

# Technological Learning: Climbing a Tall Ladder

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Innovation is defined as new ways to solve problems by combining technology (an improvement in product, process, marketing, or organization) with transformational entrepreneurship (activity typically involving commercialization of technologies via formal firms but also including value generation by informal, not-for-profit, and governmental entities). It is a major driver of economic growth and productivity. Innovation ranges from incremental new-to-the-firm adoption and adaptation of existing technologies to radical new-to-the-world creation and commercialization of disruptive products and processes.

Innovation is always accompanied by technological learning, which also requires investment. Traditionally, there has been too much focus on the creation of new high-tech products and not enough focus on the power of innovation to increase growth and jobs through technological learning and the adaptation of existing technologies across all products and sectors—agriculture; manufacturing; and services, including education, health, and infrastructure services.

Technological learning and innovation can lead to lower costs for existing and new (or higher-quality) products, enhancing productivity and thereby competitiveness and inclusive growth.<sup>1</sup> A key fact of

development is that differences in measured inputs explain less than half of the enormous differences in per capita national income (Caselli 2005; Jones and Romer 2010). Less-developed economies are less developed not only because they have less physical and human capital per worker than developed economies, but more important, also because they use their inputs less efficiently. Among other reasons, they do so because they are not learning sufficiently from existing better technologies and are not adequately improving prevailing production practices.

Do markets lead to a socially desirable level of technological learning and innovation? In contrast to investment in tangible capital, the decision to invest in technological learning and innovation involves spillovers. Ideas are nonrival in use, meaning that ideas leak across people and firms in a way that tangible capital and other products do not: ideas can be used by any number of people simultaneously without depletion or congestion. If ideas are productive, there are gains to society from sharing them globally as soon as they are discovered somewhere, provided that the costs of diffusing and using them are not prohibitive.<sup>2</sup> But markets on their own do not operate effectively with ideas, since a single price cannot allocate an idea to its most efficient uses (which would be at a marginal cost close to zero) and simultaneously provide appropriate incentives to invent and commercialize the idea in the first place. Ideas are therefore undersupplied by private markets relative to socially desirable outcomes, absent appropriate forms of public intervention. In addition to such technological externalities, investments in ideas typically involve demonstration externalities, with a positive impact of mavericks on later adopters and society at large, especially if prevailing norms favor unproductive rent extraction over productive entrepreneurship. Investments in learning and innovation also involve higher risk and asymmetries between what the firm does and what the financier can gauge, leading to funding gaps.

Given these key gaps between private and social returns, there is a strong case for appropriate public policy support. Sensible policy design requires careful attention to the characteristics of each locality. Particular policies are often necessary but not sufficient to have impact, given that complementary soft infrastructure may be missing, including appropriate competition, trade, investment, and technology policies;

rule-of-law-based policy certainty; educational, financial, legal, and other institutions; and required local capabilities.

So what are the most important determinants of innovation? Key determinants of innovation, or levers for innovation policy, can be organized into four main areas:

- Incentives for productive entrepreneurship (rule of law, sufficiently generous rewards that allow entrepreneurs to grow without fear of expropriation, sufficient competition pressures to prevent deviation from efficient innovation actions)
- Skills (including research and development [R&D] support for the building of absorptive capacity within enterprises,<sup>3</sup> the responsiveness of management and worker training to changes in market demands, technical assistance to facilitate long-term collaboration for education and research between business associations and universities, and scholarships to study abroad)
- Information (including openness to foreign trade, foreign direct investment [FDI], technology licensing, and global talent flows, specific programs to encourage multinational corporations [MNCs] to increase domestic spillovers by transferring learning to local workers and managers, and widespread access to the Internet)
- Finance (including the availability of a mix of public and private financial instruments and institutional delivery mechanisms) (see Trajtenberg 2009).<sup>4</sup>

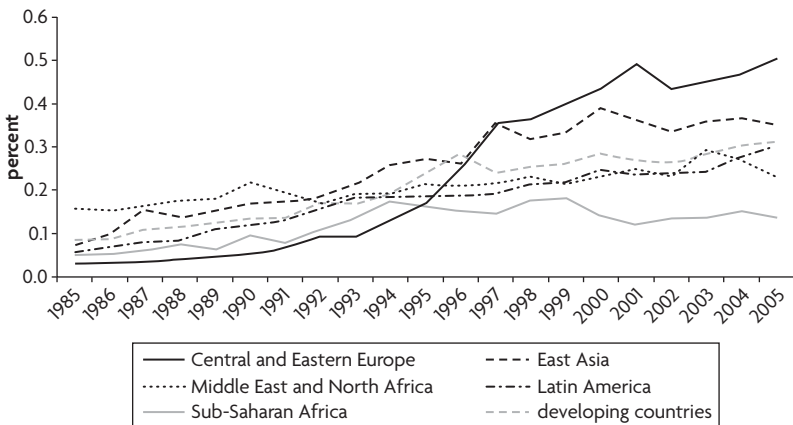
This chapter focuses on technological learning and its potential to become an even more important determinant of growth through its impact on innovation, as the stock of ideas expands and is better diffused across and within countries. The chapter begins by reviewing global trends, which make a policy focus on technological learning and innovation more important than ever before; briefly explores how the recent global financial crisis may affect these trends; and concludes by outlining several implications of these trends for innovation policy moving forward. The main message is that developing countries should prioritize diffusion, technological learning, and the adaptation of more efficient existing technologies for productivity upgrading and for the sustainable generation of more and better jobs.

## What Has Changed in Recent Years?

Four recent trends in the world economy are (a) the increasing global knowledge flows and accompanying global decomposition of production, (b) the increasing South-South trade, (c) the increased uptake of information and communication technologies (ICT), and (d) the continued growth in emerging economies. All of these trends have important implications for technological learning and innovation.

In recent decades, there has been a substantial increase in international trade in goods and services, FDI, intellectual property and technology licensing flows, and talent flows. The volume of world trade increased 27-fold between 1950 and 2006, three times more than the growth in global gross domestic product (GDP). Trade has grown twice as fast as GDP since 1990. Even more striking, the global value of stocks of FDI rose sixfold between 1990 and 2006, substantially faster than the growth in trade, which increased “only” 3.5 times over the same period. Importantly, these flows have been accompanied by a continuing trend of global decomposition of production, leading to an increasing spatially fragmented production and stage specialization. Vertical trade in developing countries increased from 8 percent in 1985 to around 33 percent in 2005 (figure 2. 1). Eastern Europe and East Asia have shown dramatic

**Figure 2.1 Regional Trends in Vertical Specialization as a Percentage of Exports, 1985–2005**

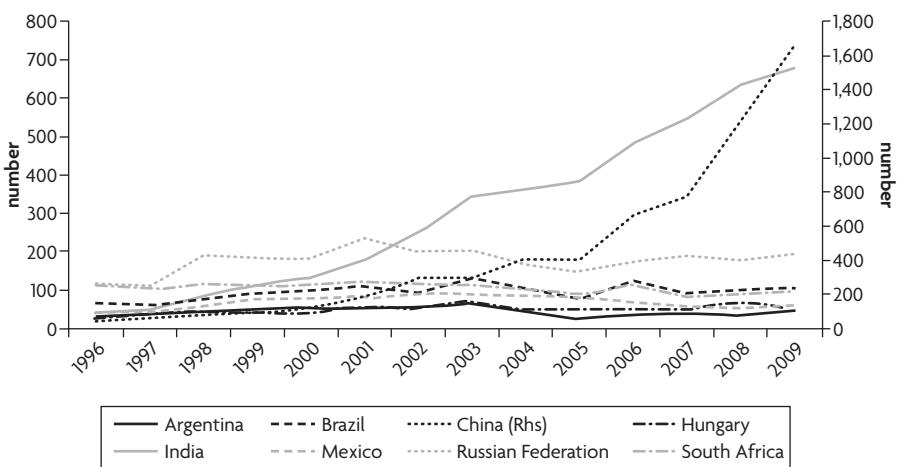


Source: Authors' calculations using United Nations Commodities Trade Statistics database (UN Comtrade).

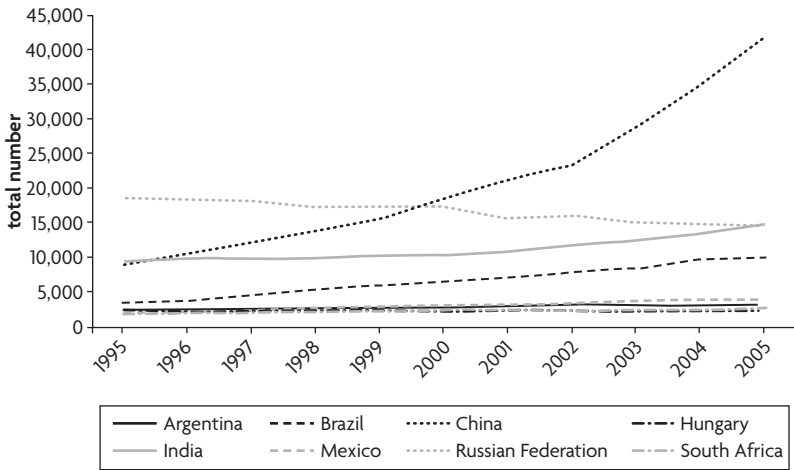
increases in vertical trade in the 1990s, whereas Sub-Saharan Africa has shown weak integration through international production chains. A global company today imports and exports parts to different countries—international trade within MNCs is estimated to account for around one-third of all international transactions—and in 2000, over 46 percent of U.S. imports were intra-firm (Corcos and others 2009; Bernard and others 2010).

With global decomposition of production, there are now more opportunities for technological learning and innovation from enterprises inserting themselves into global supply chains.<sup>5</sup> Getting started by undertaking a single task is far less daunting than breaking into the global market for an entire product. Potentially, trade in tasks could be a lifeline for countries yet to industrialize because manufacturing can start with specialization in tasks most suited to the skills available. And there is no evidence that task-based production is less technologically sophisticated than production of final products.<sup>6</sup> Recent evidence for an “emerging 8” grouping of developing countries (Argentina, Brazil, China, Hungary, India, Mexico, the Russian Federation, and South Africa) suggests an upswing in available measures of innovation, especially for China, followed by India and Brazil (see figures 2.2 and 2.3).

**Figure 2.2 Number of Annual Patents Granted in the United States, 1996–2009**



Source: U.S. Patent and Trademark Office, [http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm#by\\_geog](http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm#by_geog).  
Note: Rhs = right-hand side.

**Figure 2.3** Total Number of Scientific and Technical Journal Articles, 1995–2005

Source: World Bank, World Development Indicators database.

A second related trend has been a change in the direction of trade. The average annual growth rate in South-South trade since 1990 is almost twice that of total world trade; developing countries' trade with each other is now 39 percent of their total trade. In addition, low- and middle-income countries have increased their participation in bilateral trade relations, and the average value of such relations has been increasing in recent years (see Haddad and Hoekman in chapter 3 of this volume). This increase in South-South trade and knowledge flows raises the opportunities of learning by developing country enterprises from possibly more appropriate technologies adapted to local conditions in other developing countries. In particular, the technological challenges for many developing countries reside less in pushing outward the labor-saving technological frontier for specific product lines, but rather in business process innovations that deliver an adequate level of performance at a much lower price point.

A third important trend has been the tremendous increase in data storage and transmission capabilities, fall in costs, and uptake of ICT. The effect of ICT on economies goes far beyond their production. The innovative use of ICT by individuals, businesses, and government—and the untapped potential for the diffusion, technological learning, and use of ideas that mobile phones and fixed and mobile broadband

provide—makes a far bigger impact on economies. As a signal of just how productive ICT is viewed by firms, information-processing equipment (hardware, software, communications, and related equipment) today accounts for well over half of all business investment in equipment in the United States.<sup>7</sup> And empirical evidence has been mounting that economywide productivity growth has been driven by innovations in both products and processes in the industries that are the most intensive users of ICT (Jorgenson, Ho, and Stiroh 2008), based on technological learning that builds organizational capital, including complementary investments in new business process skills and management practices.<sup>8</sup> One implication is that for enterprises in developing countries to exploit new ICT-enabled innovations more effectively, they will need to learn and adopt complementary “people management” practices, including decentralized decision making, high-powered rewards, and flexible work rules, in addition to investing more in ICT.

A final important trend has been the continued income growth in emerging economies, including but not limited to the more technologically advanced emerging economies such as Brazil, China, India, and Russia. This process, which showed resilience to the recent economic crisis, has led to a significant reduction in poverty levels; to the gradual emergence of a large new middle class in many developing countries;<sup>9</sup> and to the creation of an attractive market, provided firms are able to explore its scale. The recent growth of developing economies is associated with a long-term trend rather than with cyclical fluctuations, suggesting a sustainable process (Hanson 2010). An implication of this trend is that selected enterprises have started new and disruptive forms of innovation in low-income economies in general, and in China and India in particular (Kaplinsky and others 2010). This new approach to innovation, also called “frugal,” “constraint-based,” or “reverse” innovation (*The Economist* 2010), is premised on the reality of growing technological capabilities in a number of developing economies, in the significant incentives provided by large and rapidly growing (albeit low-income) local consumer markets, and in low labor costs. The continued growth in emerging economies has opened the opportunity for developing countries to “piggyfrog,” a combination of piggybacking on foreign technologies by imitating them combined with leapfrogging by adapting these technologies through lower-cost solutions. Examples include Tata Motors’

US\$2,200 Nano car aimed at India's lower-middle class, with low-cost engineering adaptations such as one windshield wiper, tubeless tires, and a two-cylinder engine with top speed of 65 miles per hour (105 kilometers per hour), and Tata Consulting Services' US\$24 Swach (Hindi for "clean") water filter targeted at rural households with no electricity or running water, with adaptations such as use of one of the country's most common waste products, ash from rice milling, to filter out bacteria.

### **The Crisis and its Impacts**

The recent global financial crisis added some new elements to these trends. Technological learning and innovation could be adversely affected through lower R&D spending, loss of human capital from longer spells of unemployment, lower appetite for risk, and weaker international diffusion of technologies. On balance, however, the impact of the crisis on technological learning in developing countries is not clear and could actually spur such learning.

Innovation could be negatively affected, especially in developed economies, as some of the enabling conditions have deteriorated. Macroeconomic imbalances, with high fiscal deficits, do not work in favor of both private and public investments in innovation. This is important, because the decisions of firms to invest in innovative activities are sensitive to financial frictions (Ayyagari, Demirgüç-Kunt, and Maksimovic 2007; Gorodnichenko and Schnitzer 2010). The current trend toward more regulation, leaving less space for innovative financing, may have an impact on innovation and, hence, on productivity growth.<sup>10</sup> However, as inefficient firms go out of business, new opportunities emerge for learning, innovation, and leapfrogging.

Trade may also continue to suffer. The crisis brought the most remarkable trade contraction since the Great Depression. Between the last quarter of 2007 and the second quarter of 2009, world merchandise imports fell by no less than 36 percent. A recovery is under way, but the risks of protectionist measures still exist. So far, protectionism remains muted. Some trade-restrictive measures were adopted, but full-scale escalation of protectionism has largely been averted. The coverage of trade-restrictive policies (new import restrictions and trade remedy initiations) has been limited to about 0.4 percent of world



imports. But “murky protectionism” that is more difficult to quantify and categorize—including state emergency interventions and “buy local” requirements—remains pervasive. In addition, potentially higher future oil prices and policies to curb greenhouse gas emissions may lead to more regionalized trade flows, dampening the global diffusion of ideas.

Finally, the tightening of financial conditions may affect the ability of firms to finance FDI. While it is unlikely that FDI will be as constrained as debt flows over the medium term, FDI flows to developing countries—an important source of technology transfer with potentially large spillover effects—are nonetheless expected to be sharply lower in the next few years than in the period of accelerated growth in the past decade (World Bank 2010). Nonetheless, developing countries may end up benefitting from increased inflows of capital, provided the management of the recovery in capital flows is done in ways that effectively channel them to productive investments, in which case they could present a major boon to these countries.

### **Implications: Options for an Innovation Policy Agenda**

Changes in the global landscape and recent trends can have huge consequences for developing countries, both posing challenges and presenting new opportunities. With no intention to be exhaustive, in this final section we explore innovation policy options for developing countries in selected areas linked to technological learning.

First, and perhaps most important, the productivity upgrading potential provided by the huge precrisis increased flows of products, finance, and ideas makes a policy focus on technological learning imperative for developing countries. Even if the advance of the global technological frontier slows in the face of developed countries’ temporary lower investments in cutting-edge technologies, developing countries still have huge unrealized benefits from catching up to the frontier (Canuto 2009). Developing countries should therefore prioritize diffusion, technological learning, and adaptation of existing technologies. All developing countries have more to gain in terms of growth and improved living standards from the adoption of technologies that already exist in the world than from riskier and costlier invention and commercialization of

new technologies. In many developing countries, a thick clump of unproductive companies in each industry continues to operate far behind the industry's vanguard, even if one considers that economies of scale may explain part of these differences. In India, for example, a leading group in each industry—across 2,300 companies spanning makers of drugs, foods, car parts, and textiles, as well as metal-bashers and garment weavers in 16 states—was about five times as productive as the average firm (Dutz 2007). In Brazil, the disparity in productivity between leading and subsistence firms was even higher, a factor of 10 on average for several sectors (Rodríguez, Dahlman, and Salmi 2008).

Second, and related, policy makers need to better understand the binding constraints to technological learning and innovation facing businesses in their specific country settings. With all investment resources more limited postcrisis, sufficient investments in technological learning will not be forthcoming without focused policies addressing the underlying causes of perceived low returns to technological learning. Why do some business environments allow a large number of low-productivity enterprises to survive without workers and managers either learning and adapting existing ideas from best-practice firms or implementing new profit-enhancing ideas of their own, and how important is this lack of technological learning? In an attempt to address this question, Bloom and others (2010) have undertaken a randomized experiment on large Indian textile plants by giving treatment firms extensive consulting services to upgrade prevailing management technologies as a way to explore whether technological learning and adaptation of cutting-edge management practices have a causal impact on productivity. They find huge effects on productivity and profitability. The natural follow-on question is why profitable technological learning and innovation did not take place without the external intervention.

Not surprisingly, a range of interacting constraints underlie these and related manifestations of insufficient technological learning and innovation, including the following:

- Inadequate incentives for productive entrepreneurship (limited product-market competition; lack of rule of law leading to insufficient decision-making delegation; outsider consultants being unwelcome due to the breaking of tax, labor, and safety laws; and underreporting of profits)

- Insufficient management and worker skills (access and quality issues related to basic education, vocational, firm-based, and management training)
- Lack of information (insufficient use of ICT, little contact with knowledge intermediaries such as MNCs, and no benchmarking)
- Inadequate finance (even for larger firms, impeding of borrowing for management training or consultant advice and stifling of new entry and competition due to insufficient access).

This line of work suggests the need for better measures of different types of technological learning and innovation (the huge differences in levels of learning of management technologies across firms were not appreciated until they were actually measured) and for careful subsequent empirical analyses to pinpoint the binding constraints in different environments—and how they depend on complementary soft infrastructure, including competition, trade, investment, and technology policies; educational, financial, legal, and other institutions; and required local capabilities.

Finally, given the adverse impact of the crisis on the most vulnerable people, it is important to explore how technological learning and innovation can better help meet the needs of the poor. There are at least four distinct areas of policy intervention. For inclusive growth, the likely most important policy area is to foster a business-enabling environment that creates productive employment opportunities for the poor, through the generation of more and better jobs by transformational entrepreneurs. Here, to impact the productivity of enterprises across all sectors of the economy, innovation policy should seek to incentivize local spillovers rather than external leakages and to develop the absorptive capacity of enterprises.

A second policy area is the promotion of appropriate technological learning by grassroots entrepreneurs. These are typically farmers, artisans, and subsistence entrepreneurs who may have little or no formal education and who devise new solutions at the individual or collective level largely through improvisation and experimentation. The power of the Internet in diffusing productive information and spurring technological learning in rural areas is illustrated by the impact of the gradual introduction of Internet kiosks (called e-Choupals, from the Hindi for “village gathering place”) in the Indian state of Madhya Pradesh, starting

in late 2000. The kiosks display prices, along with agricultural information and weather forecasts, plus the purchase price that the sponsoring company is prepared to pay directly. In addition to cutting into vested interests by eliminating middlemen and providing price transparency, the kiosks increased the cultivation of crops and raised farmer profits.<sup>11</sup> Thus, policies that can help establish sustainable business models to spread the Internet in the poorest parts of the world can have significant impact on local innovation and livelihoods.

Registries and databases are a novel set of mechanisms which, among other things, can promote traditional knowledge (TK). The Indian Ministry of Science and Technology established the National Innovation Foundation in 2000 to provide institutional support for scaling up grassroots innovations. It does so by helping to manage a national register of innovations, including the HoneyBee Network database on grassroots innovations and TK practices. The database includes over 140,000 new or undocumented products and processes such as plant varieties, general machinery, farm implements, energy devices, livestock management, herbal remedies, and related ideas (Dutz 2007). This approach has not yet benefited from proper impact evaluation. The protection of TK and its commercialization stand to benefit from further analysis, including how to share rents from sales of products derived from collectively owned TK that is not already in the public domain, building on the experience of a variety of national and subnational experiments.

A third policy area is the support of incremental adaptation of existing technologies across the range of informal and formal micro and small enterprises in developing countries. These enterprises are often in traditional clusters and are typically characterized by limited deployment of capital and by low technical and managerial capabilities. Their main challenge is usually not commercializing new technologies but upgrading quality and productivity by reverse engineering existing technologies. Though policy makers typically understand the constraints to knowledge diffusion, learning, and innovation in these contexts, it would be helpful if they understood what structural changes need to be made to overcome these obstacles, including how to most effectively provide basic skills upgrading and to increase access to information about both existing technologies and the broader potential demand for the products of micro and small enterprises.

A fourth area of policy intervention is how to effectively spur technological learning efforts by larger formal enterprises for the poor—including the development of private products for underserved “bottom-of-the-pyramid” consumers and the development of new global technologies for public goods of high value to developing countries (such as medicines for neglected diseases or seeds and fertilizers for local soil and climate conditions). To promote technological learning in these areas, public policy may need to tilt incentives facing universities and local and global private firms toward the creation and commercialization of products that directly meet the needs of the poor, including via an appropriate mix of more favorable matching grants for early-stage technology development, tax subsidies, advance market commitments, prizes, patent pools, and open source approaches (Dutta, Dutz, and Orszag 2010). A related policy issue facing governments is to carefully allocate their public funding for basic and applied research, and to calibrate the incentives facing local researchers, so that there is a balance between following the priorities set by the global science and technology frontier (priorities that are generally driven by the interests and needs of developed countries) and addressing local needs.<sup>12</sup>

## Notes

1. Benhabib and Spiegel (2005) generalize the Nelson-Phelps catch-up model of technology diffusion, and find empirical support for the notion that human capital plays a positive role in the determination of productivity growth rates through its influence on the rate of catch-up, as a facilitator of technology diffusion and innovation. The direct performance of human capital on its own is less robust.
2. Jones and Romer (2010) insightfully claim that the powerful incentives to connect as many people as possible into trading networks that make ideas more widely available is the deep explanation underlying globalization.
3. Griffith, Redding, and Van Reenen (2004) find empirical support in a panel of industries across 12 countries for the two faces of R&D—the notion that R&D, in addition to stimulating the generation of new technologies, also enhances a firm’s learning or absorptive capacity, improving the firm’s ability to adopt existing technologies and allowing firms to more easily understand and assimilate the discoveries of others (tacit knowledge).
4. See also Dutz (2007) for a similar broad definition of innovation and a description of the four areas that provide key levers for innovation policy, namely

incentives (for diffusion and adoption of existing technologies and for creation and commercialization of new technologies), supporting skills, information, and finance. See Banerjee and Duflo (2005) for a more detailed discussion of many of these constraints.

5. Based on firm-level data from 27 emerging market economies, Gorodnichenko, Svejnar, and Terrell (2010) provide empirical support for the view that developing countries benefit (by increasing domestic firms' innovation activities) from globalization through the vertical transfer of capabilities from foreign to domestic firms (through supplying of MNCs, as well as exporting and importing, across manufacturing and service sectors).
6. See Breznitz and Murphree (2010) for examples of the rapid global decomposition of production, driven by specialization and capability building, and economies of scale and scope.
7. See Brynjolfsson and Saunders (2010), in particular, table 2.3.
8. Bloom, Sadun, and Van Reenen (forthcoming) document how learning to make better use of ICT is linked to innovations in how employees work, including decentralized decision making (to allow employees to experiment), promotion and higher-powered rewards (to encourage efficient exploitation of private knowledge), flexible work rules (to allow employees to take on new roles), and firing (to remove underperformers). Such complementary management practices allowed U.S. firms to exploit ICT-enabled innovations, and their absence in Europe explains why the United Kingdom and mainland European countries did not follow the U.S. ICT-led productivity acceleration after 1995.
9. Official statistics understate consumer spending in emerging markets, in part due to continued poor statistical coverage of spending on services. Asia, for example, is now the biggest market for many services, accounting for 43 percent of all mobile phones and for two-thirds of the increase in world demand for energy services since 2000.
10. Productivity is currently estimated to grow at rates well below those observed recently in the United States and Europe, given the serious macroeconomic imbalances and the procyclicality of productivity (Feldstein 2010).
11. Cultivation of soybeans increased by an average of 19 percent in districts with kiosks, and farmers' profits increased by 33 percent (Goyal forthcoming). By buying some produce directly, the sponsoring company (ITC Limited, an Indian company that is one of the largest buyers of soybeans) reduced its costs, which paid for the kiosks.
12. Given the important research incentives engendered by the inclusion of journals in globally recognized citation indexes, Xue (2008) argues that certain trends in global science threaten local innovation in developing countries. He highlights the need to reexamine the governance of global science to ensure that international norms and standards are more accommodating to the needs of developing countries and to include appropriate journals in local languages from developing countries that address local research priorities.

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