

## How to promote frontier green innovation?

A portfolio of policies for frontier innovation can generally be thought of as having both supply-side "technology-push" elements that reduce costs of knowledge creation in advance of commercialization, and demand-side "market-pull" elements that enhance net revenue from sales after commercialization. Stimulating appropriate innovations will likely require use of multiple incentives that affect investments on both cost and revenue margins.

New frontier technologies can be created and commercialized even in countries where average technological capabilities are relatively less sophisticated, provided there are one or more agglomerations of firms with sufficient technological capabilities, ideally supported by sufficiently high-quality higher education systems – provided the benefit-cost of public support is sufficiently high to warrant expenditure of scarce public resources relative to alternative uses. This can be achieved by taking advantage of the heterogeneity of public and private capabilities, with the participation in public-private dialogue processes of better-performing firms and parts of the public sector in whatever sector and urban/rural setting they are located within countries.

### Figure 1. Revealed technology advantage in environment-related technologies

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### Limit local technology-push support to countries with sufficient technological capabilities

Direct **government funding** for R&D is an important element of many innovation systems, including funding of public labs and universities, as well as grants, matching grants, soft loans, and R&D tax subsidies to private firms for early-stage, pre-commercialization technology development (for individual firms, and for collaborations between firms, and between firms and public labs/universities). Government-funded R&D of public R&D institutes is the traditional supply-push mechanism, with selection of whom to engage in research projects bureaucratically rather than market-determined, ideally through a group of independent peers (when the research-awarding process is not captured by rent seekers). One advantage of this approach is that it allows coordination of research efforts with little or no excess duplication. With respect to dissemination, publicly-produced knowledge should generally be made freely available, which is socially desirable to ensure efficient use once produced. A key shortcoming of government-funded R&D is that, as research moves from basic to more applied phases, incentives are not strong to reflect information from markets about what consumers want and are willing to pay for.

Frontier green (and non-green) innovations that are dependent on significant formal R&D support have to-date largely been concentrated in high-income countries and a few more technologically advanced developing countries, with most developing countries having little such innovations as indicated by patent data. So there is likely a more limited role for formal R&D support for frontier innovations in most developing countries, to the extent that such spending reflects underlying technological capabilities.

In contrast to the supply-push of government R&D funding, **patents** were initially devised as a decentralized demand-pull self-selection mechanism, allowing those who believe they are the most likely to succeed to risk their own resources for the 'prize' of a period of exclusivity during which they can set product prices, with the quid pro quo of full disclosure of the knowledge to other researchers. In practice, significant public funding of R&D, both to public and private entities, typically accompanies the own-resources of the researchers toward the development of patentable ideas. Patents can serve a useful signal for private finance. However, well-known problems with the patent system are that it is distortionary and inequitable in the way funds to support further research are raised, namely by charging monopoly prices, and inefficient in the way usage of new knowledge is

restricted. Researchers also face significant litigation risk. Moreover, although innovation incentives are strong in the patent system, they are distorted because there are incentives to engage in research to innovate around existing patents and to spend resources in ways that extend the life of patents. There are also other market distortions such as the largely socially-dissipative advertising and marketing expenditures designed to reduce the elasticity of product market demand in order to raise prices and profits.

Once new commercializable ideas have progressed to the proof of concept stage that demonstrates their feasibility, whether or not protected by one or more patents, further **early-stage technology development (ESTD)** finance is required. The range of ESTD finance options includes both public and private resources, with private sources at this early stage typically restricted to friends and family, angels (affluent individuals, often retired successful entrepreneurs, providing start-up capital and mentoring), venture capital (VC), private equity firms (at later stages), and private corporations (who fund ideas developed in-house and acquire young start-up companies); cheaper sources of financing, such as bank finance, are usually not available for most early-stage ventures as they are too small or young to qualify for traditional loans. Angels and VC investors make money through successful exits based on a sufficient deal flow, with the typical liquidity event being an acquisition or an initial public offering (IPO) on a local or international stock market. If the IPO market is weak with not enough companies going public, then the VC business model is threatened. The challenge facing most developing countries in this area is that these capital market-based, arms-length forms of finance that structure and price each transaction on its merits require deep financial markets underpinned by demanding institutional legal and regulatory frameworks, with monitoring and enforcement mechanisms relying on extensive formal disclosure and corporate governance standards. This is not an area where public interventions such as jump-starting a new VC industry have been successful on average – which is why the recommendation for most governments is that they should focus on "setting the table" rather than "cooking the meal" by ensuring that the basic underpinnings are in place of rule of law, contract enforcement, and broad certainty in legal and regulatory frameworks (Lerner 2009).

### **Provide global technology-push support for BoP and neglected technologies**

It is not advisable for countries with low technological capabilities and no comparative advantages in creating frontier technologies to be dedicating significant public resources to this objective within their own country. However, given the global nature of the benefits from green innovation, stable, long-term global public spending on R&D needs to increase and be channeled into programs that facilitate the development and adoption of technologies applicable to developing country contexts.

**Prize** funds are one relevant demand-pull mechanism to promote technologies at the global level for the needs of countries with lower technological capabilities, and for BoP and neglected needs. Typically, a pre-announced prize is given to whoever comes up with an innovation that meets defined objectives. Prize funds are most appropriate when objectives can be well defined but the technologies are unknown. The researcher only gets the guaranteed return, in principle more than sufficient to cover time and other resources spent, if the research is successful before that of rivals. Prizes can be designed to be paid out only when specific outcomes are delivered. The size of the prize and the number of prizes can be calibrated by the novelty and magnitude of contribution of the innovation. Like patents which are a form of prize, these more generic prizes are decentralized and based on self-selection. However, once the prize is awarded, developed knowledge can be made freely available, widely disseminated and used by all.<sup>24</sup> A proportional prize makes rewards proportional to the measured impact of any successful innovation, providing incentives to public and private sectors to generate evidence on the results of innovations, measured for instance by the degree of adoption and productivity improvement – though auditing and verification costs can be relatively high.<sup>25</sup> Ideally, the award process should require revelation of information on the innovation so that it can then be broadly disseminated. Such prize funds are particularly relevant for promoting more radical green innovations that are likely to be fostered not through the traditional linear R&D approach but rather through out-of-the-box new knowledge involving co-creation and co-design by scientists, engineers, entrepreneurs, producers and users from different disciplines. Box 6 presents a few of the green prizes that have been set up over the past years.

**Advance Market Commitments (AMCs)** are another demand-pull mechanism complementary to prizes. AMCs are most appropriate when key characteristics of the desired technology are known and can be specified in a contract. With AMCs or purchase guarantees, sponsoring international financial institutions, governments and/or private foundations make a legally-binding contractual commitment at a pre-specified price to purchase a given quantity of a qualifying product when that product becomes available on the market, without any winner-take-all requirement. According to a proposal by Barder, Kremer and Williams (2006), the AMC could be split; for example, a low-income country could commit some part of the purchase price and donors could make up the difference. The contracts may also include provisions requiring manufacturers to license their technology after the agreed-upon quantity had been purchased, or to sell further units at low prices.

In the first real-world pilot of this mechanism, a group of governments and private foundations in 2007 committed \$1.5 billion for a Pneumococcal AMC. The pneumococcal vaccine was chosen because it has a large health impact, suitable vaccines for developing countries are already in development, and the AMC can speed the products to market.<sup>26</sup> Although AMCs have so far been applied to provide affordable access to healthcare in low-income countries, the approach could be applied in a similar manner to stimulate innovations and widespread access to more affordable green solutions, such as a nutrient-fortified staple food crop or an improved storage technology in contexts of land and water scarcity, climate change, and declining crop yields.<sup>27</sup>

More generally, a strong case exists for a pool of long-term, stable funds for basic research on important frontier green innovation areas for developing countries, whether allocated through prizes, AMCs or other mechanisms.<sup>28</sup> Issues to be addressed include:

- most effective modalities for global research efforts on important topics for developing countries, including total amount of required global resources and resource allocation by areas of need and by geography (including best forms of engagement of R&D networks in developing countries), and how best to capture demand on what is most important to ensure the research is user-relevant;
- lessons from experience with encouraging development of more general purpose technologies (GPTs) such as ICT, materials, nanotech and biotech rather than spending on specific green policy areas, and on stimulating convergence across GPTs;
- the experience with institutional protections to avoid delivering subsidies to favored firms, industries and other organized interests – such as multi-year appropriations, agency independence in making grants, use of peer review with clear criteria for project selection, and payments based on progress and outputs rather than cost recovery;
- the extent of IFI coordination and assistance, given that direct support puts greater demands on government capabilities, which are typically weaker in developing countries.

## References

- Dutz, M.A. and S. Sharma (2012), "Green Growth, Technology and Innovation", Policy Research Working Paper 5932, World Bank, Washington.

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