How to promote catch-up green innovation?

Promotion of green growth for most developing countries is typically more about catch-up innovation and the diffusion of already-existing technologies than about frontier innovation. For all countries, the cost of not adopting, adapting and using existing green technologies can be high in terms of foregone greener development. Consequently, facilitating access to environmentally-friendly technologies and stimulating their uptake are essential parts of an effective green growth strategy. In most developing countries, there is significant scope for policy to remove existing distortions and address weaknesses in the business environment that impede private innovation, in particular adaptation and dissemination of technologies from more advanced countries and within developing countries from urban to rural areas, as well as strengthening the absorptive capacity of the domestic economy.

Such policy efforts can cover a broad range, including adopting more open foreign trade, investment and technology licensing regimes, strengthening the country‘s metrology, testing and quality (MSTQ) facilities to support upgrading toward more energy-efficient technologies, improving the quality of and access to mobile phones, Internet and other communications networks, reducing domestic barriers to firm entry and exit, improving access to finance, strengthening skills and capacity development, and implementing more demand-side policies such as public procurement, regulations and standards. The section begins by surveying key policies to facilitate access to existing technologies, then discusses the critical set of supporting policies to stimulate their uptake, and concludes with a discussion of the relative effectiveness of supply-push versus demand-pull policies.

Facilitate access to green technologies

Openness to **international trade and FDI** are among the key factors correlated with adoption rates for technology. Many green technologies are embodied in imported capital goods, machinery and equipment; some are knowledge-based processes or business models and diffuse via movements of people attached to MNCs (multinational corporations) or from the diaspora; and some can be copied by studying imported final goods, or by studying patents (when elapsed) or inventing around them (when still effective). There is evidence that tariffs on renewable energy technologies and subsidies for fossil fuels do more to limit technology transfer of clean technologies than patent protection. A recent study finds that eliminating tariff and non-tariff barriers in the top 18 developing countries ranked by GHG emissions would increase imports by 63 percent for energy-efficient lighting, 23 percent for wind power generation, 14 percent for solar power generation, and 4.6 percent for clean coal technology. In a study of electric power plants in India, Khanna and Zilberman (2001) find that removing import barriers to higher-quality coal would increase the adoption of more energy-efficient technology and potentially decrease carbon emissions.

The **Clean Development Mechanism** (CDM) of the Kyoto Protocol is an explicit mechanism to boost technology transfer and diffusion, as it allows high-income countries to develop or finance GHG emissions reduction projects in developing countries in exchange for emission reduction credits. However, high-income country investments tend to be small when compared to FDI. Based on an analysis of GHG mitigation technology transfers, Dechezleprêtre et al. (2008) show that international transfers have taken place in less than half of the CDM projects, typically combining transfer of equipment with knowledge and operating skills. They also find that most technology transfers concerned end-of-pipe destruction of GHGs in chemical, agricultural and waste management industries (highly specialized, with very little spillover to greening in the broader economy), and wind power. Other projects such as electricity production from biomass or energy-efficiency measures in manufacturing mainly rely on local technologies. In principle, there is an ambiguous relationship between local absorptive capacity and international technology transfer: while high technological capabilities may be required to adopt new technologies, high capabilities also could imply that many technologies are already available locally thereby reducing the likelihood of international transfer. They find that the first effect strongly dominates in the energy and chemical industries, while the second effect dominates for agricultural projects (suggesting that agricultural technologies transferred tend to be simpler). Their findings (2008, 2009) highlight the importance of local capacity building as a means to accelerate technology diffusion – with a strong push by local/municipal governments to strengthen technology capabilities facilitating both the importation of foreign technology and the local diffusion of domestic technologies.

Additional mechanisms to foster increased access to existing technologies include patent buy-outs, compulsory licenses, patent pools and open source approaches. A **patent buy-out**, as outlined by Kremer (1998), is a mechanism to increase access to existing products, or to future products that already benefit from adequate innovation incentives. The idea behind patent buy-outs is that a purchaser –for instance, an international financial institution, government or private foundation– acquires exclusive marketing rights for a patented global green product from the patent owner and offers a non-exclusive, no royalty license to any legitimate generic manufacturer to sell the product in certain target developing country markets. The patent owner is compensated under a buy-out formula. Generic pricing through multiple manufacturers prevails in the target developing countries. Regular patent-based pricing remains in all other countries. The key problems with buy-outs are the development of a mechanism to determine the buy-out price and the availability of a purchaser of the patent at the determined price. Providing more scope for compulsory licenses by making it easier for countries to issue them is another complementary way to reduce some of the inefficiencies associated with the current patent system, and ensure more affordable access to patented green innovations by poorer households in low-income countries.

In a **patent pool**, a group of patent holders agree to license a combined set of patents to one another (a closed pool) or to any party (an open pool). Patent pools have been proposed as a solution for inefficiencies that arise in the patent system when too many related fragments of patents are necessary to develop future inventions. As an illustration of a concrete initiative on this front in the context of developing country needs, the international drug-purchasing facility UNITAID agreed to provide funding for a Medicines Patent Pool, which was then established as a Swiss foundation in July 2010 to focus on increasing access to HIV medicines in developing countries. It provides a 'one-stop shop' voluntary licensing service that pools multiple patents and licenses them, with patent holders getting royalties on the sales of adapted more affordable generic medicines, and generic manufacturers getting access to broader markets. A similar approach could be used for neglected seeds for drought-prone, saline environments, or for other patented green solutions for lower-income countries.

Generally broader in scope than a patent pool, **patent commons** allow technology holders to pledge their patents for widespread use for no royalty payment. In January 2008, the not-for-profit Eco-Patent Commons initiative was created by a few large MNC patent holders in cooperation with the World Business Council for Sustainable Development. As of mid-2011, over 100 patents have been pledged by 13 participating MNCs, with all pledged patents automatically licensed royalty-free provided they are used in a product or process that produces some environmental benefit. Based on a recent analysis by Hall and Helmers (2011), pledged patents do appear to be climate-change related, though more in the form of environmental clean-up or clean manufacturing. However, evidence to-date suggests that there has been no discernible impact on the diffusion of the knowledge embedded in the protected technologies to other patenting firms. A related development on this front is **open source** innovation, where a body of original information or technology platform is made publicly available for others to use and adapt. The Open Source Drug Discovery (OSDD) initiative launched by India‘s Council of Scientific and Industrial Research (CSIR) in September 2008 is one such platform. OSDD is a public-private partnership between industry and academia in open source mode, with the purpose of hastening the discovery of drugs for neglected diseases through collaborative exchange of information. Again, a similar approach could be used for neglected green innovation needs for lower-income countries.

Stimulate absorption of green technologies

Absent environmental social costs being fully reflected in market prices, demand-side innovation policies including **public procurement, regulations and standards**, together with effective enforcement, are typically needed to stimulate both creation and diffusion of green technologies. They include guaranteed feed-in tariffs for renewables, taxes and tradable permits for emissions pollution, tax credits and rebates for consumers of new technologies (e.g. for compact fluorescent light bulbs), comparison labeling (to inform consumers about the relative efficiency of products), endorsement labeling (e.g. 'CFC-free'), government rules (e.g. limits to polluting emissions from industrial plants), and industry-driven standards (e.g. home and office building insulation). Because they can be such an important pre-condition to the diffusion and absorption of green technologies in developing countries, they are treated in this section. In contrast to most technologies which are adopted because they are inherently cost-reducing or revenue-enhancing to firms, green technologies are often more costly to adopt by firms and not immediately more attractive to end-use customers. Hence these demand-side policies are needed to provide a critical incentive to trigger their adoption. Inventors will not develop and firms will not adopt technologies for which there is insufficient demand.

Improving a country's **financial infrastructure** also can have significant effects on green growth by, among others, providing funding for adopting green infrastructure, and enabling farmers to adopt higher-return technologies that both decrease crop losses and decrease vulnerability to the losses. Barry et al. (2011) examine the adoption of efficient stoves, biogas plants and tobacco barns by commercial farmers in Malawi, Rwanda and Tanzania; financing was cited as the main stumbling block for all projects because of high start-up costs. Brunschweiler (2010) finds across a range of low-income countries that an increase in financial intermediation has a significant effect on non-hydro renewable energy generation per capita, because investment in renewable energy is constrained in environments where access to long-term loans is limited. And D'Agostino et al. (2011) find that access to financial credit is an important barrier to solar home systems adoption in China. Echoing this theme of the important supporting role of bank financing, Wolf (2011) explains how the largely bank-based, relationship-based financial systems played a key role in supporting the lower-risk technology absorption by firms during the reconstruction of continental Europe after World War II and in the subsequent years when income convergence was the main challenge.

Finally, three issues are particularly relevant for developing countries. First, as global green technologies improve, the **falling costs of adoption** relative to existing non-green technologies facilitate their adoption by firms. They also lower the costs of adopting the relevant environmental regulation by governments. In their study of the adoption of regulations limiting emissions of nitrogen oxides (NOX) and sulfur dioxide (SO2) at coal-fired plants across 39 developed and developing countries, Lovely and Popp (2011) show that countries adopting these regulations at later dates do so at lower levels of per capita income than adopters who enacted similar regulations earlier. The availability of the technology at lower cost should help shape the regulation that is required as incentive for firms in lower income countries to adopt it.

The second issue concerns the potential **longer-run benefit of well-designed environmental regulation** in enhancing innovation and competitiveness, and the extent to which benefits may more than fully offset the cost of the regulation. Especially in less mature markets characterized by inadequate physical and institutional business infrastructure prevalent in many developing countries, firms may miss profitable green investment opportunities because they are too risky, too costly for the manager, or out of the manager's habits, routines and technical expertise. By making these investments more profitable or requiring them, environmental regulations can help the manager overcome these problems. In line with this view, Alpay et al. (2002) estimate the productivity of the Mexican food-processing industry to be increasing with the pressure of environmental regulation. And in a sample of 17 Quebec manufacturing sectors, Lanoie et al. (2008) have found that stricter regulations led to modest long-term gains in productivity – first reducing productivity in year one, having a slightly positive effect in year two, and then resulting in more positive outcomes in years three and four, more than offsetting the first year's loss. Most empirical studies of the impact of well-designed environmental regulations in high-income countries have found that they stimulate innovation by firms as measured by R&D spending or patents. However, there is relatively little overall evidence to-date that the induced innovation is sufficient to overcome the added costs of regulation, with 10 of 13 studies surveyed by Ambec et al. (2011) finding that the net effect of environment regulation on productivity or profitability is negative. In terms of design of environmental regulations, the literature emphasizes that policies should strive to be win-win compatible, in particular focusing on end results rather than means, and be stable and predictable.

A third issue concerns the use of emerging **international sustainability standards** for products and processes as an instrument in helping local firms upgrade their environmental practices, a form of catch-up innovation for business practices. The linking of local firms to the global value chains of MNCs that have adopted sustainability standards helps leverage international market pressures for environmental improvement.

The relative effectiveness of supply-push versus demand-pull policies

Different mixes of policy instruments are likely to be effective for countries at different stages of technological sophistication. Some recent empirical evidence suggests that a greater emphasis on targeted supply-push government R&D funding, when local technological capabilities are in place, is more effective than demand-pull policies at generating radical, new-to-the-world frontier innovations. This evidence is based on patent applications filed worldwide from 1994 to 2005 in wind power technology: the marginal million dollars spent on public support to R&D (mostly tax credits on private R&D expenditures received by companies once expenditures have been incurred) generated 0.82 new inventions whereas the same amount spent on demand-pull policies induced at best 0.06 new inventions (Dechezlepretre and Glachant, 2011). A separate case study to assess the extent to which demand-pull policies stimulated non-incremental (radical) change in the California wind power industry in the 1975-1991 period also finds no evidence that demand-side policies alone encouraged more radical frontier-type technical change (Nemet, 2009).

However, for technologies that are more mature, a greater emphasis on demand-side policies may be more effective in spurring firms to introduce more incremental innovations. Existing or future environmental regulations, followed by market demand from customers, are identified by firms in most countries as the main driver of introducing environmental innovations (based on firm responses in 16 countries as part of the 2008 EU Community Innovation Surveys). The availability of direct public support in the form of fiscal incentives is the least important reported motivation in all countries. Interestingly, in most countries surveyed (15 of 19 for this question), a larger percentage of innovative firms perceive the environmental benefits of innovation to be on the cost side (in terms of reduced energy use per unit of output) than on the revenue side (in terms of customers being willing to pay more for new products that reduce energy usage by end-users). This suggests that most of these innovations are likely to be incremental process rather than more radical product innovations.

Thus, it appears that a greater emphasis on supply-side policies may be more effective in stimulating more radical frontier innovation when local capabilities are in place, a greater emphasis on demand-side policies may be more effective in spurring firms to introduce incremental environmental innovations (both frontier and catch-up). The available evidence does not contradict a judicious combination of supply-side and demand-side policies, appropriate to the local context.

Develop broader absorptive capacities

Policies to overcome the **stigma of failure** and encourage opportunities for re-entry and renewed experimentation seem to be important drivers of innovation. The US approach to corporate bankruptcy puts economic resources back to productive use as quickly as possible, either saving viable companies from premature liquidation or putting pressure on courts to restructure assets quickly. While closing a terminally ill business takes less than 10 months and allows over 90 cents on the dollar to be recovered in Canada or Singapore, it still takes on average 7 years in Mumbai to recover roughly 16 cents on the dollar (World Bank 2011). Although difficult legal reforms and changes in attitude to debt are involved, making it easier to wind up businesses is one of the best ways to get more people to try out new ideas and start them. In addition, it would probably also be helpful to make existing innovative role models more widely known, such as India‘s Tata group awarding an annual prize for the best failed idea. So would policies that reduce the level of sunk costs required to try out a commercializable idea in the first place. This includes improving the depth of resale markets, so that fixed assets such as the machines in a production line that didn‘t work out can be quickly and easily resold. And removing impediments for electricity and IT-serviced business premises to be easily leased or rented rather than requiring more significant investments in own assets while the market size for a product is not yet known.

Facilitating **global connectivity** of people through global alliances and insertion of firms into global value chains also is critical for enhanced learning. In both China and India's rapid development of wind energy capabilities, while licensing agreements with European manufacturers to gain initial access to turbine technology were important, international mobility of workers was as important if not more so: Suzlon, the top Indian wind turbine manufacturer, established R&D facilities in Germany and the Netherlands to have its workers learn from global expertise, while Goldwind, the top Chinese manufacturer, sent workers abroad for training. Fibrovent Wind, a Chilean wind turbine blade start-up that was created by inserting itself into a Spanish global value chain, also benefited from international mobility of skilled workers: in addition to South-South transfer of equipment knowledge, there was transfer of management knowledge when a Brazilian wind turbine expert was hired to help set up the company. There was also knowledge transfer about composite materials from the Chilean mining industry, highlighting the importance of local absorptive capacity in effective technology transfer. Learning networks also appear to have been critical in the development of China's photovoltaic (PV) industry: of the top 9 PV producers, only three received FDI while all firms exchanged knowledge with equipment suppliers and benefited from training sessions of engineers and technicians. Finally, a recent public-private partnership program —that uses large MNC ‗anchor' companies to solicit SME participation and provides education to increase productivity, competitiveness and environmental performance— appears to offer a promising model for diffusing eco-efficiency techniques to SMEs: during the 2005-07 pilot phase of Mexico's Green Supply Chains Program, 14 MNCs with operations in Mexico participated together with 146 SMEs, with the average SME participant generating environmental improvements of reduced water and electricity usage, carbon dioxide emissions and waste disposal, as well as sizeable economic savings, together with improved supply chain relationships. The impressive results suggest the presence of win-win opportunities for eco-efficiency projects to both save money and reduce environmental damages, no doubt driven by unexploited benefits from improved information dissemination, mentoring and learning.

A final policy area ripe for joint national and local policy reforms in coordination with the private sector is the **urban dimension of entrepreneurship development**, namely enhancement of the livability and "stickiness" of cities, to attract and retain talent. The shift in population as workers move from rural agriculture to urban areas that facilitate face-to-face learning and creative interactions between young entrepreneurs, skilled people, and institutions connected to global knowledge should help unleash innovation (Glaeser, 2011). Dense urban-industrial cluster agglomerations have been vital for technological upgrading and productivity growth by opening opportunities and stimulating supplies of capital and skills. China's establishment of special economic zones, followed by a range of support by national and local governments for further industrial deepening in its three major urban/industrial agglomerations (the Pearl River Delta centered on Shenzhen, Dongguan and Foshan, the Yangtze River region around the Shanghai-Suzhou axis, and the Bohai region in the vicinity of Beijing and Tianjin) and in a number of inland cities (including the footwear cluster in Chengdu and the Wuhan opto-electronics cluster) highlights how a mix of instruments can be employed together, including support to science parks and extension services, encouragement of local universities to deepen industrial linkages, attracting a major local or foreign anchor firm that can trigger the in-migration of suppliers and imitators, and above all dense transport and communication connectivity infrastructure (Yusuf, Nabeshima and Yamashita 2008).

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