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Perspectives on the Knowledge-Based Society. An Introduction to the Special Issue

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Abstract Knowledge exchange, innovation policy, and international trade flows are key aspects of the knowledge-based economy. In her introduction to the special issue on The Knowledge-Based Society: Transition, Geography, and Competition Policy the author briefly reviews these aspects. She begins with spillovers, emphasising the effects that drive the variety of results in this literature, and their role in a model of research joint venture formation among asymmetric partners. She then moves on to the linkages between universities and industry, underlining the diversity of these linkages and their goals. She discusses the interaction among innovative skills, minimum quality standards, and patent protection, noting how these generate welfare outcomes that vary with industry innovative skill levels. Finally, the author examines threshold effects in the relation between innovation and exports.

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1 Introduction

Key components of the knowledge-based economy are the creation, distribution, diffusion, use, integration and manipulation of information. Knowledge is the fundamental resource on which both competitive advantage and economic well-being are built.

Knowledge has several distinguishing features as a resource. It has public good characteristics; it is protected by special institutions, such as intellectual property rights; it can be embodied in humans as skills, meaning that its trade and diffusion can depend on human movements. These features have led to a wide range of contributions in the microeconomic literatures on innovation, optimal protection of innovation, human capital, competitive advantage based on knowledge resources, and the geographic diffusion of innovation. The role of knowledge in overall economic growth, its contribution to differential development across sectors, and the resultant effects on employment and income often are the motivating macroeconomic concerns behind these more specific microeconomic studies.

The papers contained in this special issue span the microeconomic topics, including the transfer of knowledge across organizations, the interaction between government policy and the production of knowledge, and the trade and diffusion of knowledge across geographic regions. Overall, they paint a picture of an economy with institutions and organizations that are porous to knowledge. How organizations incorporate this porousness is a key area of study in this volume. Cassiman et al. (2010) outline the wide array of techniques organizations use to access information from academic science, consistent with the "impact" policies in the UK that support a wide range of methods to achieve impact. Squicciarini (2010) suggests that particular characteristics of science parks and their tenants combine in a complementary way to spur innovation. Indeed, her work generates a set of specific design recommendations for parks. Clark and Sand (2010) find that research joint ventures may emerge endogenously only among similarly—and relatively—efficient firms. As these are also the larger firms in the industry, and as the ventures tend to be welfare improving, an implication is that policy restrictions on the market shares of firms in research joint ventures may not be optimal. Prokop et al. (2010) focus on the scope for policy intervention in fostering new knowledge, finding that both the distribution and level of skills in an industry interact with quality standards and intellectual property design to affect welfare.

Marquez-Ramos and Martinez-Zarzoso (2010) find that threshold effects exist in the relation between exports and innovation as well as complementarity between exporter and importer innovation levels. This implies that policy to manage this relation should be applied differently in countries that find themselves at different levels of technological achievement.

This introduction will summarize the contributions of the papers, putting them in the context of a—very selective—literature review. It will also conduct a brief assessment of the work and outline avenues of further research.

2 Overview of the Papers

A key feature of the knowledge-based economy is that it uses knowledge as the fundamental resource with which to build competitive advantage and economic welfare. Knowledge tends to have public good characteristics: it can flow relatively easily among agents once it has been created with little loss. Not surprisingly, then, organizations take advantage of this feature by making themselves porous to knowledge. This raises questions of how organizations exchange knowledge, how they manage knowledge flows to obtain maximum competitive advantage, and how society could promote these knowledge flows to enhance welfare.

Knowledge can pass from one organization to another in a variety of ways, including via mergers (Ang and Wu, 2011; Jost and Van de Velden, 2006), sale or licensing (Anton and Yao, 2002; Buenstorf and Geissler, 2009), technology pools (Lerner and Tirole, 2004; Lerner et al., 2007), open source protocols (Lerner and Tirole, 2002), joint investment projects (Goyal et al., 2003), demonstrations (Gill, 2008), inter-organizational spillovers (De Bondt, 1997) and research joint ventures (Amir et al., 2003; Suzumura, 1992; Roller et al., 2007). Three of the papers in this volume, Cassiman et al. (2010), Squicciarini (2010) and Clark and Sand (2010) study aspects of spillovers.

2.1 Spillovers: A Menu of Effects and a Diversity of Outcomes

A starting point of these papers is that spillovers need to be facilitated and managed to occur in the first place: both disclosure and learning may require effort. This builds on Cohen and Levinthal (1989)'s concept that an organization is only able to take advantage of a knowledge spillover if it is capable of absorbing that knowledge. Absorption can require investment in some baseline knowledge by the receiver in order to benefit from any release of information by the transmitter.

The conclusions one reaches about whether firms have an incentive to promote spillovers depend crucially on how one assumes they occur. A starting point is to model spillovers as exogenous so that a proportion of knowledge created by an organization simply leaks out automatically to others.[1] As pointed out by De Bondt (1997), this often reduces the incentive for research effort in non-cooperative settings since it generates a reduction in the benefits to R&D without an offsetting reduction in research cost. Also, in tournament settings, such leakage can reduce the difference between research winners and losers. Cooperative behavior can overcome these disincentives so that efficiencies can be achieved by pooling research efforts in the presence of large spillovers.

As one example of this type of result, Poyago-Theotoky (1999) assumes that firms can decide to disclose useful, cost-reducing knowledge to (all) competitors after it has been created by research and development activity in a non-tournament setting: a firm may allow its scientists to participate in open conferences or publish their results. In such a framework, sharing knowledge never pays since it merely strengthens competitors. On the other hand moving to a cooperative industry structure, as one would with a formal research joint venture, may achieve economies of scale—of a type—through sharing research results since results of one project can move forward another project towards completion. Hence, research joint ventures should be observed jointly with (facilitated) spillovers.

This result raises a puzzle, however, as disclosures do occur even in the absence of research joint ventures. It turns out that the level of commitment in the decisions affects the results considerably. Specifically, changing the order of the decisions to share information and conduct R&D affects the results and also broadens the interpretation we put on the spillover. When the decision to share occurs before the R&D decision, for example, we could interpret this as a case where spillovers are the result of the geographic proximity of firms. A two-way symmetric spillover effectively would be chosen at the time the firm locates

[1] See d'Aspremont and Jacquemin (1988) and De Bondt (1997) for an excellent summary.

because the spillover would occur naturally through contact among employees of neighboring firms. In this interpretation, the spillover is only partially under the control of any single firm since it depends on the joint location decisions of the firm and its neighbor. An analogous case arises when firms choose a similar research trajectory—or design—to another firm: the fact that both firms have adopted similar research approaches means that research achievements by one may spill over to the other relatively easily. In this case, “distance” is technological rather than geographic.

As pointed out by Gil-Molto et al. (2005), when the decision on the degree of spillovers precedes the R&D decision, and where spillovers are two-way, it can create free riding as firms attempt to minimize their R&D expenditures but at the same time profit from the research achievements of competitors. Kamien and Zang (2000) point out that cooperative research decisions should be associated with firms’ choosing similar research approaches so as to maximize spillovers; however, Wiethaus (2005) shows that free riding due to spillovers can be a positive feature even in a non-cooperative setting. Free riding can allow competing firms to escape from a prisoner’s dilemma where firms are doomed to over-invest in R&D in an attempt to gain competitive advantage. Firms may instead wish to make a commitment to similar research routes precisely to avoid such an outcome. Cooperative arrangements could also be associated with a choice of similar research routes, but would be associated with larger research incentives than the non-cooperative case.

There can be other reasons to share technology that neither lead to cooperative arrangements, nor arise as a “solution” to a prisoner’s dilemma. Strategic disclosure—a pure “outgoing” spillover—is a case in point. For example, Gill (2008) finds that, in the setting of an R&D race, a leading firm may have an incentive to disclose its intermediate results in order to signal its commitment to the project. This can induce lagging rivals to exit. The incentive to disclose exists as long as the information that a competitor may have gleaned from the disclosure is not too useful to the competitor’s own progress in the race. Indeed, Gill (2008) shows that even if disclosure is not chosen, the option to disclose is nonetheless crucial to signaling and inducing exit in his model. If there were no option to disclose, then there would be no information value to the event “no disclosure”, and so there would be less deterrence possible. The type of disclosure that this model captures might be preannouncements of software, or prototype demonstrations at trade shows. A completely different reason for disclosure is modeled by Lichtman et al. (2000), who show that there is an incentive to disclose research results to affect prior art and hence the patentability of others' competing inventions.

In Gill (2008), disclosure is an outgoing spillover, with no necessary "incoming" spillover. As such, it is quite distinct from geographic or technology trajectory spillovers, where outgoing and incoming spillovers are linked. While one might expect that firms would generally choose only to be receivers and not senders of spillovers, Millou (2009) points out that even if a firm has an option just to be a receiver of spillovers from others, it may choose endogenously to be a sender as well. This occurs when a firm's outgoing spillovers induce sufficient reciprocal incoming spillovers to reward the firm for the disclosure. Indeed, this effect has been observed in a variety of spillover settings, including Harhoff et al. (2003), and Bessen and Maskin (2009). Millou (2009) echoes De Bondt (1997) in pointing out that product differentiation affects this balance, as it affects the "relevance" of the information to a firm's competitive position. De Bondt (1997) and Bessen and Maskin (2009) add that the number of firms affects the balance as well, as this affects the "pool size" from which the firm draws knowledge compared to its own contribution to that pool.

Hence, exactly what we assume about how spillovers occur is crucial to this literature. Whether spillovers occur at all, their welfare effects, and their effects on innovation incentives and market structure are quite sensitive to the specifics of each model; however, the general effects of spillovers on incentives to undertake further innovation and incentives to form cooperative organizations such as research joint ventures are more universal. We have already mentioned free riding on the research of others. In addition, research is inherently complementary across firms in many of the models: firms have an incentive to share to reduce the consequences of decreasing returns to internal research. Direct cost sharing from collaborative structures or a reduction in duplicative research can also emerge. Finally, the benefits from spillovers are spread over a larger output for larger firms, meaning that more efficient firms have greater incentives to access spillovers. In sum, it is not the list of factors but rather their precise combination and weighting that generates the variety of conclusions about policy and the benefits of the specific research joint venture or other cooperative designs found in this literature.[2]

As an illustration of how these factors can be combined to answer new questions, in this volume Clark and Sand (2010) examine not so much whether research joint ventures form but rather who chooses this option when spillovers are present. Venture participants take full advantage of any technological advancement discovered by a partner, but undertake research investment decisions non-cooperatively. Spillovers are contained within the venture: there is zero spillover to the outside. In this sense, the venture is similar to choosing compatible research routes with little else that looks "joint". In this framework, firms can—and do—form coalitions that benefit them but disadvantage any outsider. In equilibrium, either all firms may join together to form a grand coalition or the more efficient firms may join together, excluding the less efficient firm. This results from several of the effects we listed above drive the results: a free riding effect due to the spillover, a more efficient joint research process due to individually decreasing returns to research, and the fact that the joint venture can potentially reduce the cost asymmetries among firms in the industry.

As in the empirical study by Roller et al. (2007), Clark and Sand (2010) find that asymmetric firms are less likely to join together to form a joint venture. Their results also are consistent with Gugler and Siebert's (2007) empirical observation that larger firms are more likely to participate in research joint ventures. On the other hand, Clark and Sand (2010) find that, while the insiders cut their research efforts somewhat and the outsider increases research, the total effect tends to drive industry costs apart when only the more efficient firms join in a venture. Contrary to the findings of Roller et al. (2007), this effect increases industry asymmetry when research joint ventures are present, raising industry profits but also those of the insiders. Indeed, consumers prefer the arrangement where the most efficient firms venture together to any other: free riding is moderate in this case, while efficiencies in research can reduce costs significantly.

[2] See De Bondt (1997) for analysis and an exhortation for more robust results.

2.2 University Linkages: Diversity and Management of Information Transfer

While theory can be developed to analyze many different observed joint venture arrangements, the theoretical literature's diversity of conclusions depending on model specifics suggests that investigating empirically how and when these spillovers occur is very important to placing appropriate values on the literature's contributions. Both Cassiman et al. (2010) and Squicciarini (2010) undertake such empirical analysis in this volume. Specifically, Cassiman et al. (2010) study university-industry linkages, emphasizing that there is no "one size fits all" way to establish this link. Squicciarini (2010) studies empirically the effectiveness of different designs of science research parks, a particular institution that facilitates linkages among universities and firms.[3]

More precisely, Cassiman et al. (2010) dive into the "black box" of how spillovers are created by examining how linkages arise between academic science and the more applied science behind inventions. Recent policy debates, including the "impact agenda" in the United Kingdom,[4] stress the importance of university-industry transfer of knowledge as a measure of the externalities generated by academic work—and hence a criterion for receiving public funds.[5] Similarly, Land Grant universities in the United States have traditionally placed value on developing practical innovations for the use—primarily—of farmers. Their land grant status is predicated on this transfer, again making public support rely directly on university-industry knowledge transfer.[6] The Bayh-Dole Act in the US also had

[3] For an excellent recent paper incorporating social network theory into an empirical model of spillovers, see Fershtman and Gandal (2011), which measures diversity within an empirical model based on social networks. The Cassiman et al. (2010) and Squicciarini papers concentrate on science spillovers to industry, rather than open source code collaborations, as does that paper.

[4] An impact exercise has been run as a pilot project as part of the 2014 Research Excellence Framework (REF). See http://www.ref.ac.uk/background/pilot/ for details. Based on the pilot, impact will be included in the 2014 REF assessments as input into the decision of how to allocate funding for public research. See http://www.ref.ac.uk/pubs/2011-01/.

[5] Impact will receive a ten percent weighting in the overall assessment of public research "quality". See http://www.ref.ac.uk/pubs/2011-01/ for discussion and justification.

[6] For example, see the First Morrill Act (1862), which required the colleges to have a practical bent, and extended to agricultural innovation via a series of experiment stations in the Hatch Act of 1887.

as one of its aims better technology transfer from academia to industry (Vivekanandan, 2008). While the policy debate makes it clear that this is an important issue, and the externality argument for funding public research makes a compelling theoretical case for university-firm transfer, the way in which this transfer is to be achieved is less obvious and is largely left to individual institutions in policy guidance.[7]

Linkages between universities and firms have been studied extensively.[8] In terms of the effect of university involvement on the speed of invention, Mansfield (1991) shows that some innovations—about eight percent of product innovations and six percent of process innovations in his sample—appear to progress faster with academic input. On the other hand, Hall et al. (2003) show that academic involvement can postpone the generation of innovative outputs. In terms of how universities participate, Monjon and Waelbroek (2003) find in their study of French firms that it is primarily those that are catching up to the technology frontier that benefit from academic work. Many works, such as Parvan et al. (2007), Arundel and Geuna (2004) and Cohen et al. (2000) find that academic linkages are relatively unimportant in generating private innovation compared to other linkages, such as those to customers and suppliers. Further, direct linkages may pale compared to indirect linkages. In other words, the contribution of a particular academic innovation to industry may be small, but the indirect benefits of general collaboration between academics and industry via conferences and publications may contribute significantly to industry research.

The reasons behind the benefits of indirect linkages may be that they codify knowledge and increase the efficiency of problem solving (Arrow, 1962), reduce wasteful experimentation (Fleming and Sorenson, 2004), help to identify and absorb external knowledge (Cohen and Levinthal, 1989; Gambardella, 1992; Henderson and Cockburn, 1996; Cassiman and Veugelers, 2006) and quicken the conversion of knowledge into innovation (Fabrizio, 2009; Cassiman et al., 2008). Knowledge of science may also encourage non-local search for improvement

The dissemination function was established in the Smith-Lever Act of 1914. For a summary, see http://www.nap.edu/openbook.php?record_id=4980&page=9.

[7] See the inclusive nature of transfer in the REF document, http://www.ref.ac.uk/pubs/2011-01/.

[8] In addition to the references given here, several excellent special issues have been prepared on university-industry linkages and related issues, including *Management Science*, 2002, 48(1) and the *International Journal of Industrial Organization*, 2003, 21(9).

technology. Scientifically active firms can, then, be expected to generate unexpected outcomes (Sobrero and Roberts, 2001; Cassiman and Valentini, 2009; Aghion et al., 2008). On another note, Stern (2004) suggests that scientifically active firms both attract employees at lower cost labor and simultaneously obtain a better bridge to the scientific world.

Echoing this wide range of possible benefits, Cassiman et al. (2010) focus on the diversity of science-industry linkages rather than their value, frequency, or use. Largely relying on Community Innovation Survey 3, they classify Flemish firms into those that use cooperative R&D agreements with public R&D centers and universities, those that use publicly available scientific information, those that access citations to the scientific literature in their patents, and those that are involved in scientific publication directly. Although their sample size is small, they observe that many firms that are science linked use multiple forms of linkages. While some do specialize, there is no clearly preferred type of linkage. The authors conclude that the management lesson to be drawn from the study is that there is no “magic bullet” for firms to use to access scientific information overall, although they do find some evidence of specialization by industry.

Cassiman et al. (2010) note the relative unimportance of direct linkages between industry and university patents, striking a cautionary note on interpreting academic-industry spillovers using patent citation data. This has been pointed out in other contexts by a variety of authors including Freeman and Van Reenen (2009) and a series of works by Zucker, Darby and others (for example, Zucker et al., 1998). Indeed, using university patent citation statistics as a reflection of university spillovers probably undercounts those spillovers very significantly. The relative unimportance of direct linkages found in Cassiman et al. (2010) and elsewhere lends support to the view that a main benefit of the Bayh-Dole Act in the US was to transfer earnings to universities from industry rather than to promote better university knowledge transfer.

In contrast to focus of Cassiman et al. (2010) on diverse linkages, Squicciarini (2010) analyses only a single method of transferring knowledge and building innovation: science parks. Squicciarini (2010) postulates that science parks provide a seedbed for innovation by bringing together firms and academia in a small geographic area, supported by dedicated management and, often, financing. She focusses on patents as indicators of concrete and commercialisable innovative output, and diagnoses the features of parks that tend to facilitate or hinder the generation of such innovative output. She finds that the presence of higher education institutions inside the parks, along with the presence of a large and highly innovative non-university entity affects the overall patenting activity of the tenants, although it is unclear whether the academic presence affects innovation via its role in influencing the type of tenant that chooses to populate the park or whether the academic contribution to innovative output is more direct. The role of a single highly innovative non-university entity is strongly positive on other tenants, while the role of higher education institutions somewhat negative, consistent with the ideas we mentioned above that academic participation in projects is associated with delayed patent output but that spillovers from other innovative private firms are a major source of knowledge for firms. Park size appears to have a mild positive agglomeration effect on innovative output. Overall, her work broadly supports science parks as an effective channel for generating academic-industry technology transfer but suggests that transfer from other types of organizations, such as large firms that are skilled at generating large amounts of patentable output, may have the most immediate benefit to smaller or younger innovators. Science parks potentially facilitate this transfer by grouping together such organizations. To the extent that an academic presence helps to attract the groups that will benefit from interaction, academic input is important to science parks even if it may not be direct.

2.3 Regulatory Design: Quality Standards and Skills

Governmental innovation policy can help to establish the conditions under which innovation can flourish. The three papers we have reviewed so far have had some innovation policy recommendations: an approach to research joint ventures that is flexible to participant size, promoting academic impact by a broad set of routes, and supporting the creation of research parks with joint university and "large firm" anchors. . The centrality of knowledge to many sectors and public good nature of knowledge mean that the role for policy extends far beyond managing spillovers, however. It includes financing innovative firms, establishing regulatory frameworks that stimulate demand and provide financial incentives for innovation, standards setting and procurement initiatives, education and labor mobility policy, intellectual property rights, sectoral policies, and trade policy.

Prokop et al. (2010) have policy design as a focus of their work. They analyze both standards setting and intellectual property rights design in a framework where these regulations interact with skill levels in industry to generate equilibrium industry configurations and welfare results.

Minimum quality standards are pervasive in most developed economies, applying to industries from building to aerospace. For example, they form the main part of the work of agencies such as the National Institute for Standards and Technology (NIST) or the Food and Drug Administration in the United States and the British Standards Agency in Britain. These agencies tend to do more than just set standards, however. They often conduct training activities and disseminate information about best practice as well as produce useful and publicly available research that extends the technology frontier. For example, the Baldridge program at NIST specifically aims to improve firms' technological and innovative performance. As such, these agencies contribute to the knowledge-based economy on a number of levels, including product design, innovation and knowledge diffusion, and development of skills. In addition, these institutions often generate new knowledge of their own.

Many standards are imposed for safety reasons.[9] Furthermore, it is intuitive that training, research, and standards activities fit together in a single agency's mandate in the sense that setting standards requires an intimate knowledge of the underlying technologies. One can ask, however, outside of safety concerns and outside of agency economies of scope, how minimum quality standards and training could interact to increase welfare. Prokop et al. (2010) find that these activities do fit together from a welfare perspective in the sense that entry patterns, the timing of entry, and the end quality of products reaching the market depend on both the level and spread of innovative abilities of an industry. As a result, the welfare effect of minimum quality standards is intimately linked to industry innovative skill levels. More precisely, when innovative skill levels are symmetric across firms and relatively high, then a minimum quality standard can always be found that improves welfare, while for intermediate levels of skill this need not be the case. When skill levels differ, minimum quality standards can constrain the

[9] Prokop et al. (2010) take the need for minimum quality standards as given; however, labelling and certification are alternatives to minimum quality standards, and can have a role where externalities from low quality are not significant. See Buehler and Schuett (2012) for a comparison.

date of entry of the low-skilled firm to a point where welfare can fall even if the standard increases the incentive of the highly skilled researcher to enter the market early with a new product. The interaction of the minimum quality standard, the resulting order of entry, and the spread of research abilities of the firms is, indeed, crucial to determining the welfare effect of the standards. An implication of this is that training and “best practice” diffusion activities and standards setting may optimally be linked when we consider their feedback effects on product introductions and profit.[10]

This focus on the interaction between minimum quality standards and skills adds to existing rationales for quality standards. These include mitigation of information asymmetries (Leland, 1979; Shapiro, 1983), and having a “knock on” effect of raising all product qualities in a market as competitors attempt to “escape the competition” from lower quality goods (Ronnen, 1991).

While minimum quality standards affect the first date of entry in an industry where quality improves over time, novelty requirements can potentially affect the time that elapses between subsequent product introductions. The private choice of these entry dates (or quality levels) may not be socially optimal because the firms do not collect all the surplus that their new products generate. Hence, policy tools may optimally require firms to postpone entry in order to develop the necessary improvements. More concretely, the Prokop et al. (2010) model incorporates both vertical and horizontal differentiation. In this context, we could consider two products that are protected by patents and currently manufactured and sold under different brand names. Taking this existing branding and design as exogenous horizontal differentiation, firms now contemplate introducing a new technological feature that will increase the quality of their offerings. The impact of a novelty requirement on the timing of introduction, order of introduction, and quality level is the focus of the study. The paper finds that symmetric high abilities combined with a novelty requirement raise welfare, with no necessary improvement for a middle range. The welfare effects are similarly ambiguous when innovative skill levels differ. Again, we see that the welfare effects of policy requirements are

[10] The minimum quality standards literature often relies on a Mussa and Rosen (1978) model of quality choice. The results on how quality restrictions can affect the range of qualities available and hence the substitutability of products, profits, consumer surplus, and dynamic incentives to collude are sensitive to this assumption as well as to the choice of strategic variable (quality or price) and the cost of quality. See Napel and Oldehaver (2011) for a recent literature review of these issues.

intimately linked with both the level and distribution of skills in the industry: raising the skills of the entire industry symmetrically improves the welfare performance of the novelty requirement. To the extent that patent office—or other government department—training and diffusion activities actually improve the skills of firms as researchers; these activities are complementary in the Prokop et al. (2010) framework.

Prokop et al. (2010) find that weaker patents, in the sense of weaker novelty requirements, can improve firms' profitability. This adds to a general literature on the private and public benefits of weaker patent protection. A combination of considerations has led to this conclusion in the literature, two of which we have already described above: (1 frictions may exist that substitute for patents to drive a wedge between diffusion of an innovation and elimination of profits via imitation, (2) research efforts of different inventors may be complementary so that there is a benefit to all firms or to society as a whole of having multiple innovators. The literature also points out that (3) there may be some benefit to coordination of the innovation adoption process (Katz and Shapiro, 1986; Glachant and Meniere, 2010), and (4) hold-up problems may drive up the societal and private cost of commercializing any single innovative product that reads on a set of fragmented patent rights (Heller and Eisenberg, 1998). An additional argument has been made that patents are not necessary to generate innovation since monetary reward is not the prime motivator for innovators; however, this is not really an objection to a system whereby obtaining a patent is voluntary: those who do not need the monetary reward need not apply (Lerner and Tirole, 2002).

The intuition of the Prokop et al. (2010) result on weak patents does not rely on the factors mentioned above. Rather, the intuition is that the stronger novelty requirement, by dint of postponing the entry time of a second mover, reduces the "opportunity cost" of moving early. As a result, the leader is tempted to enter sooner with a lower quality product as part of pre-emptive behavior. In other words, by worsening the prospects of the second mover the novelty requirement intensifies the race to be first mover. This can potentially dissipate rents, with an associated reduction in welfare for some or all firms (especially low-skilled firms) in the industry. This intuition is related to the work of O'Donoghue et al. (1998), who examine optimal combinations of patent length and breadth protection in a quality ladder setting and Horowitz and Lai (1996), who examine the incentives to produce a "big" innovative step depending on the frequency of "creative destruction”. The Prokop et al. (2010) framework is distinct, however: it considers a wider set of equilibria in a model with both horizontal and vertical differentiation and focuses on the effects on planned product introductions rather than on stochastic creative destruction. The focus of Prokop et al. (2010) also is distinct, concentrating on the interaction of skill levels of the innovators, including asymmetric skill levels, with regulatory design.

In terms of how—rather than whether—skills, welfare and behavior relate to each other, a focus of the paper is on discontinuities. In the case of both the instruments studied, the fact that parameters are allowed to take a full range means that two types of equilibria with widely differing behavior exist in the model and are present for different parameter ranges. One type of equilibrium is characterized by pre-emptive behavior where firms race to be first entrant in the industry and so dissipate the profits of moving early; the other is characterized by firms’ moving at their optimal entry dates with no dissipation of profit. Indeed, in the first type of equilibrium profits equalize across early and later movers and in the second type, late movers earn higher profits. Moving from one parameter range of innovative skills to another can induce a discrete change in the type of equilibrium so that small changes in skill levels can influence not only the order and timing of entry but also the relative profitability of the firms and the entire nature of their strategic behavior. Hence, relatively small changes in the levels and spread of innovative skills can feed into large changes in both innovative and corporate strategy. This feeds back on the welfare implications of the two instruments, causing jumps in welfare benefits (or costs) of these instruments when skill levels change.

2.4 Regional Policy: Innovation and Trade

A final characteristic of innovation policy is that it often is formulated at the regional, national and also international levels. This reflects the importance of externalities, some of which are geographic. Not surprisingly, then, trade policy is one element of innovation policy. A variety of mechanisms link innovation and international trade, most of which pose empirical hurdles. Eaton and Kortum (2002) link technology, geography and trade in a modified Ricardian framework, reflecting the forces of comparative and absolute advantage as well as geographic barriers. In this setting, trade transmits welfare effects of technological change but the effects depend on the starting conditions of the trading partners, so they are not necessarily linear. A variety of authors develop the link from technological competitiveness to trade, while others emphasize that trade generates innovativeness through learning by doing and "escaping competition" effects, suggesting that the causation can run both ways. Product cycle models take a more dynamic view of innovation and imitation cycles, often with innovation occurring in "northern" countries and imitation occurring in the "south". In these models, the role of innovation changes depending on the type of country involved, with innovation in some amounting to generating new technology and innovation in others amounting to absorbing new products generated by others.[11]

Marquez-Ramos and Martinez-Zarzoso (2010) conduct an empirical study of the linkage from technological innovation to exports, attempting to surmount many of the empirical hurdles in this literature. Their measure of technological innovation, the Technology Achievement Index (TAI), was introduced by the United Nations Development Program in 2001. It is quite comprehensive, using indicators of a country's achievements in four areas: creation of new technology, human skills, and diffusion of both old and new technology. These four areas attempt to capture both potential and achieved technology creation and absorption, allowing a very broad role for technology in both exporting and importing partners. This being said, the TAI is not unique in this area[12] and has drawbacks as well as advantages, as do its alternatives. In particular, the TAI includes a measure of exports and is a simple rather than a calibrated average of its components. In common with the techniques of other authors in this area, Marquez-Ramos and Martinez-Zarzoso (2010) attempt to exploit TAI's good qualities while offsetting some of these disadvantages by their econometric strategy.

The equations in the paper allow for a non-linear relation between technology and exports, and one is indeed supported in the results, although the nature of the relation changes depending on the nature of the trading partners, which is taken into account by a large number of controls. Consistent with earlier work on where most trade occurs, technological innovation by an exporter is positively related to exports, but the effect increases with the technological innovations of an importer. In this sense, technological achievements by exporters and importers are

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[11] See Keller (2004) for an excellent review of international technology diffusion.

[12] For a recent discussion of technology and human skills measurement, see Messinis and Ahmed (2010) and references therein.

complementary in their effects on exports: they create conditions both for supply to be forthcoming and for that supply to find local demand.

The paper also shows that the measure one uses for technological innovation affects the relation one observes between exports and trade. The diffusion of the Internet has a positive and mildly U-shaped effect on exports, with increases in Internet use from very low levels having a higher impact than increases from an already high level. In this case, technological innovation probably is working through the channel of decreasing "geographic distance" between trading partners by improving knowledge flows. Human skills also have a positive, but much larger, effect for exporters than for importers, and a pronounced inverted-U relation for exporters. This dimension is measured mainly by schooling and may suggest, following Smith (2002), that a key determinant of exports is the potential "set of ideas" from which exportable products are created, which may be attributable to the local skill set. Specifically, a minimum level of training may be necessary to generate products that others will find useful, but extremely high levels of education may be extraneous or even harmful to generating popular design. Hence, while technology and trade are related positively throughout, the shape of that relation in both exporters and importers is sensitive to the proxy used, reflecting the different roles that knowledge plays in trade.

3 Assessment

The papers in this volume lead to certain conclusions and follow-up questions. In terms of spillovers and technology transfer, one is struck by the heterogeneity in the methods with which transfer is achieved. Given that, in the words of Cassiman et al. (2010), one size does not fit all in terms of management of spillovers, nor does there appear to be a "most desirable" form of technology transfer from a welfare perspective, policies that encourage a wide variety of transfer methods seem appropriate. In this sense, the recent UK REF framework's non-prescriptive approach to how impact is achieved is appropriate. The paper's data set is quite small; however, suggesting further work would be needed for firmer conclusions. Cassiman et al. (2010) leave open the question of whether society could benefit from more firms' accessing the science base. They note but do not answer why the percentage of firms accessing university knowledge is so small. Indeed, current policy does not seem to either direct more public funds or otherwise distinguish between broad-based knowledge transfers from academia and focused but intensive transfer: transfer of large amounts of information to a few recipients or modest transfers to a large number of recipients seem to be treated more or less equally for policy and funding purposes.

Cassiman et al. (2010) tantalizingly suggest that knowing how firms access university science could help us to establish the importance of geographic linkages and social networks in that transfer: firms that obtain access primarily by publications may not benefit from geographic proximity whereas those that share personal links may. Since the preferred form of linkage seems to vary systematically by industry, one could revisit the literature on the importance of geographically based spillovers: if a country or industry primarily generates spillovers via conferences or direct collaboration rather than publications, for example, then that country or industry may be more likely to exhibit highly geographically based spillovers. This might explain some of the inconsistencies that emerge in the literature on proximity and the use of public science.[13]

Clark and Sand (2010) make clear that the welfare argument for promoting transfers depends on the precise conditions of the transfer, in line with the general spillover literature. This argues for caution in spending public moneys or instituting policies to promote blanket transfers. Clark and Sand (2010) also point out that since consumers and firms benefit from allowing the more efficient firms to form a joint venture, market share restrictions on joint venture formation do not necessarily improve welfare. Clearly, the specificity of the model suggests caution in applying this conclusion in a broad way to competition policy, but it would be interesting to attempt to generalize. Perhaps the main conclusion from the body of research on research joint ventures—and the Clark and Sand paper in particular—is that policy frameworks other than "individual assessment" are difficult to fashion. The fact that these ventures often result in welfare gains, however, does support taking an open mind to their benefits, as is reflected in current policy.

Prokop et al. (2010) suggest that innovative skill levels and their distribution interact with quality standards and patent design to affect corporate strategy and welfare. Their results have implications for agenda setting for such agencies, but also would need to be generalized before being applied in practice. In terms of

[13] See Arundel and Geuna (2004) for a summary.

their implications for research into industry entry patterns, their models indicates that there should be no presumption that early entrants are higher skilled researchers nor should there be a presumption that earlier entrants have better products in any sense. Indeed, the paper is distinct from several of the recent papers that include entry, quality, and product differentiation choice. For example, while Mazzeo (2002) conducts an experiment examining which of several discrete quality levels a proprietor would choose in an entry decision, Prokop et al. (2010) focus on how the ability to provide quality and regulation affects this type of choice. While Prokop et al. (2010) shares with models such as Mazzeo's the intuition of that entry occurs once a threshold profitability level is reached, it then determines the equilibrium product design choice in a specification that is flexible in its equilibrium concept and incorporates a role for regulation.

That being said, Prokop et al. (2010) is a special case on other dimensions: more general industry configurations, innovation profiles and skill distributions should be investigated. The paper also leaves open the question of how and to what extent changing patent parameters in the context of broader industry regulation can affect welfare. In the specific case of minimum quality standards and novelty requirements studied in this paper, it is clear that only in cases where both first and second product introductions are too early could welfare ever be improved by using these instruments jointly; the paper does not, however, explore these parameter ranges or investigate the training implications of the joint use of these instruments. It also leaves open the question of how the analysis changes with multiple introductions.[14] Carranza (2010) models multiple introductions with rational consumer expectations, but Carranza focuses on the interaction between competition and product introductions as opposed to regulation, skills, and product introductions. Clearly, more work remains to be done.

Finally, the results of the Marquez-Ramos and Martinez-Zarzoso (2010) paper confirm others' results (such as Estrada et al., 2006) that there are "threshold" effects at play in the relation between technological innovation and exports; further, it appears that technological innovation plays a large number of roles in the promotion of exports so that any analysis and policy is sensitive to the proxies it uses. Given this, the paper can be taken as supporting a broad-based approach

[14] Interestingly, Mazzeo's empirical work (Mazzeo 2002) indicates that lack of commitment to a product design choice does not seem critical to his empirical results.

towards promoting technological innovation—with many different aspects of technological achievement potentially receiving policy attention—but also one that may change its priorities as different stages of technological advance are reached and along different dimensions of technology. For example, there is little support in this paper for exporter benefits from an increase in already high diffusion of recent innovation (penetration levels of the Internet) or high levels of human capital (education) at home. In contrast, an exporter with an already high level of creating innovation from its human capital base (patenting) may do well to increase this dimension further. It would be interesting to study this in a general model where overall welfare effects can be studied: it is not clear that once these are specified fully this policy recommendation would stand.

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