An empirical analysis of the microeconomic links between trade and knowledge diffusion is useful for singling out some of the key predictions of the theory of endogenous growth in open economies. This literature postulates that total factor productivity is higher when trade gives countries access to a wider or more sophisticated range of technologies. The articles reviewed here find considerable evidence that imported technologies raise total factor productivity in importing countries, particularly developing countries and particularly when technologies are acquired by way of imports of intermediate goods. They also provide some support for the argument that exports and foreign direct investment are channels for learning. Although access to foreign technologies has a positive impact on developing countries' total factor productivity, overall these countries are shown to purchase older and simpler machines than industrial countries. Relative factor and machinery costs and skill and technology endowments affect the choice of imported technologies. However, government attempts to limit or guide the selection of technologies are likely to have a negative effect on growth because they discourage producers from purchasing the most appropriate and efficient machines. Rather, policies aimed at promoting technological development should strengthen the absorptive capacity of importing countries and address the complementarity between human and physical capital in a broader context.

In both developing and industrial countries there is an increasing institutional awareness of the importance of knowledge for business performance, economic growth, and development. The comparison of Ghana and the Republic of Korea is a tale of disparate growth that is frequently told. In 1960 both countries had the same income per capita; today Korea's is seven times higher. More staggering than the gap in performance is the inability of analysts to single out its causes.
The accumulation of physical and human capital barely justifies a threefold difference in income per capita. The remaining $4,000 gap is yet to be explained. Many analysts agree that knowledge could be the hidden factor of production that drove Korea's growth (World Bank 1999 and Rodriguez-Clare 1997).

The characteristics of knowledge as an economic good may explain why this initially neglected and now actively investigated factor of production remains relatively concealed. Knowledge is a public good with property rights that are rarely enforceable. It is seldom quantified or priced; it is sometimes codified, but more frequently tacit; and in any case it is difficult or impossible to observe. All measures of knowledge are indirect, either inputs to (years of schooling, manuals) or outputs of (human capital, patents, the unexplained residual in growth accounting) its accumulation.

Two elements combine to reveal why technology is likely to be important for economic growth: countries with higher per capita incomes also hold larger stocks of measured knowledge, and knowledge travels cheaply and fast. Although well established in theory and anecdotally, the link between growth and the accumulation of knowledge has been tested by relatively few rigorous empirical studies. The most quoted reference in this area is Coe and Helpman (1995), who focus on knowledge diffusion among Organisation for Economic Co-operation and Development (OECD) countries. Coe, Helpman, and Hoffmaister (1997) extend this work to developing economies.

Both studies use aggregate data to measure the impact of knowledge diffusion through trade flows. However, most of the effects of learning on productivity are observable primarily at the micro-level. For example, learning by doing and imported technologies are frequently sector-specific. Typically, technology is upgraded and production processes are enhanced at the firm level, guided by firms' characteristics. The organization and effectiveness of "knowledge departments" in corporations are also observable at the firm level. It is therefore important to combine the empirical analysis of generalized countrywide learning processes with a more focused understanding of how these processes take place at the micro-level.

This is precisely the objective of the articles collected in this symposium, which are devoted to the empirical analysis of the international diffusion of technological knowledge and economic performance at the micro-level. They analyze three international channels of learning: imports of machines and other inputs, along with the research and development (R&D) spillovers they generate; foreign direct investment (FDI) or other forms of collaboration between local and foreign firms; and learning by exporting.

If technology transfers are assumed to be exogenous, the scope of micro-level empirical work is simply to measure accurately the different components of this external learning process and to determine if this process does indeed work in the predicted direction. It is clear, however, that the international demand for and supply of technological inputs are not exogenous. Firms in developing countries will choose the type of technology imported so as to maximize their profits. Also,
firms in industrial economies choose the channel through which to transfer technologies based on profit-maximizing conditions. The form of the transfer (subsidiaries wholly owned by foreign investors, joint ventures, licensing, or direct sales of machinery) affects the dispersion of proprietary knowledge and thus monopoly rents. Working at the micro-level allows us to analyze the choice of the type of technology imported and the channel through which it is imported, along with its impact on economic performance.

I. TRADE, LEARNING, AND GROWTH: THE THEORETICAL BACKGROUND

The empirical studies collected here are rooted in theories developed by earlier models of endogenous growth in open economies. This literature recognizes two main mechanisms of knowledge accumulation. The first is that trade may change a country’s pattern of specialization. Learning is faster if the country specializes in goods with higher learning potential (Krugman 1987; Lucas 1993; Stokey 1988, 1991; and Young 1991). The second mechanism is that trade in goods and factors of production may open new sources of technological inputs (Grossman and Helpman 1991 and Rivera-Batiz and Romer 1991). Broadly speaking, we can therefore consider two groups of models, those in which learning is essentially a domestic affair and those in which knowledge is imported from abroad.¹

Many of the domestic learning models involve learning by doing. Young (1991), for example, develops a model in which managers and workers acquire experience through the manufacturing process that makes them more productive.² This well-documented phenomenon is typically summarized by a learning curve relating process-specific production costs to cumulative units produced.³ The learning curve is downward-sloping, but it eventually flattens out as the potential for learning is exhausted. If each process is associated with a given product, the accumulation of knowledge is a nondecreasing, concave, and bounded function of the cumulative output of that product. Stokey (1991) shows in a second model that schooling can be substituted for learning by doing without significantly changing Young’s (1991) conclusions.

Both Young (1991) and Stokey (1991) attribute productivity growth to learning processes that enable the production of increasingly sophisticated products and to the associated knowledge spillovers, which are limited to the country in which learning takes place. The more rapidly learning takes place—either through schooling

¹. We do not provide a comprehensive survey but simply convey the main findings of this type of literature. For a comprehensive survey on trade and technology diffusion, see Grossman and Helpman (1995).
². Earlier contributions involving growth and learning by doing include Lucas (1988), which elaborates on Krugman (1987), and Stokey (1988).
³. Many studies have found corroborating evidence that production experience lowers unit costs. Benkard (1997) makes an excellent contribution. He documents partial spillovers from experience in producing one generation of wide-body aircraft, making production in the next generation more efficient. Malerba (1992) provides a recent review of the literature and some evidence of his own.
or through learning by doing—the higher is the rate at which new high-end products are introduced, and the higher is the rate of productivity growth.

But if learning only takes place at home, why should we be concerned with trade? We should be concerned because trade affects the pattern of specialization in goods with different potential and indirectly influences the accumulation of knowledge. The domestic learning models imply that a likely, but not a necessary, consequence of trade liberalization in developing countries is the dampening of demand for high-end goods, thereby limiting the amount of learning.

Although the models of Young and Stokey are too restrictive to derive policy implications for developing countries, they are important contributions because they show clearly what happens when trade does not generate international knowledge flows. Indeed, not all learning is a by-product of learning by doing or of education. Knowledge diffuses across national boundaries in many ways. A country's knowledge may increase because its trading partners have accumulated knowledge, that is, there are international knowledge spillovers that are likely increased through trade.

Therefore, we now turn to models in which knowledge is not contained within national boundaries, and the channels through which it is transmitted are important. Trade (especially the import of a large variety of technological inputs), foreign investment, and travel on the part of executives and technicians are all channels through which knowledge can be transmitted internationally. Open economies benefit from an even wider range of learning channels.

One important model that allows for the international transmission of knowledge is that of Rivera-Batiz and Romer (1991). They assume an economy in which inputs are differentiated horizontally. Research creates new input varieties, and these new varieties raise productivity growth in the final-goods industry. When more input varieties are available, the final goods sector can choose inputs that more closely fit its precise requirements. Thus, for the same cost, it can purchase a more productive bundle of intermediate inputs. This is a dynamic extension of Ethier's (1982) application of the model of Dixit and Stiglitz (1977). Rivera-Batiz and Romer examine two channels for transferring technological knowledge: the transmission of ideas, which can be traded independently from goods—the knowledge-driven R&D model initially developed by Romer (1990)—and the trade of intermediate inputs that incorporate new ideas—the lab equipment model.

In both models international knowledge flows raise growth, as the stock of knowledge available to producers in any country increases. Note, though, that the two models imply very different mechanisms of technology diffusion. In the first case the stock of knowledge is common to all researchers in the world economy and is distributed at no cost by way of spillovers. In the second case knowledge is immediately excludable in that it is only transmitted through the purchase of inputs, and there are otherwise no spillovers.

4. However, once a design is incorporated in an intermediate good, producers must pay for exclusive use of the design. This mechanism generates monopoly profits for the research sector and an incentive to innovate.
In the lab equipment model knowledge is diffused internationally only if there is trade in goods, since knowledge is embodied in goods. Trade improves productivity directly, and the steady-state growth rate increases. In the knowledge-driven model, if trade is permitted, countries have an incentive to specialize in completely non-overlapping innovations. Then knowledge diffuses through both trade in goods and the exchange of ideas. The welfare effect is larger since countries benefit from both the increase in productivity in manufacturing arising from additional foreign varieties and the increase in productivity in research arising from additional foreign ideas. Thus the form of knowledge diffusion is important.

Rivera-Batiz and Romer focus on symmetric countries. Grossman and Helpman (1991) extend this framework to the case of asymmetric countries and the case in which there is more than one final good. In Grossman and Helpman's framework inputs are differentiated horizontally, and additional varieties developed by the research sector raise the productivity of the final-goods sector. The research technology is similar to that in Rivera-Batiz and Romer's knowledge-driven economy in that productivity depends on cumulative R&D stocks. An open country can use world R&D experience: if spillovers are global in scope, foreign R&D will have the same effect on productivity as domestic R&D. The same conclusions can be reached with a quality-ladder model, in which inputs are differentiated vertically.

Grossman and Helpman make one prediction analogous to that of Young (1991). Industrial economies with a relative abundance of human capital will undertake more research and grow faster than developing economies. But by engaging in international trade with industrial countries, developing countries can obtain a greater variety of intermediate inputs, and therefore grow faster, than they would otherwise. Although growth rates do not converge, openness does raise the growth rates of developing countries.

Thus, according to the endogenous growth literature, the impact of trade on the growth of developing countries depends crucially on the international scope of knowledge diffusion and on the mechanisms through which knowledge is transmitted. A way to test these predictions is to analyze how inflows of technologies affect productivity in the importing countries.

II. IMPORTED INPUTS, LEARNING, AND GROWTH: THE EMPIRICAL EVIDENCE

Although earlier work estimated international knowledge spillovers, Coe and Helpman (1995) make the first and most widely quoted attempt to establish an empirical connection between international R&D spillovers and economic

5. Grossman and Helpman (1991) also include a model with no spillovers.
6. On quality ladders see also Aghion and Howitt (1992) and Segerstrom, Anant, and Dinopoulos (1990).
7. The model in Grossman and Helpman (1991) is essentially a Heckscher-Ohlin model of international trade combined with a model of endogenous growth through profit-seeking R&D. Young (1991), like Krugman (1987), uses a Ricardian model in which trade is driven by differences in technology rather than differences in comparative advantage. See chapter 11 in Aghion and Howitt (1998) for a survey of these models.
growth.\textsuperscript{8} Coe and Helpman estimate how much of the variation in total factor productivity (TFP) for a sample of OECD countries is explained by the variation in domestic and foreign R&D capital stocks. Foreign R&D capital stocks are defined as the import share-weighted average of trade partners' domestic R&D capital stocks. The impact of foreign R&D in an importing country is expected to be higher the more the importing country buys from the foreign country undertaking the R&D.

Note the mechanisms of knowledge transmission implied by this specification. Knowledge is acquired through the purchase of intermediates, thus it does not travel if there is no trade in goods. Additionally, productivity in country $i$ is expected to increase if the R&D capital stock in country $j$ increases, even if $j$'s share in $i$'s total imports remains constant. One way to interpret this last assumption is that if the overall R&D stock in a given country grows, the goods imported from that country will be more R&D-intensive. Another interpretation is that, through trade, country $i$ gains access to the R&D of country $j$, enabling country $i$ to introduce new designs in production more easily. Coe and Helpman's (1995) empirical specification reflects Rivera-Batiz and Romer's lab equipment model in the first case and their knowledge-driven model in the second case.

Coe and Helpman find evidence that both foreign and domestic R&D improve TFP. Whereas in large countries the elasticity of TFP with respect to domestic R&D capital stocks is larger than that with respect to foreign R&D capital stocks, the opposite holds in small countries; that is, foreign R&D is more important for small countries. Coe, Helpman, and Hoffmaister (1997) confirm these results in their analysis of North-South R&D diffusion, based on a sample of 77 developing countries. They find that East Asian countries have benefited the most from foreign R&D. These results imply that access to foreign R&D is crucial for the typical developing country, and openness to and trade with industrial countries are fundamental to obtaining that access.

These two studies focus on aggregate TFP at the country level and assume that knowledge spillovers are channeled through total import flows. Yet much of the learning process is probably related to trade within industries and between firms.\textsuperscript{9} Learning and technical progress mostly take place within specific activities.\textsuperscript{10} This is certainly true for learning by doing, and it may also be true when new knowledge is embodied in specific machines or procedures.

Moreover, the potential for technical progress differs across industries. Consider two trade partners of country $i$—$j$ and $k$—that have equal R&D capital stocks and equal weights in $i$'s total imports, but differ in the basket of products that $i$ imports from them. If the products imported from $j$ are mostly consumer goods, whereas the products imported from $k$ are mostly intermediate goods, we

\textsuperscript{8} For example, Jaffe, Henderson, and Trajtenberg (1993) examine geographic localization of knowledge spillovers by looking at patent citations. Eaton and Kortum (1996) analyze patterns of productivity and international patenting.

\textsuperscript{9} Hakura and Jaumotte (1999) rigorously support this hypothesis.

\textsuperscript{10} For a pioneering case study see Lall (1987).
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would expect imports from \( k \) to have a greater impact on \( i \)'s TFP. Likewise, if most of the imports from \( k \) are goods with high learning potential relative to imports from \( j \), \( k \)'s products will have a larger effect on \( i \)'s TFP.

The article by Wolfgang Keller in this symposium addresses this problem, examining the impact of international R&D spillovers on industry-specific TFP. His measure of foreign R&D for a given country is the trade-weighted sector-specific R&D capital stocks of its foreign partner countries. Keller computes trade weights by considering only imports of machines used in production in a given industry.\(^{11}\) In doing so, he leans closer to the lab equipment model, because he focuses on imports that are more likely to embody new knowledge. His results are similar to those of Coe and Helpman (1995) in that domestic and foreign R&D stocks are estimated to have a significant and positive influence on TFP.

Keller also tests for the robustness of the trade weights used by carrying out an alternative battery of estimations using random weights for foreign R&D stocks. In line with Coe and Helpman's results he finds that domestic and foreign intermediates have a different impact and that this difference is statistically significant. Also, the impact of foreign intermediate imports is greater the smaller is the importing country. In contrast, he finds that the regression results are somewhat invariant to the import weights of trading partners' R&D stocks, especially when importing countries are large, when the trade shares of partners are evenly distributed, and when partners have similar R&D stocks. Consequently, trade is a more important conveyor of foreign technological knowledge to small countries than to large ones.

Since Keller studies only OECD countries, the question arises as to the implications of his results for developing countries. His finding that imported inputs are particularly effective for small OECD countries is important in this context. Developing countries typically have a weak domestic R&D sector and mainly acquire technologies internationally. For this reason it is likely that a change in import shares assigning a larger weight to developing economies, which have smaller R&D stocks, would clearly diminish their access to foreign technologies. In other words, the likely effect of a developing country's shift in acquiring machinery from Germany rather than from France is likely to be smaller than a shift in acquiring machinery from Ethiopia rather than from France.

Coe and Hoffmaister (1999) argue that Keller's random weights are in fact not random, but simple averages with a random error. They derive three alternative sets of random weights and with them restore fully their original results. However, this controversy concerns mostly technological flows between large countries, because Keller never dismisses the evidence that trade flows to small countries are important in transmitting foreign knowledge.\(^{12}\) This is also consistent with the findings of Eaton and Kortum (1996). On the basis of patent data

\(^{11}\) Coe, Helpman, and Hoffmaister (1997) also use imports of intermediates, not total imports, to construct import shares.

\(^{12}\) See also the estimates for developing countries in Coe, Helpman, and Hoffmeister (1997).
they argue that 90 percent of growth in small OECD countries derives from foreign innovations.

In conclusion, the available empirical evidence supports the direct and indirect role of trade in diffusing knowledge and suggests that it is particularly important for developing countries to trade with technologically rich countries. This result is not surprising, given that rich countries have many more means of exchanging knowledge between themselves than developing countries. The articles reviewed so far also provide indirect evidence that channels other than foreign trade are at work, which may not be observed in aggregate estimations.

III. LEARNING AT THE FIRM LEVEL: FOREIGN DIRECT INVESTMENT AND EXPORTS

There is now fairly well documented evidence that multinational enterprises are a major channel for transferring technologies. According to UNCTAD (1997), more than 80 percent of royalty payments for international technology transfers were made from subsidiaries to their parent firm. This is not surprising, given that multinationals are more often found in industries with high R&D expenditures relative to sales, a larger number of scientists and technicians, new and technically complex products, and high levels of product differentiation and advertising. These stylized facts are well rooted in theory: intangible assets like knowledge are more mobile than tangible assets and are semi-public goods in the sense that knowledge used in one application does not reduce its availability for other applications either within or across firms.

The fact that multinationals transfer technologies does not necessarily imply that such transfers are beneficial for the local economy. It is necessary to determine whether the productivity of foreign-owned companies is higher than that of domestic companies and whether foreign-owned companies transfer knowledge to domestic companies. These spillovers can take place through many channels, including the movement of employees from foreign affiliates to domestic companies, backward and forward links between multinationals and domestic firms, and demonstration effects.

Early statistical analyses of spillovers at the industry level use a production function framework to estimate the impact on labor productivity of FDI (measured by the foreign share of each industry's employment or value added). They all find significant evidence of positive spillovers.

More recent studies use panel data at the firm level for a few developing countries. Their conclusions are controversial. They report that firms with foreign ownership have higher TFP. In contrast, there is no evidence of positive short-run spillovers to domestic firms, and the concentration of foreign investment in particular sectors sometimes lowers the productivity of domestic firms in the same

13. This figure is reported in Saggi (1999), who extensively reviews this evidence. Blomström and Kokko (1998) offer another major survey of the role of multinationals in diffusing technology.
These results are partly explained by the fact that foreign investors acquire market shares at the expense of domestic producers, which face negative scale effects. Overall, the effects of FDI depend heavily on the absorptive capacity and the competitiveness of local firms. Spillovers will be larger if local firms are able to quickly adopt new imported technologies and to face the competition posed by more efficient foreign producers.

The article by Simeon Djankov and Bernard Hoekman in this issue examines the impact of foreign investment on productivity for a sample of 513 Czech enterprises listed in the Prague stock exchange between 1992 and 1997. Their sample includes firms with foreign links (firms that had formed joint ventures or whose equity was at least partially foreign-owned) and firms without such formal links. In line with earlier contributions, Djankov and Hoekman examine the impact of formal foreign links on TFP and whether the presence of foreign investors generates positive indirect intraindustry spillovers on firms that have no foreign links.

As expected, the authors find evidence that firms with foreign links have higher TFP growth rates than firms without foreign links. Like some of the earlier studies using firm-level data, Djankov and Hoekman find that foreign investment lowers the productivity growth of domestic firms that have no formal foreign links. This result may reflect a competitive effect, as local firms without foreign links lose market share to those with foreign links. Firms without foreign links are still able to restructure and improve their productivity, but at a slower pace than their foreign-owned counterparts and at a slower pace than if there were no foreign investment in the industry.

Exporting is another channel through which firms based in open economies can acquire foreign knowledge. By learning about foreign markets, technologies, and products, they may specialize in products with high learning potential. Both case studies and empirical evidence support this view, showing that exporting firms are more efficient than nonexporting firms (Pack 1993). Yet this evidence says little about the causal relationship between firms' exporting status and their productivity. It may be that firms become more productive because they learn by exporting or it may be that more productive firms enter the export market in the first place. Clerides, Lach, and Tybout (1998) test the relevance of these two hypotheses for Colombia, Mexico, and Morocco, and Bernard and Jensen (1999) test them for the United States. Both studies find that self-selection is the dominant explanation and that there is little evidence of learning by exporting.

In this issue Bee Yan Aw, Sukkyun Chung, and Mark Roberts address this question for the Republic of Korea and Taiwan (China), using panels of exporting and nonexporting firms. They study the relationship between productivity and transitions into and out of the export market. If self-selection is the important explanation, then we have little evidence of learning by exporting.

16. Harrison (1996); Aitken, Hanson, and Harrison (1997); and Haddad and Harrison (1993).
17. A key element missing from these studies, however, is an examination of the impact on downstream industries and overall economic welfare or growth. For example, if there is FDI in accounting services, although the domestic accounting sector may be adversely affected, productivity and welfare in the economy may rise. On this point see also Lall (1999).
tant explanation, then a firm's initial productivity should be higher when they enter the export market than firms that stay out. If learning by exporting is the relevant explanation, then producers who enter the market should experience higher productivity growth than firms that stay out.

For firms in Taiwan (China) Aw, Chung, and Roberts find evidence that both explanations are important. For Korea the results are much less satisfactory. There is weak evidence for the self-selection hypothesis and no evidence for the learning-by-exporting hypothesis. Aw, Chung, and Roberts claim that the weak results for Korea could be explained by the country's export policies, among other factors. Firms' decisions to enter the export market are linked more closely to their access to government promotion policies than to their ex ante productivity levels.

This discussion of Korea brings policy into the picture. It is clear that the link between international knowledge flows and productivity is affected by many factors, including policy. But to understand the role of policy we should briefly explore how the market for international knowledge flows works. Aw, Chung, and Roberts make endogenous the decision to export and, implicitly, the decision to learn. In the next section we explore the decisionmaking process characterizing other channels for acquiring knowledge.

IV. MARKETS FOR IMPORTED TECHNOLOGIES AND THE ROLE OF POLICY

The empirical literature discussed above implicitly assumes that any country opening its borders to trade, even the most advanced country, will benefit from a wider variety of technologies and from technologies that are, at least in some fields, superior to those available in the domestic market. But the absorptive capacity of the liberalizing country is important in determining the input mix or the technologies imported.

We focus here on machines used in production, which represent the bulk of imported technologies. The choice of appropriate technology depends on the relative costs of the machines and on the costs of the factors of production needed to use them. Also, the availability of the required skills in a given firm or country is important in the choice of technology. Skills, such as human capital or other technological capabilities, acquired through learning by doing or through formal training can be specific to a given technique. The greater is the complementarity between the required skills and the new technology, the more costly is the switch to an alternative technology.

The article by Giorgio Barba Navaretti, Isidro Soloaga, and Wendy Takacs in this symposium looks at the choice between new and used equipment when there are labor-saving technical progress and complementarity between technology and skills within the firm. Their analysis is based on a theoretical model of trade in used equipment among heterogeneous firms. If factor markets are imperfect, firms

will face different factor prices even if they are based in the same country. The model allows firms to differ in their technical and managerial skills. Heterogeneity among firms located in different countries provides the underlying motive for trade in new and used machines and the basis on which the authors predict the share of used equipment imported.

They test these predictions by looking at U.S. exports of metalworking machine tools to 23 countries. Machines can be classified according to their vintage (new or used) and their technical complexity, which is measured in terms of the minimum skills necessary to use the machines. The empirical analysis shows that the share of used equipment is larger the lower is the per capita income of the importing country. Moreover, for low-income countries the share of used machines is larger the greater is the technical change embodied in new machines relative to old ones and the more complex are the skills required to use them efficiently. These results imply that technological factors and skill constraints are as important as relative factor prices in determining the choice of technology. They are thus consistent with results of other studies emphasizing that the ability of a given country to benefit from imported technologies depends on its absorptive capacity, that is, on its ability to master new and more complex technologies quickly and efficiently.¹⁹

These results also have important policy implications. First, policies designed to promote technological development should address the complementarities between different factors of production. For example, if there are explicit market failures in the education sector, fostering human capital should be a central policy goal. Second, policies that limit access to foreign capital—in particular, quantitative restrictions on imports of used machines—are ineffective and damaging. The aim of such policies is to foster technological upgrading. But, in fact, they deny firms access to more appropriate techniques and force them to buy machines that they may be unable to use efficiently.

This point is pursued further by David Guisselquist and Jean Marie Grether in the last article in the symposium. They analyze several case studies of technology transfer in agriculture, revealing that government attempts to select the right technologies to import in fact prevent local producers from gaining access to the best technologies. They identify two stylized patterns in the institutional arrangements governing the international flow of new agricultural inputs. Most economies, particularly industrial economies, rely on multiple channels in which farmers are exposed to new technologies because of the activities of different private and public actors. In contrast, many developing and transition economies centralize access to foreign technologies, making them subject to the approval of government committees based on lengthy performance tests.

Relying on two case studies in Bangladesh and in Turkey, Gisselquist and Grether show that deregulation leads to a significant increase in the transfer of technologies, a fall in the price of technologies, an increase in the use of new technologies.

¹⁹. See, for example, Nelson and Pack (1999) on the Asian Miracle.
technologies, and a dramatic increase in farmers' productivity. At least for seed technology, enough varieties were available worldwide to enable these developing countries to import and effectively use a subset of varieties to increase productivity.

V. Conclusions

The empirical analyses in this symposium allow us to assess some of the key predictions derived in the theoretical literature on endogenous growth. The articles reviewed here find considerable evidence that imported technologies raise TFP in the importing countries, particularly when technologies are acquired through imports of intermediate goods (Keller; Gisselquist and Grether). There is also some support for the view that exporting improves firm productivity (Aw, Chung, and Roberts). The role of FDI is more mixed. Although the productivity of the economy increases, foreign investment sometimes generates negative externalities on domestic producers in the same industry (Djankov and Hoekman).

Skill and knowledge endowments, along with relative costs, are shown to affect the choice of imported technologies. Developing countries are more likely to purchase older and simpler technologies the faster is the rate of technological progress embodied in new machines (Barba Navaretti, Soloaga, and Takacs).

These results bear important policy implications, especially for developing countries. The fact that imported technologies do not invariably carry a great potential for learning does not support government attempts to limit or guide the selection of technologies. Such policies hamper growth, because either they force producers to choose sophisticated technologies that they are unable to use or they prevent producers from buying the most appropriate and efficient technologies. The fundamental policy objective should be to allow as diverse a choice of technology inputs as possible, since diverse inputs are likely to increase productivity. Attempts to centralize decisionmaking and limit technology imports reduce productivity (Gisselquist and Grether).

Moreover, policies aimed at promoting technological development and at strengthening the absorptive capacity of importing countries should address the complementary relationship between human and physical capital. If the development of human capital is constrained by market failures in the education sector, technology policies should directly target such constraints. Indeed, all the theoretical literature and the evidence reviewed support the conclusion that inflows of technology are more beneficial the more quickly importers are able to master new and complex knowledge.20

The works discussed here can be extended in many directions. First, there is a clear need to better our understanding of learning processes at the micro-level.

20. Neary (1999) reviews research on R&D policy in developing countries and concludes that raising the general level of education is likely to have a more important impact than targeted policies like R&D subsidies.
We must define more accurate measures of technology flows and extend the collection of panel data at the firm level. Second, the literature on North-South technology flows generally assumes that the South purely imitates northern technologies. There is now growing evidence of dynamic R&D activity in many developing countries.\textsuperscript{21} Further development of southern technologies could change the pattern of international knowledge flows. These developments should be studied more closely. Finally, innovations in information technology make it even more difficult to observe patterns of knowledge diffusion empirically. Thus empirical analysts attempting to identify international technology flows should be aware that the hidden factor of production they are searching for is becoming more and more concealed.

\textbf{REFERENCES}

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\textsuperscript{21} See Barba Navaretti and Carraro (1999).


Barba Navaretti and Tarr


