



# Economic Premise

JULY 2010 • Number 21

## Technological Learning and Innovation: Climbing a Tall Ladder

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*As the global stock of ideas expands and diffuses across and within countries, technological learning is poised to become an even more important determinant of growth through its impact on innovation. This note reviews global trends that make a policy focus on technological learning and innovation more important than ever for developing countries. The note explores how the recent global financial crisis may affect these trends and outlines several implications of these trends for innovation policy moving forward. Developing countries would benefit from an increased policy emphasis on technological learning and the adoption of more efficient existing technologies to generate more and better jobs and higher standards of living.*

*Innovation* is defined as new ways to solve problems by combining technology (an improvement in product, process, marketing, or organization) with transformational entrepreneurship (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—and preceded—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 do developed economies; but, more important, 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 their 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 non-rival in use. That is, ideas leak across people and firms in a way that tangible capital and other products do not; and 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 because 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 therefore are 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, or levers for innovation policy, can be organized into the following four main areas:

1. incentives for productive entrepreneurship—rule of law, sufficiently generous rewards that enable entrepreneurs to grow without fear of expropriation, sufficient competition pressures to prevent deviation from efficient innovation actions;
2. skills—including research and development 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;
3. 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; and
4. finance—including the availability of a mix of public and private financial instruments and institutional delivery mechanisms).<sup>4</sup>

This note 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. We begin by reviewing global trends that make a policy focus on technological learning and innovation more important than ever before; briefly explore how the recent global financial crisis may affect these trends; and conclude by outlining several implications of these trends for innovation policy moving forward. The main policy 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.

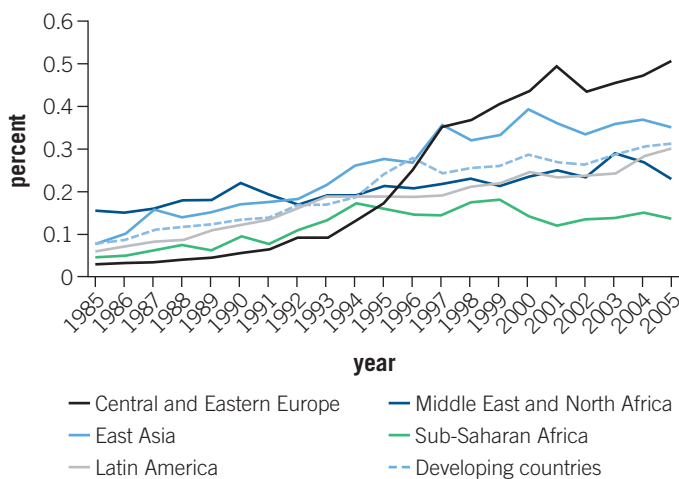
## What Has Changed in Recent Years?

Four recent trends in the world economy are (1) the increasing global knowledge flows and accompanying global decomposition of production, (2) the increasing South-South trade, (3) the increased uptake of information and communication technologies (ICT), and (4) 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 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 (WTO 2007). It is important to note that these flows have been accompanied by a continuing trend of global production decomposition, leading to an increasing spatially fragmented production and stage specialization. Vertical trade in developing countries increased from 8 percent in 1985 to approximately 33 percent in 2005 (figure 1; Pitigala [2009]). Eastern Europe and East Asia have shown dramatic 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 roughly one third of all international transactions; and, in 2000, more than 46 percent of U.S. imports were intra-firm (Corcos et al. 2009; Bernard et al. 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 en-

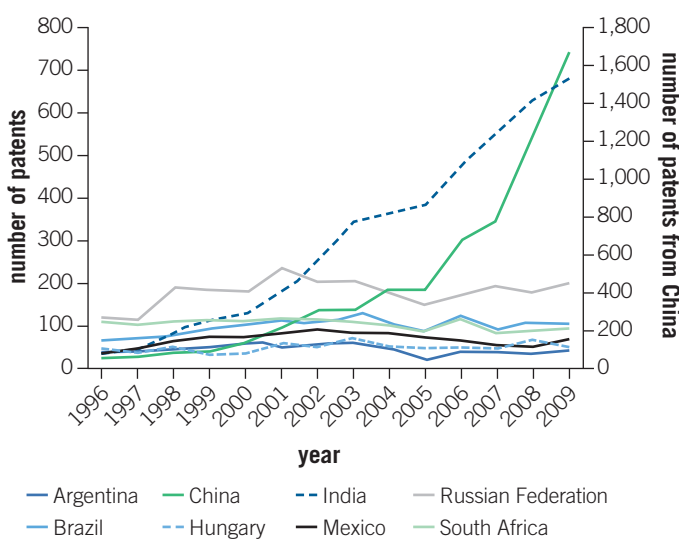
**Figure 1. Regional Trends in Vertical Specialization as a Percent of Exports, 1985–2005**



Source: Pitigala 2009.

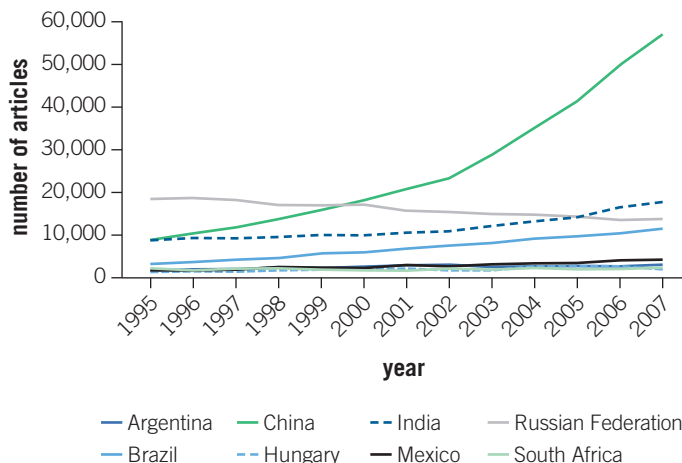
tire product. Potentially, trade in tasks could be a lifeline for countries yet to industrialize because manufacturing can start with specialization in tasks most suited to the skills available. And there is no evidence that task-based production is less technologically sophisticated than production of final products.<sup>6</sup> Recent evidence for an “emerging-eight” group 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 and 3).

**Figure 2. 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).

**Figure 3. Scientific and Technical Journal Articles Published, 1995–2007**



Source: World Bank's World Development Indicators.

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 [forthcoming]). This increase in South-South trade and knowledge flows increases the opportunities for enterprises in developing countries to learn by adapting other developing countries' technologies to local conditions. In particular, the technological challenges for many developing countries reside less in pushing outward the labor-saving technological frontier for specific product lines than in developing 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, the decline in costs, and the uptake of ICT. The effect of ICT on economies goes far beyond their production efforts and outcomes. 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—make a far bigger impact on economies. As a signal of how beneficial firms view ICT's effect on productivity, 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 (see Brynjolfsson and Saunders [2010], particularly table 2.3). And empirical evidence has been mounting that economy-wide productivity growth has been driven by innova-

tions in both products and processes in the industries that are the most intensive users of information technology (IT) (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>7</sup> One implication is that for enterprises in developing countries to exploit new IT-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) and invest more in IT.

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>8</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 et al. 2010). This new approach to innovation—also called “frugal,” “constraint-based,” or “reverse” innovation (*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 and 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 a 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, using 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 research and development spending, loss of human capital from longer spells of unemployment, a smaller appetite for risk, and weaker in-

ternational diffusion of technologies. On balance, however, the impact of the crisis on technological learning in developing countries is not clear, and it actually could spur such learning.

Innovation could be negatively affected, especially in developed economies, because 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 firms’ decisions 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>9</sup> On the other hand, as inefficient firms go out of business, new opportunities emerge for learning, innovation, and leapfrogging.

Trade also may continue to suffer. The crisis brought the most remarkable trade contraction since the Great Depression of the early 20th century. Between the last quarter of 2007 and the second quarter of 2009, world merchandise imports fell by no less than 36 percent (see Haddad and Hoekman [forthcoming]). 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. 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. Although 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 expected to be sharply lower in the next few years than in the period of accelerated growth in the last decade (World Bank 2010). Nonetheless, developing countries may end up benefiting 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 may have huge consequences for developing countries, both posing challenges and presenting new opportunities. With no inten-

tion to be exhaustive, in this final section we explore innovation policy options linked to technological learning for developing countries in selected areas.

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 temporary lower developed-country investments in cutting-edge technologies, developing countries still have enormous unrealized benefits from catching up to the frontier (Canuto 2009). Developing countries therefore should 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 considering 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; metal bashers; and garment weavers in 16 states—was about five times more productive than the average firm (Dutz 2007). In Brazil, the disparity in productivity between leading and subsistence firms was even greater: a factor of 10, on average, for several sectors (Rodríguez, Dahlman, and Salmi 2008).

A second and related option is for policy makers to better understand the binding constraints to technological learning and innovation facing businesses in their specific country settings. With all investment resources more limited following the crisis, 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 et al. (2010) have undertaken a randomized experiment on large Indian textile plants to explore whether technological learning and the adaptation of cutting-edge management practices have a causal impact on productivity. They have given treatment firms extensive consulting services to upgrade prevailing management technologies. They find huge effects on productivity and profitability. The natural follow-on question is, why did profitable technological learning and innovation not take place without the external intervention?

Not surprising, a range of interacting constraints undergird these and related manifestations of insufficient technological learning and innovation. These constraints include

1. inadequate incentives for productive entrepreneurship—limited product market competition; lack of rule of law leading to insufficient decision-making delegation; outsider consultants being unwelcome because of the breaking of tax, labor, and safety laws; and underreporting of profits;
2. insufficient management and worker skills—access and quality issues related to basic education and to vocational, firm-based, and management training;
3. lack of information—insufficient use of ICT, little contact with knowledge intermediaries such as MNCs, and no benchmarking; and
4. inadequate finance, even for larger firms—insufficient access impeding borrowing for management training or consultant advice and stifling new entry and competition.

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 actually were measured). Also needed are 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 poor people by transformational entrepreneurs generating more and better jobs. Here, innovation policy should seek to incentivize local spillovers rather than external leakages and to develop the absorptive capacity of enterprises to impact the productivity of enterprises across all sectors of the economy.

A second policy area is the promotion of appropriate technological learning by grassroots entrepreneurs. These people 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 gath-

ering place”) in the Indian state of Madhya Pradesh, starting in late-2000. The kiosks display prices, 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 have increased the cultivation of crops and raised farmers’ profits.<sup>10</sup> Thus, policies that can help establish sustainable business models to spread the Internet in the poorest parts of the world may have significant impact on local innovation and livelihoods.

Registries and databases are a novel set of mechanisms that, among others, can promote traditional knowledge. In 2000, the Indian Ministry of Science and Technology established the National Innovation Foundation to provide institutional support in championing and scaling up grassroots innovations. It supports and manages a national register of innovations, including the HoneyBee Network database on grassroots innovations and traditional knowledge practices. The database comprises more than 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 traditional knowledge and its commercialization stand to benefit from further analysis, including how to share rents from sales of products derived from collectively owned traditional knowledge 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 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 they typically are characterized by limited deployment of capital and low technical and managerial capabilities. Their main challenge usually is not in commercializing new technologies but in upgrading quality and productivity by reverse-engineering existing technologies. Though policy makers typically have a good understanding of the broad nature of binding constraints to knowledge diffusion, learning, and innovation in these contexts, it would be important to better understand the most appropriate forms of institutional infrastructure to address binding constraints in such environments—including how best to provide basic skills upgrading and how best to increase access to information about both existing technologies and broader potential demand for their products.

A fourth area of policy intervention is how best to spur technological learning efforts for the poor by larger formal enterprises—including the development of private products for underserved “bottom-of-the-pyramid” consumers and of new global technologies for public goods of high value to developing countries (such as medicines for neglected dis-

eases 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/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). Related policy issues facing governments are the careful allocation of their public funding for basic and applied research, and the calibration of incentives offered to local researchers so that there is a balance between following the priorities set by the global science and technology frontier (priorities that generally are driven by the interests and needs of developed countries) and addressing local needs.<sup>11</sup>

## Notes

1. Benhabib and Spiegel (2005) generalize the Nelson-Phelps catch-up model of technology diffusion, and they find empirical support for the notion that human capital plays a positive role in determining 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 incentive to connect as many people as possible in trading networks that make ideas more widely available is the underlying explanation for globalization.

3. Griffith, Redding, and Van Reenen (2004) find empirical support in a panel of industries across 12 countries for the two faces of research and development: the notion that, in addition to stimulating the generation of new technologies, research and development also enhances a firm’s learning or absorptive capacity, increasing the firm’s ability to adopt existing technologies, allowing the firm to more easily understand and assimilate the discoveries of others (tacit knowledge).

4. See Trajtenberg (2009); and see 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—in Dutz (2007). 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 (by supplying MNCs and by 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 by economies of scale and scope.

7. Bloom, Sadun, and Van Reenen (forthcoming) document the ways in which learning to make better use of IT is linked to innovations in how employees work, including decentralized decision making (so employees can 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 enabled U.S. firms to exploit IT-enabled innovations, and their absence in Europe explains why the United Kingdom and mainland European countries did not follow the IT-led productivity acceleration in the United States after 1995.

8. Official statistics understate consumer spending in emerging markets, partly because of continued poor statistical coverage of spending on services.

9. 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 pro-cyclicality of productivity (Feldstein 2010).

10. 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 enough to pay for the kiosks.

11. 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 the need to include appropriate journals in the local languages of developing countries that address local research priorities.

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