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The quality of innovation and the extent of the market

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ABSTRACT

I present a comprehensive model of international trade in technology that considers both the demand for inventions and the supply of inventions. On the demand side, domestic and foreign firms make strategic technology adoption decisions. On the supply side, inventors compete to sell licenses for their technology to domestic and foreign firms. Countries benefit from international trade in technology because they obtain the best invention from a larger pool of inventions. International trade in technology increases the extent of the market for inventions and thereby improves the quality of innovation. Technology trade lowers prices, increases outputs, and increases the volume of trade in differentiated products. When traded products are not close substitutes, international markets for technology generate gains from trade. The results of the analysis are robust to the possibility of technology transfer either through expropriation or imitation. Protection of intellectual property rights preserves incentives for entry of inventors and improves the quality of innovation.

1. Introduction

There is a growing international market for technology, with trade in ideas, training, inventions, copyrights, trademarks, business processes, software, consulting, and industrial designs. Research and development (R&D) is spreading globally with the dispersion of inventive efforts across a wide range of industrialized countries accompanied by expansion of invention in leading developing countries (OECD, 2008a,d). Multinational enterprises are turning to the "world-wide supply of science and technology" through arms-length license purchases, collaborative invention, and internal transfers from foreign subsidiaries (OECD, 2008b,c).[1] OECD countries other than the five leading research economies (U.S., Japan, U.K., Germany, and France) obtain over 90% of their productivity growth from ideas originating abroad (Eaton and Kortum, 1996). Companies increasingly rely on world-wide outsourcing of invention to independent inventors, customers, suppliers, universities, and research institutes, as well as alliances and joint ventures (De Backer et al. 2008). Patent families increasingly provide protections for international technology sales.[2] An extensive series of international treaties covers intellectual property (IP) including TRIPS.[3]

To understand the global market for technology, I develop a comprehensive model that includes both the international supply of inventions and the international demand for inventions. On the supply side, the model features entry of inventors who invest in uncertain R&D and then compete to sell their inventions to domestic and foreign downstream firms. On the demand side, the model features strategic adoption decisions by downstream firms who then compete to sell differentiated products in international markets. The international technology market model identifies critical tradeoffs between the costs of R&D and the benefits of technology transfer that could not be obtained by looking at either technology demand or supply in isolation.

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[1] Many multinational corporations engage in global R&D, see for example Kuemmerle (1999), Anand and Khanna (2000), Arora et al. (2001a,b), and Khanna and Singh (2002).

[2] The number of patent families, with each protecting a single invention and taken at the European Patent Office (EPO), the Japan Patent Office (JPO) and the US Patent and Trademark Office (USPTO), more than doubled in a period of two decades reaching 52,000 families by 2005 (OECD, 2008d).

[3] TRIPS refers to the international agreement on Trade-Related Aspects of Intellectual Property Rights. Other IP treaties include the Paris Convention for the Protection of Industrial Property, the Berne Convention for the Protection of Literary and Artistic Works, the International Convention for the Protection of Performers, Producers of Phonograms and Broadcasting Organizations (Rome), and the Treaty on Intellectual Property in Respect of Integrated Circuits (Washington). The TRIPS Agreement is contained in Annex 1C of the Marrakesh Agreement Establishing the World Trade Organization, April 15, 1994, see www.wto.org.

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The comprehensive model of the international technology market provides several important results. An international technology market improves the quality of innovation by increasing the extent of the market for inventions. First, I show that more inventors enter the international technology market than enter in any country with domestic technology competition. This means that with technology trade, more inventors compete to supply technology to each country. When inventors compete globally rather than domestically, the best ideas are chosen from a global pool rather than country-specific pools. More inventors increase the quality of the ideas in the global pool relative to smaller domestic pools so that international trade in technology improves the expected quality of ideas. Second, I show that by increasing the quality of innovation, international trade in technology reduces product prices, increases outputs, and increases the volume of product trade.

Third, I obtain conditions under which the international market for technology generates gains from trade. By improving the expected quality of ideas, the international market for technology generates benefits because countries have access to the best technology. However, by stimulating entry of inventors, the international market for technology may raise the total costs of invention in comparison with domestic technology markets. When products are not close substitutes, product-market competition is mitigated so that international technology markets do not increase world-wide R&D costs. When products are not close substitutes, transferring technology generates benefits that outweigh R&D costs so that international technology markets yield gains from trade.

Fourth, the model of the international market for technology provides a way to evaluate the effects of expropriation and imitation on the quality of innovation and gains from trade. As Arrow (1962) pointed out, inventors face the risk of expropriation when they offer their inventions to a prospective buyer. The risk of expropriation in some countries diminishes incentives for inventors to enter international technology markets and reduces the quality of innovation. In the imitation mode of technology transfer, inventors face the risk that their technology will be imitated whether or not they try to license their technology. The risk of imitation partly offsets the benefits of internationally extending the market for technology. I show that all of the properties of the international technology market equilibrium are robust to the effects of either expropriation or imitation.

The model of the international market for technology has three stages. In the first stage, inventors enter the market and invest in uncertain R&D. In the second stage, inventors engage in domestic competition if there is no technology trade or they engage in global competition if there is technology trade. Because of asymmetric information about technology, inventors choose positive royalties and earn information rents. Downstream firms then make strategic technology adoption decisions. Without trade in technology, firms have different costs that depend only on domestic innovation, and with trade in technology firms have the same costs. In the third stage, downstream firms innovate by applying inventions and engaging in international duopoly competition with differentiated products.

The international trade literature has addressed various important technology issues in isolation although it does not offer a comprehensive model of international technology transfers. The supply-side incentives of international technology sales are well understood. For example, Deardorff (1992) points out that extending patent protection internationally involves a tradeoff because it increases incentives to invent while generating rents for a monopoly inventor. Grossman and Helpman (1991, pp. 200–205) examine international exchange of licenses and the resulting Walrasian factor price equalization, with licensing of product patents serving as a means of taking advantage of low-cost foreign manufacturing costs. Taylor (1994) considers non-market spillovers and allows for costless technology transfers by inventors based on comparative advantage in R&D and goods, although there is no market for technology in his model. My model differs from earlier analyses by fully examining both the demand side and the supply side of the technology market.

The notion that a larger sample of inventions will improve the best invention is well understood, see Nelson (1961). Eaton and Kortum (2001, 2002) find that enlarging the trading area for final products improves the statistical chances of domestic inventors in each country finding a better innovation. Eaton and Kortum (2001) look at uncertain R&D and trade in goods, although without any international technology transfers. Their analysis is carried out with country-specific technologies and without an international market for technology. In a study of international technology diffusion, Eaton and Kortum (1996) observe that in comparison with growth studies of the effects of technological change on worker productivity, "Where technological change originates and how it spreads across countries is less well understood."

Clearly, innovation improves productivity so that transferring technology internationally should improve productivity in other countries. Various theoretical and empirical studies examine technology transfer by non-market spillovers. Rivera-Batiz and Romer (1991) show that economic integration of two countries improves growth through a non-market transfer of ideas. Grossman and Helpman (1990) show that innovation is complementary to product trade, although they assume that knowledge diffuses internationally by non-market spillovers and inventions are not tradable, so that there is no international market for technology. In Eaton and Kortum's (1999) model of endogenous innovation, international technology occurs through an exogenous diffusion process rather than a market for technology. Eaton and Kortum (2002) formulate and test a multi-country Ricardian trade model in which the benefits of technological innovation are realized through trade in goods rather than trade in technology itself.

In Spulber (2008), I present a general equilibrium model of international trade with technology transfers to consumers who can enhance their human capital. Goods are provided by firms that engage in monopolistic competition and employ consumers as workers. The model shows that technology transfer yields gains from trade. The present analysis differs from this model in two ways. First, technology is adopted by firms who have market power and engage in duopoly competition in traded goods. This changes the strategies of inventors who compete to sell their inventions to downstream firms. Second, the present analysis features a strategic model of technology adoption. Downstream firms adopt inventions to increase their productivity in the traded good. Each firm's technology adoption decision is a best response to the equilibrium technology adoption decision of the other firm. The present analysis generates a tradeoff between the costs and benefits of technology markets that affects the gains from trade.

The paper is organized as follows. Section 2 sets out the basic framework. Section 3 considers differentiated duopoly competition in the international product market with domestic competition between inventors. Section 4 introduces international competition between inventors into the duopoly product trade model. Section 5 examines international technology trade with the risk of expropriation and Section 6 examines international technology trade with the risk of imitation. Section 7 concludes the discussion.

2. The technology transfer model

To examine the effects of the extent of the market on the quality of innovation, I compare domestic technology markets with an international market for technology. International trade in goods and technology takes place within a two-country framework. A firm in each country produces a differentiated product and engages in international duopoly competition. Multiple inventors in each country engage in R&D. With international trade in technology, inventors compete to sell their discoveries to both domestic and foreign firms. I