Ideas and trade display the same gravity forces; innovation and investment require many of the same basics. Regional knowledge now also flows through patented processes and technologies.

CHAPTER 3

INNOVATION

The generation, diffusion, absorption, and application of new ideas are widely perceived as crucial drivers of economic growth and development. Modern growth theory stresses the importance of overcoming idea gaps relative to object gaps in the process of development, that is, overcoming barriers to the productive absorption of available ideas versus overcoming gaps in the availability of objects such as factories or raw materials. Innovation efforts by forward-looking firms are at the heart of new theories of endogenous economic growth emerging over the last couple of decades.[1] This chapter looks at innovation in East Asia, including the diverse activities being pursued, the problems being faced, and the innovation outcomes being achieved in economies at different levels of development, as well as lessons learned about policies and institutions that have been helpful in fostering innovation.[2]

In advanced economies and, increasingly, in leading emerging economies such as the Republic of Korea, Singapore, and Taiwan (China), business firms are among the principal engines for creating new ideas and learning through systematic, long-term, and large-scale investments in research and development (R&D), resulting in discoveries that add to global knowledge, that may be patented, and that are the principal sources of competitiveness and profitability. Most innovation by firms in developing countries, however, entails not advances in the frontier of global knowledge, but, instead, catching up to the global frontier through the adoption and adaptation of existing products, production processes, and methods that are new to the firm, though not to the world. This chapter surveys both these forms of innovation, looking at patenting activity in East Asia, as well as broader (firm-level, survey-based) measures of innovation in some of the low- and middle-income economies in the region. It also takes up the two main complementary branches of activity resulting in innovation, that is, on the one hand, indigenous R&D and other domestic innovation activities, and, on the other, the absorption of knowledge from abroad through a variety of channels such as participation in international trade, foreign direct investment (FDI), or crossborder flows of disembodied knowledge often transmitted through telecommunications networks (see map 3.1).

This chapter examines the correlates of innovation, studies the efforts of East Asian economies to absorb ideas from abroad and to encourage innovation at home, and attempts to identify the correlates of success. Among the main findings:

- *Innovation activity is a form of investment* and has many prerequisites in common with general capital investment. Sound fundamentals such as macroeconomic stability, financial sector development, the protection of property rights, and the adequate provision of core public goods are no less important for innovation than for general investment. Knowledge also has distinctive economic features that create specialized preconditions for innovation activity. The partial nonexcludability feature of knowledge (see box 3.1) creates a need for specialized intellectual property rights regimes that allow inventors to recoup the rewards from highly uncertain innovation investments. Public resources are typically needed to fund investments in basic research.
- *Technology from abroad and R&D at home are mutually supporting elements.* It is a mistake to think that poor countries may rely entirely on technology transfer from abroad, while developed countries should switch entirely to domestic R&D. Both are necessary at all levels of income, although the balance between the two may change. Even in poor economies, some indigenous innovation effort increases the country's capacity to absorb knowledge from abroad. As countries approach the global technology frontier, their expanded domestic R&D efforts draw more intensively on the stock of advanced scientific knowledge in the world.
- *Intraregional knowledge flows are small but rising rapidly.* A small number of emerging economies—principally Hong Kong (China), Korea, and Taiwan (China)—are now producing new knowledge at or near the global technology frontiers. Like trade in goods, flows of ideas tend to be greater among neigh-

bors. This chapter provides new evidence that such intraregional knowledge flows are rising rapidly in East Asia.

The next section analyzes knowledge adoption and adaptation in East Asia, looking first at broad measures of innovation among firms from the World Bank's investment climate surveys for low- and middle-income economies, particularly data on the introduction of new product lines and production processes. The investment climate surveys also provide a view into the sources of knowledge that firms in these low- and middle-income economies use to make innovations. By far the largest fraction of firms in all economies (on average over 40 percent) have cited the technology embodied in new machinery or equipment (most of which may be assumed to be imported) as their most important source of technological innovation. These observations provide a good springboard for a more detailed inspection of the methods by which firms absorb knowledge from abroad, for example, imports of advanced capital equipment, industrial upgrading via exports through the global production and marketing networks of foreign multinational companies, technology licensing, and FDI.

The subsequent section takes up trends in indigenous knowledge creation within East Asia, in particular the growth and distribution of R&D. Over the last decade, R&D spending grew much more in East Asia than in any other world region. But already large disparities in R&D spending among economies in the region have also widened. On the one hand, newly industrializing economies (NIEs) such as Korea, Singapore, and Taiwan (China) now devote 2 percent or more of gross domestic product (GDP) to R&D, which is among the most intensive R&D efforts in the world, while the business sector generally performs over two-thirds of the R&D. China has also been rapidly boosting its R&D spending toward an official target of 1.5 percent of GDP. On the other hand, middle-income economies such as Indonesia, the Philippines, and Thailand spend a miniscule 0.1–0.2 percent of GDP on R&D, which is low relative to other economies at similar per capita income levels.

Many studies document high social rates of return to R&D spending in the countries of the Organisation for Economic Co-operation and Development (OECD). Recent World Bank research suggests that the social returns to R&D are even higher in developing countries. Why then are there such large disparities in R&D spending within East Asia and around the world? Part of the answer derives from the peculiar *nonexcludability* characteristic of knowledge, which makes it difficult for investors in business R&D to establish property rights over knowledge under the best of circumstances, but especially so because the legal and institutional framework for protecting intellectual property rights is much weaker in some economies than it is in others (see box 3.1). Since it is a type of investment, business R&D spending is also affected by cross-country differences in many standard factors affecting investment, for example, the extent of financial sector development, macroeconomic volatility, and the cost of capital, as well as by differences in the quality and availability of complementary factors of production, notably, the level of education of the workforce (human capital) and related factors, such as the quality of academic (nonbusiness) R&D.

Using patenting in the United States as an index, the penultimate section of this chapter assesses East Asian prowess in generating innovations that advance the global frontier of knowledge. East Asian patenting per 100,000 population is, in fact, closely related to R&D intensity patterns. It is growing at a pace in the NIEs that is about four times the pace in the developed world and has now reached levels not too distant from developed-country averages. On the other hand, it remains negligible in per 100,000 population terms in most of the middle-income economies in Southeast Asia and practically nonexistent among low-income economies. Patent citation analysis shows that not only the quantity per

BOX 3.1 **Ideas and Knowledge: Nonexcludability and Nonrival Consumption**

Two features of ideas and knowledge have special economic importance. Because they are generally *nonexcludable* (it is impractical or impossible to stop people from using them once they have become available), ideas and knowledge tend to spill over and benefit many others besides those who have invested in their creation. The private returns to R&D are therefore typically much less substantial than the social returns, and the amount of R&D is often lower than the socially optimal level.

Another feature of ideas and knowledge that is important is the *nonrival* characteristic of their consumption. A piece of knowledge—say, a chemical formula—may require a large fixed cost in R&D to create, but, once it exists, it may be employed by any number of users without reducing the ability of anyone else to use it also. Thus, unlike an apple, for example, consumption by one consumer does not prevent consumption by another consumer. This combination of high fixed or sunk costs and low or zero marginal costs is a potent source of increasing returns to scale among firms; this, in turn, has significant implications for industrial organization and processes of geographical agglomeration.

Arrow (1962), Romer (1990a, 1990b), and Foray (2004) discuss the implications of the nonrival, nonexcludable, and cumulative characteristics of knowledge as an economic good. Baumol (2002) observes that large sunk costs for innovation serve as a barrier to entry and may contribute to a structure of oligopolistic competition among a small number of large firms, whereby innovation is used as a prime instrument for competition. For the role of the increasing returns among firms, of localized technological spillovers, and of pecuniary external economies in fostering geographical agglomeration or clustering, see Fujita and Thisse (1996), Quigley (1998), and Audretsch (1998).

capita but also the quality of patents in the most advanced innovators such as Korea and Taiwan (China) are approaching the levels in developed economies.

The penultimate section also analyzes the technical and scientific citations of East Asian patents so as to trace the international knowledge flows on which this high-level type of domestic knowledge creation rests. As might be expected, East Asian patented innovations continue to draw heavily on knowledge flows from Japan and the United States. But citations to other, compatriot patents in the same East Asian economy or to other East Asian economies are rising quickly, indicating the emergence of East Asian national and regional knowledge stocks that are providing an indigenous or regional foundation for new innovations and crossborder knowledge flows.

The final section discusses the main policy-related findings that might help foster domestic innovation, as well as the absorption of knowledge from abroad. These factors are grouped under three main heads: the overall business environment for innovation, including macroeconomic stability, financial sector development, intellectual property rights, and the quality of the information and communications technology infrastructure; human capital development; and direct government support for innovation activities, including government funding for public sector and university R&D, fiscal subsidies and tax incentives for business R&D, fiscal incentives for FDI, and policies aimed at promoting FDI-related technology transfers.

Acquiring Knowledge From Abroad: Technology Transfers and Spillovers

Most innovation by firms in developing countries does not entail advances on the frontier of global knowledge, but, instead, catching up to the global frontier through the adoption and adaptation of existing products, processes, and methods that are new to the firms though not to the world since they have typically originated in advanced countries. This section takes up such acquisition of existing knowledge from abroad in more detail. The next two sections look at the growing success of some of East Asian economies in carrying out formal R&D and making patentable innovations that advance the global technology frontier.

Innovation Outcomes: A Broad Perspective

Table 3.1 presents information on broad innovation activities among firms in five low- and middle-income East Asian economies. The information is derived from

TABLE 3.1 **Indicators of the Dynamism of Firms**
percent of firms in the sample

Outcomes	Cambodia 2002	Indonesia 2003	Philippines 2003	Thailand 2004	Vietnam 2005	Average	Other (34)[a]
Core outcomes							
New product line	0.53	0.38	0.49	0.50	0.44	0.47	0.44
Upgraded product line	0.90	0.68	0.64	0.71	0.66	0.72	0.59
Introduction of new technology[b]	0.60	0.22	0.42	0.52	0.45	0.44	0.38
Other outcomes							
Discontinued product line	0.05	0.22	0.42	0.19	0.19	0.21	0.24
Opened new plant	0.18	0.07	0.13	0.08	—	0.12	0.14
Closed existing plant	0.02	0.08	0.11	0.02	—	0.06	0.10
New foreign joint venture	0.21	0.06	0.06	0.04	0.06	0.08	0.08
New license agreement	0.21	0.08	0.13	0.11	0.10	0.12	0.16
Outsourcing[c]	0.33	0.13	0.21	0.18	0.09	0.18	0.13
Insourcing[c]	0.41	0.10	0.14	0.11	—	0.19	0.12
Core (new product+new technology)	1.14	0.60	0.92	1.02	0.89	0.91	0.82
Dynamism (sum of all)	3.44	2.03	2.76	2.44	—	2.67	2.39

Sources: World Bank investment climate surveys, http://iresearch.worldbank.org/ics/jsp/index.jsp; Ayyagari, Demirgüç-Kunt, and Maksimovic 2006.
Note: — = no data are available.
a. Figures produced on an average among 34 other developing economies.
b. New technology that substantially changes how a main product is produced.
c. Outsourced (insourced) a major production activity previously carried out in house (externally).

World Bank investment climate surveys. The first three rows cover core innovation outcomes and show the proportion of firms that, in the three years preceding the survey, had introduced a new product line, upgraded a product line, or introduced a new technology that substantially changed the method of production. The remaining rows include a number of other activities that Ayyagari, Demirgüç-Kunt, and Maksimovic (2006) propose are indicative of the dynamism of firms. These are activities that promote knowledge transfers, including foreign joint ventures and licensing agreements, and activities that adapt the organization of the production processes of firms, such as opening a new plant or outsourcing a production activity.

Interestingly, even though firms in low-income Cambodia do not do any U.S. patenting at all, they are among the most active in adopting and adapting activities; over half of the firms in the sample introduced or upgraded product lines and production processes. Firms in Thailand are also relatively innovative according to these measures, while those in Indonesia have been laggards. Ayyagari, Demirgüç-Kunt, and Maksimovic (2006) study the correlates of firm innovation and dynamism in a worldwide sample of firms and find:

- Core innovation increases with firm size and with high capacity utilization, understood as indicating significant growth opportunities, while it declines with the age of the firm (that is, younger firms are more innovative).
- These broader measures of innovation are not closely related to per capita income levels, suggesting that, given favorable economic and institutional conditions, firms may be highly innovative and dynamic in this broad sense in even the poorest economies. (As we indicate below, formal R&D and sophisticated innovations that lead to patents are quite different in this respect, tending to rise sharply with per capita income.)
- There is a strong negative association between state ownership and innovation, but there is no discernible difference whether a firm is domestic or foreign and privately owned.
- There is also a strong association between innovation and most types of external financing (equity financing, local or foreign-owned commercial banks, lease finance, investment funds, trade credits, and funds from family and friends), corroborating the importance of financial sector development for innovation revealed in a number of other studies cited in this chapter.[3]
- There is a positive association between innovation and the extent of competition faced by firms.

The World Bank investment climate surveys provide a view into the sources of knowledge that firms in these low- and middle-income economies use to make innovations. Table 3.2 shows the responses of firms to a question about the most important source for the technological innovations they achieved during the preceding three years. By far the largest share of firms in all economies (on average, over 40 percent) cited the technology embodied in new machinery or equipment (most of which may be assumed to be imported). The next two sources of innovation cited most frequently were technology developed in cooperation with client firms and the hiring of key personnel (each cited by 12–13 percent of firms), while innovations developed or adapted within the firm were cited by only 11–12 percent of firms on average, that is, only about one-quarter of the share cited new machinery and equipment. These observations provide a good

TABLE 3.2 **Most Important Source of Technological Innovation**
percent of firms

Source	Cambodia 2003	Indonesia 2003	Malaysia 2002	Philippines 2003	Thailand 2004	Average
Embodied in new machinery or equipment	42.1	48.7	49.9	43.0	33.1	43.4
Developed in cooperation with client firms	11.9	15.1	8.6	9.7	17.2	12.5
Hiring key personnel	14.5	17.9	11.4	14.2	3.0	12.2
Developed or adapted within the firm locally	16.1	4.7	7.2	8.3	19.4	11.1
Transferred from a parent company	6.0	2.7	11.0	4.3	11.8	7.2
Developed with the equipment or machinery supplier	1.6	7.0	5.2	5.0	7.2	5.2
Other	7.8	3.9	6.7	15.5	8.2	8.4

Source: World Bank investment climate surveys, http://iresearch.worldbank.org/ics/jsp/index.jsp.

springboard for a more detailed inspection of the methods by which firms absorb knowledge from abroad (see box 3.2 for a listing of the methods).

Firms and economies at all levels of development rely extensively on knowledge from outside their boundaries. Eaton and Kortum (1996) estimate that, even among developed economies, foreign sources of technology account for 80 percent or more of domestic productivity growth in most OECD countries, the only exceptions being Japan and the United States. Bottazzi and Peri (2005) estimate that a 1 percent increase in R&D in the United States leads to a 0.35 percent rise in knowledge creation (patenting) in other OECD countries within 10 years.

Most obviously, developing-country firms may acquire technology through firms in developed economies by purchasing and importing advanced capital equipment embodying new technologies that could not have been produced at home or could only have been produced at a much higher domestic opportunity cost. The reverse engineering of imported capital equipment has also been an important way that firms in NIEs such as Korea and Taiwan (China) have strengthened their technological understanding and capabilities.

There is a large body of case study literature arguing that East Asian firms also derive significant technological benefits through exportation, especially under longer-term contracts, as part of the global production networks of foreign multi-

BOX 3.2 Channels for Acquiring Technology from Abroad

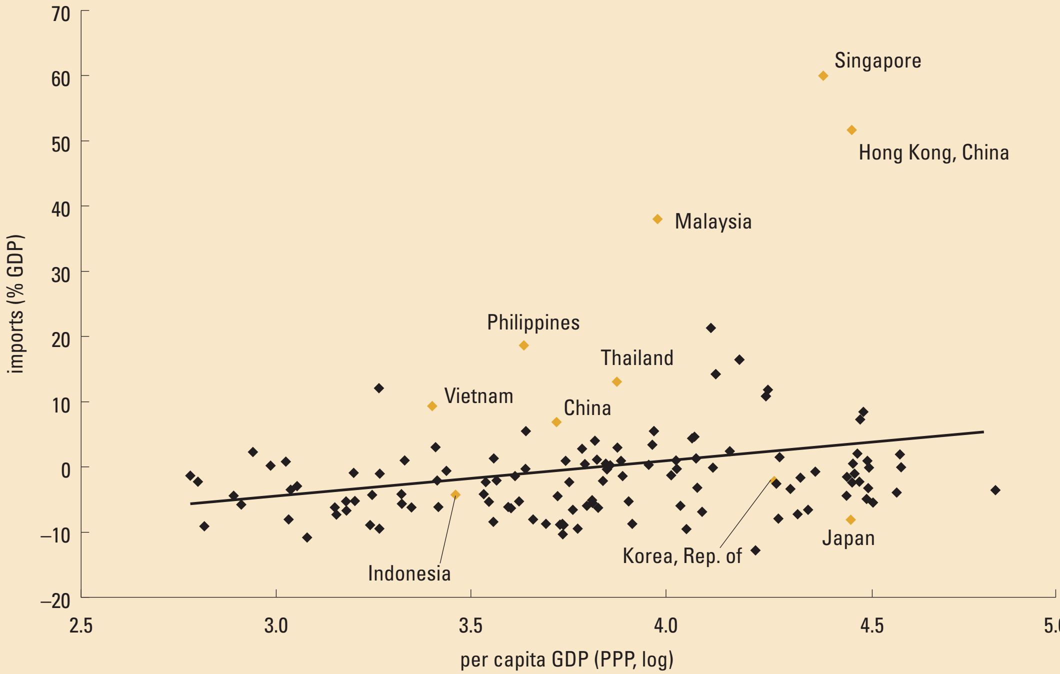
Close to 80 percent of world R&D is carried out in developed countries. Knowledge flows from rich nations thus remain the primary mode by which developing countries acquire new ideas. One of the most distinctive features of East Asian economies is their extensive engagement in international trade, reflected in exceptionally high levels of imports and exports. The following are tried and true means of acquiring technology:

- *Purchases of capital equipment.* Among the various channels for technology transfer from abroad, the importance of advanced capital equipment imports as a source of new technologies has been more clearly documented than any other.
- *Industrial upgrading through exports.* A rich body of case study literature argues that East Asian firms have also derived significant technological benefits from exports, especially exports under longer-term original equipment manufacturing (OEM) contracts or similar contracts as part of the global production networks of foreign multinationals (a model of technological development sometimes described as supplier-oriented industrial upgrading).[4]
- *Purchases of technology.* East Asian firms have also generally availed themselves of opportunities to purchase disembodied external knowledge, for example, through the acquisition of patents, nonpatented inventions, licenses, disclosures of know-how, trademarks, designs, patterns, and other technological services. This has generated unusually high levels of balance of payments royalty flows.
- *Foreign direct investment.* Local firms may also learn valuable lessons through interactions with local affiliates established by foreign multinationals using FDI. Some East Asian economies have historically adopted less open FDI policies than others, and yardsticks such as the stock of inward FDI relative to GDP are generally less exceptional than measurement results on other modes of global integration. Technology flows via FDI may occur through so-called horizontal technological spillovers from foreign affiliates competing in the same industry, although the evidence for this is mixed. More convincing is the evidence for technology transfers through vertical relationships when affiliates of multinational corporations undertake to strengthen their suppliers by providing them with training, technical support, and collaboration to solve production and design issues, another form of supplier-oriented industrial upgrading.

nationals, a model of technological development referred to as supplier-oriented industrial upgrading (although the econometric evidence for this is mixed). Certainly, exceptionally high levels of engagement in international trade are a common feature across most East Asian economies, as evidenced by the high ratio of trade to GDP. Figure 3.1 shows that the ratios of imports of machinery and transport equipment to GDP (including much of what is classified as high technology goods) in East Asia are mostly well above the levels associated with countries at similar per capita incomes.[5]

Firms may also purchase disembodied external knowledge, for example, through the acquisition of patents, nonpatented inventions, licenses, disclosures of know-how, trademarks, designs, patterns, and other consultancy and technological services. Royalty payments abroad provide a rough measure of this form of technology transfer. Figure 3.2 indicates that royalty payments abroad by East Asian

FIGURE 3.1 **East Asia Shows High Imports of Machinery and Transport Equipment**

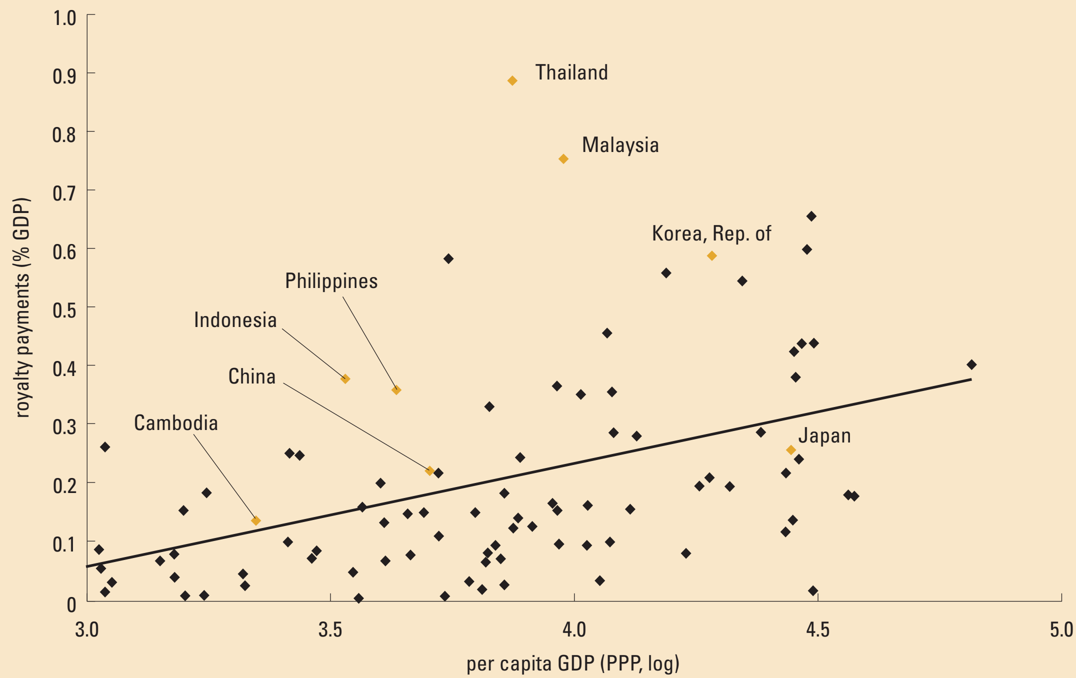


Source: Data and staff estimates of the World Bank.
Note: The ratios of imports to GDP have been adjusted for the country size effect; see endnote 5. Per capita GDP is measured in purchasing power parity dollars, stated as a logarithm.

economies are generally much higher than those by other economies at similar income levels. Firms may also derive disembodied knowledge flows through technological spillovers, benefiting from a wide range of open source information, for instance, scientific, technical and industry journals, informal contacts, and communications through networks of researchers and specialists, trade and industry associations, and trade fairs.

Local firms may likewise learn valuable lessons through interactions with local affiliates established by foreign multinationals using FDI. This might occur through so-called horizontal technological spillovers from foreign affiliates competing in the same industry, although the evidence for this is mixed. More convincing is the evidence on cooperation in innovation and agreed technology transfers through vertical relationships with customers and suppliers, particularly

■ FIGURE 3.2 **East Asian Countries Make Relatively Large Royalty Payments**



Source: Data and staff estimates of the World Bank.
Note: Per capita GDP is measured in purchasing power parity dollars, stated as a logarithm.

in the case of developing-country firms that become suppliers to multinational affiliates (another form of supplier-oriented industrial upgrading).

Historically, the differences in the level of reliance of East Asian economies on FDI have been wider than the differences in the level of their reliance on trade or technology licensing, although, in recent years, there has been a convergence toward more openness to FDI. Korea and, to a lesser extent, Taiwan (China) have tended to restrict FDI, while emphasizing the licensing of foreign technology and the upgrading of domestic technological capabilities, including through domestic R&D and the strengthening of technical education and labor force skills. Singapore, on the other hand, has been exceptionally welcoming to FDI, while also fostering domestic technology efforts. China, too, has drawn heavily on FDI inflows, emphasizing joint ventures, while also emphasizing domestic R&D more recently. Middle-income Southeast Asian economies such as Indonesia, Malaysia, the Philippines (since the 1980s), and Thailand have also been open to FDI, although, as we show below, the level of indigenous technological effort in these economies (especially R&D) has been limited.[6]

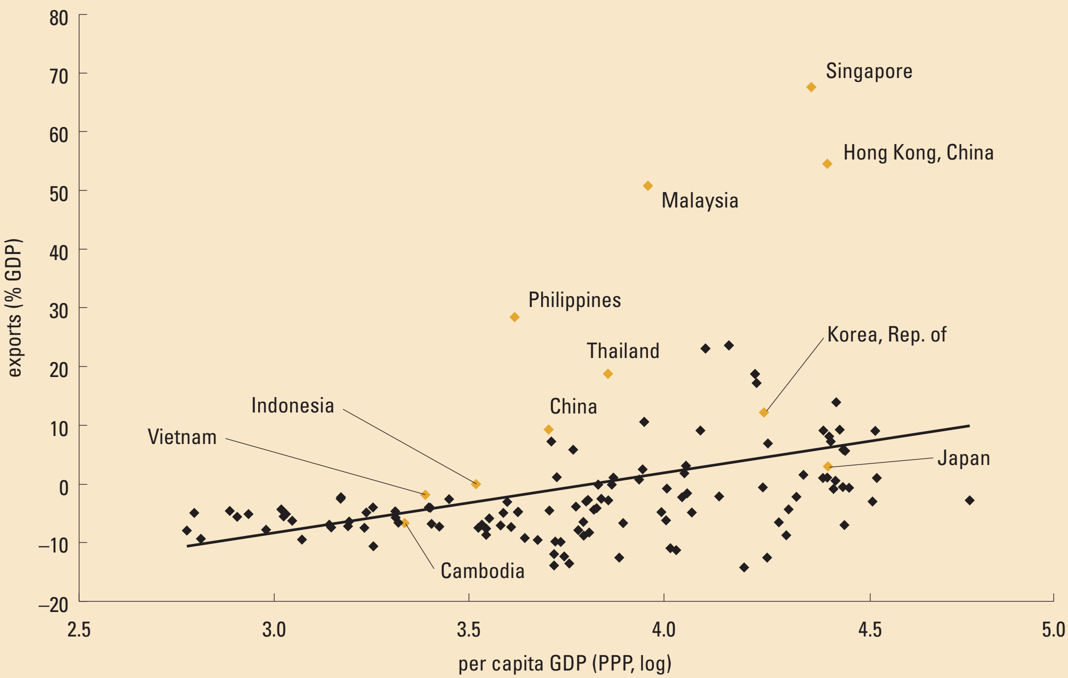
The rest of this section examines the role of these channels in fostering technological advances in East Asia. A theme that emerges is that, whatever combination of channels is employed, the returns to technology transfer from abroad are dependent on the absorptive or learning capacity of the economy, which, in turn, depends on the education and training of the labor force and the extent of domestic R&D. At the same time, domestic R&D and innovation in nearly all countries would be inconceivable if they were not able to "stand on the shoulders" of the enormous stock of accumulated scientific and technical knowledge worldwide that becomes accessible through spillovers and technology transfers. We therefore analyze the sources of international knowledge that East Asian innovation draws upon using patterns of patent citations. Rather than substitutes for each other, domestic innovation and the absorption of knowledge from abroad emerge as activities that buttress and foster each other.

Learning by Exporting?

The rapid, sustained growth of East Asian manufactured (and, increasingly, high-technology) exports in recent decades warrants attention for the potential role exports may play as a channel for technology transfer. At the simplest level, exports provide the resources for imports of capital equipment that embody modern technologies. More directly, technology transfer may also be facilitated by interactions between developing-country exporters and their developed-country customers, who have an incentive to help suppliers upgrade technical capabilities, productivity, and product quality. East Asian exports of machinery and transport equipment (containing much of what is classified as high-technology products) are generally much higher than those of other economies at similar incomes (see figure 3.3).

The potential for technology transfer through exporting is considered important in the case study literature.[7] Hobday (1995, 2000) stresses the role of the original equipment manufacture (OEM) subcontracting system in fostering industrial exports and technology transfers in the NIEs, particularly in Korea and Taiwan (China) (see box 3.3). Nevertheless, while the case study literature has emphasized the opportunities for technological learning through exports, systematic econometric evidence for this proposition is mixed.[8] There is certainly plenty of evidence that, in general, firms that export exhibit significantly higher productivity than firms that do not export. But this appears to be mainly the result of self-selection by more productive firms, since these are more likely to undertake

■ FIGURE 3.3 **East Asia Is a Prolific Exporter of Machinery and Transport Equipment**



Source: Data and staff estimates of the World Bank.
Note: The ratios of exports to GDP have been adjusted for the country size effect; see endnote 5. Per capita GDP is measured in purchasing power parity dollars, stated as a logarithm.

the higher fixed costs and rigors of competing in international markets. Clerides, Lach, and Tybout (1998), for example, discover little evidence for learning effects from exports in plant-level data from Colombia, Mexico, and Morocco. On the other hand, Kraay (2006) and Aw, Chen, and Roberts (1997) do find evidence that experience in exports helps explain the productivity levels of firms in China and Taiwan (China).

Pack (2006) observes that data on exports typically do not separate exports carried out under long-term OEM-type contracts from other types of exports, although it is only the former that are expected to produce learning benefits. Thus, it is perhaps not surprising that econometric studies based on generic export data arrive at only mixed results in explaining export learning effects. There is, however, a good deal of recent econometric evidence for the existence of technology transfers from

BOX 3.3 Scale Economies and the OEM and Design and Brand Manufacturing Sequence

Under the OEM system, a supplier undertakes production (typically, at thin profit margins) according to the precise design specifications of the foreign buyer, which then markets the product under its own brand name through its international distribution channels. OEM production and exports in the NIEs evolved rapidly during the 1970s and 1980s. Surveys suggest that some 70–80 percent of Korea's electronics exports were occurring under OEM-type contracts by 1990, while over 40 percent of the computer hardware exports from Taiwan (China) took this form. Over the past 15 years, OEM-type contracting has also been central in the enormous expansion of manufactured exports from China. During this time, the OEM model itself has developed into more complex patterns of global production networking in which first-tier suppliers are themselves purchasers from second- and third-tier suppliers.

The potential benefits of OEM-type contracts for developing-country exporters include economies of scale in production that involve less risk and cost relative to firms that attempt to break into global markets on their own, as well as possible assistance in mastering new technologies through technology transfers, services, and training offered by the customer. By building up its technological capabilities in this way, a firm may lay the groundwork for more sophisticated (and profitable) ventures, for example, through original design manufacturing (whereby the firm also takes over responsibility for the postconceptual design and development of products sold under the customer's brand) and original brand manufacturing (whereby the firm produces its own brand after it has mastered the entire product cycle of R&D, innovation, design, development, production, and marketing). This sequential OEM–original design manufacturing–original brand manufacturing pathway has been labeled supplier-oriented industrial upgrading (see above).[9]

Samsung Electronics of Korea is an example of a developing-country firm that has successfully traveled this road, building on OEM and technology licensing deals with advanced multinational corporations such as GTE, Philips, Sony, and Toshiba in the 1980s and then making huge efforts to build up its own design capabilities, R&D, and independent brand in the 1990s. By 2004, it had annual R&D expenditures of US$4 billion–US$5 billion (representing 8–9 percent of sales and employing close to a quarter of the firm's workforce), the largest global market share in sales of dynamic random access memory and static random access memory semiconductor chips, flash memories, televisions, computer monitors, and liquid crystal display panels, as well as the second or third largest market shares in mobile phones and DVD players.

multinational firm affiliates in a host country to local suppliers in the same host country (discussed hereafter). Given this evidence for one form of supplier-oriented industrial upgrading, it may be reasonable to suppose that similar spillovers also exist for another, that is, for crossborder trade carried out under long-term OEM-type contracts between a multinational corporation purchaser abroad and developing-country OEM exporter firms that are part of the purchaser's global production network.

Tybout (2006) also notes that many studies of export learning effects fail to take into account the possibility that future exporters may come into contact with and begin cooperating with potential foreign customers well *before* export flows actually take place. Kim (1997) describes Samsung's efforts to master the production of microwave ovens in the 1970s in response to a prospective order from J. C. Penney in the United States. Here, the prospect of an export market larger than any available at home was the spur to the firm's large investment in mastering microwave technology, and the improvements in its productivity preceded actual export flows.

This and other case studies suggest that the relationship between exports and productivity involves more than a simple choice by firms that are productive for some exogenous reason and that then self-select to become exporters. It seems, rather, that firms make deliberate decisions to improve their productivity so as to serve export markets. Hallward-Driemeier, Iarossi, and Sokoloff (2002) provide firm-level evidence from five East Asian economies for this hypothesis. Domestic firms that begin as exporters have significantly higher levels of productivity than other classes of firms (in particular, firms that only become exporters later), and they also differ systematically in the training of the workforce, the vintage of their capital equipment, the use of outside auditors, and other aspects of production processes and operations. The authors interpret this finding as evidence that the decision to export encourages firms to undertake productivity enhancing improvements, including the technologies applied. They point out that the gap in productivity between firms that begin as exporters and others is largest and most significant in middle-income economies such as Indonesia, the Philippines, and Thailand, less so in Malaysia, and essentially nonexistent in the most developed economy, Korea. They conclude that "to those concerned with policy . . . , the message would be that it is the least developed economies that have the most to gain from measures that would broaden the markets they face" (p. 36).

Nevertheless, while firms in less well developed economies may have the most to gain from taking on the challenges of exporting, they may also be the least well equipped to do so. Nabeshima (2004) observes that, to be selected as an OEM supplier, firms need to possess a certain level of production and technological capabilities that allows them to meet demanding quality, cost, and delivery requirements. Firms have to grapple with even more complex problems in attempting the transition to original design or original brand manufacturing, which helps explain why firms such as Samsung are among only a few East Asian or developing-country firms to have made the transition to primary reliance on internal R&D and their own global brands.

Drawing on extensive interviews with lead firms and suppliers in the electronics and auto parts industries, Sturgeon and Lester (2004) suggest that recent trends are raising significantly the economies of scale and technological competencies required for participation in the global production networks of multinational companies, putting in question the usefulness of the supplier-oriented model for many developing economies. Excellent manufacturing performance and low costs are considered widely available and commodified; moreover, potential suppliers now need to provide the lead firm with value adding capabilities in product and component design, component sourcing, inventory management, testing, packaging, and logistics. Increasingly, suppliers also need to be global in scope so that they are able to support their lead firms all over the world. Besides, lead firms are now less inclined to establish long-term relationships with suppliers who threaten to turn into competitors, preferring to do business with pure play OEM and original design manufacturing suppliers.

Reflecting these trends, since the early 1990s, leading firms in the electronics industry have been outsourcing a larger share of their supplier business to a small group of contract manufacturers that operate extensive global networks of production facilities to support the worldwide operations of their clients, including high-volume production sites in Central and Eastern Europe, East Asia, and Mexico, as well as more specialized sites close to clients in developed economies.[10] As table 3.3 indicates, most of the top contract manufacturers are firms in advanced economies, and only a limited number of firms in Taiwan (China) have broken into the top ranks of this business. The 1990s also saw a huge wave of investment in auto assembly and component supply plants in emerging markets, especially in China and elsewhere in East Asia. As in electronics, the major assemblers are increasingly outsourcing to a small number of component suppliers with global reach, typically advanced economy firms, such as Bosch, Delphi, Denso, and Visteon, that take up the responsibility for the design and supply of

TABLE 3.3 **The Top Five Electronic Contract Manufacturers, 1994 and 2004**

Company	1994 revenue (US$ million)	Company	2004 revenue (US$ million)
Sanmina[a]	2,363	Flextronics[c]	15,355
Celestica[b]	1,989	Hon Hai[d]	13,190
Solectron[a]	1,642	Sanmina[a]	12,205
Jabil[a]	404	Solectron[a]	11,638
Flextronics[c]	211	Celestica[b]	8,840

Sources: Sturgeon and Lester 2004; Reed Business Information 2005.
a. United States.
b. Canada.
c. Incorporated in Singapore; managed from the United States.
d. Taiwan (China).

the major component modules going into an automobile and that are able to col-locate near the assembler's worldwide operations. Doner, Noble, and Ravenhill (2004, 2006) observe that these assembler strategies are tending to raise barriers to developing-country firms aiming to enter the global auto parts industry.

According to these case studies, growing competitive pressures are raising the technological capability and scale thresholds required of East Asian firms to participate effectively in global production networks. If, in the past, low production costs were an adequate entry ticket for participation in production networks, the price of entry today also increasingly requires firms to possess more sophisticated learning, innovation, and design capabilities. (The final section of this chapter looks at policies that governments may use to further these learning efforts and capabilities.)

Technology Transfer Through Imports

Figure 3.1 above highlighted the exceptionally high levels of imports of capital equipment and components in many East Asian economies. Table 3.2 above showed that three or four times more firms in low- and middle-income economies in East Asia rely on capital equipment imports as a source of technological innovation rather than on any other method. Grossman and Helpman (1991) have analyzed the role of imports of capital equipment as a channel for technology transfer in theoretical models of endogenous growth. Coe and Helpman (1995) have found that the level of total factor productivity in countries is significantly related to the stocks of R&D in trading partners, weighted by overall imports from the trading partners as a share of GDP. In general, the impact of foreign R&D on domestic total factor productivity rises with the openness of the economy, as measured by the level of total imports to GDP. Coe, Helpman, and Hoffmaister (1997) have extended the analysis to developing economies and find that the total factor productivity of these economies is also significantly related to the stock of R&D in developed economies (weighted by imports from developed economies), as well as to the overall share of imports to GDP and the secondary school enrollment rate. Their study finds that East Asian NIEs such as Hong Kong (China), Korea, and Singapore have elasticities of total factor productivity to foreign R&D stocks that are generally higher than the average for developing economies.

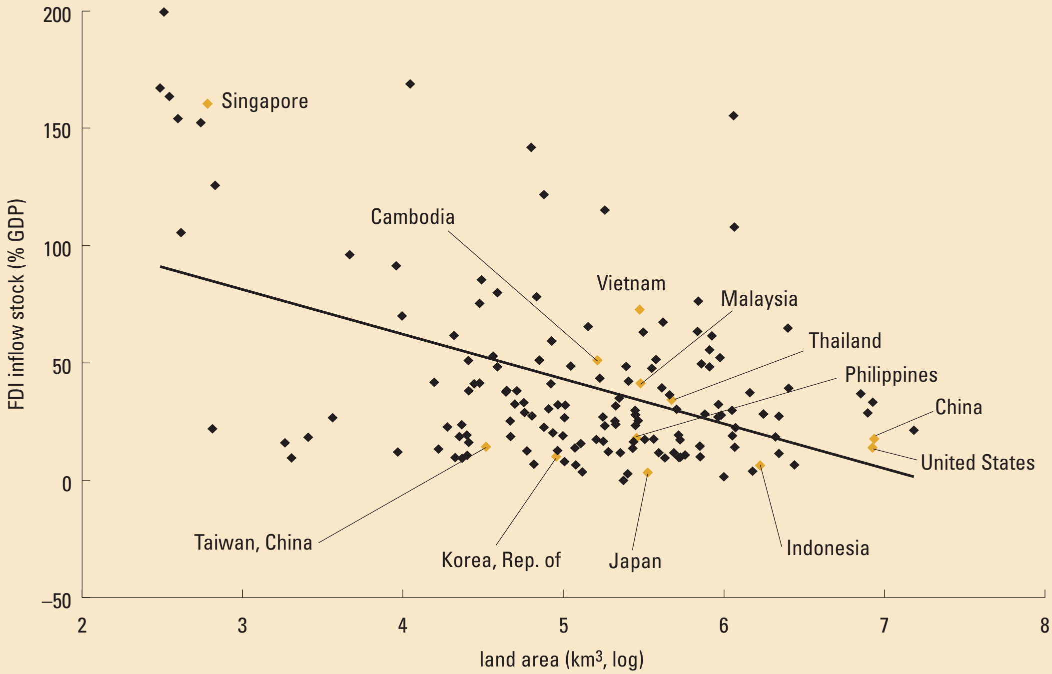
Subsequent studies have mainly confirmed these results and elaborated on them in several directions. Keller (2002) offers one of relatively few studies to look at the impact of international trade, FDI, and disembodied knowledge flows (for example, through direct communication) together as channels of knowledge flow.[11] He finds that all three channels are significant for knowledge flows, but that imports are the most important channel, explaining about two-thirds of the estimated impacts, while FDI and disembodied flows (as measured) explain about one-sixth each on average. Xu and Wang (1999) find that imports of capital equipment provide a better index for measuring R&D spillovers than does trade as a whole. Schiff, Wang, and Olarreaga (2002) look not only at the impact on the productivity of developing countries of the R&D stocks accumulated in the North, but also those accumulated in the South, that is, in developing countries.[12] They find that the productivity in developing economies does rise with the R&D in other developing economies (and thus with openness to these economies), but that the elasticity is smaller than it is with respect to the R&D in the North. They find that these kinds of South-South R&D spillovers are mostly important for industries that have a low R&D intensity, but not for industries with a high R&D intensity, which benefit more from R&D in the North (and openness to the North).

Transfers and Spillovers Through FDI

There is a good deal of variation in the levels of FDI in East Asian economies. For these economies, figure 3.4 shows a scatter plot of the accumulated stocks of inward FDI (relative to GDP) versus land area.[13] Economies such as Japan, Korea, and Taiwan (China) have historically exercised relatively restrictive policies on FDI inflows and continue to show low stocks of inward FDI relative to other economies of comparable geographical size (or per capita income). FDI stocks are also low relative to country size and per capita income in Indonesia and the Philippines. On the other hand, FDI stocks in economies such as China, Hong Kong (China), Singapore, and most middle- (and low-) income economies in Southeast Asia are generally at or above the levels predicted by country size or (for the most part) per capita income, partly reflecting more open policies toward FDI. (In a slight exception to these observations, despite the high absolute flows of FDI to China in recent years, the stock of FDI relative to China's GDP remains low compared to the situation in most other economies at a similar per capita income.) Figure 3.5 shows that, while stocks of FDI in manufacturing in East Asia are the highest in the world, FDI in the much larger services sector of these economies is appreciably lower than is the case in other regions.

These results suggest that, broadly, if FDI is indeed a significant source of knowledge transfer and spillovers, then more than a few East Asian economies

FIGURE 3.4 **FDI Inflows Vary Considerably across East Asia**

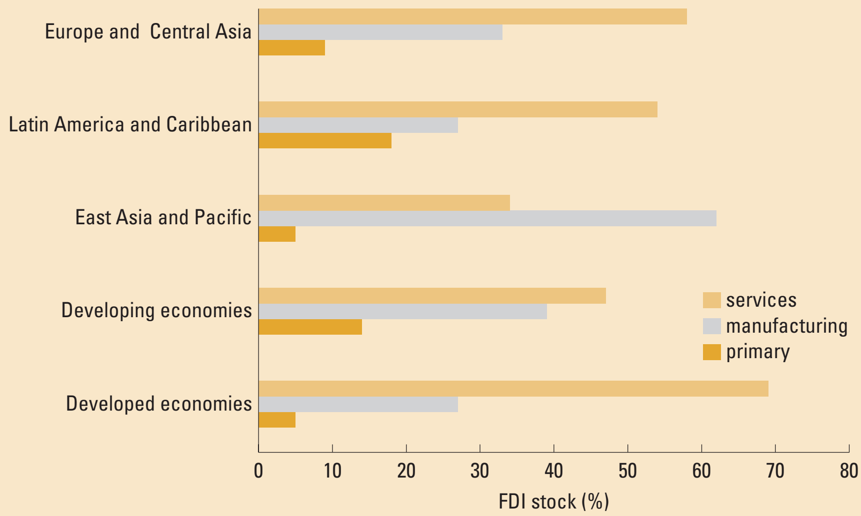


Source: UNCTAD 2005.
Note: The figure shows the situation in 2003.

may be able to tap greater productivity benefits from greater FDI. Modern theories of the multinational enterprise and FDI emphasize their character as sources of product innovations, new process technologies, managerial expertise, higher quality standards, and export access to global markets. These theories ask why multinationals opt for FDI rather than production technology licensing through arm's-length market transactions. The answer hinges on the existence of the significant externalities or market failures associated with knowledge that prevent firms from protecting or exploiting fully their intangible knowledge assets in arm's-length transactions and lead them to deploy these assets through transactions within the boundaries of the firms through FDI.[14]

FDI is expected to bring a number of benefits. Foreign affiliates of multinational corporations obtain easier access to superior parent company technologies and achieve higher levels of productivity in their operations, which, in a competitive

FIGURE 3.5 **FDI Stock in East Asia: Manufacturing Is High, and Services Are Low**



Source: World Bank 2004a.
Note: The figure shows the situation in 2002.

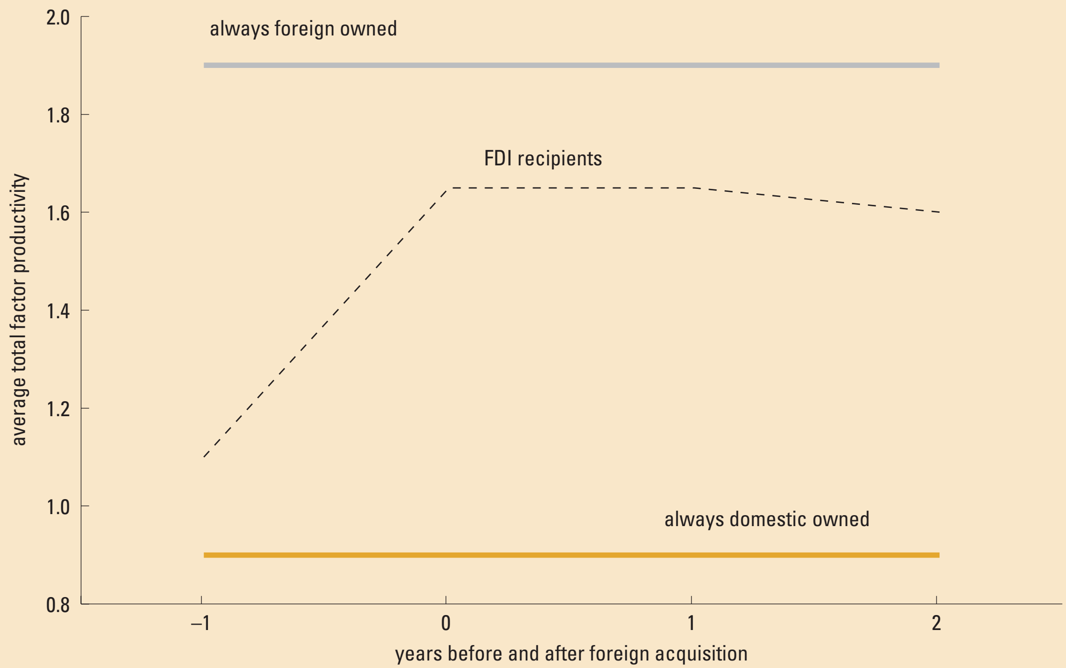
environment, translate into higher wages for employees and greater welfare for consumers because higher-quality goods and services become available at lower prices. FDI may also enhance productivity in the rest of the economy by increasing competition or through spillovers of technology and expertise. Some research finds that FDI crowds in domestic investment[15] and may create new export opportunities for domestic firms. Here, we review evidence for two propositions: does foreign ownership convey large productivity benefits for the local firms or operations that are acquired or established by the multinational corporation, and, if these benefits exist, do they spill over to other domestic, unacquired firms?

First, does FDI convey large productivity benefits for the local operations that a multinational corporation acquires? There is much evidence that such operations generally show higher levels of labor productivity, total factor productivity, and wages than do local firms. What has not been clear, however, is whether this superiority is brought about by the restructuring and the infusion of new technology undertaken by the foreign owners or, instead, simply reflects the fact that foreign firms may acquire local firms that were already superior in these respects.

Recent World Bank research addresses some of the difficult econometric problems that bedevil studies of this question. The research uses firm-level data from 1983 to 1996 from the Indonesian census of manufacturing.[16] The analysis shows that Indonesian plants, through foreign acquisition, benefit from a rapid and substantial improvement in total factor productivity, averaging about 46 percent (see figure 3.6). In the first one or two years after acquisition, an acquired plant experiences much more rapid growth in output, employment, investment, and wages than do other local plants. The proportion of skilled workers in the plant labor force increases, and the export orientation of the plant is augmented, as is the plant's use of imported intermediates. All this is consistent with significant restructuring in plant operations after acquisition.

Second, does superior technology among the affiliates of multinational corporations spill over to unacquired local firms? This might happen, for example, if local firms are able to improve their productivity by copying products, technologies,

FIGURE 3.6 **Indonesian Plants Acquired by Foreigners Experience Higher Productivity**



Source: World Bank 2005.

methods, or strategies from the affiliates of the multinational corporations through observation (*imitation*) or by hiring workers trained by the affiliates (*skill set acquisition*).[17] The entry of multinational corporations might also lead to more *competition* in the host country market, forcing local firms to use their existing resources more efficiently or to search for new technologies.

In evaluating the evidence for spillovers, one should distinguish between horizontal (or intraindustry) and vertical (or interindustry) knowledge transfers or spillovers. Horizontal or intraindustry spillovers refer to a situation wherein local firms benefit from the presence of foreign competition in their own sector. The foreign competitors will, however, have a strong incentive to prevent technology leakages and spillovers. They will try to achieve this through the formal protection of intellectual property, trade secrecy, paying higher wages, or locating in countries or industries where local firms have limited imitative capacity.

Broadly speaking, recent research tends to cast doubt on the existence of horizontal spillovers in developing countries. A recent survey by Görg and Greenaway (2004) takes stock of 40 studies on horizontal productivity spillovers in manufacturing industries in developed, developing, and transition countries. While 22 of these studies find positive and significant horizontal spillover effects, the authors challenge the results of the 14 that do not use panel data. They write that such studies are unable to deal with problems of reverse causality. There are then only eight studies using panel data that find unambiguous evidence of positive horizontal spillovers, and most of these are on firms in developed economies.[18] On the other hand, several studies using firm-level panel data find evidence of the negative effects of FDI on domestic firms. This is the case, for instance, in the analysis of Aitken and Harrison (1999) on the República Bolivariana de Venezuela and the study of Konings (2001) of firms in Bulgaria, Poland, and Romania. One suggested explanation for negative effects on the productivity of domestic firms is that, in the short run, greater competition from foreign-invested firms reduces the market available to local firms and forces them higher up on the given cost curves. This would not be inconsistent with the fact that competition may also force local firms to improve efficiency (shift their cost curves downward) in the longer run.

There is a good deal of evidence that the extent of horizontal FDI spillovers and technology transfers depends on the capacity of the local economy to assimilate new knowledge. Differences in absorptive capacity would help explain why, for example, there is more evidence for horizontal spillovers in developed countries than in developing economies. Glass and Saggi (2002) find that the greater the technology gap between local and foreign firms, the lower the quality of technology transferred and the lower the potential for spillovers. Along the same lines, Kokko, Tansini, and Zejan (1996) find that, in Uruguay, there have been productivity spillovers to domestic firms with moderate technology gaps, but not where the gaps are large. Borensztein, De Gregorio, and Lee (1998) and Lipsey (2000) emphasize the need to improve education in the host economy as a means of strengthening the capacity to incorporate positive spillovers. Kinoshita (2001) finds that, in the Czech Republic, only domestic firms that undertake their own R&D enjoy horizontal FDI spillovers. Furthermore, distinguishing between "the two faces of R&D" analyzed by Cohen and Levinthal (1989), Kinoshita finds that domestic Czech firms performing R&D benefit not only from the innovations produced by the R&D, but also by becoming more able to learn and absorb outside knowledge. The learning effect is several times larger than the innovation effect.

Todo and Miyamoto (2006) observe that the extent of horizontal FDI spillovers to domestic firms is also likely to depend on the level of R&D undertaken in the host country by foreign firms. Local workers and engineers employed in R&D–performing foreign affiliates may be able to gain more knowledge than those working in foreign firms not undertaking local R&D, and this knowledge may diffuse to local firms through job turnover, work-related discussions, and so on. Looking at Indonesian firms in 1994–97, Todo and Miyamoto find that domestic firms received positive spillovers from R&D–performing foreign firms, but not from non-R&D–performing foreign firms. Taken together, the Kinoshita, Todo, and Miyamoto studies suggest that in-country R&D may be important in terms both of foreign affiliates generating spillovers and domestic firms absorbing spillovers.

While foreign investors have an incentive to prevent knowledge leakage to local firms with which they compete, they may gain by transferring knowledge to their local suppliers or customers through vertical input-output links. As in the case of OEM-type supplier-customer relationships, these vertical or interindustry knowledge flows may take place directly through knowledge transfers from foreign firms to local suppliers or customers (for example, through training programs, technical support, and collaboration on production and design issues), indirectly through the movement of workers between customers and suppliers, or simply through higher standards for product quality and on-time delivery that provide an incentive to domestic suppliers to upgrade their production management or technology. Local suppliers may also reap the benefits of economies of scale because of increased demand for intermediate products from new multinational customers, although this is not a knowledge transfer in the strict sense.

There is a good deal of evidence on vertical technology transfers in developing economies. Blalock and Gertler (2005) find strong support for vertical technology transfers from multinational corporation customers to local suppliers in Indonesia, as Javorcik (2004) does in Lithuania. Saggi (2002) finds that Mexican *maquiladoras* (product assembly plants for export), which began as producers of more labor-intensive products, adopted more sophisticated production techniques over time. Many of these techniques were imported from U.S. customers. The size of the effects is generally meaningful. Javorcik (2004) finds, for example, that a 1-standard deviation increase in foreign presence in the purchasing sector of the economy in Lithuania is associated with a 15 percent rise in the output of local firms in supplier sectors. However, as noted in the discussion above on supplier-oriented industrial upgrading through OEM-type contracts, the potential for vertical technology transfers depends, to some extent, on whether domestic firms are chosen as suppliers by the affiliates of multinational corporations, on the technological ability of these firms to meet demanding quality, cost, and delivery requirements, and on the amount of technological learning the firms obtain through vertical spillovers. Blalock and Gertler (2005) find, for example, that, in Indonesia, domestic firms with high levels of human capital are the prime beneficiaries of vertical knowledge transfers.

R&D Efforts in East Asia

Total world spending on R&D reached US$830 billion in 2002 in purchasing power parity terms.[19] Almost by definition, the greater part of world R&D is performed in developed countries: around 78 percent in 2002, much higher than the 59 percent share of these countries in world GDP in purchasing power parity terms. The proportion of R&D done in developed countries has fallen over the last decade, however. Developing economies have been devoting more resources to R&D, and they raised their share in the world total from around 13 percent in 1992 to 22 percent in 2002. East Asia has contributed almost three-quarters of the increase in developing-country R&D over the last decade. In nominal terms, R&D spending in East Asia quintupled over the decade, reaching US$112 billion in 2002, or 13.5 percent of the world total. The R&D intensity in East Asia—the ratio of R&D spending to GDP—also rose, from 0.7 percent in 1992 to 1.2 percent in 2002.

As table 3.4 shows, however, the East Asian economies differ widely in R&D performance. Korea, Singapore, and Taiwan (China) now devote 2.2–2.5 percent of GDP to R&D spending, which is comparable to R&D levels in the United States and at the upper end of the scale among developed economies. Meanwhile, R&D spending in economies such as Indonesia, the Philippines, and Thailand is only 0.1– 0.2 percent of GDP, which is among the lowest levels among all economies

TABLE 3.4 **R&D Expenditures**
at purchasing power parity

Region or country	R&D spending, 2002		R&D as % of GDP[a]	
	US$ billions	% of world	1992	2002
East Asia	111.7	13.5	0.7	1.2
NIEs	36.4	4.4	1.6	2.2
Hong Kong, China	1.1	0.1	0.3[b]	0.6
Korea, Rep. of	20.8	2.5	1.9	2.5
Singapore	2.2	0.3	1.2	2.2
Taiwan, China	12.2	1.5	1.8	2.3
Southeast Asia	3.3	0.4	0.1	0.2
Indonesia	0.3	0.0	0.1[c]	0.1[d]
Malaysia	1.5	0.2	0.4	0.7
Philippines	0.4	0.0	0.2	0.1
Thailand	1.1	0.1	0.2	0.2
China	72.0	8.7	0.8	1.2
World	829.9	100.0	1.7	1.7
Developed countries	645.8	77.8	2.3	2.3
Japan	106.4	12.8	2.9	3.1
United States	275.1	33.1	2.6	2.6
Developing countries	184.1	22.1	0.6	0.9
Latin America	21.7	2.6	0.5	0.6
Emerging Europe	30.3	3.7	1.0	1.2

Source: UNESCO 2004, 2006.
a. Regional data are the sum of R&D divided by the sum of GDP.
b. 1995.
c. 1994.
d. 2001.

for which we have data. Between these two extremes is China, where R&D spending rose at 20 percent a year over the last decade to reach 1.4 percent of GDP by 2004, or US$109 billion in purchasing power parity terms.[20] R&D spending in Malaysia also accelerated after the mid-1990s, reaching 0.7 percent of GDP by 2002.

The wide range of R&D intensities in East Asia is of course consistent with the broad cross-country pattern whereby richer countries such as Korea have higher

R&D intensities than poorer ones such as Indonesia. Figure 3.7 shows a scatter plot of available panel data on R&D intensities and per capita GDP for a large number of developed and developing economies between the mid-1970s and the early to mid-2000s. Econometric estimates suggest that R&D intensity not only increases with per capita GDP, but does so at an accelerating pace. As figure 3.7 also indicates, the trajectories of R&D spending in several East Asian economies show significant and sustained deviations from the levels suggested by per capita GDP alone. R&D intensity in economies such as China, Korea, and Taiwan (China) is twice as great as those suggested by per capita income. On the other hand, R&D intensity in Southeast Asian economies such as Indonesia, the Philippines, and Thailand has systematically undershot the estimated average relationship over a long period (both before and after the financial crisis of the late 1990s).

FIGURE 3.7 **R&D Efforts Have Increased More Rapidly in East Asia**

Source: Data of the OECD and World Bank staff estimates.
Note: The figure shows the situation from the mid-1970s to the early to mid-2000s. The golden points refer to the named economies.

Research at the World Bank by Lederman and Maloney (2003)—one of only a few studies to examine R&D in developing countries systematically—finds that policies and institutions play an important role in explaining these systematic deviations, while structural differences such as the size of the economy, the size of the labor force, and the relative abundance of natural resources do not. As with other types of investment, the intensity of R&D declines at higher real interest rates and greater macroeconomic volatility. It rises with greater financial depth and stronger intellectual property rights. Subjective measures of the quality of research institutions such as universities and public research centers and the quality of collaboration between these institutions and the private sector also show a positive impact on R&D intensity. The discussion of policy issues at the end of this chapter looks at how East Asian economies rank on these broader aspects of the economic and institutional environment that are relevant for R&D intensity and innovation; it finds marked differences between high- and low-R&D performers.[21]

Are these large differences in R&D performance significant for economic performance? Is formal R&D important only for a few advanced economies such as Korea, while most developing countries need only focus on absorbing advanced knowledge from abroad, for example, through openness to trade and foreign investment? The study by Lederman and Maloney (2003) also estimates the impact of R&D intensity on total factor productivity growth for a sample of developed and developing economies. They find that a 1 percentage point increase in R&D intensity is associated with a 0.78 percent rise in total factor productivity growth: in effect, a 78 percent social rate of return on R&D investment. The term "social" here indicates that the returns measured include not only private returns to the firm making the R&D investment, but also the benefits for others that are generated by R&D spillovers.

The very high social rate of return found here is similar to results in earlier studies for the United States and other OECD countries. Compared to the prevailing costs of capital, these high rates of return imply that actual levels of R&D investment are only a fraction of socially optimal levels. Looking at how returns to R&D in rich countries differ from those in poor ones, the study finds that returns to R&D fall substantially with the level of per capita income; in other words, returns are *higher* in poor countries than they are in rich ones. This result is consistent with the intuition that a dollar of R&D should be more valuable in poor countries that are far from the technology frontier than it is in advanced countries that must focus on cutting-edge innovations that shift the frontier forward. This is likely to be the case especially for the development component of R&D, particularly expenditures devoted to adapting foreign technologies into forms useful in the local environment.

Overall, then, there is at least some evidence that R&D benefits not only rich economies, but may also yield substantial benefits for poor economies. Buttressing a point made above, poor economies may especially benefit from development expenditures that facilitate the absorption of knowledge from abroad (see box 3.4). Although potential returns to R&D in poor countries are high, the levels of R&D in these economies tend to be held back by macroeconomic instability, underdeveloped financial systems, weak intellectual property rights, and low-quality public research institutions.

R&D by Sector of Performance

The business sector in East Asia plays an unusually big role in performing R&D.[22] The median share of national R&D undertaken by the business sector among the main East Asian economies is a little over 60 percent (see table 3.5). That is about

BOX 3.4 Foreign Technology and Domestic Innovation May Support Development

Development experience suggests that domestic knowledge creation and the absorption of knowledge from abroad provide essential support for each other in many ways and in countries at all levels of per capita income, though the balance between the two varies.

On the one hand, it is clear that knowledge absorption from abroad needs a strong domestic technical capacity that is able to adapt and adjust foreign knowledge so as to make it usable and useful under local circumstances. Problems arise because much knowledge cannot be codified, but is tacit; it requires costly face-to-face interactions and learning processes to master. On the other hand, domestic R&D and innovation in nearly all countries would be inconceivable if they were not able to stand on the shoulders of the enormous stock of accumulated scientific and technical knowledge worldwide that they are able to access through spillovers or technology transfers. Openness and close interaction with international scientific, technical, and research communities (firms, universities, and so on) remain fundamental.

Cohen and Levinthal (1989) point out that R&D has two faces: innovation and learning. R&D not only generates new knowledge, but also enhances a firm's ability to assimilate and exploit existing knowledge. For example, developing-country firms are more likely to benefit from FDI spillovers if they conduct R&D themselves. Similarly, being selected as an OEM supplier in a global production chain is increasingly becoming more likely if the developing-country firm already possesses significant in-house design, engineering, and other technical capabilities. The quality of the broader educational and labor force training systems becomes important, as do high-quality national and international telecommunications systems for both the knowledge creation and the knowledge absorption facets of innovation. Telecommunications systems are an important channel for the flow of disembodied knowledge. Elsewhere below, we note evidence that the role of these systems in facilitating knowledge flows may be at least as great as that of trade and FDI. The rapid growth of crossborder intraregional telecommunications flows in recent years suggests that the countries of the region are becoming more integrated through not only trade and financial flows, but also flows of information and ideas.

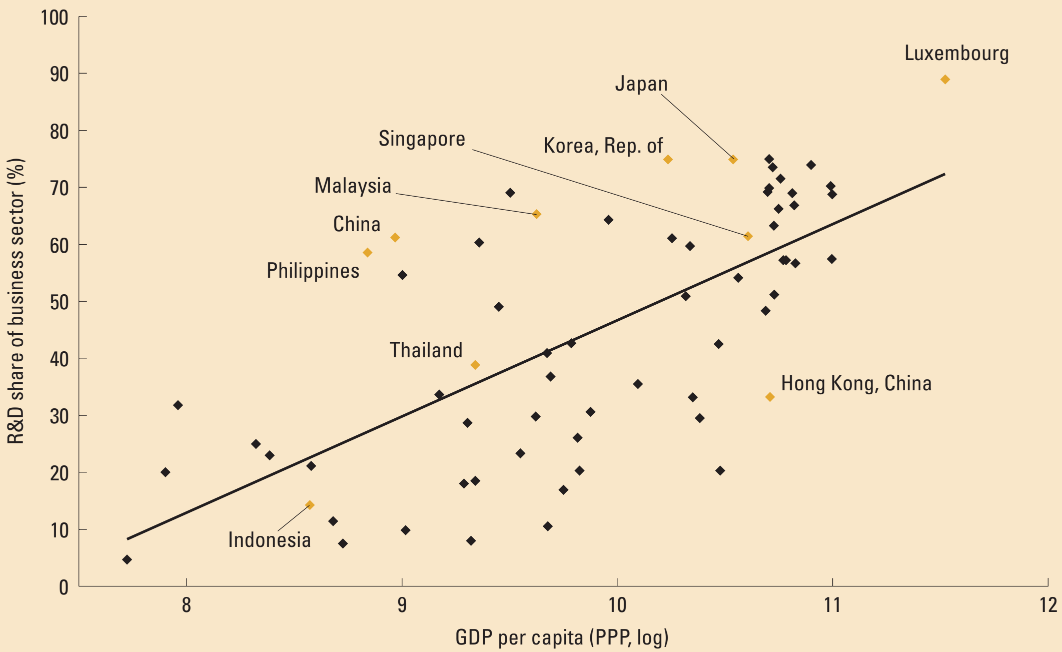
TABLE 3.5 **R&D by Sector of Performance and Funding**

Region or country	Sector of performance			Sector of funding		
	Business	Government	Higher education	Business	Government	Higher education
East Asia	62.2	21.7	14.4	54.3	35.2	2.3
NIEs	63.0	11.7	18.8	58.7	35.9	1.7
Hong Kong, China	33.2	3.1	63.6	35.3	62.8	0.2
Korea, Rep. of	76.1	12.6	10.1	74.0	23.9	1.7
Singapore	63.8	10.9	25.4	54.3	36.6	2.3
Taiwan, China	62.2	24.8	12.3	63.1	35.2	0.0
Southeast Asia	51.3	22.1	15.7	46.6	35.4	6.2
Indonesia	14.3	81.1	4.6	14.7	84.5	0.2
Malaysia	65.3	20.3	14.4	51.5	32.1	4.9
Philippines	58.6	21.7	17.0	59.7	24.6	7.5
Thailand	43.9	22.5	31.0	41.8	38.6	15.1
China	62.4	27.1	10.5	60.1	29.9	. .
Developed (21)	62.9	13.3	27.0	49.2	33.6	2.1
Japan	75.0	9.3	13.7	74.5	17.7	6.3
United States	70.1	12.2	13.6	63.7	31.0	. .
Latin America (11)	29.0	27.2	32.7	32.9	37.3	27.4
Emerging Europe (9)	42.7	29.8	20.1	38.3	54.2	0.5

Source: UNESCO 2006.
Note: The table covers 2002–05 or latest available year and shows medians for regions and subregions.
. . = negligible. The number of countries involved is shown in parentheses.

the same as the median for developed economies, but higher than the share for Latin America (around 30 percent) or emerging Europe (a little over 40 percent). Figure 3.8 indicates that the share of the business sector in R&D generally rises with per capita income. However, several East Asian economies—China, Korea, Malaysia, and the Philippines—are outliers in this regard, showing much higher shares of business R&D than would be expected from the simple cross-country relationship with per capita GDP. Hong Kong (China) is an outlier in the other direction: not only is overall R&D intensity low for an economy at its level of per capita income, but the proportions of R&D performed by the business and government sectors are also low, with the bulk of R&D occurring in institutions of higher education.

FIGURE 3.8 **Businesses Lead in the R&D Effort in East Asia**



Source: Data of the OECD and World Bank staff estimates.
Note: The figure shows the situation in 2002. Per capita GDP is measured in purchasing power parity dollars, stated as a logarithm.

Table 3.5 indicates that, for the East Asia region overall, the median proportion of R&D performed by government—about 22 percent—is much higher than the corresponding figure among developed economies, while the proportion performed by institutions of higher education is lower. This points to a need to strengthen the role of research in East Asian universities, particularly among the NIEs.

R&D by Sector of Funding

Table 3.5 shows that the median share of government funding for R&D in East Asia is about one-third, roughly the same as the share among developed economies. In most cases, the proportion of R&D funded by the business sector is close to the proportion of R&D carried out by business. Two exceptions are Malaysia and Singapore, where the proportion of R&D performed by business is significantly higher than the proportion of R&D financed by business, indicating significant levels of funding support by government for R&D performed in the business sector. Table 3.5 does not include tax incentives for business R&D, a widely used policy instrument.

Does one type of R&D contribute more to growth than another? Most of the work on this question relates to developed economies, but it is informative generally. Guellec and Van Pottelsberghe de la Potterie (2004) look at the long-term impact of business sector R&D, public R&D (defined to include R&D performed by universities), and R&D performed in the outside world on total factor productivity growth in 16 OECD economies. The authors introduced R&D in the outside world to capture the effect of international technology spillovers and transfers. Over the period 1980–98, they find the elasticity of productivity with respect to the stocks of business and public R&D to be the same. Indeed, they find the return to public R&D to be somewhat higher, though the return to business R&D was trending higher, while that to public R&D was declining. Crucially for developing countries, the stock of foreign R&D appears to have an impact two to three times as large as domestic business or public R&D, underlining the importance of openness and of the capacity to absorb international knowledge.

What conditions might affect how much impact each type of R&D stock has on growth? A key finding of Guellec and Van Pottelsberghe de la Potterie is that a higher current flow of business R&D increases the economy's ability to absorb benefits from the accumulated *stocks* of business, public, and foreign R&D. This suggests that a higher flow of current business R&D by domestic firms increases the ability of these firms to absorb the results of R&D carried out past and present by other domestic firms. Similarly, higher business R&D intensity also appears to enhance the ability of firms to access knowledge created by public R&D, raising the impact of public R&D stocks on productivity. Perhaps of most importance for developing countries, higher business R&D intensity also raises the impact of foreign R&D stocks on growth, suggesting that domestic business R&D is important in making firms more capable of absorbing foreign knowledge. Significantly, foreign R&D appears to benefit small economies more than it does large ones.

Advancing the Global Frontier: Patenting in East Asia

Just as R&D expenditures provide a partial measure of the resources an economy devotes to innovation, so do patents and patent citations supply a valuable, though partial, view of an economy's innovation outputs. This view is partial because—at least in theory—patents focus only on those innovations that advance the frontier of global knowledge. A patent gives an inventor a temporary legal monopoly over the exploitation of his invention; it is a device to address some of the problems deriving from the nonexcludability or nonappropriability characteristics of knowledge. To confer this temporary monopoly (in itself a costly economic distortion), an invention must typically satisfy requirements of novelty and nonobviousness, which require that innovations represent a substantial advance over existing knowledge.[23]

Most innovation in developing countries, however, involves the adoption and adaptation of existing knowledge that is mostly derived from abroad. Nevertheless, patentable innovations that, in principle, advance the frontier of global knowledge are growing in importance in East Asia, where a number of economies now generate these kinds of frontier innovations at around the same rate as the advanced economies. This section looks first at patenting activity in East Asia, drawing (in common with many studies in this area) on the database of patents granted by the United States Patent and Trademark Office (USPTO).[24] It then examines at evidence on the factors determining patenting, the distribution of patenting across technology fields, and the quality of patenting in East Asia. Finally, we use patent citations to study flows of knowledge within East Asia and between East Asia and the rest of the world.

Patenting in East Asia

As table 3.6 indicates, the average annual number of patents granted to East Asian economies was at 12,108 per year in 2000–04, more than five times the number a decade earlier, in 1990–94. Over the same period, the number of patents registered by selected Latin American countries rose from 173 to 368. Table 3.6 also shows patents relative to population (patents per 100,000 people). In the early 1990s, the number of patents per 100,000 people in East Asia, at 0.14, was two to three times the number in Latin America and emerging Europe. By 2000–04, East Asian patents per 100,000 had risen to 0.72, six to nine times the levels in the other two regions. The vast majority of patents in the region are generated by the NIEs, particularly Taiwan (China) and Korea, which, by 2004, had become the 4th and 5th biggest recipients of USPTO patents in the world, after the United States, Japan, and Germany.

As with R&D, there is also wide variation in patenting across East Asia. At the head of the league, Taiwan (China) now generates around 30 patents per 100,000 population, about as many as Japan and the United States, the best performers among the developed economies. Another group including Hong Kong (China),

TABLE 3.6 **Patents Granted by the USPTO**
annual averages

	Number of patents		Patents per 100,000 population		
Region or country	**1990–94**	**2000–04**	**1990–94**	**2000–04**	**% change**
East Asia (9)	2,239	12,108	0.14	0.72	17.6
NIEs	2,159	11,601	2.93	14.74	17.5
Hong Kong, China	184	616	3.15	9.32	11.4
Korea, Rep. of	633	4,009	1.44	8.67	19.7
Singapore	36	382	1.09	9.87	24.6
Taiwan, China	1,307	6,593	6.30	30.17	17.0
Southeast Asia	31	140	0.01	0.04	15.3
Indonesia	6	15	0.00	0.01	8.8
Malaysia	13	64	0.07	0.28	15.3
Philippines	6	18	0.01	0.02	10.4
Thailand	6	43	0.01	0.07	20.9
China	48	368	0.00	0.03	22.9
World	107,361	182,523	1.98	2.95	4.1
Developed (21)	104,170	168,017	12.88	19.58	4.3
Japan	22,647	35,687	18.23	28.54	4.6
United States	59,024	97,104	23.00	33.56	3.9
Developing					
Latin America (11)	173	368	0.04	0.08	6.3
Emerging Europe (9)	205	348	0.07	0.12	5.6

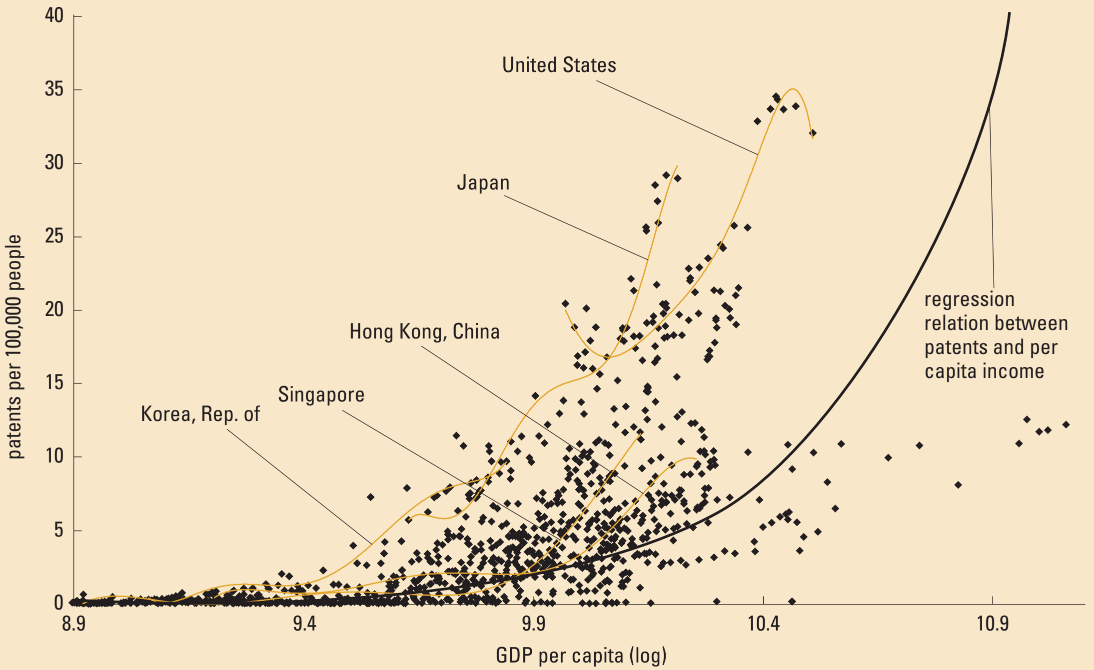
Source: Data of the USPTO.
Note: The number of countries involved is shown in parentheses.

Korea, and Singapore generate around 8–10 patents per 100,000 per year, similar to the performance of the developed OECD countries in the mid-1980s, although only about half the average level in the OECD today. Farther down the scale, Malaysia generates 0.2–0.3 patents per 100,000, similar to Korea in the mid-1980s. Finally, countries such as China, Indonesia, the Philippines, and Thailand bring up the rear with patents per 100,000 in the 0.01–0.07 range, although patenting in China is rising rapidly from a low base. Hu and Jefferson (2005) suggest several reasons for the acceleration in Chinese patenting: (1) the acceleration in China's R&D spending (noted above); (2) the strengthening of

China's patent law in 1992 and 2000; (3) the vast influx of FDI to China, which has greatly increased the market value of intellectual property for foreign and domestic firms; (4) the rapid relative growth in complex industrial sectors, such as electronics and machinery, that involve many separately patentable subproducts and processes; and (5) the acceleration in enterprise reform since the mid-1990s, which has greatly strengthened private property rights with respect to state-owned enterprises.

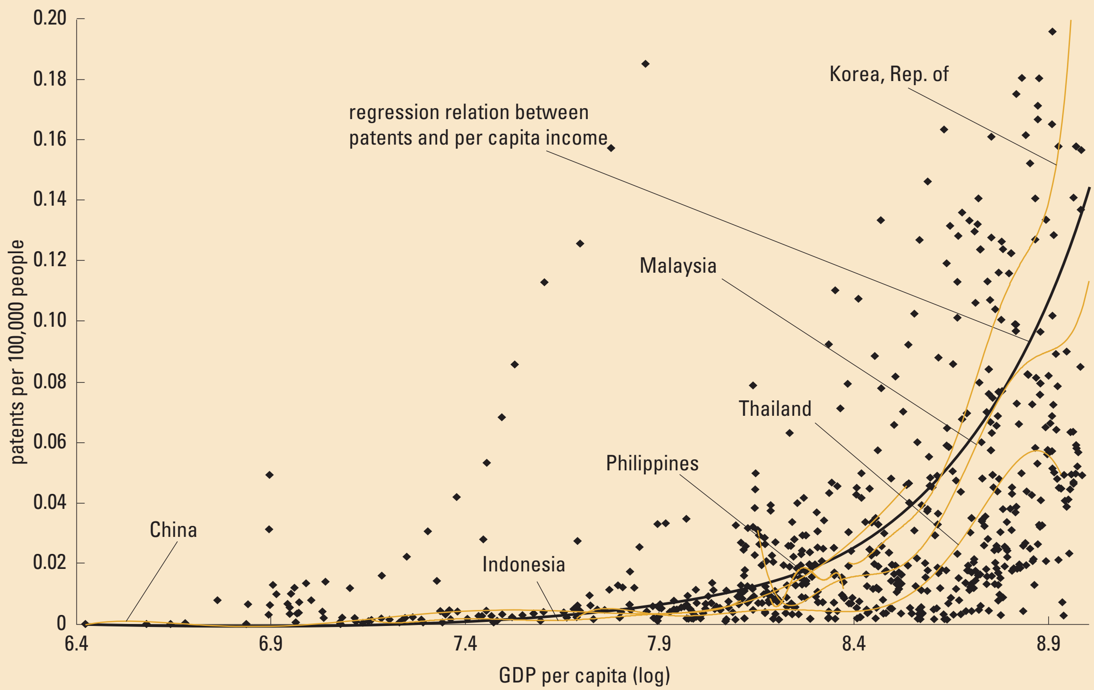
Figures 3.9 and 3.10 plot patents per 100,000 population versus per capita income (in purchasing power parity terms) using an annual panel data set over the period 1977–2004. (The sample is shown in two figures to permit the display of greater detail at different scales.) As with R&D intensity, patents per 100,000 population tend to rise more than proportionately relative to per capita income, seven to eight times more in this case. Thus, for example, patents per 100,000 population in Singapore are 30 times the corresponding figure for Malaysia, even though

FIGURE 3.9 **The East Asian Tigers Are Extraordinary Generators of New Ideas**



Source: Data of the USPTO and staff estimates of the World Bank.

FIGURE 3.10 **East Asia's Middle-Income Countries Are Merely Routine Patent Developers**



Source: Data of the USPTO and staff estimates of the World Bank.

Singapore's per capita income (in purchasing power parity terms) is only about three times higher than Malaysia's. The figures pick out the trajectories of patents and income for individual countries over time. Figure 3.9 shows that East Asian NIEs such as Korea and Singapore have generated many more patents per 100,000 population than predicted by the income levels alone, much as the R&D levels in these economies are also much higher than predicted by income. The same is true of Japan and the United States. Interestingly, in recent years patenting in Hong Kong (China) has also exceeded predicted levels, even though R&D there is much lower than the predicted levels. Figure 3.10 shows that China and Malaysia have generally innovated at around the levels predicted by income, although, as noted, China's patenting in recent years has accelerated to levels greater than predicted by income. Indonesia, the Philippines, and Thailand, on the other hand, have performed below the predicted levels, in line with their underperformance in R&D.

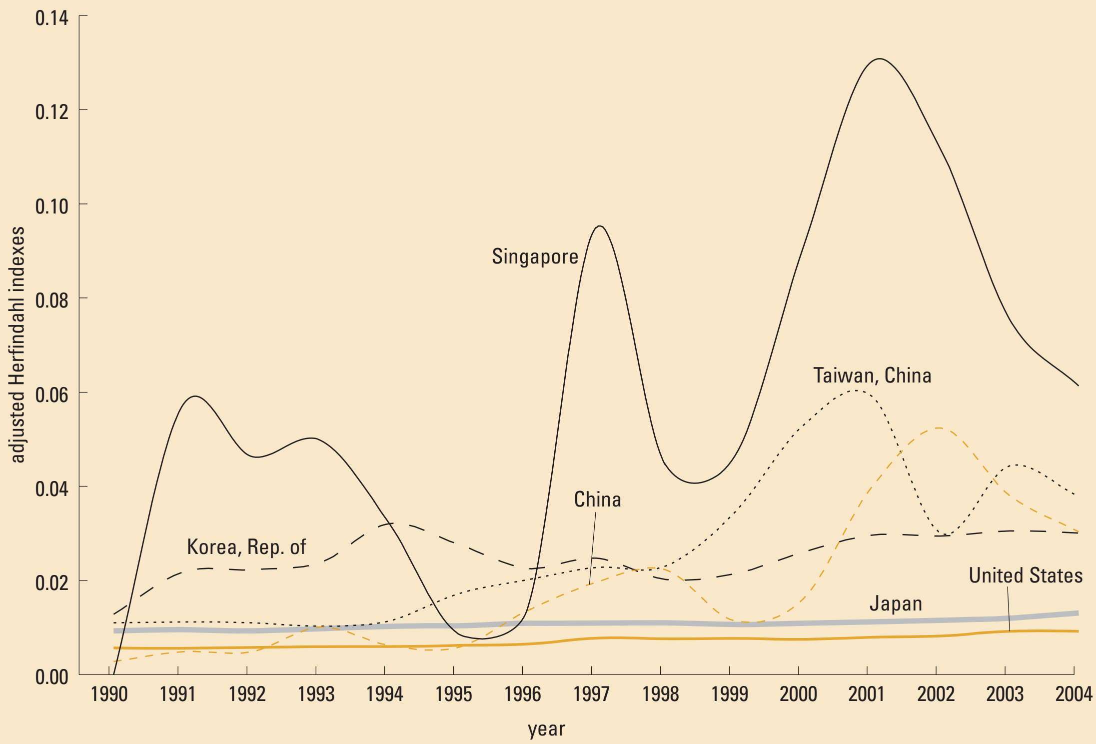
What factors determine the flow of innovation outputs in an economy? There is considerable empirical literature estimating the knowledge production functions in developed economies. The literature typically finds a strongly significant relationship between innovation inputs such as R&D expenditure and innovation outputs such as patent counts.[25] Bottazzi and Peri (2005) study the short- and long-run dynamics of the knowledge production sector in OECD countries by relating the flow of patent counts both to domestic R&D flows and to the existing stocks of domestic and international knowledge, measured by the stocks of patents accumulated, respectively, in the country and in the rest of the OECD. The idea is that innovation depends not only on the current resources devoted to R&D, but also on the knowledge spillovers arising from the nonrival and nonexcludable characteristics of knowledge, particularly knowledge spillovers from the whole body of earlier knowledge accumulated in a country, as well as the international spillovers from accumulated knowledge in the world as a whole. Bottazzi and Peri find long-run elasticities of patenting on R&D and the stock of foreign knowledge of around 0.8 and 0.6, respectively. Thus, in addition to domestic R&D, openness to foreign knowledge plays a big part in domestic innovation, a point made in detail above in the section on technology transfers and spillovers.

Recent World Bank research by Bosch, Lederman, and Maloney (2005) looks at the relationship between patenting and R&D worldwide, including in developing economies. The study finds that there is a significant relationship between patenting and R&D at the global level, but that the elasticity of patenting with respect to R&D is substantially higher in OECD economies (around 1) than among developing economies. The lower productivity of R&D spending in developing economies appears to be due to weaknesses in the national innovation systems of these countries. In particular, the study finds that R&D productivity has a significant positive relationship with years of education, the quality of academic institutions, the quality of intellectual property rights, and the level of collaboration between research institutions and the private sector, all factors that, on average, are substantially lower among developing countries than among OECD economies. Among these factors, years of education and intellectual property rights appear to have the most significant impact on R&D efficiency.

Which Technologies Is East Asia Innovating?

Is patenting activity in East Asia diversified, or are there particular sectors in which the region tends to concentrate? The USPTO classifies the patents it grants according to around 480 different categories of technology. Figure 3.11 shows adjusted

FIGURE 3.11 **Patenting in East Asia Is Concentrated in a Relatively Few Sectors**



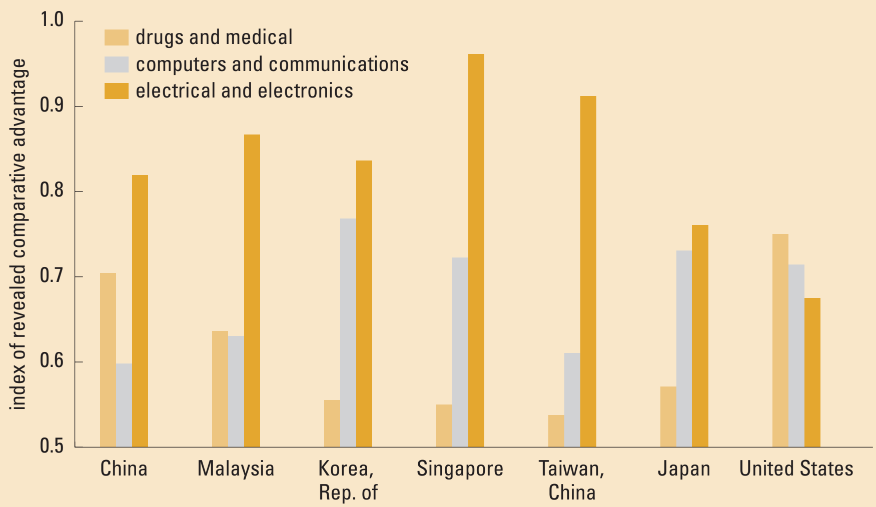
Source: Hu 2006.

Herfindahl indexes of concentration across these technology classifications. An index level of 1 would indicate complete concentration in only one technology class, while an index of around 0.002 would mean relatively equal distribution across all classes. Figure 3.11 suggests that patenting is considerably more concentrated in East Asian economies than it is in mature developed economies such as Japan and the United States.

In which technologies is East Asian patenting concentrated? Jaffe and Trajtenberg (1999) group the lengthy list of USPTO patent categories into six broad classes: chemicals, computers and communications, drugs and medical technologies, electrical and electronics, mechanical, and all other. A major area of concentration in East Asia is electrical and electronics technologies. The median share of patenting in this technology area among seven East Asian economies in 2002–04 was 38 percent, ranging from a low of 25 percent in Hong Kong (China) to 45–50 percent in Singapore and Taiwan (China). The second most important area of concentration is computers and communications, with a median East Asian share of 15 percent, ranging from a low of 12 percent in China and Malaysia to 25–30 percent in Korea and Singapore. The share of East Asian patenting in these two areas has been generally rising since the early 1990s.

In part, the high concentration of East Asian patenting in these sectors reflects the significant technological opportunity and propensity to patent in these sectors worldwide. However, East Asian patenting in electrical and electronics technologies (in particular) is also high relative to the average world share of patenting in this sector; in other words, the East Asian revealed comparative advantage indexes in this sector are generally substantially greater than 1, reflecting world-class levels of sophistication in specific areas of specialization, for example, Korea in dynamic random access memory technology and liquid crystal display manufacture or Taiwan (China) in the wafer foundry industry, testing, and packaging services. By comparison, most East Asian economies show a distinct revealed comparative disadvantage in the drugs and medical sector (see figure 3.12).

FIGURE 3.12 **East Asia Is Advancing the Technology Frontier in Electronics**



Source: Hu 2006.

How Good Is East Asian Patenting?

Although the volume of patenting in economies such as Korea and Taiwan (China) has equaled or exceeded that in most developed economies, is the same also true of the technological quality of their patented innovations? The technological or economic value of patents varies enormously. In fact, the distribution of patent values is highly skewed. A survey of the realized economic value of samples of patents in Germany and the United States, for example, found that the top 10 percent of patents accounted for over 80 percent of the total economic value of all patents (Scherer and Harhoff 2000). Thus, a simple count of patents may not provide an adequate summary of the quality of the underlying innovations.

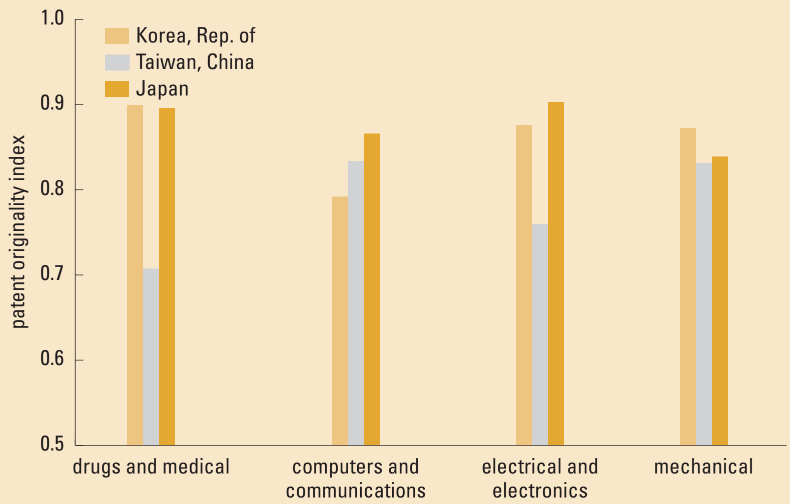
An especially useful feature of patents for purposes of investigation is the fact that they contain citations to previous patents and the scientific literature, thereby serving to define the "art" to which each patent is making an original contribution. Trajtenberg, Henderson, and Jaffe (1997) have proposed an approach for measuring the quality of patents by constructing indexes of patent generality and patent originality that are based on analyses of patent citations. A patent is deemed to have greater generality and a greater impact if, after assignment of the patent, it is cited more frequently within a wider range of patent technology classifications. Similarly, a patent is deemed more basic or original if it cites a wide range of patent technology classifications.

In a comparison of the quality of patents in the East Asian economies, Japan, and the United States, U.S. patents generally show higher generality and originality indexes across all technology fields. Figures 3.13 and 3.14 show these indexes for Japan, Korea, and Taiwan (China) as a ratio of the index for the United States.[26] Japanese patents generally achieve quality ratings that are 80 to 90 percent or more of the U.S. quality ratings. Korea is close to Japan in most technology areas and even matches or exceeds it in some. Taiwan (China) tends to achieve somewhat lower generality and originality scores than Korea, but is still not too far from Japanese levels, generally scoring at 70–80 percent of U.S. levels.

Knowledge Flows To, From, and Within East Asia: Patent Citations

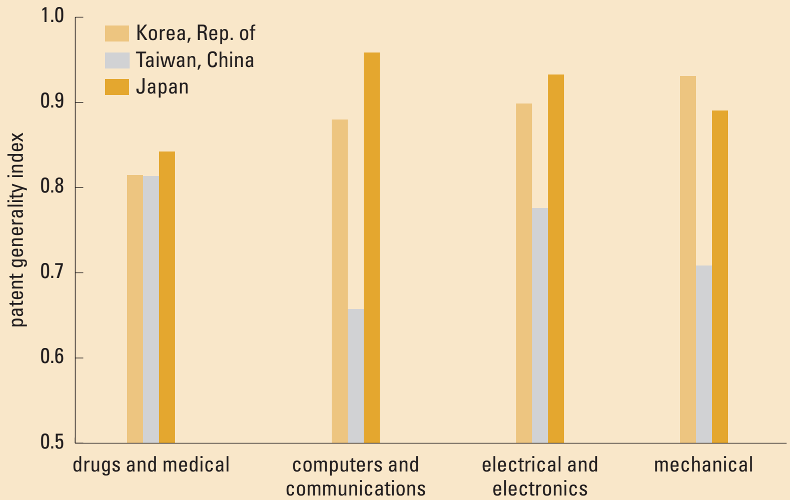
Knowledge flows from abroad also play a crucial role in domestic R&D and innovation, which would be inconceivable in most economies without access to the accumulated body of knowledge throughout the world. Patent citations provide a unique window into the flows of knowledge between the inventors, firms, and economies upon which the process of innovation draws. This is possible because

FIGURE 3.13 **East Asian Patents Show Considerable Originality**



Source: Hu 2006.

FIGURE 3.14 **East Asian Patents Are Widely Applicable**

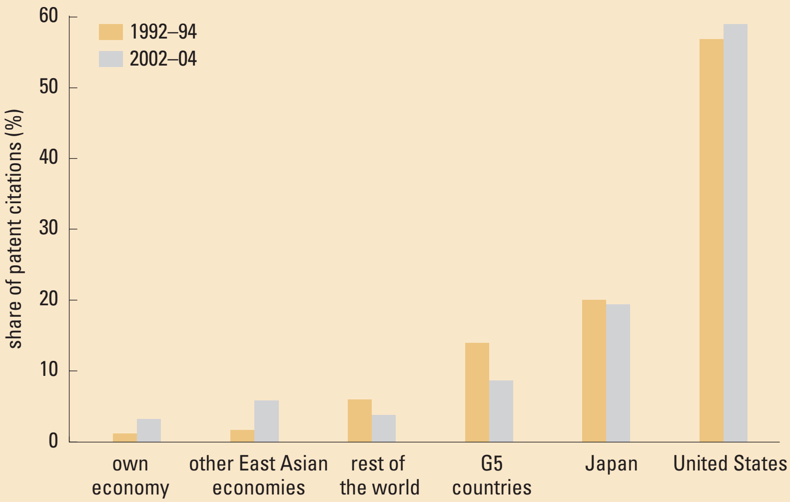


Source: Hu 2006.

patents are required by law to provide citations to previous patents and the scientific literature on which they reside, thereby serving to define the "art" covering the patent.

Figure 3.15 offers an overview of patent citations in seven East Asian economies, showing the average share of various foreign economies as sources for East Asian patent citations. The United States is by far the largest source of citations for East Asian innovators, providing close to 60 percent of the total. This proportion rose slightly between 1992–94 and 2002–04. Japan is the second largest source of citations for East Asia, contributing close to 20 percent, on average. Korea is an interesting exception to this general pattern; its reliance on U.S. citations is substantially lower than the reliance of other East Asian economies, around 45 percent, while its reliance on Japanese knowledge is greater, around 33 percent. The share of G-5 economies, defined here as comprising Canada, France, Germany, Italy, and the United Kingdom, is lower, less than 10 percent, having fallen over the last decade. Perhaps most interesting, the share of citations made by East Asian economies to patents of other East Asian economies, while still low, is rising rapidly; it has picked up from an average 1.7 percent of all citations in 1992–94 to

FIGURE 3.15 **Japan and the United States Account for Most Patent Citations in East Asia**



Source: Data of the USPTO.
Note: G-5 = Canada, France, Germany, Italy, and the United Kingdom.

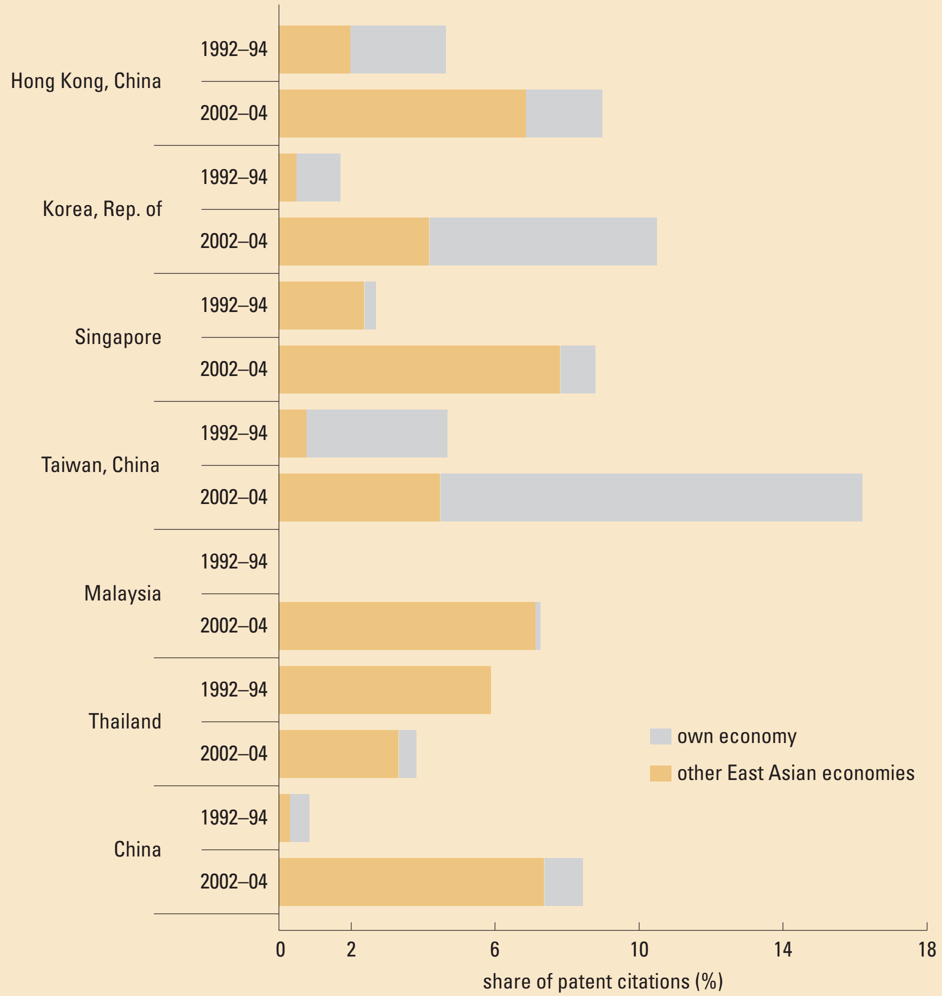
5.9 percent in 2002–04. Most of these intra–East Asian patent citations refer to patents held by Korea and Taiwan (China), the two largest innovators in the region. Thus, much as intraregional flows of trade and foreign investment have been rising in relative importance in recent years, so have intraregional knowledge flows, although the size of the intraregional share is much lower at present than the flows for trade and investment. In addition, as figure 3.15 indicates, the share of citations by inventors in one East Asian economy to other patents in the same economy (referred to as compatriot citations) is also rising, reaching 3.3 percent, on average, in 2002–04.

Figure 3.16 supplies a closer look at the rise of intraregional and compatriot knowledge flows for individual East Asian economies. The figure indicates that the share of citations to other East Asian economies (typically to patents of Korea and Taiwan [China]) is highest—around 7–8 percent—in China, Hong Kong (China), Malaysia, and Singapore. On the other hand, the share of own or compatriot patents is highest in Korea (around 6 percent) and Taiwan (China), where it is over 10 percent.

The raw citation shares discussed in the preceding paragraphs provide useful information on the gross or absolute flows of knowledge among economies, but say little about the *intensity* of the various knowledge relationships. For example, it is not too surprising that, in East Asian economies, there should be large shares of citations to U.S. patents, simply because the United States is by far the greatest generator of patents, providing the largest pool of patents that may potentially be cited by other economies. Even in Japan, which produces almost as many patents per 100,000 population as the United States, over 40 percent of patent citations are to the United States. Researchers have therefore developed a *citation frequency* measure that looks at how intensively patents in one country cite patents in another country after controlling for the size of the potential pool of citations in the two countries.[27] In arithmetic terms, the measure represents the number of citations in country A to patents in country B, divided by the product of the potential number of citing patents in country A and the potential number of citable patents in country B.

Figure 3.17 shows patent citation frequencies for Japan, the United States, and various East Asian economies in electrical and electronics technology. To keep the information manageable, we show frequencies of citations to Japan, Korea, Taiwan (China), and the United States. There are several striking features of the data. One is that each of these four main innovating economies cites compatriot patents from the same economy much more intensively than patents in the rest of the world. For instance, after controlling for the fact that the potential pool of citable electrical and electronics patents in Korea is much smaller than the poten-

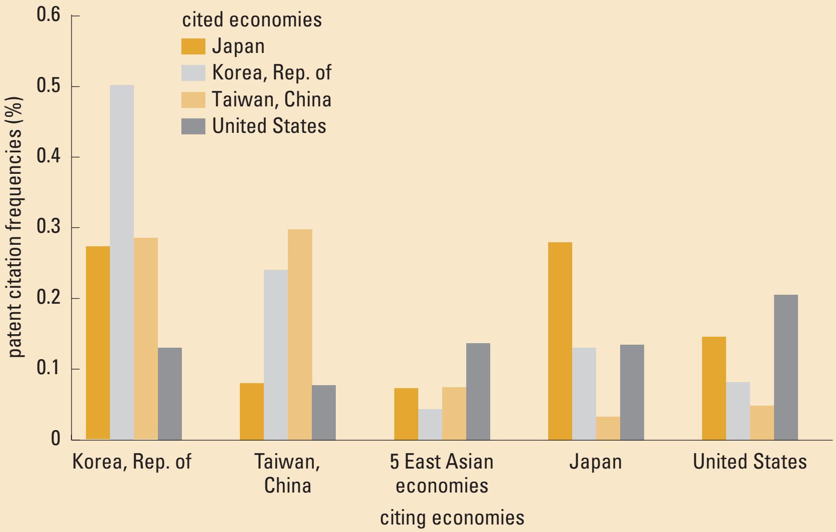
FIGURE 3.16 **Intraregional Knowledge Flows Have Increased Since the 1990s**



Source: Hu 2006.
Note: There were zero patent citations in Malaysia in 1992–94.

tial pool in the United States, Korean patents cite other Korean patents almost five times as intensively as they cite U.S. patents. This finding by Hu (2006) is consistent with earlier findings of *geographical* matters for knowledge spillovers. Thus, Jaffe, Trajtenberg, and Henderson (1993) have found that, even within the United States, the frequency of citation in a patent in one U.S. state to other

FIGURE 3.17 **Geographical Proximity Increases Knowledge Exchanges**



Source: Hu 2006.
Note: The figure shows the case of electrical and electronics patents, where East Asia is active. The normalized citation frequency index is measured relative to the citation frequency among U.S. patents to other U.S. patents, which is set equal to 1. For a more detailed explanation, see the text. The five East Asian economies are China, Hong Kong (China), Malaysia, Singapore, and Thailand.

patents in the same state is significantly higher than the citations to patents in other U.S. states, while Jaffe and Trajtenberg (1998) confirm that citation frequencies within OECD economies are much greater than the frequency of citation from one OECD economy to another (see box 3.5).

Figure 3.17 also provides evidence for the high relative intensity of intra–East Asian crossborder knowledge flows. Thus, the citation frequency in Korean patents to patents from both Japan and Taiwan (China) is more than twice as high as the corresponding citation frequency to U.S. patents. Likewise, the citation frequency in patents in Taiwan (China) is almost as high to Korean patents as to compatriot patents in Taiwan (China), while the citation frequency of patents in Japan is almost as high to patents in Korea as to U.S. patents. These trends confirm the growing regional dimension in East Asian knowledge flows.

Hu (2006) estimates a more rigorous model for the citation frequency data for East Asian economies using the double exponential model of knowledge diffu-

BOX 3.5 Geography and Knowledge Spillovers

The main reason for the geographical localization of knowledge spillovers is thought to be the *tacitness* of much knowledge. Many types of information, for example, the price of a commodity, may be easily codified and cheaply transmitted across the world by electronic means. Complex scientific and technical knowledge, however, often may not be readily codified or fully captured in a manual or computer file. The accurate and thorough communication of this knowledge often requires face-to-face interaction.

Tacitness and geographical localization provide an important economic advantage to cities and industrial clusters: they facilitate face-to-face interactions and knowledge spillovers. At the national level, they offer more evidence for the value of domestic R&D and innovation efforts: the absorption of knowledge spillovers by local residents is easier from local innovations than it is from foreign innovations.

There is also useful information for policy makers in a study finding that the geographical localization of knowledge spillovers seems to be particularly important for new knowledge and in the early stages of a new industry's life cycle. Jaffe, Trajtenberg, and Henderson (1993) find that the advantage of geographical localization within U.S. states fades gradually. Audretsch and Feldman (1996) find that geographical clustering is greatest in industries with high R&D intensity and high employment of skilled labor, as well as in industries at an early stage of the life cycle, when knowledge about the industry is still located mainly in the minds of staff and workers rather than codified in manuals and protocols.

sion introduced by Caballero and Jaffe (1993). The idea is to derive more refined estimates of citation frequencies among countries after taking into account such factors as the technological proximity between each pair of economies,[28] time lags between citing and cited patents, obsolescence over time, and fixed effects for different technology classes. Table 3.7 shows these estimates, normalized relative to the citation frequency among U.S. patents to other U.S. patents, which is set equal to 1. The results for Japan, Korea, Taiwan (China), and the United States are substantively similar to those for the raw citation frequencies discussed earlier. In the case of other East Asian economies, Singapore shows an exceptionally high citation frequency to patents in Taiwan (China) and also Korea, both of which significantly exceed (also high) citation frequencies to patents in Japan and the United States. Citation frequencies to Korea and Taiwan (China) in China and Malaysia also exceed those to Japan and the United States.

Policy Considerations

This section discusses the policies and institutions that may help foster domestic innovation, as well as the absorption of knowledge from abroad, and briefly reviews differences in the quality of these policies and institutions across East

TABLE 3.7 Citation Frequencies: Estimated Country-Pair Fixed Effects

	Cited economies			
Citing economies	**Japan**	**Korea, Rep. of**	**Taiwan, China**	**United States**
China	0.31	0.44	0.41	0.36
Hong Kong, China	0.41	0.42	0.40	0.45
Japan	0.80	0.44	0.23	0.46
Korea, Rep. of	0.70	1.16	0.69	0.46
Malaysia	0.32	0.53	0.57	0.44
Singapore	0.60	0.93	1.63	0.95
Taiwan, China	0.25	0.71	0.83	0.26
Thailand	0.33	0.27	0.10	0.66
United States	0.57	0.38	0.29	1.00

Source: Hu 2006.
Note: The table shows an index whereby U.S. patent citations to U.S. patents = 1.

Asian economies. These factors are grouped under three main heads: the overall business environment for innovation, human capital development, and direct government support for innovation activities.

The Business Environment for Innovation

Given that R&D and other innovation activities by firms are a form of capital investment, it is not surprising that they are influenced by many of the same factors—macroeconomic stability, cost of capital, openness, competition, intellectual property rights regimes, and infrastructure—that affect the overall business investment.

Macroeconomic stability. As is well known, persistent macroeconomic instability is among the factors most adverse to private investment and is also found to have a clear adverse impact on R&D intensity. In one of the few studies of R&D in both developing and developed countries, Lederman and Maloney (2003) find that macroeconomic volatility as measured by the standard deviation of per capita GDP growth has a significant negative relation with R&D intensity. In their study of OECD countries, Jaumotte and Pain (2005a) find that low, stable inflation has a positive influence on the rate of growth of R&D stocks.

Cost of capital and financial development. A second major set of factors in the broad macroeconomic and business environment relates to the cost of capital, the availability of credit, and the level of development of a financial system. Jaumotte and Pain (2005a) find that a measure of the user cost of capital (taking account of the real interest rate, depreciation, and tax allowances) has a significant negative relation with the growth of R&D stocks in OECD countries, while Lederman and Maloney (2003) obtain a similar result for a real interest rate measure with respect to R&D intensity in their broader set of countries. In addition to the cost of capital, the quantity of credit and financial sector depth are also discovered to be important influences on innovation. A well-developed financial sector and capital market help meet the various financing needs of more or less risky short- and long-term innovation projects being undertaken by firms. As noted in the section on technology transfers and spillovers, Ayyagari, Demirgüç-Kunt, and Maksimovic (2006) find that the availability of financing from sources external to the firm shows a strong association with broader measures of firm innovation in developing countries. Jaumotte and Pain (2005a) arrive at similar conclusions for growth in R&D stocks in OECD countries with respect to corporate profits (internal finance for firms), credit to the private sector from financial institutions, and stock market capitalization. Table 3.8 uses credit to the private sector as a rough indicator of financial sector development and shows that financial depth is significantly lower in various middle-income East Asian economies than in the NIEs.

Aghion, Angeletos, et al. (2005) emphasize that credit availability and financial development are particularly important when firms are in a volatile macroeconomic environment. When firms face significant credit constraints, they will be less able to overcome short-term liquidity pressures during economic downturns and so will be less willing to undertake long-term R&D investments. The availability of long-term credit allows firms to look beyond cyclical volatility and liquidity pressures to pursue longer-term innovation objectives. Looking at panel data for OECD countries, the authors find that the interaction term between financial development and volatility has a significantly positive impact on the ratio of R&D to total investment spending. In related work, Aghion, Bacchetta, et al. 2006 demonstrate how financial development may condition the impact of exchange rate volatility on long-run productivity growth; in countries with low financial development, exchange rate volatility has a significant negative impact on productivity growth, while, in financially developed countries, the impact is insignificant.

Openness. The discussion above of imports as a channel for technology transfer suggests that excessively restrictive trade policies may prove a significant barrier to

TABLE 3.8 **National Innovation Systems and the Business Environment: Selected Variables**

Region or country	1. Credit market depth, 2000–04[a]	2. Starting a business, days	3. Average years of schooling, 2000	4. Researchers per million population, 2003	5. Quality of scientific research institutions[b]	6. University-industry research collaboration[b]	7. Intellectual property protection[b]	8. Phone subscribers, 2003[c]
East Asia (9)	102	40	7.6	1,375	4.5	4.1	4.3	878
NIEs	125	22	9.2	3,165	5.2	4.7	5.1	1,475
Hong Kong, China	153	11	9.5	1,564	4.9	4.1	5.0	1,640
Korea, Rep. of	98	22	10.5	3,187	5.1	4.8	4.5	1,240
Singapore	115	6	8.1	4,745	5.5	5.0	6.1	1,284
Taiwan, China	135	48	8.5	. .	5.2	4.9	4.9	1,735
Southeast Asia	75	66	6.6	210	4.1	3.6	3.8	398
Indonesia	20	151	4.7	207	3.9	3.4	3.2	127
Malaysia	141	30	7.9	299	5.0	4.7	5.1	642
Philippines	38	48	7.6	48	3.3	2.7	2.8	322
Thailand	102	33	6.1	287	4.0	3.6	4.1	499
China	118	48	5.7	663	3.8	3.9	3.2	413
High income (21)	112	20	9.5	3,616	5.1	4.4	5.5	1,392
Japan	100	31	9.7	5,287	5.6	4.6	5.3	1,151
United States	249	5	12.3	4,484	6.4	5.7	6.4	1,175
Latin America (11)	36	67	6.7	300	3.5	3.0	3.1	409
Emerging Europe (9)	29	30	8.7	1,503	4.0	3.1	3.3	850

Sources: 1 and 8: World Development Indicators Database, World Bank, http://www.worldbank.org/data/datapubs/datapubs.html. 2: Doing Business Database, World Bank and International Finance Corporation, http://www.doingbusiness.org/. 3: Barro and Lee 2000. 4: UNESCO 2006. 5, 6, and 7: López-Claros, Porter, and Schwab 2005.

Note: For region or country, the number of countries involved is shown in parentheses.

. . = negligible.

a. Credit to the private sector as a % of GDP.

b. This is an index ranging from 1 (weakest) to 7 (strongest).

c. Fixed line and mobile subscribers per 1,000 population. All regional data are simple averages.

international technology transfer. In addition, preferential trading arrangements that create a bias against trade with R&D–rich developed economies will tend to choke off knowledge transfers and spillovers from those economies, which (following the results of Schiff, Wang, and Olarreaga 2002) may be especially detrimental to the development of R&D–intensive industries. Hoekman, Maskus, and Saggi (2005) point out that these arguments for open trade policies are not entirely unconditional, however. If the development of a national industry creates localized knowledge spillovers in the country, there may be a rationale for intervention to foster such development. This was one of the justifications for protectionism and import-substitution-led industrialization strategies in many developing countries in the 1950s and 1960s. Nevertheless, trade restrictions are unlikely to be the most effective or most efficient way of fostering domestic R&D, industrial development, or spillovers, since they create new distortions, reward domestic firms whether they innovate or not, and have a high cost, not least by restricting international knowledge inflows. More direct policies to subsidize domestic R&D, improve the investment climate, and strengthen education are likely to be superior policy instruments.

Competition. As with trade openness, the question whether greater competition in domestic product markets serves to foster innovation does not have an entirely simple answer. A survey of evidence for OECD countries by Ahn (2002) comes to the agnostic conclusion that "empirical evidence does not support the view that market concentration is an independent and significant determinant of innovative behavior and performance" (p. 16). Other studies (for example, Nickell 1996 and Blundell, Griffith, and van Reenen 1999) have pointed to a positive correlation between product market competition and innovation. As usual, the evidence is much thinner for developing economies, but Ayyagari, Demirgüç-Kunt, and Maksimovic (2006) also find a positive relation between several competition indicators and their measure of firm dynamism in low- and middle-income economies (which, as noted above, encompasses the introduction of both new technology and new products).

Aghion, Bloom, et al. (2005) observe that, in theory, greater product market competition between incumbent firms may have two different effects, one discouraging innovation, the other promoting it. Particularly in industries where the existing competition is low and firms have similar levels of technological capability, more competition may promote innovation by giving the innovating firm a competitive advantage over other firms in the industry. On the other hand, in industries where there is already high product market competition and one firm has a large technological lead over others, an increase in competition may discourage innovation by lagging firms because it reduces the rewards for trying to catch up with the leader. The study finds strong evidence for such an inverted-U curve in multi-industry panel data on firms in the United Kingdom: innovation rises as product market competition increases, but, for a minority of firms and industries at already high levels of competition, additional intense competition tends to discourage innovation. In related work, Aghion, Blundell, et al. (2006) argue that the entry of technologically advanced firms into an industry may have a dual-edged effect on innovation among incumbent firms, tending to stimulate innovation when incumbent firms are close to the global technology frontier, but discouraging it when incumbent firms are technological laggards and far from the frontier. They again find evidence for this proposition in multi-industry panel data on firms in the United Kingdom.

Given the limited amount of empirical work available so far, it is probably unwise to draw any strong conclusions for policy in developing countries. A few observations may be ventured, however. First, increased competition has a wide array of potential effects on economic performance other than the impact on innovation. There is a good deal of evidence, for example, of the positive effect of competition on firm efficiency and overall productivity growth.[29] Thus, conclusions about the role of competition policy need to be based on an assessment of all these effects. Second, the balance of the empirical work cited finds a positive association between more competition between incumbent firms and innovation, and, while the study by Aghion, Bloom, et al. (2005) reaches more qualified results, it too suggests that more competition is favorable for innovation if competition is low to start with, that is, when the lack of competition is most likely to be of concern to policy makers.

Turning to new firm entry, the interesting findings by Aghion, Blundell, et al. (2006) for the United Kingdom obviously need to be buttressed by more empirical work across a wider range of countries (including developing countries). Several hypotheses that have relevance for policy emerge from the study and call for more empirical analysis and testing. One hypothesis is that an opening-up to entry by technologically sophisticated competitors may be especially beneficial for innovation through incumbent firms in advanced emerging economies such as Korea, Singapore, and Taiwan (China), where many key sectors now function close to the global technology frontier. It may also be a relevant policy consideration in rapidly moving middle-income economies that are aspiring to follow in the tracks of the advanced emerging economies.

By the same token, the study suggests the possibility that opening-up to technologically sophisticated firms may have a depressing effect on innovation in economies and sectors that are far from the global technology frontier. But a number of other considerations need to be kept in mind in drawing possible policy conclusions from this finding. First, new firm entry may have other, offsetting effects on economic performance, particularly gains in the overall productivity of the economy and in consumer welfare due to the replacement of low-productivity firms by high-productivity firms and the reallocation of resources to more productive uses. Bartelsman, Haltiwanger, and Scarpetta (2004) note that the process of creative destruction—the entry of new firms and the exit of less efficient ones—is important for productivity growth in both developed and developing countries. They find that it contributes from 20 to 50 percent of total labor productivity growth according to a large firm-level panel data set covering 10 developed and 14 developing economies. In contrast to Aghion, Blundell, et al. (2006), they also find a positive relation between the pace of creative destruction (that is, of net entry) and productivity growth in already existing (incumbent) firms. They interpret these results as implying that the increased contestability of markets introduced by new entrants induces incumbent firms to perform more efficiently. A second consideration is that new entry by technologically sophisticated firms is also likely to facilitate vertical technology transfers to local suppliers in upstream sectors. (Evidence for this is presented in the review of FDI elsewhere.) This discussion suggests that, even in less well developed economies, blocking off entry by sophisticated foreign firms is unlikely to be the most efficient way of promoting technological development and productivity growth, especially when looked at from an economy-wide perspective. As with trade, more direct fiscal measures or other measures may provide superior instruments for fostering domestic R&D and innovation. We return to such instruments below in this section.

The intellectual property rights regime. Another factor affecting innovation is the quality of the intellectual property rights regime (for example, patent law). Theoretically, the direction of this effect is ambiguous. On the one hand, a weak regime hampers firms in the appropriation of the returns on their investments in R&D and thus acts as a disincentive to undertaking the investments in the first place. On the other hand, intellectual property rights also create an economic distortion by granting a temporary monopoly to innovators. This may make it more difficult for other firms to access the knowledge they need for their own innovation activities. Intellectual property rights may also dampen innovation if they reduce competition in product markets and if less competition tends to reduce innovation.

Which of these effects prevails is an empirical question. Table 3.8 shows that the quality of the intellectual property rights regime is rated significantly weaker in China and several Southeast Asian economies than it is in the NIEs. Lederman and Maloney (2003) find that stronger rights regimes have a highly significant positive impact on R&D intensity in their sample of developing and developed economies, while Bosch, Lederman, and Maloney (2005) find that the quality of the rights regime has a significant positive impact on the productivity of R&D as measured by patents per dollar of R&D. For OECD countries, Jaumotte and Pain (2005a) find, however, that intellectual property rights have little discernible influence on the growth of R&D stocks, although they do influence the flow of patenting. The authors interpret these results to suggest that, in OECD countries, intellectual property rights influence the propensity to patent within the underlying stream of innovations, but not the flow itself. The lack of influence on R&D in the OECD may reflect the fact that there is much less variation in the quality of the rights regimes across OECD countries than in the world as a whole. The coefficient of variation in the measure of the rights regimes shown for high-income countries in Table 3.8 is only one-third as large as it is for the whole sample of developed and developing countries.

Recent research suggests that rights regimes may influence not only indigenous R&D and innovation, but also the scope of interactions between countries and the outside world, which, as this chapter has stressed, are a primary means of absorbing new knowledge in most developing countries through trade, FDI, the licensing of foreign technologies, or other means. In a survey of this research, Fink and Maskus (2005) note that the potential impact of intellectual property rights on inward technology transfers is also theoretically ambiguous: stronger rights will improve the incentives for a foreign rights-holder to enter the domestic market, but will also increase the market power of that rights-holder, which may lead to restricted sales. Foreign technologies will become more available in the domestic market, but the ability of domestic firms to imitate these technologies is more constrained. The net effect on the volume of international transactions and on domestic productivity growth is an empirical question, the answer to which may differ across countries and sectors.

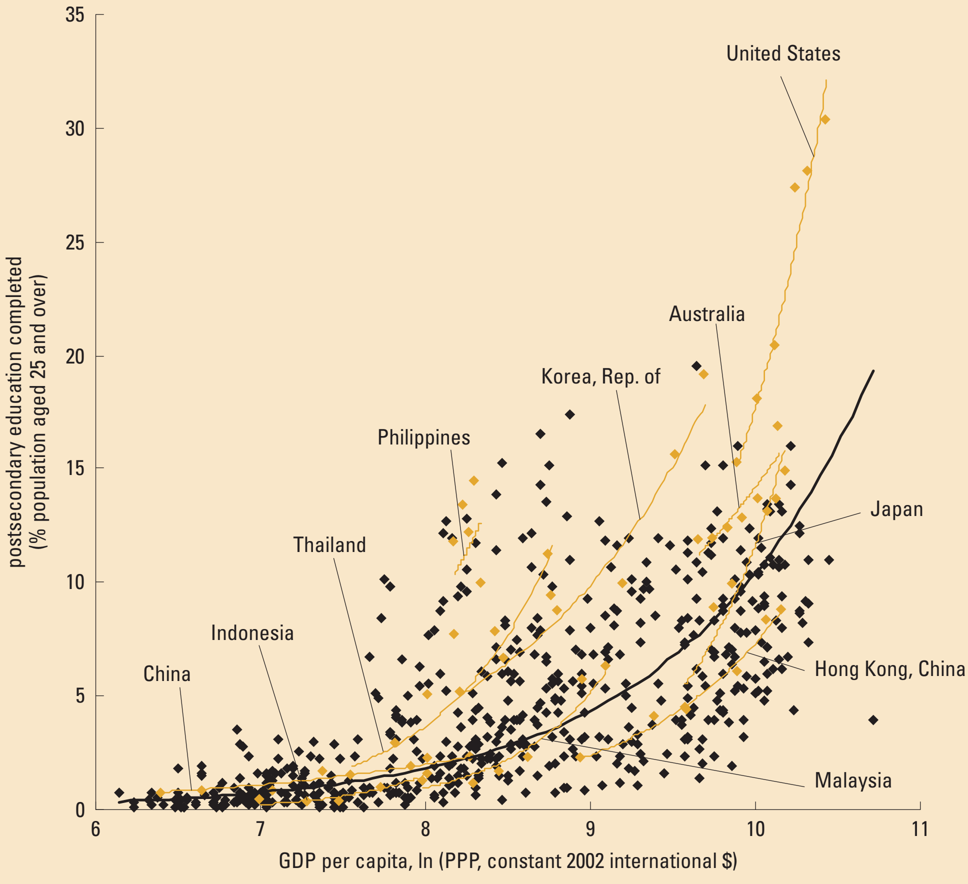
Fink and Maskus (2005) note a number of recent studies that find a significant positive link between stronger intellectual property rights and international trade. Stronger patent rights in large middle-income economies appear to have the most significant influence on the propensity of multinational companies to export to those economies, given the greater threat of imitation and reverse engineering. The evidence is less conclusive on the impact of intellectual property rights on FDI. However, there is a certain amount of evidence that intellectual property rights are a significant consideration among multinational companies making location decisions in regard to middle-income countries. There is also some evidence that foreign firms may be more likely to invest in local production and R&D facilities rather than in distribution facilities if there are stronger intellectual property rights. Finally, there is clear-cut evidence that stronger rights have a positive impact on international technology licensing (as measured by licensing royalty payments). This kind of technology transfer is sensitive to the reduction in the cost of making and enforcing licensing contracts that is provided by a stronger rights regime.

Information and communications technology infrastructure. The availability of good-quality information and communications infrastructure plays an important role in fostering innovation both by facilitating the cheap circulation of disembodied knowledge flows across and within national boundaries, as well as by reducing the transaction costs of international trade and foreign investment flows. Rapid rates of advance in the availability of information and communications services in developing countries have been driven forward in part by the liberalization of telecommunications markets and regulatory reform in recent decades. Nevertheless, wide disparities remain in information and communications technology development across East Asia. As Table 3.8 indicates, the number of phone subscribers per 1,000 population (to take one example) averages close to 1,500 in the NIEs, but only around 400 among the Southeast Asian economies and in China. The importance of the information and communications infrastructure for innovation and productivity growth is suggested in Wong (2006). This background study for this volume looks at the impact on productivity and growth of various types of crossborder flows, including trade, FDI, and disembodied knowledge flows, the last proxied by international telephone traffic. Telephone traffic is found to have the most robust positive effect on productivity and income.

Human Capital Development

Education and other forms of human capital development clearly provide a fundamental underpinning for domestic innovation activity and the absorptive (learning) capacity of the economy. Table 3.8 shows that populations in Southeast Asian economies and China possess around three fewer average years of schooling relative to those in the NIEs. Higher education is becoming a critical factor for innovation in the region, but the efforts to improve higher education are not uniform across countries. Figure 3.18 shows that the proportion of adults with higher education tends to rise more than proportionately with income. Some countries, such as Korea, have increased higher-education attainment even more rapidly, while others have lagged.

FIGURE 3.18 **Improvements in Higher Education Have Been Uneven in East Asia**



Source: Barro and Lee 2000.
Note: Points for each economy have been plotted at five-year intervals between 1975 and 2000.

There are also sharp differences in the quality of education around the region. For example, the four East Asian NIEs achieved the four highest mathematics and science scores among the 45–46 countries and territories participating in the 2003 Trends in International Mathematics and Science Study exercise. On the other hand, the Philippines was among the bottom five countries for both mathematics and science, while Indonesia was among or close to the bottom 10. Similarly, in the 2003 OECD Program for International Student Assessment for mathematics proficiency, Hong Kong (China) and Korea were among the top five in a sample of 40 countries and territories, while Indonesia and Thailand were among the bottom five. There are also wide differences around the region in the extent and quality of tertiary and specialized scientific and technical education, as reflected in the number of researchers per million population shown in Table 3.8. This measure averages over 3,000 in the NIEs and fewer than 10 percent as many, on average, in Southeast Asian economies.

Direct Support for Innovation Activities

So far, this section has mostly covered broad policy areas such as the maintenance of macroeconomic stability, financial sector development, and human capital development, which, while they are expected to promote innovation and technology transfers, are also expected to have other, wider economic and social benefits. This subsection looks briefly at several specific public policies that aim to foster domestic innovation or technology transfer from abroad, typically through targeted fiscal incentives or regulations. The theoretical rationale for direct public interventions of this sort derives from the possibility that they may help offset various types of market failures associated with knowledge, for example, nonexcludability, which makes it difficult for private firms to appropriate all the returns to their R&D investments and which may lead the private sector to fail to undertake adequate innovation activities. The problems of nonexcludability or nonappropriability are likely to be particularly significant in the basic research that provides the foundation for a variety of innovations by many firms or that helps countries gain more access to the global pool of knowledge. Four types of policies are assessed: support for research institutions, incentives for business R&D, fiscal incentives for FDI, and policies to enhance knowledge spillovers.

Support for science and for university and public sector research. As shown in Table 3.5, the public sector in developed countries supplies, on average, about one-third of all R&D funding, amounting to an average 0.6–0.7 percent of GDP, including funding for the basic scientific research undertaken by universities or public sector research laboratories and institutes. In East Asia, public funding for R&D reaches this level of GDP only in a few advanced economies such as Korea, Singapore, and Taiwan (China).

There is a significant body of evidence indicating the positive effect of R&D funded or performed by universities and the public sector on overall productivity and on business R&D. Guellec and van Pottelsberghe de la Potterie (2004) find that the positive impact of university and public R&D stocks on productivity growth in OECD countries is even larger than the impact of business R&D stocks. Jaumotte and Pain (2005b) find that nonbusiness R&D spending has a large and significant impact on growth in business R&D stocks in OECD countries and also offer evidence for two important features of the impact of public and university R&D. First, the impact of public and university R&D is likely to depend on the quality of the links between these sectors and the business R&D sector, which uses the results of more basic research to develop commercially valuable innovations and products. Second, a greater volume of public sector R&D may crowd out business R&D by pushing up the wages of scientific and technical staff. The latter may be a particular concern in developing countries where such specialized skills are in scarce supply. At least in OECD countries, the overall impact of nonbusiness R&D on business R&D remains significantly positive, even after taking crowding-out effects into account.

As regards the evidence on developing countries, Lederman and Maloney (2003) find that the perceived quality of research institutions such as universities and public research institutes has a significant positive impact on overall R&D intensity in developed and developing countries, as does the perceived quality of the interaction between these institutions and the private sector. Bosch, Lederman, and Maloney (2005) find that these two factors also have a significant impact on the productivity of R&D in developed and developing countries. Table 3.8 above shows that there are significant disparities in the quality of scientific and other academic research institutions and the quality of university-industry research collaboration; the NIEs and Malaysia score substantially higher than other Southeast Asian economies and China. To ensure that public research efforts yield good results, policy makers should be concerned about adequate funding and good public-private links, but also see that public funding is allocated among research areas according to transparent, competitive, and merit-based procedures and criteria that strike a proper balance between short-term commercial interests and longer-term needs.

Fiscal subsidies and tax incentives for business R&D. In addition to direct funding of public R&D, many countries also devote significant fiscal resources to subsidies or tax incentives for business R&D. Although, as noted, there is a theoretical rationale for such fiscal measures as a means to counteract market failures related to knowledge, there are also serious informational and incentive problems in implementing such policies, and the limited amount of empirical work has not produced a consensus on the overall effectiveness of these policies.

Among the practical difficulties, two stand out. First, governments are unlikely to possess any special information on which sectors might yield the largest knowledge spillovers from innovation and might therefore merit fiscal incentives. In the face of this severe informational problem, government attempts to pick winners might conceivably lead to outcomes that are worse than those based purely on private decisions about R&D investment that, by definition, remain unconcerned about externalities and market failures.[30] Reviewing research on the effectiveness of preferential industrial policies in Japan, Noland and Pack (2003) conclude that these policies tend to concentrate on declining sectors rather than on industries experiencing rapid technological change or increasing returns and have had no noticeable impact on national or sectoral rates of total factor productivity growth. On reviewing research for Korea, they conclude that the evidence does not support the notion that selective intervention has had a decisive impact on the Korean economy. Outlining principles that should guide the design of a modern or new industrial policy, Rodrik (2004) observes that it should no longer aim to pick winners or sectors; it should be targeted instead at key activities that are likely to be underprovided or underperformed because of specific market failures, for example, through a generalized tax credit that does not discriminate across sectors or through support for the adaptation of foreign technologies to local conditions.

The second major difficulty is that a program of fiscal incentives for innovation may easily become a gateway for corruption and rent seeking. It is thus not clear if the social gains from a fiscal incentives program would offset all the compliance and administrative costs associated with such a program.

Cross-country experience with fiscal incentives for innovation has not been studied well until recently. In a review of the empirical literature, García-Quevado (2004) discovers little consensus on the effectiveness of public R&D subsidies. A number of studies find that such subsidies do have a significant positive impact on business R&D, but that this impact declines after a certain point and even becomes negative, so that subsidies are substituting for private financing sources that would have been used in the absence of the subsidies. Jaumotte and Pain (2005b) find that R&D subsidies have a slightly negative impact on growth in business R&D stocks, evaluated at the mean for a sample of OECD countries. The evidence seems clearer on the effectiveness of R&D tax credits. Bloom, Griffith, and van Reenen (2000) find that changes in R&D tax credits have a large impact on the user cost of capital for R&D and that the long-run elasticity of business R&D with respect to tax incentives may be substantial, on the order of −1. While such analyses suggest that tax incentives are effective in stimulating business R&D, they do not necessarily prove that the incentives would be welfare enhancing overall. A full cost-benefit analysis would also need to account for the alternative uses to which the forgone tax revenues might have been put, the administrative costs of the R&D tax credit system, and the various new distortions the tax scheme might itself introduce.

Fiscal incentives for FDI. This section concludes with a look at the uses and effectiveness of two sets of policies: those to attract FDI to a country and those to enhance the benefits of FDI to a domestic economy. The impact of the policy and institutional environment in host countries on the volume, composition, and benefits of FDI flows has been extensively researched. Recent surveys of this work include Balasubramanyam, Salisu, and Sapsford (2001) and Hanson (2001). A general point is that fundamentals important for encouraging and benefiting from capital investment as such—a market-friendly business climate, macroeconomic stability, political stability, good-quality infrastructure (particularly in communications and transport), a relatively open trade policy regime, and the availability of relatively skilled labor—are also important for FDI.

However, governments around the world also deploy a variety of more well targeted policies to attract FDI, such as tax incentives, import duty exemptions, or land and power subsidies. To the extent that FDI does create positive spillovers (or externalities) for a domestic economy, there is a theoretical economic rationale for such incentives. However, as the preceding discussion indicates, the evidence for horizontal FDI spillovers is mixed, especially in developing economies. There is evidence that domestic firms with good human capital and R&D receive more FDI spillovers and also that foreign firms doing more R&D in host countries tend to generate more spillovers. But this evidence provides a rationale for strengthening education and training and perhaps for more tax incentives for local R&D (whether by local or foreign firms) rather than for subsidizing FDI. Given the stronger evidence for vertical technology transfers between the customers of multinational corporations and developing-country suppliers, it is clear that policies that *discourage* FDI carry a high price tag in forgone technology and, all else being equal, should be avoided. However, this type of vertical technology transfer is internal to supply chain transactions, and the benefits are realized by the supplier and the buyer. By themselves, such technology transfers do not provide a rationale for government intervention.[31]

Overall, the empirical research to date does not provide conclusive evidence that would warrant substantial fiscal incentives to promote FDI on welfare grounds. Nevertheless, more than 100 countries were offering fiscal incentives to attract FDI in the mid-1990s, a pattern that continues. A recent survey of 45 developing countries found that 85 percent offer some kind of tax holiday or reduction of corporate income tax for foreign investment.[32] Given the interest of many governments in FDI promotion, it is worth asking how effective such measures are. A range of econometric studies and survey data over the last few decades show that such incentives are one among a set of fundamental factors, such as market growth, macroeconomic and political stability, the quality of transportation and communications infrastructure, the availability of skilled workers (or at least the available capacity to train workers), and labor market flexibility, including the ability to downsize the labor force or exit an industry without undue complications. Indeed, the World Bank's investment climate surveys show that unreliable power supply, weak contract enforcement, corruption, and crime may impose costs several times greater than taxes. A MIGA (2002) survey of 191 companies with plans to expand operations found that only 18 percent in manufacturing and 9 percent in services considered grants and incentives to be influential in their choice of location. Of 75 Fortune 500 companies surveyed, only four identified grants and incentives as influential.[33]

This, however, does not mean that fiscal incentives are unimportant. When other fundamental considerations have been satisfied, they clearly play a role in the final choice of location on a short list of desirable sites. A growing body of evidence shows that incentives may be influential in a choice of location within regional groupings such as the Association of Southeast Asian Nations, the European Union, or the North American Free Trade Agreement and also in the composition of the kind of FDI that is attracted to a country. However, that incentive packages may be costly for host countries is not in dispute, most obviously through the loss of tax revenue and, hence, of resources for necessary government functions. In Tunisia, the cost of fiscal incentives amounted to almost 20 percent of total private investment in 2001. The package India offered Ford in 1997 was estimated to cost US$200,000–US$420,000 per job. Large incentives are not limited to developing countries. It is estimated that the government of Alabama paid the equivalent of US$150,000 per employee to Mercedes to locate its new plant in the state in 1994.[34] In addition to fiscal costs, fiscal incentives also lead to distortions in resource allocation, for example, by discriminating against local investors or by attracting short-term investors, and they are often costly to administer. Overly discretionary incentive regimes create uncertainty for investors and foster corruption, especially in countries without strong institutions to ensure transparency and accountability over time.

Given these costs and difficulties, there has been a recent trend to eliminate or simplify tax incentives. In general, simple, predictable, and nondiscretionary incentive schemes will be attractive to investors even if they are not excessively generous, while being less costly and distorting for host countries. Fiscal experts are also critical of tax holidays or temporary rebates on corporate income for some types of investments, which tend to attract short-term investments typical of footloose industries, while discouraging investments that rely on long-lived capital, and which also tend to reward the formation of new companies rather than continued investment in new companies. Governments also increasingly try to attract FDI through investment promotion agencies that address possible information failures. There are now at least 160 national and more than 250 subnational investment promotion agencies, compared to only a handful two decades ago. These agencies play a variety of roles: information dissemination, image building, investment facilitation, investment generation, investor monitoring and aftercare, and policy advocacy.

Policies to enhance FDI spillovers. In addition to incentives offered to attract FDI, governments also sometimes use a variety of regulatory, trade-related investment measures to try to enhance the positive spillovers from FDI flows. Domestic content requirements aim to raise the share of inputs that foreign firms buy from local producers on the assumption that this would increase vertical technology transfers. However, it is unlikely that forcing foreign firms to buy inputs from inefficient local firms is the best way to foster vertical transfers. Instead, this may create a disincentive for FDI. Local content requirements in the automobile sectors in Australia and Chile were found to result in large inefficiencies.[35] McKinsey Consultants estimates that local content requirements for Chinese auto parts made cars produced in China 20–30 percent more expensive than those produced in the United States. On the other hand, the lack of local content requirements in the consumer electronics sector in China or the phasing out of such restrictions in the Mexican auto sector has in no way hindered the rapid development of increasingly sophisticated supplier industries in these countries.[36]

Mandated joint ventures or local equity participation regulations also aim to encourage technology spillovers to local partners, but seem mainly to result in rendering foreign firms wary of using their most advanced or sensitive processes, thereby reducing rather than enhancing spillovers. Again, because foreign investors in the automobile sector in China were required to have a local partner, major international firms were reluctant to use the latest processes. As a result, manufacturing methods lagged behind industry standards by about 10 years. Similarly, Kodak was required to have local joint venture partners in its investments in China, but was allowed to have one wholly owned subsidiary. It invested six times more in the wholly owned firm than it did in the average joint venture partner. Its wholly owned subsidiary ended up producing its most advanced film and camera technologies, while the joint ventures produced conventional film under the Kodak label. On the other hand, multinationals are often quite willing to form joint ventures with local partners when this makes economic and strategic sense, even without local equity regulations, as has been the case in the retail sector in Brazil and Mexico. Given the lack of evidence for a link between these kinds of trade-related investment measures and productivity spillovers, countries have also adopted more general strategies to work with foreign affiliates and local firms to overcome information and cultural barriers. These programs are often combined with incentives to help the domestic suppliers meet the production standards demanded by foreign investors. This approach has been followed in economies such as Ireland, Malaysia, Singapore, and Taiwan (China).[37]

Notes

1. See Romer (1990a, 1990b, 1993); Aghion and Howitt (1992, 2005).

2. The *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data* (OECD and EC 2005) explicitly follows Joseph Schumpeter's pioneering 1934 analysis by defining innovation quite broadly as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (p. 46). The basic requirement for an innovation in the manual's approach is that it be new to the firm implementing it. Thus, innovations include not only products, processes, or methods originally developed by the firm, but also those adopted from other firms or organizations. They include significant improvements or adaptations of existing product, process, marketing, or organizational methods. Innovation activities are defined as "all scientific, technological, organisational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations" (p. 47). Innovation activities include not only research and experimental development, but also the acquisition of external knowledge and technology (for example, purchases of patents and nonpatented inventions, licenses, know-how, trademarks, designs, and patterns from other firms), the acquisition of the capital goods, both those embodying improved technological performance and those with no improvement in technological performance, that are required for the implementation of new or improved products or processes, and a

wide range of other activities needed to prepare an innovation, such as industrial design, engineering and setup, trial production, patent and license work, production start-up, and testing.

3. Ayyagari, Demirgüç-Kunt, and Maksimovic (2006) use instrumental variables to control for the obvious possibility of reverse causation (whereby external financing flows to more innovative firms), but find that the instrumented external financing variable remains significant.

4. Although, as indicated elsewhere here, the econometric evidence for technology transfer and productivity gains through exporting is mixed.

5. Small countries (in geographical terms) tend to export and import more per dollar of GDP than do large ones. This is known as the country size effect.

6. Lall (2003) elaborates on the diverse strategies employed by East Asian economies to strengthen industrial competitiveness.

7. For example, Hobday (1995, 2000), Kim (1997), Matthews and Cho (2000), Kim and Lee (2002), and Nabeshima (2004).

8. The relevant literature is surveyed in Hoekman and Javorcik (2006) and Tybout (2006).

9. See Sturgeon and Lester (2004).

10. See Ernst (2004).

11. Keller (2002) proxies disembodied knowledge flows through bilateral language skills (the proportion of the population in the recipient country that speaks the language of the spillover sender country). The study looks at knowledge flows among industries in countries at the world's technology frontier, the G-7 industrialized economies.

12. Schiff, Wang, and Olarreaga (2002) do not measure the R&D actually performed in developing economies. Instead, they construct an indirect measure of the R&D that developing economies have absorbed from the North through trade. They then look at the possible international spillovers through trade of this indirect R&D stock in developing economies.

13. There is a weak and slightly positive correlation between FDI stocks and per capita income across countries, but there is a more significant negative correlation between country size and FDI stocks as a share of GDP.

14. For example, see Caves (1996) and Markusen (2002).

15. Using panel data for 58 developing countries, Bosworth and Collins (2003) show that there is a nearly one-to-one relationship between FDI and domestic investment.

16. See Arnold and Javorcik (2005); World Bank (2005). Arnold and Javorcik (2005) use a nonparametric matching estimator to calculate the causal effect of foreign ownership on plant productivity. This technique creates a missing counterfactual of the acquired firm had it remained under domestic ownership. It does so by pairing up each future acquired plant with a domestic plant from the same sector and year that had observable characteristics similar to the acquisition target prior to the foreign acquisition. The causal effect of foreign ownership is estimated by the average divergence of the total factor productivity growth paths between each acquired plant and its matched control plant, starting from the preacquisition year.

17. Blomström and Kokko (1997) and Glass and Saggi (2002) provide a more detailed exposition on the role of competition; Das (1987) and Wang and Blomström (1992), on imitation; and Haacker (1999), Fosfuri, Motta, and Rønde (2001), and Djankov and Hoekman (2000), on skill set acquisition. For a general literature review of FDI spillover channels, see Görg and Greenaway (2004).

18. For example, Haskel, Pereira, and Slaughter (2002) and Griffith, Redding, and Simpson (2003) find small, but significant effects in the United Kingdom, while Keller and Yeaple (2003) find large and significant effects for the United States. For developing or emerging economies, Javorcik and Spatareanu (2003) find evidence for horizontal spillovers in Romania.

19. See UNESCO (2005, 2006). R&D data are available for a number of economies through 2004 or 2005, but 2002 seems to be the most recent year for which comprehensive data are available for the world as a whole.

20. It is worth noting that the absolute value of China's R&D in purchasing power parity terms is particularly affected by the unusually large disparity between the country's purchasing power parity exchange

rate (as calculated by World Bank staff and other researchers) and its market exchange rate. Thus, China's R&D expenditures in 2004 at market exchange rates were US$23.8 billion, or only 21 percent of the purchasing power parity figure (UNESCO 2006). By comparison, Korea's R&D spending in 2003 was US$22.8 billion in purchasing power parity terms and US$16 billion at market exchange rates, or 70 percent of the purchasing power parity figure. In Malaysia, R&D at market rates was 42 percent of R&D in purchasing power parity terms. Note, however, that, while this issue is relevant for measuring absolute levels of R&D, it does not affect R&D intensity (the ratio of R&D to GDP), since both the numerator and denominator of that ratio rely on the same conversion rate.

21. Jaumotte and Pain (2005a) also provide an extensive analysis of the determinants of business sector R&D in the OECD countries. Among the more important influences on business R&D are economic framework variables such as the user cost of capital, corporate profits, financial development, international trade openness, and product market restrictions (lack of competition). Among significant national innovation system variables are government subsidies for business R&D (although only under some conditions), the level of nonbusiness R&D (largely in universities and nonprofit bodies), business-academic links, and a lagged term for the number of scientists and engineers.

22. The business sector R&D discussed here includes R&D performed by domestic private firms, public sector firms, and foreign affiliates operating in a country. Government R&D refers to organizations not engaged in production, but belonging to the executive branch of government.

23. See the discussion of the definition of innovation in endnote 2. Scotchmer (2004) provides a nontechnical primer on intellectual property law. Issues and pitfalls in the use of patents as innovation indicators are discussed in Hall, Jaffe, and Trajtenberg (2001), Jaffe and Trajtenberg (2002), and Jaffe and Lerner (2004). Apart from the legal requirements for patenting, firms may also make a strategic choice to protect their inventions by means other than patents, for example, secrecy, lead times, first-mover advantages such as moving down the learning curve, and the provision of sales and services that complement the innovation. Levin et al. (1987) and Cohen, Nelson, and Walsh (2002) document the importance of methods other than patents for protecting intellectual property.

24. In particular, the section draws on the NBER Patent Citation Database (http://www.nber.org/patents/), which is described in Hall, Jaffe, and Trajtenberg (2001) and updated through 2002 by Bronwyn Hall (http://elsa.berkeley.edu/~bhhall/bhdata.html) and through 2004 by Albert Hu (Hu 2006). The discussion in this section draws extensively on Hu (2006), a background paper prepared for this report. The paper focuses on patent and citation data on eight East Asian economies: China, Hong Kong (China), Korea, Malaysia, the Philippines, Singapore, Taiwan (China), and Thailand. The use of U.S. patents may be justified by the fact that inventors in other countries have a strong incentive to take out patents in the United States for commercially valuable inventions, given the position of the United States as the largest market in the world. Close to 50 percent of the patents granted by the USPTO in 2000–04 went to foreign inventors. Nevertheless, there is a large home bias in patenting (inventors are much more likely to patent in their home jurisdiction than elsewhere), and inventors in different economies may also face different incentives to patent in the United States (for example, economies that export a great deal to the United States versus those that export little), and this may introduce another source of bias for which adjustment may need to be made.

25. For example, see Hausmann, Hall, and Griliches (1984); Hall, Griliches, and Hausman (1986); Griliches (1990); Blundell, Griffith, and van Reenen (1995); and Jaffe and Trajtenberg (2002).

26. Some East Asian economies have very few if any patents in some technology fields. This means that there are few citations with which to compute generality or originality indexes. In such cases, the indexes may reflect only a few unrepresentative cases rather than the economy's intrinsic inventive capability. To avoid this problem, the discussion focuses on Korea and Taiwan (China). These economies exhibit sufficient patenting activity for meaningful measurement.

27. For additional details, see Jaffe and Trajtenberg (2002) and Hu (2006).

28. Technological proximity is defined as the correlation between the technology vectors of the two economies, wherein each technology vector is defined as the shares of total patents taken out by the economy in all 428 technology classes.

29. For instance, see Ahn (2002).

30. See Pack and Saggi (2006); Klimenko (2004).

31. Blalock and Gertler (2005) argue that there may nevertheless be an externality associated with vertical technology transfers that warrants some public intervention. If a multinational corporation transfers technology to only one supplier, this may enhance the market power of that supplier, which may tend to hold up competition. Thus, the multinational corporation has an incentive to transfer technology to several competing suppliers, leading to a more productive supply base and lower supply prices. However, the multinational corporation is unable to prevent the new supply base from also selling to the competitors of the multinational corporation. These competitors will then be in a position to increase competition and lower prices in the downstream market. The original multinational corporation would not, however, take all these social welfare gains into account and may transfer a less than optimal amount of technology to suppliers.

32. See World Bank (2004b).

33. See World Bank (2004b); MIGA (2002); Morisset (2003); Farrell, Remes, and Schulz (2004); Oman (2000).

34. See Görg (2003).

35. See World Bank (2004b).

36. See Farrell, Remes, and Schulz (2004).

37. See World Bank (2004b).

References

Aghion, Philippe, and Peter Howitt. 1992. "A Model of Growth through Creative Destruction." *Econometrica* 60 (2): 323–51.

______. 2005. "Appropriate Growth Policy: A Unifying Framework." The 2005 Joseph Schumpeter Lecture, delivered to the 20th Annual Congress of the European Economic Association, Amsterdam, August 25. http://post.economics.harvard.edu/faculty/aghion/papers/Appropriate_Growth_Policy.pdf.

Aghion, Philippe, George-Marios Angeletos, Abhijit Banerjee, and Kalina Manova. 2005. "Volatility and Growth: Credit Constraints and Productivity-Enhancing Investment." Draft working paper, April, National Bureau of Economic Research, Cambridge, MA.

Aghion, Philippe, Philippe Bacchetta, Romain Rancière, and Kenneth Rogoff. 2006. "Exchange Rate Volatility and Productivity Growth: The Role of Financial Development." Draft working paper, March, National Bureau of Economic Research, Cambridge, MA.

Aghion, Philippe, Nick Bloom, Richard William Blundell, Rachel Susan Griffith, and Peter Howitt. 2005. "Competition and Innovation: An Inverted-U Relationship." *Quarterly Journal of Economics* 120 (2): 701–28.

Aghion, Philippe, Richard William Blundell, Rachel Susan Griffith, Peter Howitt, and Susanne Prantl. 2006. "The Effects of Entry on Incumbent Innovation and Productivity." Draft working paper, National Bureau of Economic Research, Cambridge, MA.

Ahn, Sanghoon. 2002. "Competition, Innovation, and Productivity Growth: A Review of Theory and Evidence." OECD Economics Department Working Paper 317, Economics Department, Organisation for Economic Co-operation and Development, Paris.

Aitken, Brian J., and Ann E. Harrison. 1999. "Do Domestic Firms Benefit from Direct Foreign Investment?: Evidence from Venezuela." *American Economic Review* 89 (3): 605–18.

Arnold, Jens Matthias, and Beata Smarzynska Javorcik. 2005. "Gifted Kids or Pushy Parents?: Foreign Acquisitions and Plant Performance in Indonesia." CPER Discussion Paper 5065, Center for Econ. Policy Research, London.

Arrow, Kenneth. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors,* ed. Richard R. Nelson, 609–26. Princeton, NJ: Princeton University Press.

Audretsch, David B. 1998. "Agglomeration and the Location of Innovative Activity." *Oxford Review of Economic Policy* 14 (2): 18–29.

Audretsch, David B., and Maryann Feldman. 1996. "R&D Spillovers and the Geography of Innovation and Production." *American Economic Review* 86 (3): 630–40.

Aw, Ben Yan, Xiaomin Chen, and Mark J. Roberts. 1997. "Firm-Level Evidence on Productivity Differentials, Turnover, and Exports in Taiwanese Manufacturing." NBER Working Paper 6235, National Bureau of Economic Research, Cambridge, MA.

Ayyagari, Meghana, Asli Demirgüç-Kunt, and Vojislav Maksimovic. 2006. "Firm Innovation in Emerging Markets: Role of Governance and Finance." Unpublished working paper, World Bank, Washington, DC.

Balasubramanyam, V. N., M. A. Salisu, and D. R. Sapsford. 2001. "FDI and Economic Growth in LDCs: Some Further Evidence." In *Creating an Internationally Competitive Economy*, ed. H. Block and P. Kenyon, 233–49. London: Macmillan.

Barro, Robert J., and Jong-Wha Lee. 2000. "International Data on Educational Attainment: Updates and Implications." CID Working Paper 42, Center for International Development, Harvard University, Cambridge, MA.

Bartelsman, Eric, John Haltiwanger, and Stefano Scarpetta. 2004. "Microeconomic Evidence of Creative Destruction in Industrial and Developing Countries." Policy Research Working Paper 3464, World Bank, Washington, DC.

Baumol, William J. 2002. *The Free Market Innovation Machine: Analyzing the Growth Miracle of Capitalism.* Princeton, NJ: Princeton University Press.

Blalock, Garrick, and Paul J. Gertler. 2005. "Foreign Direct Investment and Externalities: The Case for Public Intervention." In *Does Foreign Direct Investment Promote Development?*, ed. Theodore H. Moran, Edward M. Graham, and Magnus Blomström, 73–106. Washington, DC: Institute for International Economics.

Blomström, Magnus, and Ari Kokko. 1997. "How Foreign Investment Affects Host Countries." Policy Research Working Paper 1745, World Bank, Washington, DC.

Bloom, Nick, Rachel Susan Griffith, and John van Reenen. 2000. "Do R&D Tax Credits Work?: Evidence from a Panel of Countries 1979–97." CEPR Discussion Paper 2415, Center for Economic Policy Research, London.

Blundell, Richard William, Rachel Susan Griffith, and John van Reenen. 1995. "Dynamic Count Data Models of Technological Innovation." *Economic Journal* 105 (429): 333–44.

______. 1999. "Market Share, Market Value, and Innovation in a Panel of British Manufacturing Firms." *Review of Economic Studies* 66 (3): 529–54.

Borensztein, Eduardo, José De Gregorio, and Jong-Wha Lee. 1998. "How Does Foreign Direct Investment Affect Economic Growth?" *Journal of International Economics* 45 (1): 115–35.

Bosch, Mariano, Daniel Lederman, and William F. Maloney. 2005. "Patenting and Research and Development: A Global View." Policy Research Working Paper 3739, World Bank, Washington, DC.

Bosworth, Barry P., and Susan M. Collins. 2003. "The Empirics of Growth: An Update." Brookings Papers on Economic Activities 2003–2, Brookings Institution, Washington, DC.

Bottazzi, Laura, and Giovanni Peri. 2005. "The International Dynamics of R&D and Innovation in the Short and in the Long Run." NBER Working Paper 11524, National Bureau of Economic Research, Cambridge, MA.

Caballero, Ricardo J., and Adam B. Jaffe. 1993. "How High Are the Giants' Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth." In *NBER Macroeconomics Manual*, ed. Olivier Jean Blanchard and Stanley M. Fischer, 15–74. Cambridge, MA: MIT Press.

Caves, Richard. 1996. *Multinational Enterprises and Economic Analysis.* 2nd ed. Cambridge: Cambridge University Press.

Clerides, Sofronis K., Saul Lach, and James R. Tybout. 1998. "Is Learning by Exporting Important?: Micro-Dynamic Evidence from Colombia, Mexico, and Morocco." *Quarterly Journal of Economics* 113 (3): 903–47.

Coe, David T., and Elhanan Helpman. 1995. "International R&D Spillovers." *European Economic Review* 39 (5): 859–87.

Coe, David T., Elhanan Helpman, and Alexander W. Hoffmaister. 1997. "North-South R&D Spillovers." *Economic Journal* 107 (440): 134–49.

Cohen, Wesley M., and Daniel A. Levinthal. 1989. "Innovation and Learning: The Two Faces of R&D." *Economic Journal* 99 (397): 569–96.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh. 2002. "Links and Impacts: The Influence of Public Research on Industrial R&D." *Management Science* 48 (1): 1–23.

Das, Sanghamitra. 1987. "Externalities and Technology Transfer through Multinational Corporations: A Theoretical Analysis." *Journal of International Economics* 22 (1–2): 171–82.

Djankov, Simeon, and Bernard Hoekman. 2000. "Foreign Investment and Productivity Growth in Czech Enterprises." *World Bank Economic Review* 14 (1): 49–64.

Doner, Richard F., Gregory W. Noble, and John Ravenhill. 2004. "Production Networks in East Asia's Automobile Parts Industry." In *Global Production Networking and Technological Change in East Asia*, ed. Shahid Yusuf, M. Anjum Altaf, and Kaoru Nabeshima, 159–208. Washington, DC: World Bank; New York: Oxford University Press.

______. 2006. "Industrial Competitiveness of the Auto Parts Industries in Four Large Asian Countries: The Role of Government Policy in a Challenging International Environment." Unpublished working paper, World Bank, Washington, DC.

Eaton, Jonathan, and Samuel Kortum. 1996. "Trade in Ideas: Patenting and Productivity in the OECD." *Journal of International Economics* 40 (3/4): 251–78.

Ernst, Dieter. 2004. "Global Production Networks in East Asia's Electronics and Upgrading Perspectives in Malaysia." In *Global Production Networking and Technological Change in East Asia*, ed. Shahid Yusuf, M. Anjum Altaf, and Kaoru Nabeshima, 89–158. Washington, DC: World Bank; New York: Oxford University Press.

Farrell, Diana, Jaana K. Remes, and Heiner Schulz. 2004. "The Truth about Foreign Direct Investment in Emerging Markets." The McKinsey Quarterly 2004–1, 25–35.

Fink, Carsten, and Keith E. Maskus. 2005. *Intellectual Property and Development: Lessons from Recent Economic Research*. Washington, DC: World Bank.

Foray, Dominique. 2004. *The Economics of Knowledge*. Cambridge, MA: MIT Press.

Fosfuri, Andrea, Massimo Motta, and Thomas Rønde. 2001. "Foreign Direct Investment and Spillovers through Workers' Mobility." *Journal of International Economics*, 53 (1): 205–22.

Fujita, Masahisa, and Jacques-François Thisse. 1996. "The Economics of Agglomeration." CEPR Discussion Paper 1344, Center for Economic Policy Research, London.

García-Quevado. José. 2004. "Do Public Subsidies Complement Business R&D?: A Meta-Analysis of the Econometric Evidence." *Kyklos* 57 (1): 87–102.

Glass, Amy Jocelyn, and Kamal Saggi. 2002. "Intellectual Property Rights and Foreign Direct Investment." *Journal of International Economics* 56 (2): 387–410.

Görg, Holger. 2003. "Fancy a Stay at the 'Hotel California': Foreign Direct Investment, Investment Incentives, and Exit Costs." Draft paper, School of Economics, University of Nottingham, Nottingham, United Kingdom.

Görg, Holger, and David Greenaway. 2004. "Much Ado about Nothing?: Do Domestic Firms Benefit from Foreign Direct Investment?" *World Bank Research Observer* 19 (2): 171–97.

Griffith, Rachel Susan, Stephen J. Redding, and Helen Simpson. 2003. "Productivity Convergence and Foreign Ownership at the Establishment Level." CEPR Discussion Paper 3765, Centre for Economic Policy Research, London.

Griliches, Zvi. 1990. "Patent Statistics as Economic Indicators: A Survey." *Journal of Economic Literature* 28 (4): 1661–1707.

______. 1995. "R&D and Productivity: Econometric Results and Measurement Issues." In *Handbook of the Economics of Innovation and Technological Change*, ed. Paul Stoneman, ed., 52–89. Oxford: Blackwell.

Grossman, Gene M., and Elhanan Helpman. 1991. *Innovation and Growth in the Global Economy.* Cambridge, MA: MIT Press.

Guellec, Dominique, and Bruno van Pottelsberghe de la Potterie. 2004. "From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter?" *Oxford Bulletin of Economics and Statistics* 66 (3): 353–78.

Haacker, Markus. 1999. "Spillovers from Foreign Direct Investment through Labor Turnover: The Supply of Management Skills." Discussion Paper, Centre for Economic Performance, London School of Economics, London.

Hall, Bronwyn Hughes, Zvi Griliches, and Jerry A. Hausman. 1986. "Patents and R&D: Is There a Lag?" *International Economic Review* 27 (2): 265–84.

Hall, Bronwyn Hughes, Adam B. Jaffe, and Manuel Trajtenberg. 2001. "The NBER Patent Citations Data File: Lessons, Insights, and Methodological Tools." CEPR Discussion Paper 3094, Center for Economic Policy Research, London.

Hallward-Driemeier, Mary, Giuseppe Iarossi, and Kenneth L. Sokoloff. 2002. "Exports and Manufacturing Productivity in East Asia: A Comparative Analysis with Firm-Level Data." NBER Working Paper 8894, National Bureau of Economic Research, Cambridge, MA.

Hanson, Gordon H. 2001. "Should Countries Promote Foreign Direct Investment?" G-24 Discussion Paper 9, United Nations, Geneva.

Haskel, Jonathan E., Sonia C. Pereira, and Matthew J. Slaughter. 2002. "Does Inward Foreign Direct Investment Boost the Productivity of Firms?" NBER Working Paper 8724, National Bureau of Economic Research, Cambridge, MA.

Hausman, Jerry A., Bronwyn Hughes Hall, and Zvi Griliches. 1984. "Econometric Models for Country Data with an Application to the Patents-R&D Relationship." *Econometrica* 52 (4): 909–38.

Hausmann, Ricardo, and Dani Rodrik. 2002. "Economic Development as Self-Discovery." NBER Working Paper 8952, National Bureau of Economic Research, Cambridge, MA.

Hobday, Michael. 1995. *Innovation in East Asia: The Challenge to Japan.* Cheltenham, UK: Edward Elgar.

______. 2000. "East Versus Southeast Asian Innovations: Comparing OEM- and TNC-Led Growth in Electronics." In *Technology, Learning, and Innovation: Experiences of Newly Industrializing Economies,* ed. Linsu Kim and Richard R. Nelson, 129–69. Cambridge: Cambridge University Press.

Hoekman, Bernard M., and Beata Smarzynska Javorcik, eds. 2006. *Global Integration and Technology Transfer.* Trade and Development Series. Washington, DC: World Bank; Basingstoke, Hampshire, United Kingdom: Palgrave Macmillan.

Hoekman, Bernard M., Keith E. Maskus, and Kamal Saggi. 2005. "Transfer of Technology to Developing Countries: Unilateral and Multilateral Policy Options." *World Development* 33 (10): 1587–1602.

Hu, Albert Guangzhou. 2006. "Knowledge Flow in East Asia and Beyond." Background paper, World Bank, Washington, DC.

Hu, Albert Guangzhou, and Gary H. Jefferson. 2005. "A Great Wall of Patents: What Is behind China's Recent Patent Explosion?" Paper presented at the joint conference of the School of Economics, Shanghai University of Finance and Economics, Shanghai, and the Department of Economics, Örebro University, Örebro, Sweden, "Globalization and Economic Growth: The Role of Openness, Innovation, and Human Capital, Evidence from Micro Data," Shanghai, November 4–6.

Jaffe, Adam B., and Josh Lerner. 2004. *Innovation and Its Discontents.* Princeton, NJ: Princeton University Press.

Jaffe, Adam B., and Manuel Trajtenberg. 1998. "International Knowledge Flows: Evidence from Patent Citations." NBER Working Paper 6507, National Bureau of Economic Research, Cambridge, MA.

______. 1999. "International Knowledge Flows: Evidence from Patent Citations." *Economics of Innovation and New Technology* 8 (1–2): 105–36.

______. 2002. *Patents, Citations, and Innovations: A Window on the Knowledge Economy.* Cambridge, MA: MIT Press.

Jaffe, Adam B., Manuel Trajtenberg, and Rebecca Henderson. 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics* 108 (3): 577–98.

Jaumotte, Florence, and Nigel Pain. 2005a. "From Ideas to Development: The Determinants of R&D and Patenting." OECD Economics Department Working Paper 457, Economics Department, Organisation for Economic Co-operation and Development, Paris.

______. 2005b. "An Overview of Public Policies to Support Innovation." OECD Economics Department Working Paper 456, Economics Department, Organisation for Economic Co-operation and Development, Paris.

Javorcik, Beata Smarzynska. 2004. "Does Foreign Direct Investment Increase the Productivity of Domestic Firms?: In Search of Spillovers through Backward Linkages." *American Economic Review* 94 (3): 605–27.

Javorcik, Beata Smarzynska, and Mariana Spatareanu. 2003. "To Share or Not to Share: Does Local Participation Matter for Spillovers from Foreign Direct Investment?" Policy Research Working Paper 3118, World Bank, Washington, DC.

Jones, Charles I., and John C. Williams. 1997. "Measuring the Social Return to R&D." *Quarterly Journal of Economics* 113 (4): 1119–35.

Keller, Wolfgang. 2002. "Knowledge Spillovers at the World's Technology Frontier." CEPR Discussion Paper 2815, Center for Economic Policy Research, London.

______. 2004. "International Technology Diffusion." *Journal of Economic Literature* 42 (3): 752–82.

Keller, Wolfgang, and Stephen R. Yeaple. 2003. "Multinational Enterprises, International Trade, and Productivity Growth: Firm-Level Evidence from the United States." Working Papers 2003–06, Department of Economics, Brown University, Providence, RI.

Kim, Linsu. 1997. *From Imitation to Innovation: Dynamics of Korea's Technological Learning.* Boston: Harvard Business School Press.

Kim, Linsu, and Richard R. Nelson. 2000. *Technology, Learning, and Innovation: Experiences of Newly Industrializing Economies.* Cambridge: Cambridge University Press.

Kim, Youngbae, and Byungheon Lee. 2002. "Patterns of Technological Learning among the Strategic Groups in the Korean Electronic Parts Industry." *Research Policy* 31 (4): 543–67.

Kinoshita, Yuko. 2001. "R&D and Technology Spillovers via FDI: Innovation and Absorptive Capacity." CEPR Discussion Paper 2775. Center for Economic Policy Research, London.

Klimenko, Mikhail M. 2004. "Industrial Targeting, Experimentation, and Long-Run Specialization." *Journal of Development Economics* 73 (1): 75–105.

Kokko, Ari, Ruben Tansini, and Mario C. Zejan. 1996. "Local Technological Capability and Productivity Spillovers from FDI in the Uruguayan Manufacturing Sector." *Journal of Development Studies* 32 (4): 602–11.

Konings, Josef. 2001. "The Effects of Foreign Direct Investment on Domestic Firms." *Economics of Transition* 9 (3): 619–33.

Kraay, Aart. 2006. "Exports and Economic Performance: Evidence from a Panel of Chinese Enterprises." In *Global Integration and Technology Transfer*, ed. Bernard M. Hoekman and Beata Smarzynska Javorcik, 139–61. Trade and Development Series. Washington, DC: World Bank; Basingstoke, Hampshire, United Kingdom: Palgrave Macmillan.

Lall, Sanjay. 2003. "Foreign Direct Investment, Technology Development and Competitiveness: Issues and Evidence." In *Competitiveness, FDI and Technological Activity in East Asia*, ed. Sanjay Lall and Shujiro Urata, Chapter 2. Cheltenham, United Kingdom: Edward Elgar.

Lall, Sanjay, and Shujiro Urata, eds. 2003. *Competitiveness, FDI and Technological Activity in East Asia.* Cheltenham, United Kingdom: Edward Elgar.

Lederman, Daniel, and William F. Maloney. 2003. "Research and Development (R&D) and Development." Policy Research Working Paper 3024, World Bank, Washington, DC.

Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter. 1987. "Appropriating the Returns from Industrial Research and Development." Brookings Papers on Economic Activity 1987–03, Brookings Institution, Washington, DC.

Lipsey, Robert E. 2000. "Interpreting Developed Countries' Foreign Direct Investment." NBER Working Paper 7810, National Bureau of Economic Research, Cambridge, MA.

López-Claros, Augusto, Michael E. Porter, and Klaus Schwab. 2005. *Global Competitiveness Report 2005–2006: Policies Underpinning Rising Prosperity.* Geneva: World Economic Forum; Basingstoke, Hampshire, United Kingdom: Palgrave Macmillan.

Markusen, James. 2002. *Multinational Firms and the Theory of International Trade.* Cambridge, MA: MIT Press.

Matthews, John A., and Dong-Sung Cho. 2000. *Tiger Technology: The Creation of a Semiconductor Industry in East Asia.* Cambridge: Cambridge University Press.

MIGA (Multilateral Investment Guarantee Agency). 2002. *Foreign Direct Investment Survey.* Multilateral Investment Guarantee Agency, World Bank Group, Washington, DC. http://www.ipanet.net/fdisurvey/.

Moran, Theodore H., Edward M. Graham, and Magnus Blomström, eds. 2005. *Does Foreign Direct Investment Promote Development?* Washington, DC: Institute for International Economics.

Morisset, Jacques. 2003. "Tax Incentives." Viewpoint Note 25, World Bank, Washington, DC.

Nabeshima, Kaoru. 2004. "Technology Transfer in East Asia: A Survey." In *Global Production Networking and Technological Change in East Asia*, ed. Shahid Yusuf, M. Anjum Altaf, and Kaoru Nabeshima, 395–434. Washington, DC: World Bank; New York: Oxford University Press.

Nickell, Stephen J. 1996. "Competition and Corporate Performance." *Journal of Political Economy* 104 (4): 724–46.

Noland, Marcus, and Howard Pack. 2003. *Industrial Policy in an Era of Globalization: Lessons from Asia.* Washington, DC: Institute for International Economics.

OECD (Organisation for Economic Co-operation and Development). 2000. "Policy Brief: Science, Technology and Innovation in the New Economy." OECD Observer, September, Organisation for Economic Co-operation and Development, Paris.

______. 2003. *Frascati Manual. Proposed Standard Practice for Surveys on Research and Experimental Development.* Measurement of Scientific and Technological Activities Series. Paris: Organisation for Economic Co-operation and Development.

OECD (Organisation for Economic Co-operation and Development) and EC (European Commission). 1997. *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: Oslo Manual.* 2nd ed. Measurement of Scientific and Technological Activities Series. Paris: Organisation for Economic Co-operation and Development.

______. 2005. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data.* 3rd ed. Measurement of Scientific and Technological Activities Series. Paris: Organisation for Economic Co-operation and Development.

Oman, Charles P. 2000. *Policy Competition for Foreign Direct Investment: A Study of Competition among Governments to Attract FDI.* Development Center Studies Series. Paris: Organisation for Economic Co-operation and Development.

Pack, Howard. 2006. "Econometric Versus Case Study Approaches to Technology Transfer." In *Global Integration and Technology Transfer*, ed. Bernard M. Hoekman and Beata Smarzynska Javorcik, 29–50. Trade and Development Series. Washington, DC: World Bank; Basingstoke, Hampshire, United Kingdom: Palgrave Macmillan.

Pack, Howard, and Kamal Saggi. 2006. "The Case for Industrial Policy: A Critical Survey." Unpublished working paper, World Bank, Washington, DC.

Quigley, John M. 1998. "Urban Diversity and Economic Growth." *Journal of Economic Perspectives* 12 (2): 127–38.

Reed Business Information. 2005. *Electronic Business*, September 1. http://www.edn.com/article/CA6252391.html?partner=eb&pubdate=9%2F1%2F2005.

Rodrik, Dani. 2004. "Industrial Policy for the 21st Century." Unpublished working paper, September, John F. Kennedy School of Government, Harvard University, Cambridge, MA.

Romer, Paul M. 1990a. "Are Nonconvexities Important for Understanding Growth?" NBER Working Paper 3271, National Bureau of Economic Research, Cambridge, MA.

______. 1990b. "Endogenous Technological Change." *Journal of Political Economy* 98 (5): 71–102.

______. 1993. "Idea Gaps and Object Gaps in Economic Development." *Journal of Monetary Economics* 32 (3): 543–73.

Saggi, Kamal. 2002. "Trade, Foreign Direct Investment, and International Technology Transfer: A Survey." *World Bank Research Observer* 17 (2): 191–235.

Scherer, F. M., and Dietmar Harhoff. 2000. "Technology Policy for a World of Skew-Distributed Outcomes." *Research Policy* 29 (4–5): 559–66.

Schiff, Maurice, and Yanling Wang. 2006. "On the Quantity and Quality of Knowledge: The Impact of Openness and Foreign R&D on North-North and North-South Technology Spillovers." In *Global Integration and Technology Transfer*, ed. Bernard M. Hoekman and Beata Smarzynska Javorcik, 99–112. Trade and Development Series. Washington, DC: World Bank; Basingstoke, Hampshire, United Kingdom: Palgrave Macmillan.

Schiff, Maurice, Yanling Wang, and Maurice Olarreaga. 2002. "Trade-Related Technology Diffusion and the Dynamics of North-South and South-South Integration." Policy Research Working Paper 2861, World Bank, Washington, DC.

Schumpeter, Joseph. 1934. *The Theory of Economic Development.* Cambridge, MA: Harvard University Press.

Scotchmer, Suzanne. 2004. *Incentives and Innovation.* Cambridge, MA: MIT Press.

Sturgeon, Timothy J., and Richard K. Lester. 2004. "The New Global Supply Base: New Challenges for Local Suppliers in East Asia." In *Global Production Networking and Technological Change in East Asia*, ed. Shahid Yusuf, M. Anjum Altaf, and Kaoru Nabeshima, 35–88. Washington, DC: World Bank; New York: Oxford University Press.

TeleGeography Research. 2006. *TeleGeography Report.* Washington, DC: TeleGeography Research. http://www.telegeography.com/products/tg/report.php.

Todo, Yasuyuki, and Koji Miyamoto. 2006. "Knowledge Spillovers from Foreign Direct Investment and the Role of Local R&D Activities: Evidence from Indonesia." *Economic Development and Cultural Change* 55 (1): 173–200.

Trajtenberg, Manuel, Rebecca Henderson, and Adam B. Jaffe. 1997. "University versus Corporate Patents: A Window on the Basicness of Invention." *Economics of Innovation and New Technology* 5 (1): 19–50.

Tybout, James R. 2006. "Plant- and Firm-Level Evidence on 'New' Trade Theories." In *Global Integration and Technology Transfer*, ed. Bernard M. Hoekman and Beata Smarzynska Javorcik, 67–98. Trade and Development Series. Washington, DC: World Bank; Basingstoke, Hampshire, United Kingdom: Palgrave Macmillan.

UNCTAD (United Nations Conference on Trade and Development). 2005. *World Investment Report 2005: Transnational Corporations and the Internationalization of R&D.* Geneva: United Nations.

UNESCO (United Nations Educational, Scientific, and Cultural Organization). 2004. "A Decade of Investment in Research and Development (R&D): 1990–2000." *USI Bulletin on Science and Technology Statistics* 1 (April). Montreal: Institute for Statistics, United Nations Educational, Scientific, and Cultural Organization.

______. 2005. *UNESCO Science Report 2005.* Paris: UNESCO Publishing.

______. 2006. "Statistics on Research and Development." Data table, updated on May 3. Montreal: Institute for Statistics, United Nations Educational, Scientific, and Cultural Organization. http://www.uis.unesco.org/ev.php?ID=5182_201&ID2=DO_TOPIC.

Wang, Jian-Ye, and Magnus Blomström. 1992. "Foreign Investment and Technology Transfer: A Simple Model." *European Economic Review* 36 (1): 137–55.

Wong, Wei-Kang. 2006. "Do Crossborder Flows Raise Income and Productivity?" Background paper, World Bank, Washington, DC.

World Bank. 2004a. *Global Development Finance 2004: Harnessing Cyclical Gains for Development.* Washington, DC: World Bank.

______. 2004b. *World Development Report 2005: A Better Investment Climate for Everyone*. Washington, DC: World Bank; New York: Oxford University Press.

______. 2005. "Raising Investment in Indonesia: A Second Generation of Reforms." Report, World Bank, Washington, DC.

World Bank, the International Finance Corporation, and OUP (Oxford University Press). 2005. *Doing Business in 2005: Removing Obstacles to Growth*. Washington, DC: World Bank; New York: Oxford University Press.

Xu, Bin, and Jianmao Wang. 1999. "Capital Goods Trade and R&D Spillovers in the OECD." *Canadian Journal of Economics* 32 (5): 1258–74.

Yusuf, Shahid, M. Anjum Altaf, and Kaoru Nabeshima, eds. 2004. *Global Production Networking and Technological Change in East Asia*. Washington, DC: World Bank; New York: Oxford University Press.