Gaining competitive advantage with green policy

by Stefan Ambec
INRA Research Professor
Toulouse School of Economics

Sustainability should be part of the development process. Economic growth is often associated with more pollution and the degradation of ecosystems, which in turn negatively impact human health and economic activities relying on natural resources. Yet, despite this negative feedback of poor environmental quality to the economy, policy makers are generally reluctant to impose more stringent environmental regulations on firms. They fear that it might erode firms' global competitiveness, thereby slowing down the development process.

The conventional wisdom concerning environmental protection is that it comes at an additional cost to firms. Reducing pollution from production processes requires that firms replace dirty inputs by cleaner but costlier ones, and therefore switch to more expensive technologies, invest in devices that clean-up polluting emissions, treat their waste, recycle water, and improve energy efficiency. All these strategies add new expenses to their balance sheets. Such expenses can nevertheless turn out to be profitable in the long run.

The aim of this chapter is to review economic arguments and to show that the additional cost of environmental protection can sometimes lead to a competitive advantage for firms. This implies that green policy can boost a firm's competitiveness while at the same time improving environmental quality. We distinguish between four channels for which green policy might enhance competitiveness. First, green labels enable firms to differentiate their products from those of their competitors. In Section 1 we explain why this product differentiation strategy can be profitable and what the role of public policy can be. Second, firms can make money by selling and adopting green technology. As explained in Section 2, this argument applies particularly to climate-friendly technologies that are bought by developed countries due to energy mandates, or financed by carbon offsetting projects in developing countries. Third, investment in greener technology might lead to productivity improvements that more than offset the additional costs of environmental protection. This argument relies on the well-known Porter Hypothesis that we review in Section 3. In Section 4 we examine how green policy can increase competitiveness due to knowledge spillovers in the innovation process. We conclude with policy recommendations for designing green growth policies that are likely to leverage competitive advantages in international markets.

1-Higher market shares by differentiating products based on environmental quality

1.1 Supplying greener products as a vertical differentiation strategy

Firms can reduce their negative impact on the environment by improving the environmental quality of their products throughout their lifecycle. They can use less polluting inputs (e.g., fewer pesticides or other harmful chemicals), increase their share of renewable sources of energy (e.g., wind and solar power), or adopt sustainable production procedures (e.g. replant forests after harvesting or use fishing practices less damaging to ecosystems). They can also make their product easier to recycle, and can save on packaging.[1] Firms are sometimes forced to do so when governments set more stringent standards, but in many cases firms go beyond minimal standards on environmental quality.

Supplying greener products generally entails additional costs. By going beyond mandatory standards and thus increasing their costs, companies put themselves at a disadvantage compared to competitors. Yet they might be able to recover this extra production cost through revenue if consumers agree to pay more for environmental quality. Supplying greener quality products can be viewed as a vertical differentiation strategy. Firms can enjoy a competitive advantage by differentiating their products from those of competitors, with regard to environmental quality. By doing so they move away

[1] Haned et al (2015) have investigated the "ecodesign" practises based on life-cycle analysis implemented using a questionnaire. In their sample, 45% of the firms found those practices profitable.

from the head-on competition among perfectly substitutable products that erodes profits. They take advantage of market power in a niche of consumers who are willing to pay more for greener products. Ultimately, the price premium on greener products can offset their higher production costs. Such a successful vertical differentiation strategy requires that consumers be able to identify products with higher environmental quality, through eco-labels.

1.2 Labelling and certification

Firms can signal the higher environmental quality of their products through certification and labelling. Examples include the Forest Stewardship Council (FSC) certificate for wood produced from sustainably managed forests, and the Marine Stewardship Council (MSC) certificate for seafood harvested using sustainable fishing procedures. Organic food labels issued by the U.S. Department of Agriculture or by the European Commission are presently one of the most popular ways to differentiate products in the food industry. This does matter, since the similitude of many agricultural products means that differentiation is often the only way to secure a competitive advantage. Organic food labels are well known by consumers and often supported by public authorities.[2] This system induces higher costs and lower yields for producers at least in the short run as it restricts the use of many inputs (pesticides, antibiotics, fertilizers).[3]

Fair trade labels also have a green component insofar as they favour less intensive agricultural practices. Environmental criteria in fair trade production include the banning of certain harmful chemicals, reduction of the use of pesticides, and promotion of natural biological methods to preserve soil and biodiversity such as crop rotation. Evidence shows that producer-label fair trade and organic products enjoy higher prices. For instance, in a survey of coffee producers in Central America and Mexico, Méndez et

---

[2] In a recent paper on subsidies provided by the European Union in France to encourage greener agricultural practices, Chabé-Ferret and Subervie (2013) found that conversion to organic farming was the most cost-effective practice among all agro-environmental schemes implemented in France since many farmers would not switch to organic without the subsidy.

[3] For instance, Ramesh et al. (2010) found that organic farming reduced yields by 9.2% on average in the sample of certified farms they surveyed. This figure dropped to 20% for rice and wheat and was up to 25% lower than conventional farming for cotton.

al. (2010) found a significant positive correlation between average sales prices for coffee for both fair trade and organic labels. In Nicaragua, Bacon evaluated an average price of \$0.84 per pound for fair trade coffee,[4] \$0.63 for organic coffee and \$0.41 for conventional coffee in 2000-2001 (see Dragusanu et al. 2014 for a survey).

The final consumers are not the only ones to value the environmental attributes of products. Private companies often take steps to green their supply chain. For instance, production plants involved in the ISO 14001 certification procedure commit to using environmental performance criteria for selecting their suppliers.[5] Governments also favour products and suppliers with better environmental performance through green public purchasing policies. In the U.S., the Federal Acquisition Regulations provide detailed rules governing procurement by all federal agencies. For instance, these rules specify that the Environmental Protection Agency (EPA) has to prepare guidelines on the availability, sources, and potential uses of recovered materials and associated products, including solid waste management services. They require federal agencies themselves to develop and implement affirmative procurement programs for EPA designated products (Kunzik, 2003: 203).

1.3 Labelling and certification: a role for green policy

For the vertical differentiation strategy to be successful, the eco-label should convey credible and transparent information to consumers. Credibility requires that consumers trust what a label means in terms of environmental protection. The criteria for labelling and its implementation should be advertised in an understandable way for non-experts. Procedures for certification should be immune to corruption and manipulation by companies that would like to "greenwash" their own products, i.e., obtain a green logo without paying the cost in terms of environmental protection. The label itself should be legible and easily identifiable by consumers. Public policy can help on that matter in several respects. Public administrations can facilitate the definition and dissemination of labelling criteria, support certification by agencies and NGOs, ensure the traceability of

[4] Price paid to farmers at farm gate net of costs paid to the cooperative for transport, processing, certification, debt service, and export.

[5] In a sample of four thousand facilities in seven OECD countries, Johnstone et al. (2007) found that 43% assess their suppliers' environmental performance.

products along the supply chain, and simplify and harmonise the framing of labels to consumers. At a country level, public authorities should make labelling on international markets both feasible at a reasonable cost, and credible. This does not necessarily mean setting up their own labels. Relying on the most respected and internationally known labels often turns out to be a more effective strategy. Public administrations should facilitate the implementation of the more successful eco-labels within their juridical boundaries. This would open the door to international markets in regions where the labels are valued, especially in higher income countries. It would also attract foreign investment in firms supplying labelled products.

2- Selling and adopting green technologies

2.1 Environmental policy triggers the demand for green technologies

Environmental constraints are not detrimental to all sectors. Solving environmental problems has become a business opportunity for the companies supplying pollution-control technologies. For instance, the implementation of more stringent air quality standards in Europe and the US increased the demand for scrubbers to filter SO2 and NOx emissions from coal power plants. It also fostered innovation in scrubber and coal combustion as more patents were issued following the application of the regulation (Popp 2006). The growth of the so-called "eco-industry", which supplies technologies that mitigate or clean-up pollution, is driven by government interventions on environmental protection.

Government strategies are not limited to more stringent standards to fuel the demand for pollution-control technologies. Subsidies are a more popular means and are therefore widely used to support cleaner but often more costly technologies. Firms can make money by harvesting those subsidies. Perhaps the most famous example is the feed-in tariffs for renewable sources of energy implemented in more than 50 countries including many developing countries. Public authorities have committed to buy electricity produced from wind and solar power at a fixed price well above the wholesale market price. Some countries like the U.S. have opted for renewable portfolio standard programmes, which generally require a minimum proportion of electricity demand to be met by renewable sources. Those programmes are usually implemented on the basis of renewable energy certificates issued by state-certified renewable generators. Those entities exceeding their renewable energy obligations can earn money by selling certificates to other entities that fail to meet their obligations. Both types of support to renewables have been very successful. They have boosted the wind and solar power industries not only where they were implemented but also abroad. Massive investment in solar power in countries like Germany has not only given jobs to new companies involved in installing photovoltaic (PV) panels, but has also contributed to making China the largest solar PV cell producer in the world (see Pegels in this volume).

2.2 Photovoltaic in China

The exponential growth of photovoltaic installations from 2003 to 2009 was concentrated in a few developed countries, primarily Germany, Spain, Japan and the US. Yet, during this period, the production of photovoltaic cells moved to emerging economies, notably China. Starting with a 1.6% market share for cell and module assembly production in 2003, China became the world leader with a 35% market share in 2007, just five years later, followed by the European Union, with 29% market share.[6] China's share manufactured PV panels has grown to 50% in 2015.[7] This shift of leadership from Europe to China has triggered much criticism in Europe's policy debate as feed-in tariffs were supposed to give first-mover advantages to European companies in the wind and solar power industries. They did indeed benefit activities that were not exposed to international competition, such as PV installation. However, China took advantage of low-cost labour and relatively cheap energy to set up cell production and module assembly lines without much prior experience in manufacturing cells. According to De La Tour et al. (2011), China managed to obtain the technology through two channels. First, they hired highly skilled executives trained abroad in universities or in the PV industry.[8] Second, they attracted foreign direct investment under a policy that forced foreign investors to accept joint ownership. Such joint ventures are likely to induce more knowledge spillovers between the foreign investor and the local firm. From

[6] Source : De La Tour et al. (2011)
[7] Source : http://solarcellcentral.com/index.html
[8] De La Tour et al. (2011) report that 61% of the board members of the three largest Chinese PV firms have studied or worked abroad.

a country receiving technological transfers, China became one of the main innovators in photovoltaic solar.

2.3 CDM and carbon offset

Companies in developing countries have benefited from another policy involving transfers from developed countries: the Clean Development Mechanism (CDM) part of the Kyoto Protocol (KP). This policy allows greenhouse gas emitters subjected to emission reduction obligations (in countries included in Annex B of the KP) to offset their own emissions by investing in emission-reducing projects in other countries (non-Annex B countries). The aim is to take advantage of cheaper mitigation opportunities in developing countries. The CDM can be used by companies (e.g. electricity producers, cement and glass manufacturers, etc.) involved in the European Union Emission Trading Scheme (EU ETS) to obtain new allowances. It has been substantial: during phase 2 (2008-2012) around 1 billion tonnes of CO2 credits where brought in the EU ETS by participants.[9] More generally, many firms meet corporate social responsibility obligations by offsetting their own carbon emissions through carbon credits granted by the CDM.

The CDM creates carbon credits based on projects certified by the UNFCCC provided that an emission reduction is "additional" to any that would have occurred in the most plausible alternative scenario to the implementation of the CDM project (e.g. business-as-usual scenario). Projects must also be accredited by the host government, based on sustainable development criteria.[10] The additionality criterion has been criticised for creating perverse incentives for developing countries as it rewards the absence of climate mitigation policy (e.g. subsidies to renewables). The CDM has nevertheless been very successful in bringing foreign direct investment into developing countries. It has turned into a lively market with 180 transactions (i.e. accredited CDM projects) for $2.5 billion in total in 2005 and up to $6.5 billion in 2008 (Lecoq and Ambrosi 2007, Kossoy

[9] Source : European Union:
http://ec.europa.eu/clima/policies/ets/linking/index_en.htm

[10] See Olsen and Fenhann (2008) for a description of the criteria and process for accreditation by national authorities in China, India, Brazil, Mexico, South Africa, Morocco and Armenia.

and Ambrosi 2010). One drawback of the CDM is that projects have been concentrated in few emerging countries, mainly China, India and Brazil, for few specific technologies. Despite the narrow scope of the CDM project, it has brought green technologies to developing countries.

2.4 Getting competitive advantage by issuing carbon credits

The projects financed by the CDM are diverse. Carbon credits can be acquired by increasing the energy efficiency of buildings (insulation), and by recovering biogas from agriculture and landfills. Most of the credits gained by Chinese companies have relied on HFC-23 destruction. HFC-23 is a by-product of HCFC-22, a widely used refrigerating gas, which is also a powerful greenhouse gas.[11] Worldwide, a large share of CDM projects concerns electricity production through investments in renewable sources of energy such as hydro, wind, solar or biomass.

The economic gains that host countries derive from CDM projects spread out of the company that implements a project to issue the carbon credit. These gains spread to the supply of green technologies, which are sometimes located in developing countries. For instance, most wind power projects implemented in India use equipment produced by local manufacturers, mainly Suzlon and Enercon India (Dechezleprêtre et al. 2009). Furthermore, many firms have used CDM projects as collateral to obtain upfront financing from financial partners. For instance, Lecocq and Ambrosi (2007) report the case of pig-iron producers in Brazil who obtained loans from a Dutch bank by issuing carbon credits for a project consisting in replacing coal by charcoal. Future credits are valuable collateral because they are payable in strong currencies (dollars, euro or yen) by investors with high credit ratings.

Local companies have benefited from another key component of many CDM projects: technology transfers. In the sample of 3296 CDM projects examined by Schmid (2012), 36% of them claimed to have a technological transfer, accounting for 59% of total

[11] The CDM projects on HFC-23 have been criticised for providing windfall gains to firms, as these projects would likely have occurred eventually, even without the aid of developed countries. Indeed, as the cost of eliminating HFC-23 is low, firms producing the gas made more money from selling CDM credits than from selling the gas itself (Wara 2007).

emission reduction.[12] In a closer look at CDM projects, Dechezleprêtre et al. (2008) distinguish between two types of technology transfer: knowledge transfer and equipment transfer. Knowledge transfer takes place when the local project benefits from the transfer of knowledge, know-how, information or technical assistance from a foreign partner. Equipment transfer consists in importing devices such as wind turbines. In their sample of 644 CDM projects, these authors find that 43% of them had technology transfers: 9% only equipment, 15% only knowledge, and most of them (19%) both equipment and knowledge. They investigated empirically the determinants of technology transfers among CDM projects. Unsurprisingly, the size of the project and the openness to trade for the host country positively influence the probability of technology transfers. One key ingredient that matters at the country level seems to be its absorptive or technological capability.[13] Dechezleprêtre et al. (2008) found that absorptive capacity has a positive influence on technology transfers in the energy sector and the chemical industry but a strong negative impact in agriculture (it is not significant in most industry sectors and waste management). According to the authors, it seems to reflect the antagonistic effect that technological capacity has on international technology transfers. On the one hand, it facilitates transfer when firms in the host country have skills to use the technology. On the other hand, it increases the local availability of technology, and therefore reduces the need for international transfers. The latter effect seems predominant in agriculture, while the opposite holds in the energy sector and the chemical industry, which involves more advanced techniques. Overall, empirical studies have found an ambiguous role of absorptive capacity on technological transfer. It seems to be sector specific in Dechezleprêtre et al. (2008). Other studies have found no robust effect of absorptive capacity on technological transfer (see Schmid 2012, Murphy et al. 2015, Gandenberger et al. 2015).

[12] Haites et al. (2006) found a rate of technical transfers of the same magnitude in a sample of 860 CDM projects: one-third involved technology transfers and accounted for two-thirds of the annual emission reductions.

[13] Technology capacity is measured by an index developed by Archibugi and Coco (2004) that includes the measure of innovation activity (number of patents and number of scientific articles), the technological infrastructures (Internet penetration, telephone penetration and electricity consumption) and the development of human skills (percentage of tertiary science and engineering enrolment, mean years of schooling, literacy rate).

2.5 Green growth by attracting investment in carbon offsetting

Given the amount of money drained by carbon credits, it might appear as a surprise that most of the projects ended up in three countries: China, India and Brazil, which together accounted for nearly 80% of the credits in 2006.[14] Most countries from Africa were left out. This can be explained by the administrative costs of accreditation. To respect sovereignty, countries hosting projects have been associated in the accreditation process by the KP. The so-called designated national authorities had to support the project by signing a letter of approval to issue carbon credits (see Olsen and Fenhann, 2008, on how this is done in practice). As a result, no international standard for accreditation exists: countries have established their own distinct procedures and criteria. This easily explains why companies find it easier to specialise in few countries and few technologies.

Governments can take action to attract CDM projects – and more generally investment for carbon offsetting – by making accreditation easier. Procedures could be standardized to help alleviate the administrative cost of setting up a CDM project.[15] Governments can also design accreditation procedures to maximise the economic benefits from carbon offsetting investment. For instance, they can include technological transfers as criteria for accreditation. As Popp (2011) argued, this has been done in South Korea, which requires that ''environmentally sound technologies and know-how shall be transferred'' by CDM projects in Korea. As a result, 88 percent of the emissions reductions from CDM projects in South Korea come from projects that involve technology transfer. Similarly, Chinese guidelines for CDM project approval stipulate that ''CDM project activities should promote the transfer of environmentally sound technology to China'' (Haites et al. 2006).

Another way to make technology transfer more likely for a country hosting a project in some sectors is to improve its absorptive (or technological) capacity (see Dechezleprêtre et al. 2008 for empirical evidence). Absorptive capacity refers to a country's ability to conduct research in order to understand, implement, and adapt

[14] Source: Lecoq and Ambrosi (2007).

[15] Schmid (2012) provides empirical evidence that burdensome administrative procedures to start a new business impact negatively the likelihood of a technological transfer.

imported technologies (Popp 2011). It has to do with the workforce's technological literacy and skills, which are influenced by many factors that are controlled by public authorities, such as education and infrastructures. Although most emerging countries are nowadays equipped with relatively high absorptive capacity, it can make a difference in the low developed countries.

Finally, openness to trade seems to matter. According to Schmid (2012), higher applied tariffs on environmental goods and services impacts negatively the likelihood of technological transfer in CDM projects. Reducing tariffs of those environmental products might make technological transfer easier.

3- Increase a firm's productivity: the Porter Hypothesis

3.1 The Porter Hypothesis

More than 20 years ago, Professor Michael Porter suggested that pollution was generally associated with a waste of resources, or with lost energy potential: "Pollution is a manifestation of economic waste and involves unnecessary or incomplete utilisation of resources… Reducing pollution is often coincident with improving productivity with which resources are used" (Porter and van der Linde 1995: 105). Based on this reasoning, Porter argues that "properly designed environmental regulations can trigger innovation that may partially or more than fully offset the costs of complying with them". This has come to be known as the Porter Hypothesis (PH). In other words, it is possible to reduce pollution emissions and production costs at the same time, resulting in "win-win" situations.

The PH is controversial. First, the evidence initially provided to support it is based on a small number of company case studies, in which firms were able to reduce both their pollution emissions and their production costs. As such, it can hardly be generalised to the entire population of firms. Second, economists would suggest that, if there are opportunities to reduce costs and inefficiencies, companies should identify them by themselves without the need for government intervention (Oates et al., 1995). However, over the last twenty years, many studies have proposed analytical justifications for the PH. It could be that the interests of companies and their managers are not aligned, for several reasons (e.g. risk aversion, time-inconsistency, asymmetric information). Regulations force firms to adopt innovations that are profitable for the firm but not for its managers. As Ambec and Barla (2006) argue, the PH can be valid if a market failure exists in addition to the environmental externality. Examples include knowledge spillovers (see Section 4) or market power. For instance, Simpson and Bradford (1996) investigate the impact on environmental regulation in a model with firms competing on international markets. They show that more stringent environmental regulations commit a domestic firm to an aggressive cost-reducing programme, thereby enjoying a first-mover advantage.

3.2 Empirical evidence of the PH

On the empirical side, Jaffe and Palmer (1997) present three distinct variants of PH. In their framework, the "weak" version of the hypothesis is that environmental regulation will stimulate certain kinds of environmental innovations, although there is no claim that the direction or rate of this increased innovation is socially beneficial. The "narrow" version of the hypothesis asserts that flexible environmental policy instruments, such as pollution charges or tradable permits, give firms a greater incentive to innovate than do prescriptive regulations such as technology-based standards. Finally, the "strong" version posits that properly designed regulation may induce innovation that more than compensates for the cost of compliance and improves the financial situation of the firm. Many researchers have tested the different versions of the PH empirically. Overall, the empirical literature provides evidence for the weak version but not for the strong one. Most studies find a positive although sometimes weak relationship between, on the one hand, more stringent environmental policies and innovation measured by investment in R&D and, on the other, new technologies or successful patent applications. However, the impact of environmental regulations on productivity or business performance turns out to be negative in general (see Ambec et al. 2013 for a review).[16]

[16] A seminal contribution to this literature is Lanoie et al. (2011), who was the first to analyse the full causality chain of the PH. The authors examine both the weak and the strong versions of the Porter Hypothesis, based on a survey at the production plant level in seven OECD countries. Their methodology managed to disentangle the direct effect of environmental regulation on business performance from the indirect effect through more investment in R&D. They found a positive indirect effect, which tends to validate the weak version of the PH. However, it does not outweigh the direct negative effect, so

Several empirical investigations suggest that the net impact of regulations seems to be less negative when stringency increases. For instance, Berman and Bui (2001) found that refineries located close to Los Angeles are significantly more productive than other US refineries, despite the more stringent air quality regulation in the Los Angeles area. Similarly, Alpay et al. (2002) report that the productivity of the Mexican food-processing industry is increasing with the pressure of environmental regulation, which leads them to conclude that more stringent regulations are not always detrimental to productivity. It seems that, even if there is no systematic evidence of a "win-win" situation à la Porter, more stringent environmental regulation is not always bad for business. It sometimes fosters innovation that gives firms a competitive advantage. The open question for policy makers is how to design policies to obtain a causality chain à la Porter.

3.3 Public policies for profitable green innovations

Michael Porter favours stringent but flexible instruments such as pollution charges or tradable emission permits. These so-called "economic instruments" are more likely to enhance innovation than "command-and-control" instruments such as technological standards. They give more freedom to firms as regards the technology used to abate pollution. In contrast, by imposing a given technology or certain inputs, a technological standard provides fewer incentives to innovate. Similarly, emission standards – i.e. caps on emissions – or performance standards – cap on emission per output – do not encourage firms to go beyond standards. On the other hand, they can save money by reducing emissions further with pollution charges. Similarly, firms would purchase fewer permits on the market or even sell their own emission endowments by cutting emissions beyond their own emission rights.

The use of economic instruments appears to be a necessary condition for the PH to hold. This is known as its "narrow version". Once an economic instrument has been selected, it should be designed to be less harmful to the regulated industry. To reduce the negative impact on profits, pollution charges should be earmarked within the taxed

---

that the net effect turns out to be negative, which invalidates the strong version of the PH.

industry. The money collected can be redistributed directly to firms, depending on size measured as output or worker force. It could also be used to subsidy environmental R&D or the adoption of cleaner technologies. Another way to make pollution taxation neutral for the industry is through a differentiated tax and subsidy scheme around an emission target. Firms are taxed for pollution emissions above the target, and subsidised for emission units below it.[17] Similarly, emission permits can be assigned for free to firms at least during an initial phase. This would guarantee the political feasibility of a cap-and-trade system. Firms still have incentives to invest in pollution abatement technologies as long as they can make money by selling permits. Later on, fewer permits should be granted for free and more sold by auction, to ensure entry of new players into the industry.

Other policy instruments can be effective in greening firms. Voluntary approaches can be a substitute for mandatory environmental constraints in countries with weak institutions (see Never and Kemp in this volume). Examples include information disclosure programmes or programmes to encourage ISO 14001 certification through training and advertising the benefits of certification. There is evidence of successful information disclosure programmes. For instance, Powers et al. (2011) found that India's Green Rating Program caused large pulp and paper plants with the worst environmental performance to reduce emissions of certain pollutants by 9% to 19%. In the same vein, Garcia, Sterner and Afsah (2007) estimated that Indonesia's PROPER programme reduced firms' emissions by one-third.

4- Increase a sector's productivity through knowledge spillovers

4.1 Knowledge spillovers as a market failure

Green policies foster innovation in environment-friendly technology and may therefore generate positive externalities among firms in the R&D process. As knowledge is by nature a public good, and new technologies become public knowledge when transferred

[17] Examples include the so-called "eco-bonus-malus" scheme implemented in France for car CO2 emissions. Cars that are emitting more than the standard (around 130g of CO2 per 100 km) are taxed, while those which are emitting less are subsidised. The scheme is designed to be budget-balanced.

to production processes, firms will not get the full return on their R&D investment. Some (if not all) of the knowledge embodied in the invention also becomes available to competitors which can (fully or partly) copy or improve the new technology. These knowledge spillovers benefit the economy whenever new technologies are developed, yet they are dissuasive to investment in new technologies. As a result, market forces under-provide R&D investment. Public policies that foster investment in environment-friendly technologies mitigate this market failure to the benefit of all, including innovative firms.

4.2 Knowledge spillovers in green innovation

Recent estimates suggest that knowledge spillovers are significant in green innovation. Dechezleprêtre et al. (2014) analyse knowledge spillovers in clean and dirty technologies, based on patent citations. This information is part of the "state-of-art" on a patent application: innovators applying for a patent are required to cite all previous innovations on which the new innovation is based. A citation indicates that the knowledge contained in the document has been useful to develop the innovation. For this reason, patent citation can be been seen as a measure of knowledge spillovers. The study by Dechezleprêtre et al. covers four technological fields: energy production, automobiles, fuel, and lighting. Clean patents receive on average 43% more citations than dirty patents, and are cited by more prominent patents. These results suggest that public support to R&D would be more effective in boosting innovation and growth if they targeted green technologies.

The positive impact of R&D-enhancing policy is likely to hold primarily in developed countries where most of the innovation occurs, including for green technologies. For instance, Lanjouw and Mody (1996) found that the United States, Japan and Germany accounted for two-thirds of climate-friendly innovation. Yet some emerging countries do manage to produce a significant share of green innovations. In the sample they analysed, Dechezleprêtre et al. (2011) found that 18.5% of the climate-friendly innovations patented from 2000 to 2005 originated in China, South Korea, Russia or Brazil. It is likely that emerging countries will catch-up in green innovation, triggered by domestic green policies (see case studies on Brazil and China in this volume), the demand for green technologies from developed countries and by investment in carbon offsetting.

Another important component of the geography of innovation is knowledge dissemination. Dechezleprêtre et al. (2011) estimated the export of climate-mitigation inventions by country. They found that emerging countries tend to export less than developed countries: around 7% for China and Brazil, as compared to 42% for the United States or 56% for Germany. This suggests two particularities of the innovation process in emerging economies. First, emerging countries tend to specialise in adapting green technologies to local conditions. Second, spillovers are likely to be greater within the country itself than abroad, which is an argument for increasing support to R&D in emerging countries.

4.3 Policies for green innovation

As we have seen in the previous section, there is now ample evidence that environmental regulations stimulate innovation in green technologies. Knowledge spillovers reinforce the benefit of pushing for more environmental innovation, as firms are likely to get a higher return on their investments in R&D for environment-friendly technologies. Moreover, the spillovers can spread out to productivity-enhancing innovation in the spirit of the Porter Hypothesis. Public policies that foster demand for green technologies do not only reduce pollution and the use of natural resources; they also foster innovation and therefore growth.

Governments can help to make this scenario more likely in several ways. First, firms should be rewarded for investing in R&D, which means protecting their inventions with effective patents. Public authorities can improve intellectual property rights by granting patents more easily, reducing transaction costs for submitting new patents, and enforcing them. This means facilitating patent monitoring and litigation through the judicial system. It should also facilitate technology transfers through licensing agreements. Firms can also be rewarded through industrial policies, including investment in big equipment and infrastructure, subsidies or tax cuts for R&D.

Second, since technological absorptive capacity seems to be an important determinant of a country's ability to innovate, government should invest in education, technological training and knowledge dissemination infrastructure (e.g. internet access). In emerging countries, it should foster innovation in green technologies that is best suited to local conditions. In less-developed countries, it should facilitate the transfer of green but complex technologies such as wind and solar power. As Vidican shows in her case study on renewable energy in Morocco in this volume, even here certain products and services can be localised and green jobs be created. Moreover, such investments may be able to help attract some CDM and carbon offset projects.

Summary and conclusion for green growth

Being green is not always detrimental to competiveness. A firm can deploy several strategies to reduce its negative impact on the environment, while at the same time securing a competitive advantage in international markets. It can invest in environmental R&D, adopt cleaner technologies, supply environment-friendly technologies, and enhance its product's environmental quality throughout its life. Even if those strategies are costly, they might turn out to be profitable. Investment in cleaner technologies can lead to productivity improvement in the long run, which would spread in the economy through knowledge spillovers. With a demand driven by carbon finance (investment in CDM and other carbon offsetting projects) and renewable energy mandates (feed-in tariffs and renewable portfolio standards), firms specialised in producing climate-friendly technologies (e.g. solar photovoltaic panels and wind turbine) are expanding, particularly in emerging countries. Finally, the growth of organic farming and fair trade has created new opportunities in agriculture and the food industry in many developing countries.

Many public policies can help to secure a competitive advantage with green business strategies. First, environmental policy should be flexible to foster innovation. This means implementing economic instruments such as refunded emission taxes or tradable allowances rather than technological standards. Second, industrial policy should make patenting and technological transfer easier and more effective. It should also favour public support to environmental innovation to mitigate under-investment due to knowledge spillovers. Third, technological absorption capacity must be improved by investing in education, technological training and infrastructures (communication, transportation, energy, etc.). Fourth, government should work with NGOs and international organisations to facilitate environmental labelling with transparent criteria and a reliable traceability of products throughout the supply chain.

To conclude, I briefly mention three issues that deserve further discussion. First, public policies that have been successful in the past in bringing green growth might not be effective in the future. In the last years, the generous support to wind and solar power has been cut in many countries in Europe. Investment in new renewable energy production capacity in Europe has dropped from a record of $ 155 billions in 2011 to only $ 48 billions in 2013.[18] Similarly, CDM projects have become less attractive in the last years. The volume of carbon-offsetting projects has fallen since 2012. In 2015, the market experienced an excess supply of projects, an average price of $ 3.3 per ton of CO2 on all projects in 2015 with a record $ 0.1 for the lowest valued projects.[19] Hopefully, the 2015 Paris agreement within the UNFCCC could reverse the trend. It launches in Article 6 a new mechanism that aims at financing carbon offsetting projects in developing countries: the internationally transferred mitigation outcomes. A signatory country should be allowed to invest in another country to meet its nationally determined contribution on climate change mitigation.

Second, the policy implemented for enhancing profitable green growth should vary with the level of development in a country. Less developed countries should prioritize improving their technological absorptive capacity, simplifying and standardizing the accreditation process for carbon offsetting projects and building up a reliable supply of green labelled products. Emerging countries can afford to subsidise investment in green technologies to support their own industry. They should also strengthen their intellectual property rights to attract technological know-how from foreign investors and encourage its transfer.

Lastly, it is worth to mention that protecting natural resources and reducing pollution impact positively society through several channels that can be indirectly beneficial to firms. Many economic activities rely on ecosystem services provided by forest, water

[18] Source : REN21 10 years of renewable energy progress 2004-2014 http://www.ren21.net/Portals/0/documents/activities/Topical%20Reports/REN21_10yr.pdf

[19] Source :Raising Ambition : State of the Voluntary Carbon Market 2016, Ecosystem Marketplace, http://www.forest-trends.org/documents/files/doc_5242.pdf

stream and oceans. Workers are in better health and thus more productive with cleaner air and water. All those indirect effects should be included in a cost-benefit analysis of green policies.

Acknowledgements: I would like to thank Tilman Altenburg , Antoine Dechezleprêtre, Mathieu Glachant, Paul Lanoie, Pepita Miquel-Florensa, Gisèle Mueller and Nicolas Treich for helpful comments and suggestions.

References:

Alpay, E., Buccola, S. and Kerkvliet, J. (2002). "Productivity Growth and Environmental Regulation in Mexican and U.S. Food Manufacturing", American Journal of Agricultural Economics, 84(4), 887–901.

Ambec S. and P. Barla (2016) Can environmental regulations be good for business? An assessment of the Porter Hypothesis, Energy Studies Review, 14: 42-62.

Ambec S., M.A. Cohen, S. Elgie and P. Lanoie (2013) The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness? Review of Environmental Economics and Policy, 2013 7(1), 2-22

Ambec, S., and P. Lanoie (2008). "Does it Pay to be Green? A Systematic Overview", Academy of Management Perspectives, vol. 22, pp 45-62.

Archibugi, D. and A. Coco (2004) "A new indicator of technological capabilities for developed and developing countries", World Development 32 (4), 629–654.

Bacon, C. (2005)" Confronting the Coffee Crisis: Can Fair Trade, Organic, and Specialty Coffee Reduce Small-Scale Farmer Vulnerability in Northern Nicaragua?", World Development, 33(3): 497-511.

Berman, E. and L.T.M. Bui (2001), "Environmental regulation and productivity: Evidence from oil refineries" The Review of Economics and Statistics 83(3), 498-510.

Chabé-Ferret, S. and J. Subervie (2013) "How much green for the buck? Estimating additional and windfall effects of French agro-environmental schemes by did-matching", Journal of Environmental Economics and Management, 65(1): 12–27.

Dechezleprêtre A., M. Glachant and Y. Ménière (2008) "The Clean Development Mechanism and the international diffusion of technologies: An empirical study", Energy Policy 36: 1273-1283.

Dechezleprêtre A., M. Glachant and Y. Ménière (2009) "Technological transfer by CDM projects: A comparison of Brazil, China, India and Mexico", Energy Policy, 37: 703-711

Dechezleprêtre, A., Martin, R., and M. Mohnen (2014). "Knowledge spillovers from clean and dirty technologies: A patent citation analysis", CEP Discussion Papers, CEPDP1300. Centre for Economic Performance, London School of Economics and Political Science, London, UK.

De La Tour A., M. Glachant and Y. Ménière (2011) "Innovation and international technology transfer: The case of the Chinese photovoltaic industry", Energy Policy 39, pp. 761-770

Dragusanu, R., D. Giovannucci, and N. Nunn (2014) "The Economics of Fair Trade", Journal of Economic Perspective, 28(3) 217-236.

Garcia, J., T. Sterner and S. Afsah (2007) "Which firms are more sensitive to public disclosure schemes for pollution control: Evidence from Indonesia's PROPER program?", Environment and Resource Economics 42: 151-168.

Gandenberger, C., M. Bodenheimer, J. Schleich, R. Orzanna and L. Macht (2015) Factors driving international technology transfer: empirical insights from a CDM project survey, Climate Policy, available at: DOI: 10.1080/14693062.2015.1069176

Haites, E., Duan, M. and S. Seres (2006) "Technology transfer by CDM projects", Climate Policy 6 (3), 327–344.

Haned, N. P. Lanoie, S. Plouffe and M.F. Vernier (2015) Profitability of Ecodesign: An Economic Analysis, Working Paper HEC Montreal Canada.

Jaffe, A.B. and K. Palmer (1997), "Environmental Regulation and Innovation: A Panel Data Study", The Review of Economics and Statistics 79(4), 610-619.

Kossoy, A. and P. Ambrosi. (2010). State and trends of the carbon market 2010. Washington, DC: The World Bank.

Kunzik, P. (2003), "National Procurement Regimes and the Scope for the Inclusion of Environmental Factors in Public Procurement", in OECD, The Environmental Performance of Public Procurement: Issues of Policy Coherence, Paris: OECD, 193–220.

Lanoie, P., J. Laurent-Lucchetti, N. Johnstone and S. Ambec (2011) Environment policy, innovation and performance: New insights on the Porter hypothesis, Journal of Economics and Management Strategy 20(3): 803–841.

Lecocq F. and P. Ambrosi (2007) "The Clean Development Mechanim: History, Status, and Prospects", Review of Environmental Economics and policy, 1(1): 134-151.

Méndez, V.E., C.M. Bacon, M. Olson, S. Petchers, D. Herrador, C. Carranza, L. Trujillo, C. Guadarrama-Zugasti, A. Cordón, and A. Mendoza (2010) "Effects of Fair Trade and Organic Certifications on Small-Scale Coffee Households in Central America and Mexico", Renewable Agriculture and Food Systems 25(3): 236-251.

Murphy, K., G.A. Kirman, S. Seres and E. Haites (2015) "Technology transfer in the CDM: an updated analysis", Climate Policy, 15(1): 127-145.

Olsen, K.H. and J. Fenhann (2008) "Sustainable development benefits of clean development mechanism projects: A new methodology for sustainability assessment based on text analysis of the project design documents submitted for validation", Energy Policy, 36: 2819-2830.

Palmer, K., Oates, W. E. and Portney, P. R. (1995). "Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm?", Journal of Economic Perspectives, 9(4),
119–132.

Popp, D. (2006) "International innovation and diffusion of air pollution control technologies: The effects of NOX and SO2 regulation in the US, Japan, and Germany", Journal of Environmental Economics and Management 51 : 46–71

Porter, M. (1991). "America's Green Strategy". Scientific American, 264(4), 168.

Porter, M. and Van der Linde, C. (1995). "Toward a New Conception of the Environment-Competitiveness Relationship", Journal of Economic Perspective, 9(4), 97–118.

Powers, N., A. Blackman,T. Lyon and U. Narain (2011) "Does disclosure reduce pollution? Evidence from India's green rating project", Environmental and Resource Economics 50: 131-155.

Ramesh, P., N.R. Panwar, A.B. Singh, S. Ramana, S.K. Yadav, R. Shrivastava and A. Subba Rao (2010) "Status of organic farming in India", Current Science, 98 (9): 1190-1194.

Schmid, G. (2012) Technology transfer in the CDM: the role of host-country characteristics, Climate Policy, 12(6): 722-740.

Simpson D. and Bradford, R. L. (1996). "Taxing Variable Cost: Environmental Regulation as Industrial Policy", Journal of Environmental Economics and Management, 30(3),
282–300.

Wara, M. (2007). "Is the global carbon market working?", Nature 445: 595–596