Background Report for World Development Report 2000/2001

The Impact of Removing Licenses and Restrictions to Import Technology on Technological Change

Michelle Connolly

Duke University

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I. What are the main questions?

Technological change in a country is really a combination of access to foreign technological progress and domestic technological progress. There are therefore two issues to consider when contemplating the impact of removing import restrictions (of any type) on technological change in a developing country. The first is the use of foreign technology in domestic production. The second is the domestic creation of technology. The first aspect is important since an overwhelming majority of innovations occur in only a handful of developed countries (the United States, Japan, Germany, the United Kingdom, and France). For example, the G-7 countries accounted for 92 percent of all research and development (R&D) in 1991.[1] Hence, countries that are very open to imports of goods that embody technology will be able to immediately take advantage of foreign technological progress by using imported intermediate goods as inputs into domestic production. In so doing, these countries will have immediate access to better quality intermediate goods without having to wait for domestic firms to try to either reverse engineer the good or invent it on their own. Independently of anything else, this can have a large impact on a country's growth rate of per capita income (Lee 1993, Sala-i-Martin 1997, Connolly 1998).

The second aspect, that of domestic technological progress, relates to issues of spillovers from foreign to domestic research. In this case exposure to and use of foreign imports is an important channel through which technology can diffuse. For example, importing advanced goods from developed countries lowers the cost of reverse engineering because of general exposure to imports, and servicing and distribution by local importing firms. In other words, if each individual exposed to a good has a certain probability of reverse engineering it, then the number of people exposed to the good, and hence the volume of imports, will positively affect the overall probability that the good is reverse engineered.[2] Moreover, the process of reverse engineering the foreign

[1] Coe, Helpman and Hoffmaister (1997).

[2] The importance of exposure to a good is demonstrated in Ross Thompson's (1992) study of 3,500 U.S. sewing machine patents, in which he finds that patenting activity followed sewing machine sales both geographically and temporally. Similarly, Sokoloff (1988) finds that U.S. counties from 1790 to 1846 with access to navigable waterways had higher patenting rates than counties without such access. Furthermore, Sokoloff finds an increase in the patenting rates of counties after the introduction of new waterways in or

technology, whether for the purpose of pure imitation or as an intermediate step in the process of bringing about the next innovation, gives researchers in developing countries experience beneficial to future research efforts whether they be in imitative or innovative activities (Connolly 1999).

Spillovers from foreign to domestic research can potentially occur in different manners. This report focuses on reverse engineering since this channel of technological diffusion is more closely linked to trade than other possible channels of diffusion such as direct communications, labor mobility, or foreign direct investment. Moreover, in a survey of 26 U.S. firms whose technology had diffused to non-U.S. competitors, Mansfield and Romeo (1980) found that U.S. firms felt that reverse engineering was the most frequent channel through which technology "leaked-out."

Successful imitation allows for the diffusion of technology embodied in a product as researchers reverse engineer that good. Moreover, imitation, like innovation, has learning-to-learn properties. In particular, successful imitation by a firm increases that firm's insight into how goods are engineered and improved upon. So imitation not only makes a firm better at future imitation, but also improves its chances of successfully inventing the next quality level or product type on its own. A well-known example of this process is the experience of the Japanese automakers as they decided to enter the luxury car market. The makers of Acura, Lexus, and Infinity initially reverse engineered European luxury cars in order to better design their own luxury automobiles, eventually increasing their share of the luxury automobile market from 4.4% in 1986 to 26.6% in 1991 (Bolton 1993, p.36).[3]

Learning-to-learn differs from learning-by-doing in that the skills gained are general and thus applicable to different types of research within an industry. This suggests that a country that is handed technology will not be able to move beyond that technology as easily as if the country had created or reverse engineered that technology on its own in the past. In other words, there is a tradeoff between facing a lower access

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adjacent to these counties. Thus, exposure to goods and access to larger markets both appear to play important roles in the research activity.

[3] Following a similar process, Advanced Micro Devices, Inc. and Samsung both initially specialized in reverse engineering and cloning leading edge technology, but then switched to innovative research. AMD reverse engineered and cloned Intel's 386 and 486 chips in the 80's and early 90s, but has since begun

cost to technology today if being given the foreign technology and a lower productivity of research in the future because of the foregone learning that would have occurred through reverse engineering.

II. What are the main findings?

Four principal findings emerge from the empirical literature on technological diffusion/spillovers to date. They are

1. *Technological diffusion from the key innovating countries to the rest of the world is large* (Eaton and Kortum 1994 and 1996, Coe and Helpman 1995, Coe, Helpman and Hoffmaister 1997).

2. *The extent to which countries benefit from this diffusion appears to be positively related to* ***general*** *openness to trade* (Ben-David 1996, Ben-David and Rahman 1996, Coe and Helpman 1995, Coe Helpman and Hoffmaister 1997, Lichtenberg and de la Potterie 1998).

3. *Imports of goods that embody technology (high technology goods) are an important channel for spillovers from foreign to domestic research. Moreover, this channel is more important for developing countries than for developed countries* (Connolly 1998).

4. *Use of imports that embody foreign technology contributes positively to growth of GDP per capita* (Lee 1993, Sala-i-Martin 1997, Connolly 1998). *Again the contribution of this foreign technology to domestic growth is greater for developing countries than for developed countries* (Connolly 1998).

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developing its own microprocessor chips, first the K5 and now the K6. Similarly, Samsung moved from imitating technology to developing its own, particularly successfully with DRAM computer chips.

III. Which methodologies were used?

1. *Technological diffusion from the key innovating countries to the rest of the world is large.*

Eaton and Kortum (1996) show using international patent data that with the exception of the United States, OECD countries derive almost all their productivity growth from abroad. Specifically, they estimate that only the U.S., Japan, and Germany derive more than 10 percent of their productivity growth from domestic research. This study does not include developing nations. Still, it demonstrates how concentrated the process of technological innovation is and how important the diffusion of this technology is to productivity growth in all countries.

2. *The extent to which countries benefit from technological diffusion appears to be positively related to **general** openness to trade.*

Coe and Helpman (1995) create measures of domestic and foreign R&D capital stocks for 21 OECD countries plus Israel. They find that both domestic and the average import-share-weighted foreign R&D capital stocks of each country's trading partners positively affect domestic total factor productivity (TFP).[4] Moreover they find that the benefits from foreign R&D capital stocks are greater the more open the economy is to foreign trade. Coe, Helpman, and Hoffmaister (1997) use a similar approach to consider the importance of foreign R&D stocks of industrialized countries and a country's imports from industrialized countries as a share of GDP on total factor productivity in 77 developing countries. They find that foreign R&D stocks and the import share both positively affect domestic TFP. For example, the authors estimate that a $100 increase to either the U.S. or Japanese domestic R&D capital stocks would increase total GDP in the 77 developing countries by nearly $25. Lichtenberg and de la Potterie (1998) suggest an

[4] Keller (1998) casts doubt on Coe and Helpman's (1995) results by replicating their study using randomly generated trade shares and still finding evidence of international R&D spillovers. However, Coe and Hoffmaister (1999) have since shown that Keller's "random" weights are essentially simple averages with a random error. If alternative "random" weights are employed they find no evidence of international R&D spillovers.

improved weighting mechanism for Coe and Helpman (1995)'s foreign R&D capital stocks. Using these newly weighted stocks, Lichtenberg and de la Potterie confirm the initial results that the more open a country is to trade, the more likely it is to benefit from foreign R&D.

Trade based convergence clubs also provide evidence that trade is likely an important channel for technological diffusion. Ben-David (1993) examines trade reform programs and income convergence across groups of countries. Among groups with no evidence of income convergence prior to trade reforms, he finds significant convergence along with significant increases in the volume of trade beginning to occur contemporaneously with the removal of trade barriers. Moreover, Ben-David (1996) finds that trade-based country groupings (whether import or export-based) are more likely to converge in income levels than randomly selected groupings. Ben-David and Rahman (1996) build upon this result by suggesting that convergence in trade-based country groupings can be attributed to convergence in technologies. This is demonstrated by a high incidence of total factor productivity convergence among trade-based country groups, whereas no such convergence is found among randomly selected groupings.

3. *Imports of goods that embody technology (high technology goods) are an important channel for spillovers from foreign to domestic research. Moreover this channel is more important for developing countries than for developed countries.*

Connolly (1998), using panel data for up to 30 developed and less developed countries, finds a significant positive relationship between high technology imports from developed countries as a share of GDP and measures of domestic innovation and imitation based on international patent data. Assuming initial rates of domestic innovation and imitation of 1%, the estimated elasticities imply that a sustained 10% increase in imports of high technology capital goods would have raised the domestic innovation rate to 1.13% and the imitation rate to 1.14% during that same period, all else equal. Moreover, the importance of high technology imports on domestic research is far greater in developing countries than in developed countries. This may reflect the fact that since developing countries are often not highly integrated with developed countries, the role of trade in physical goods is all the more important for international technology spillovers to occur in a developing nation.

4. *Use of imports that embody foreign technology contributes positively to growth of GDP per capita. Again the contribution of this foreign technology to domestic growth is greater for developing countries than for developed countries.*

Lee (1993) looks at 81 countries and finds that trade distortions caused by tariffs and exchange controls generate divergence in both growth rates and per capita income levels. Levine and Renelt (1992) criticize much of the existing empirical growth literature by using Leamer's (1985) extreme bounds analysis to check for the robustness of variables commonly used in growth regressions. Using this very stringent methodology, Levine and Renelt find only three of these variables (initial income, the investment share of GDP, and openness to trade) to be robust. They find a positive, robust correlation between growth and the investment share in GDP, and between openness to trade and the investment share. So while they do not find that general openness to trade robustly affects growth, they do find that it robustly affects the investment share, one of the only two factors that they find robustly contribute to growth. Sala-i-Martin (1997) argues that the extreme bounds analysis employed by Levine and Renelt (1992) is too extreme since it "… amounts to saying that if one finds a single regression for which the sign of the coefficient … changes or becomes insignificant, then the variable is not robust."[5] Sala-i-Martin suggests instead considering a variable to be significantly correlated with growth if 95 percent of a weighted distribution of its coefficient estimates lies to one side of zero. Using that approach he finds that many variables (22 out of 59) appear to be significant. Among these, Sachs and Warner's (1996) number of years an economy has been open between 1950 and 1990 comes in positively.

Connolly (1998) considers growth of GDP per capita for 40 developed and developing countries and finds that the effect of foreign technology (through growth of high technology imports per capita) on per capita GDP growth is far greater than that of

[5] Sala-i-Martin (1997), p. 178.

domestic technology. This result, consistent with Eaton and Kortum's (1996) findings, reflects the fact that most technology used in a country comes from abroad and is dependent on access to goods embodying this foreign technology. The paper estimates that if the growth of high technology imports from developed countries increased from its average of 2 percent to 4 percent, then GDP growth per capita for the mean country would increase from its average of 2 percent to 2.2 percent. Once again the contribution of high technology imports to growth is statistically significantly greater for developing countries than for developed countries. These results suggest that trade plays an important role in technological diffusion and, in turn, conditional convergence, particularly for developing nations which may have fewer alternative links with developed countries.

IV. What are the policy implications?

A majority of current endogenous growth models focus on technological progress as the driving force behind per capita GDP growth. Yet, we observe that most technological progress occurs in only a handful of countries. How then is it that other countries also grow? Technological diffusion from the few lead innovating countries to other countries in the rest of the world is a likely answer. This suggests that it is important for us to study the process of technological diffusion and how governmental policies can affect growth outcomes.

The empirical findings from the literature on trade and growth establish not only that technological diffusion from lead innovating countries is large, but that they are positively linked to imports. The implication of these studies is that imports of goods that embody technology serve both as a channel for technological spillovers in research and as a direct input into domestic production. Moreover, since developing countries generally have fewer industrial, political, or cultural ties with developed economies (through which technology could potentially diffuse), trade appears to be even more important to developing countries than to developed countries, which are highly integrated with one another.

It is therefore crucial for a developing country to remain as open as possible to imports, particularly imports which embody technology. This is due to the fact that these imports serve two purposes. Firstly they can immediately be used in domestic production (and will be of better quality and cheaper per unit of quality than if domestic firms initially attempted to produce them locally). Secondly, through reverse engineering domestic firms gain not only knowledge of the technology embodied in the good, but also research experience, which can help them undertake future technological progress.

This analysis implies that the removal of licenses and restrictions to import technology would greatly increase the speed of technological catch up (both in terms of use of and in terms of creation of technology) in a developing nation. In turn, the speed with which income levels per capita conditionally converge with developed countries would also increase.

This conclusion has an interesting implication for the proliferation of preferential trade agreements in the world. Consider a regional trade agreement (such as Mercosur) that includes only developing countries. Suppose that as a result of the regional trade agreement, trade diversion takes place in industries with strong technology components. Then the regional trade agreement, by substituting lesser quality intra-regional imports for imports from developed countries that embody the highest technology, will potentially lower the rate of domestic technological progress. Even more importantly given the estimated relative contribution of foreign versus domestic technological progress to growth, this trade diversion would reduce access to foreign innovations implying an even greater negative effect on the growth rate of per capita GDP in member countries.

It is important to mention that this background report has abstracted from other potential growth effects of international trade through integration of markets (scale effects) and specialization due to comparative advantage. The report has also abstracted from issues such as loss of government revenues and rent seeking behaviors, which are part of any overall discussion on the removal of trade restrictions, in order to focus solely on the impact of removal of import restrictions on technological progress.

All else equal there is growing evidence that openness to imports, particularly in high technology industries, is of crucial importance for growth and development in less developed countries. Unfortunately, these are often the very industries which developing countries choose to protect using trade barriers in an attempt to foster industrialization in infant domestic industries. Still this suggests room for important dynamic gains if governments can successfully lower or even eliminate these restrictions.

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