasible by exploiting FDA data on approvals of subsequent clinical trials. We construct a measure of follow-on innovation by identifying the subsequent clinical drug trials that are related to the active ingredient of the litigated drug patent. We are then able to match Federal Circuit drug patents with clinical trials by several different methods (details in Galasso and Schankerman, 2015). Using this clinical trials measure of cumulative innovation in our empirical model, we find that the loss of patents through invalidation has no statistically significant effect on cumulative innovation in the non-complex field of pharmaceuticals.

Overall, this analysis with product-based measures of innovation confirms our earlier conclusions from regressions based on patent citation data.

Who is blocking whom?

We showed that the blocking effect of patents on later innovation depends on how concentrated patent rights are, i.e. on the structure of technology markets. However, the influence can also run in the other direction. Patent rights can shape the industrial structure of innovation by impeding the entry of new innovators or the expansion of existing firms, and this potential blocking effect may be stronger for certain kinds of patentees or downstream innovators. We also examine this issue and show that the blocking effect of patents depends critically on the size of the patentee and the downstream innovators.

To understand better where bargaining (licensing) failures occur, we examine whether the blocking effect is stronger for certain kinds of patentees or downstream innovators. We split patentees and citing innovators in three size groups, based on the size of their patent portfolio: 'small' (fewer than 5 patents), 'medium' (6-101 patents), and 'large' (more than 102 patents, which is the 75th percentile of the distribution). This means that we can study the effects of patent invalidation on later citations for six different pairings of patentees and later innovators in terms of their size: small-small, small-medium, small-large, medium-small, medium-medium, medium- large, large-small, large-medium and large-large. The results are very striking. We find that the loss of patent rights has a statistically significant effect only for the large-small pair, that is, patents appear to block only when the patent is owned by a large firm and their impact is only on later citations by small firms.

This finding indicates that patent rights held by large firms appear to impede the 'democratisation' of innovation among small innovating firms. This is of public policy concern, especially because of the increased focus on entrepreneurial, high technology firms. However, it is equally important that we find that patents do not have any significant blocking effect among other types of patent holders and potential licensees. The blocking problem appears to be highly localised, both in terms of the types of technology fields, as described earlier, and the types of contracting parties.

These findings show that fragmentation of patent ownership and complexity of technology fields, and the types of contracting parties – in particular, their size – are key empirical determinants of the relationship between patent rights and cumulative innovation. Of course, other factors can also affect the impact of patent rights on subsequent innovation. One is product market competition. Aghion et al. (2013) provide evidence that strong patent protection stimulates innovation only when product market competition is fierce. A second factor is the degree to which 'tacit cooperation' can be used by firms to mitigate potential bargaining failures and litigation that might otherwise arise from dispersed ownership of patent rights (Lanjouw and Schankerman, 2001, 2004). Understanding where and how these differences operate is a valuable direction for future theoretical and empirical research.

5.4 Policy implications and challenges

Governments use the patent system as an important policy instrument to provide incentives for innovation, and thereby to promote long-run productivity and economic growth. In recent years, however, many scholars and other commentators in the public debate over patent reform have argued that patents are getting in the way of innovation and have recommended scaling back patent rights in various ways. The core concern is that patents are increasingly making it harder for firms to license inputs required for their research, exposing them to hold-up through patent litigation, and generally raising the cost of doing R&D.

If this is true, we should see evidence that patent rights are blocking follow-on innovation. A few recent, high-quality studies have provided credible, causal evidence that patents block cumulative innovation in very specific biomedical subfields. Our research, using a completely different identification strategy to pin down causal effects, demonstrates that, while there is some blocking effect of patents, it is localised and not pervasive. We find that patents block only in very specific technology areas (including biomedical) and only between specific types of contracting parties (large patentees and small later innovators). In other technology fields, and between other contracting parties, there is no evidence that patents block follow-on innovation.

The fact that the impact of patent rights on cumulative innovation is localised, rather than pervasive, suggests that remedial government policies should be targeted. In particular, a 'broad-based' scaling back of patent rights is unlikely to be the appropriate policy. As we argued, blocking occurs when patent owners and potential licensees fail to exploit profitable opportunities for follow-on research. This could be because they are unaware of these opportunities, or because bargaining between the parties breaks down for some reason. In the first case, an appropriate policy response is to promote private institutions, or if necessary to set up public ones, that disseminate information to potential licensees – some form of information repository that can be easily and affordably accessed. If the source of the problem is bargaining failure – in particular, as we have shown, between large patent owners and small follow-on innovators – the appropriate response is to design policies and institutions that facilitate more efficient bargaining (as with arbitration and other dispute resolution mechanisms, for example). One interesting example of such institutions are the biological resource centres in the United States studied by Furman and Stern (2011), which reduce the transactional costs of accessing knowledge inputs for biomedical research.

The key focus in patent reform should be on finding ways to reduce transaction costs and bargaining failure in licensing. In this way, governments can promote the process of cumulative innovation (and the long-run productivity growth it creates) without diluting the innovation incentives that patent rights provide.

Finally, while we have focused on the link between patents and cumulative innovation, in formulating public policy toward patent rights it is also important to bear in mind that patents can encourage innovation through a variety of other channels. Perhaps the most important of these is their role in facilitating access to the capital markets for high-technology entrepreneurial firms, both as a source of investment capital and as a means of exit for successful startups. For such firms, whose primary assets are their innovations, patents help secure their rights in these assets and thus allow them to signal their potential more effectively to venture capital and the stock market. There is growing evidence of the importance of this function of patents (Conti et al., 2013). And beyond the capital markets, patents enhance knowledge and technology diffusion across firms (and countries) by allowing innovators to capture part of the benefits from such transfers, most notably through international trade and foreign direct investment (Branstetter et al., 2006; Delgado et al., 2013). These other socially valuable functions of the patent system must also be considered in any evaluation and policy proposals for patent reform.

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