WPS6677

Policy Research Working Paper 6677

Green Industrial Policies

When and How

Stéphane Hallegatte
Marianne Fay
Adrien Vogt-Schilb

The World Bank
Sustainable Development Network
Office of the Chief Economist
October 2013

Policy Research Working Paper 6677

Abstract

Green industrial policies can be defined as industrial policies with an environmental goal—or more precisely, as sector-targeted policies that affect the economic production structure with the aim of generating environmental benefits. This paper provides a framework to assess their desirability depending on the effectiveness and political acceptability of price instruments. The main messages are the following. (i) Greening growth processes to the extent and with the speed needed cannot be done without industrial policies, even if prices can be adjusted to reflect environmental objectives. (ii) "Sunrise" green industrial policies are needed because they support the development of critical new technologies and sectors, bring down costs, and allow for reduced emissions in the short term even in the absence of carbon pricing. (iii) "Sunset" green industrial policies and trade policies may be needed in conjunction with safety nets to make carbon pricing politically or socially acceptable. They can help mitigate the impact of a carbon price on competitiveness and unemployment and smooth the transition by helping industries adjust to the new conditions. (iv) Green or not, industrial policy requires carefully navigating the twin dangers of market and governance failure. The viability of supported technologies and sectors is difficult to assess through a market-test given their dependence on continued environmental policies or pricing—such as a carbon price. Particular attention must be paid to avoid potential unintended negative effects, such as rebound effects (especially if prices are inappropriate), misallocation of capital, or capture and rent-seeking behaviors.

This paper is a product of the Office of the Chief Economist, Sustainable Development Network. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at shallegatte@worldbank.org.

Green Industrial Policies:

When and How

Stéphane Hallegatte, Marianne Fay and Adrien Vogt-Schilb [1]

keywords: climate change mitigation policies, industrial policies, acceptability, transition, green growth.

JEL codes: L52, O25, O44, Q52, Q54, Q56

---

[1] Stéphane Hallegatte (shallegatte@worldbank.org), Marianne Fay (mfay@worldbank.org) are with the World Bank, Sustainable Development Network, and Adrien Vogt-Schilb with the Centre International de Recherche sur l'Environnement et le Développement. This work benefited from extensive inputs from and discussion with Milan Brahmbhatt, Mark Dutz, Bernard Hoekman, Atsushi Iimi, Ulf Narloch, Philippe Quirion, Julie Rozenberg, Jun Rentschler, Benjamin Simmons, Michael Toman, David Treguer. We also thank the participants at the conference on the economics of green growth, organized in London on October 1, 2013, by the Grantham Research Institute and the Global Green Growth Institute.

1. Introduction

The need to reconcile rapid economic growth with greater environmental sustainability has led to calls for "greener growth" (World Bank 2013). A key question is how to achieve this greener growth. It is, after all, neither by chance nor by deliberate policy design that the growth of the last 250 years has largely come at the expense of the environment. Market mechanisms, by definition, cannot efficiently manage ill-priced resources. And environmental goods and services are plagued by market failures, such as externalities, and government failures, such as inadequate taxation (Hallegatte et al., 2012).

Epitomizing these challenges, climate change has been called the biggest market failure in the history of humanity (Stern, 2006). Today, the international community has committed to maintain the increase in global temperature below 2˚C above pre-industrial levels. Such a commitment entails decarbonizing the world economy by 2100, hence a complete transformation of our economic systems. It also requires a very rapid decline in emissions. Figure 1 shows the speed at which global emissions of greenhouse gases need to decrease to respect this objective, as a function of when global emissions peak. To put this challenge in perspective, the figure also shows the most rapid decrease in emissions ever recorded in a single country over a 5-year period, namely the French shift to nuclear electricity in the 1980s.[2] Even if emissions peak soon, global emission reductions will need to proceed at a pace similar to or quicker than what was achieved in France then.

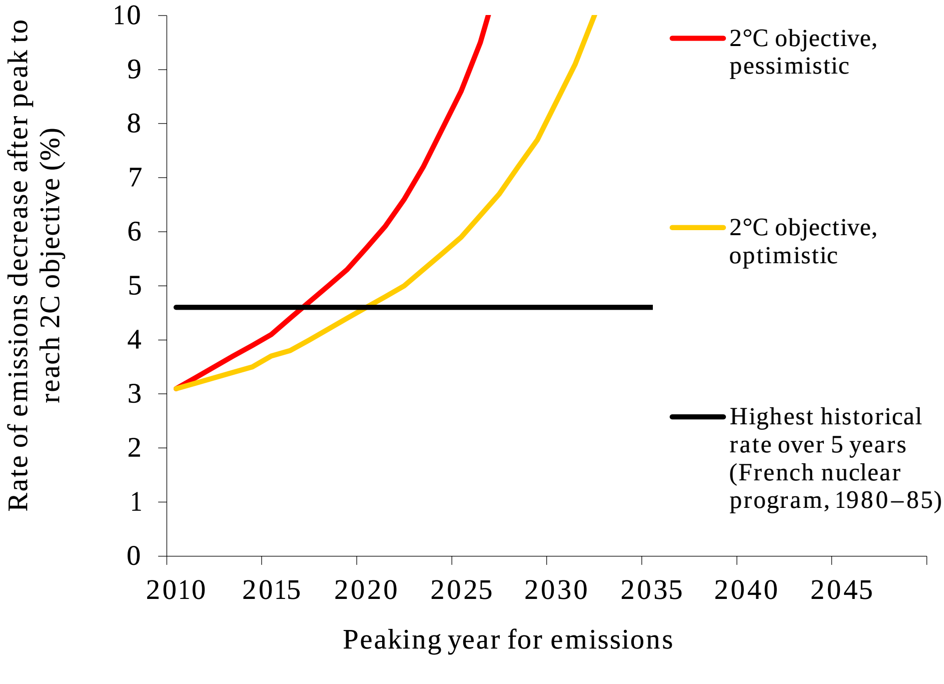

Figure 1: Rate of emission decrease that is necessary after the global peak in emissions to keep man-made temperature increase below 2C. Source: (Guivarch and Hallegatte, 2013).

Government actions are needed urgently to make growth more sustainable. An obvious first step is for policies to price externalities, notably by removing distortive subsidies such as fossil fuel subsidies (IMF, 2013) and imposing carbon prices.

---

[2] Excluding the decrease in emission resulting from major economic crisis such as the recent one or the GDP drop in former Soviet Union in the 90's.

Unfortunately, there is limited appetite around the world for carbon taxes and we are unlikely to see the emergence of a global carbon market any time soon. More generally, it is often difficult to raise prices to the extent needed to generate the desired behavior. For example, raising fuel taxes has proven politically unpalatable in the United States –where an inefficient car fleet and a national transport system heavily dependent on individual cars and trucks imply that a gasoline price hike would have a substantial negative impact on the average voter. As a result, fuel prices are substantially lower than in Europe. More generally, energy price hikes raise fears of competitiveness losses: in a world of partial participation in international agreements and differentiated responsibility across countries, trade and competitiveness concerns will be invoked to oppose price-based policies.

Even when it is politically feasible to change them, prices are often not enough to trigger a rapid economic transition. Indeed, environmental policies that aim to spur an economic transition toward new or different economic sectors (e.g. by creating a renewable energy sector or developing new urban transport technologies) are hampered by economies of scale issues, knowledge externalities and other classic non-environmental market failures that are usually mentioned to justify industrial policies (Acemoglu et al., 2012; Rodrik, 2013).

Further, the idea that a unique carbon price in the economy is the optimal policy has been challenged in second-best settings: in the absence of predictability and credibility of future carbon prices (Vogt-Schilb and Hallegatte, 2011), in the presence of technology lock-ins (Kalkuhl et al., 2012), in case of learning-by-doing (del Río González, 2009), or in the presence of distortion in labor markets and of distortionary revenue-raising taxes (Richter and Schneider, 2003). In such cases, there is a potential justification for overlapping policies, i.e. for specific sector-targeted policies in addition to price-based economy-wide instruments (such as a carbon tax). Importantly, a decision to deploy a sector-targeted policy should be conditional on a precise assessment of the market failure it seeks to address, as well as its costs and benefits.

So greening growth requires that prices be adequate (in that they reflect environmental externalities) and effective (in that they trigger the needed response). Achieving such a goal will often require a combination of environmental and industrial policies – what we call green industrial policies. We define green industrial policies as industrial policies with an environmental goal – or more precisely, as *sector-targeted policies that affect the economic production structure with the aim of generating environmental benefits*.

Green industrial policies are plagued with the same challenges that confront both industrial and environmental policies. On the industrial policy side, this entails the well-known risks of government failures: governments may lack the resources required to monitor the outcome of an industrial policy, or the will to do so, in case of regulatory capture. On the environmental side, this includes the political and social challenges of adequately pricing resources and externalities and/or creating a demand for greener products. As a result, the success of green industrial policies may be particularly difficult to evaluate: the demand for many of the products and behaviors they aim to develop (for instance, carbon capture and storage) usually depends on the existence of supporting public policies. They cannot, therefore, be easily subjected to a market test if prices do not internalize the environmental externality.

The paper is organized as follows. After a brief review of the lessons of past industrial policies as to when and where they can be useful, Section 3 makes the case for green industrial policies, arguing that industrial policies are needed in addition to environmental policies to trigger the transformations required for more sustainable economic growth. Section 4 then reviews when and how to effectively deploy green industrial policies, offering a simple framework to help ensure policy responses are matched to the particular failure they seek to resolve. Section 5 concludes.

2. Lessons from industrial policies

Harrison and Rodríguez-Clare 2009 define industrial policy as any non-neutral policy that implies distortions beyond the ones associated with revenue constraints.[3] Beyond this broad definition, industrial policies can be differentiated according to their goals (Gual 1995):

- **Enhancing the overall innovation capacity of the economy**-- typically through horizontal industrial policies such as innovation or investment support extended regardless of economic sector, to address knowledge externalities or capital market imperfections;

- **Economic development, job creation, and rent capture—**through vertical (sector- or technology-specific) industrial policies that support a particular industry or firm to address sector-specific market failures;

- **Equity, acceptability or other social concerns.** This entails policies that support uncompetitive sectors or regional production on distributional grounds, or to prevent abrupt adjustments with negative social impacts.

Most recently, industrial policies have also been reframed as a process to discover and support comparative advantages, through close collaboration between government organizations and the private sector (Rodrik, 2004).

The main tools of industrial policies are (1) subsidies in their many forms—from production subsidy to lower interest rates; protection from imports; (2) direct public participation; (3) public procurement rules (e.g., "domestic sourcing" requirements); (4) targeted public investments, for example in infrastructure; and (5) cluster policies and other forms of innovation policies.

The market failures that are usually invoked to justify the use of industrial policies include knowledge externalities (Hausmann and Rodrik, 2003), latent comparative advantage and increasing returns (Rodrik, 2004), coordination failures (Murphy et al. 1988; Okuno-Fujiwara 1988; Pack and Westphal 1986; Rosenstein-Rodan 1943), capital market imperfection and asymmetric information, international rent shifting (Baldwin and Krugman 1988; Helpman and Krugman 1989), and distributional effects (Noland and Pack, 2003).

Experience with industrial policy has been varied, but none has been so much studied as that of the East Asian Tigers, with many analysts trying to draw lessons from these experiences (Noland and Pack, 2003). Their conclusions are relevant for the development of green industrial policies.

2.1. The experience of Japan and Korea

During most of its recent history, Japan relied on industrial policies to drive economic development. From 1950, these policies included direct subsidies to sectors that the government considered promising; specific tax policies (e.g., special depreciation schemes in some sectors), and off-budget finance to support some sectors; subsidized credit, including channeling capital to specific sectors;

[3] Optimal taxation theory explains why different goods and services should be taxed differently, to account for differences in substitutability. Non-neutral policies (i.e. for policies that target a product, a firm, or a sector) can thus be justified by the need for the government to raise revenue.

R&D incentives; controls of international trade, investment, technology imports, and direct allocation of foreign exchange; tolerance or even encouragement of cartels and other anti-competitive behaviors; informal administrative guidance, coercion of recalcitrant firms, and target-setting.

Government procurement also played a role. The Japanese government acted as a monopsonist to purchase Western technologies at lower price (Goto and Wakasugi 1988). For instance, MITI negotiated the importation of an Australian steel production technology for 1 cent per ton while US companies were paying up to 35 cents per ton. (Borrus et al. 1986) show how the Japanese government used the same method to obtain US technologies in microelectronics at very low prices. The avoided expenditures may have been small in aggregate terms, but their impact was likely significant in terms of technology adoption.

Japan's policy mix also included significant support to traditional industries, to ease the transition toward more productive sectors, and to make this transition more acceptable from a political and social point of view. For instance, according to (Beason and Weinstein 1996), rapidly-growing sectors like electronics and manufacturing have been taxed more than declining sectors like textile, which received subsidies. The 1978 Law "*Temporary Measures for Stabilization of Specific Depressed Industries*" was designed to facilitate the adjustment to declining demand in 14 "structurally depressed" industries, including textiles and ship-building. This law planned capacity reduction, reallocated resources within and outside the depressed industries, provided financial assistance to troubled firms, and mitigated negative impacts on labor (Krauss, 1992; Peck et al., 1987).

There is no agreement as to the overall impact of industrial policies on the Japanese economy. According to (Noland 1993), industrial policies had an impact on economic structure and trade, but did not enhance welfare. However, in the absence of a counterfactual it is difficult to estimate how the Japanese economy would have developed in the absence of these policies or what their real impact was. Peck et al. (1987) suggests that the 1978 Law in Japan helped reduce the negative impact of structural change, especially in concentrated industries where firm bankruptcies have major impacts.

Analyses of Korea lead to similar conclusions. Industrial policies were comparable to those of Japan, with a particular focus on "policy loans" with negative real interest rates. By the late 1970s, 60% of business loans were 'policy loans' made on the basis of industrial policy objectives. Annual interest subsidy rose from 3% of GNP in 1962-1970 to 10% of GNP in 1972-1979 (Noland and Pack, 2003). Moreover, targeted industries were protected from imports and benefited from a lower corporate tax (20% against 50% for non-favored firms). Approximately 80% of fixed investments in Korea went to targeted industries in the late 1970s.

Again, while there is agreement on the fact that industrial policies changed the economic structure of Korea, the debate continues as to their impacts on welfare or economic growth. According to Kim (1990), the policy created significant over-capacity in the targeted sectors, with negative public finance consequences. It has also been argued that the creation of oligopolies in industrial sectors during the 1970s retarded technological change, and Lee (1996) finds that sectors with more support had lower productivity growth.[4] More positive assessments argue that government interventions were needed to cope with coordination failures and externalities, and that large investments in Korea in the

[4] Chang (2010) questions these estimates based on the chosen time period (short compared with industry development timescales and ending during a recession linked to the 1979 oil shock) and the definition of sectors (too large compared with the targeting of industrial policies in Korea or Japan).

1950s went to infrastructure that was critical for exports, and thus played an important role in the country's subsequent export-based economic development.

2.2. Lessons learned

Some consider that industrial policies played a key role in the catching up of Japan and other Asian countries (Chang, 2006). Others believe that this success is a consequence of large investments (and the associated catch up in capital intensity) in countries that already had high education levels and institutional capacity (Krugman 1994). With high human and social capital, and large investment ratios, it should indeed be no surprise that these countries exhibited high growth rate during the catch-up phase. But even then, there is no consensus on the policy lesson: one can conclude that industrial policies do not explain the high Asian growth and they are not useful instruments; or that an activist industrial policy is the right approach to address the particular challenges that Asia faced at that time, namely the lack of physical capital in an economy with high human and social capital. In that latter case, industrial policies can be valuable instruments, provided they are applied in the right context.

Despite the lack of consensus on the success of industrial policies, some lessons have emerged. First, it appears critical not to try blindly to replicate the (generally more positive) experience of East Asia in countries with very different characteristics, including lower education level and weaker institutions. Multiple experiences show that ill-designed industrial policies will not only waste resources, but also foster corruption and capture, and distort competition against the most promising development options, sectors, and technologies (Ades and Tella 1997; Klimenko, 2004). Managing the rents created by industrial policies is a critical challenge (Perrels 2014). Many industrial policies included financial repression to channel capital. That created a number of negative side-effects, including the use of bribery to access rationed credit and a reduction in the overall quality of financial intermediation (Ades and Tella 1997), whose consequences can extend well beyond the perimeter of the industrial policies.

A second lesson is the need for the government to identify and analyze the market failures that are to be overcome in order to adapt industrial policies to a specific context and minimize negative side-effects (Pack and Saggi, 2006). For instance, governments need information on which firms and industries generate knowledge spill-overs, or benefit from economies of scale and dynamics effects (e.g., learning by doing). (Baldwin 1969) claims for instance that trade barriers are not the best tool to support infant industries, mainly because trade barriers are not the best tool to correct the very specific externalities that prevent them from developing.

Another lesson is the critical importance of termination clauses to ensure support is discontinued when a business or sector fails. Regardless of the ability of governments to "pick winners", there are plenty of political economy reasons to explain why governments are worse than the private sector at "dropping losers" or terminating support when a project or business fails. Yet, industrial policies necessarily support risky projects, and are therefore expected to experience a significant share of failures—unless a low-risk-low-return strategy is being followed (Rodrik, 2013). Given that industrial policies support a portfolio of projects, overall performance will depend on both the successful projects and their benefits, and on how the policy deals with inevitable failures to minimize their cost.

East Asian countries addressed this problem by using export performance—an indicator difficult to manipulate by local firms—as a marker of success. Authorities were fairly ruthless in making continued protection in the domestic market contingent on export performance (World Bank 1993).[5] Thus a critical take-away from the Asian experience is that industrial policies should include a "termination clause" (or "exit strategy") in their initial design, to avoid locking into undesirable policies. We will see below that applying this lesson to green industrial policies creates specific challenges.

Importantly, industrial policies should be evaluated taking into account the entire policy mix. For example, industrial policies have been widely used to smooth transitions for declining sectors (Peck et al., 1987). Such policies were likely critical to the political acceptability of other economic policies such as trade openness and increased competition – even if their direct outcome was negative in monetary terms. Support to traditional industries in Japan is probably a good illustration. In such cases, industrial policy is a complementary policy, whose goal is to permit the implementation of pro-growth policies. Attributing a negative value to those policies is inappropriate if they made possible the implementation of very positive pro-growth policies.

In sum, industrial policies appear reasonably effective in influencing the composition of the economy—which makes them important instruments of the green growth toolkit. But their relevance must be assessed on a case by case basis, depending on a country's economic situation, the benefits it can expect from these policies, and its ability to deal with unavoidable failures and to avoid capture by vested interest.[6] Sources of industrial-policy implementation failures are numerous, ranging from simple lack of administrative capacity to the inability to resist rent-seeking by vested interests (Laffont 1999). Industrial policies (green or not) seem particularly risky for countries with weak institutional capacity, weak civil society, low transparence or accountability of governmental organizations. They appear more likely to succeed in high-capacity countries, with educated population, high accountability, and where the main obstacle to economic growth is the low amount of physical capital, as in East Asia in the 1950s and 1960s.

3. A case for green industrial policies

3.1. Defining green industrial policies

We exclude from our definition of green industrial policies pricing policies to correct environmental externalities (e.g., carbon tax or other Pigouvian taxes) and regulation affecting only consumption (and not the supply-side of the economy)–although we argue below that the success of green industrial policies will typically require the deployment of these complementary instruments. We also exclude pure R&D subsidies that do not affect the supply of goods and services. [7]

Green industrial policies are usually based on a mix of different policies affecting different stages of technology development and sector growth, and targeting both supply and demand. Examples of include subsidies to green R&D, access to cheaper capital for green projects (notably through government direct participation and subsidized loans[8]), feed-in tariff policies for renewable energy, consumer mandates and green public procurement rules.

[5] Note however that subsidies conditional to export are formally prohibited by WTO rules (Agreement on Subsidies and Countervailing Measures 1995; see Charnovitz, 2013).
[6] See an analysis on South Africa in World Bank (2011).
[7] Innovation policies are not discussed in details in this paper, but are investigated in Dutz and Sharma (2011).
[8] See (Rozenberg et al., 2013a) for an example of a proposal to provide lower interest rates to green project.

Our definition of green industrial policies is based on a combination of *objectives* (green and industrial restructuring or job creation) and *tools* (non-neutral policies). Thus, biofuel policies in Sweden and Portugal may be considered green policies inasmuch as their objective was to green the fuel mix (whether biofuels do that is another debate) but to the extent they were limited to consumer mandates, they do not qualify as industrial policies. In the US and France, however, biofuel policies clearly qualify as industrial policies as they included support to domestic producers and had the objective of developing a domestic industry, using domestic raw material. De facto, green industrial policies will usually require a combination of industrial and environmental policy tools.

In China, support to solar energy was first largely motivated by a desire to develop domestic knowledge creation and innovative industrial sectors, in addition to reducing energy imports (Fischer 2013). This is why, when demand was high in Europe, China only focused on supply-side support, mostly using direct subsidies (including subsidized land). When demand collapsed in Europe following the economic crisis and the revision of feed-in tariffs, the continued development of the sector in China had to rely on domestic demand, leading to the introduction of a series of demand-side instruments: the Chinese government first used tenders to collect information on actual production costs of solar panels, then introduced a national-level feed-in tariff later adjusted for regional differences in solar potential. The mix is complemented with regulations and subsidies for grid integration of renewable energy.

This section reviews the justifications for the use of green industrial policies, as a complement to – or even substitute for – economy-wide price instruments. These justifications are based on market failures that may impede the transition toward a greener economy.

3.2. Sunrise industrial policies

Industrial policies designed to help develop new technologies or grow new sectors are referred to as "sunrise" policies. They aim at compensating for market failures related to knowledge and increasing returns. These failures are discussed below.

Knowledge externality and capital market imperfections

Greening the world's economy will require substantial innovation: for example, existing technologies – if fully deployed and brought to scale – should be enough to keep the world on track to keep warming to below to 2˚C up to 2050, but new technologies will be needed beyond that (World Bank, 2010). For instance, technologies that allow for negative emissions (e.g., biofuel electricity production with capture and sequestration of CO_2) will be needed to maintain the human-caused temperature increase below 2˚C over the long-term (Guivarch and Hallegatte, 2013). These technologies do not exist today and are unlikely to emerge in the absence of significant investment in research and development and pilot projects.

However, a combination of factors results in under-investment in innovation (green or not) by the private sector and the need for public action to promote socially optimal levels of new production, research, or training (Dutz and Sharma, 2012). Because new knowledge can be acquired at low cost by competitors, innovations generally produce benefits beyond what their inventor can fully capture (the "knowledge externality"). This, combined with uncertainty regarding future production costs and the risks inherent to any innovation, results in private investments in innovation always below what would be socially desirable (Hausmann and Rodrik, 2003). This problem is compounded by information asymmetry in capital markets: competitive innovative projects often struggle to find the necessary funding because investors lack knowledge and information to assess the quality of innovative and risky projects, especially when technical details cannot be shared by the developers without risking their innovation to be reproduced by competitors.

In addition, the success of green innovation is even more uncertain than other types of innovation: the eventual competitiveness of a technology will depend on environmental policies remaining in place over the long term. Even the most efficient technology for carbon capture and sequestration cannot be competitive in the absence of a carbon price or other incentive to reducing carbon emissions in the atmosphere.

Under-investment in innovation slows down economic growth (which is the reasoning behind policies such as R&D subsidies). It also impairs green technological change and prevents or slows down a green transition, with consequences on how best to design a green growth strategy. Even with a carbon price, the transition toward a low-carbon economy can be slowed down by insufficient innovation and investment in technology development. The carbon price can therefore be usefully complemented with innovation policies (Acemoglu et al., 2012).

R&D support directly targeted to green innovation can also make sense – and in fact be helpful--even if a carbon price cannot be implemented. This is especially the case in sectors where green technologies may eventually compete with carbon-based technologies even in the absence of carbon pricing. An example could be hybrid cars if they become competitive without a carbon price, at current and expected gasoline price. Another is photovoltaic solar electricity who may become competitive by 2020 in countries with the appropriate potential (Tour et al., 2013).

Support directly targeted to green technologies, or even targeted toward specific green technologies, can also be needed even in the presence of a carbon tax. First, support is often needed to overcome the natural tendency to innovate and invest in technologies that are already mature and have a large market share (Acemoglu et al., 2012). Second, spill-overs can be larger in the green sector than in the non-green sectors, as suggested by (Dechezlepretre et al., 2013). Third, as stressed in (Smulders et al., 2013), returns on green innovation are likely to be realized over longer time horizons than in other domains (e.g., information and communication technologies). Green innovation may thus be less well supported by traditional intellectual property rights instruments such as patents, and require additional encouragement. While a 20-year patent is more than sufficient for cell phone innovations that offer very rapid return on R&D investment, such a time horizon may be too short to motivate investments in innovation on solar panels or electric cars. And poorly-designed intellectual protection systems can limit knowledge sharing and spill-over, therefore hampering green innovation instead of promoting it.

Latent comparative advantages and increasing returns

Harrison and Rodríguez-Clare (2009), Rodrik (2004), and Kahn (2009) review the justification for growth-enhancing industrial policies based on the existence of a latent comparative advantage, i.e. a comparative advantage that can be realized only if public action allows the economy to get out of a low-productivity trap. This is the case for instance if the advantage includes increasing return to scale, requiring support at the early stage.

Green industrial policies can help develop a green export sector. (Dutz and Sharma, 2012) find that many developing countries exports goods and services that are "close" to green goods and services, in the sense that they require the same set of skills and technologies. According to this analysis, therefore, there is a real potential for developing countries to grow their exports through policies that support green sectors. And developing a green export sector can be good for growth in general. Indeed, most analyses of the impact of trade openness on growth find that exports enhances growth, especially if they are in non-traditional sectors such as manufacturing or skill-intensive goods, rather than primary products or raw materials (Harrison and Rodríguez-Clare, 2009; Nunn and Trefler, 2010). In terms of growth, *what* a country exports is more important for growth than *how much* it exports. The case can be made therefore that an industrial policy favoring skill-intensive green products has the potential to accelerate economic growth.

The case of solar panels in China illustrates the export potential of green sectors, based on a latent comparative advantage that could not have grown without initial support. Indeed, the sector illustrates well the role of increasing returns. The recent drop in production costs can be largely explained by scale effects, including direct scale effects and material and equipment discounts (and not so much by labor costs or land subsidies, see (Goodrich et al., 2013)).[9]

In this context, the aim of industrial policy is to discover the comparative advantage of a given country, through exchanges between government organizations and the private sector (Harrison and Rodríguez-Clare, 2009; Rodrik, 2004); see Section 4.2).

In some cases, a latent comparative advantage that can be observed ex ante and thus justify a targeted industrial policy. Renewable energy potential, for example, is dependent upon observable country conditions. Even though climate and geographic characteristics are not sufficient to create a comparative advantage in renewable energy exports (the ability to connect to market is also critical), they play a large role in the assessment of production potentials (Figure 2).

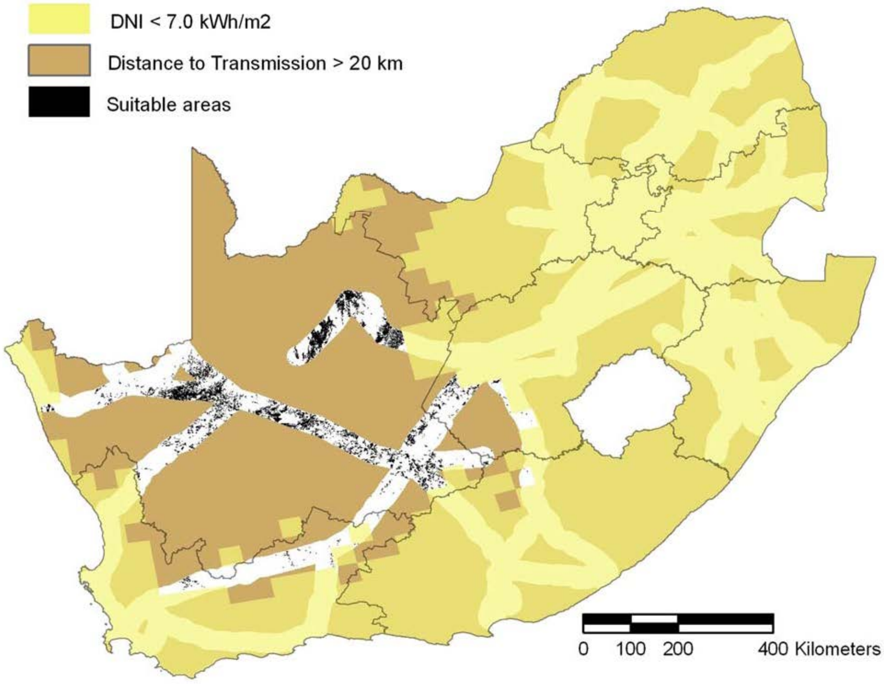

Figure 2: Map of South Africa indicating areas which are suitable for the installation of large concentrating solar power plants. Proximity to transmission lines and for solar irradiation are also shown. Source: (Fluri, 2009)*. Note: DNI stands for "direct normal irradiance", a measure of how much solar energy can theoretically be captured at ground level.*

The observation of a latent comparative advantage is the basis of large-scale renewable energy projects in North Africa. Even though the first projects are more expensive than an equivalent fossil-

---

[9] Overcapacity led to a drop in prices that was even larger than the production-cost reduction.

fuel based production (e.g., the Ouarzazate concentrated solar plant in Morocco), some countries hope to reduce the price of solar technologies to capture the advantage their climate and solar influx offer and transform it into cheap resources. They also consider the prospect of exporting electricity (e.g., the Desertec project that aims to produce green electricity in North Africa and export it to Europe).

Coordination failures

Another argument for industrial policies relies on the need to solve coordination failures within and across sectors to develop new activities (Murphy et al. 1988; Okuno-Fujiwara 1988; Pack and Westphal 1986; Rosenstein-Rodan 1943). The idea is that one activity with a comparative advantage can be dependent on the existence of another activity in the region or country.

Green growth strategies are by essence multi-sectoral and require inter-agency, inter-sectoral, and public-private coordination—a challenge in all countries. Increasing the share of electric cars, for instance, requires long-term coordinated investments by carmakers, electricity providers, and infrastructure providers. The needed coordination requires adequate institutions (both market and regulatory) and possibly some active policies.

The lack of long term credibility of today's price signals and the unpredictability of regulatory frameworks create an inter-temporal coordination problem, discouraging investors from financing innovative environmental firms and to invest in long term projects. For these projects, and in very inert sectors (e.g., urban planning, infrastructure), early actions are needed that cannot be triggered by price instruments but require addition actions, possibly through regulations, norms, or direct investments (Vogt-Schilb and Hallegatte, 2011).

Rent-shifting

Industrial policies are sometimes motivated by a desire to redistribute monopoly rents. Sectors characterized by fixed costs or indivisibilities that limit the number of entrants are often dominated by oligopolies with significant rents. Classic examples include the competition between Airbus and Boeing or between Kodak and Fuji in photographic film (Helpman and Krugman 1989). Due to the large entry cost and long learning curve, poly-silicon production concentrates a large part of the profits in the solar panel supply chain and the market may become an oligopoly. In that case, temporary support to increase competition (and then anti-trust regulation to prevent excessive concentration) can be economically efficient.

Rent shifting may require specific instruments, including trade policies. An example is the success of the high-speed train program initiated in the Republic of Korea in 1993 by the purchase of the French Alstom TGV (*train à grande vitesse*). The contract included technology transfers (partly through training Korean workers in France) and local content requirements (LCR) with 50 percent of manufacturing being in Korea (Lee and Moon, 2005). Today, Korea is among the five top world competitors in exports of high-speed trains, and part of an oligopoly of few players in a high-tech sector.

Industrial policies that reduce monopoly rents can increase global welfare. However, their benefits will depend on the scale upon which they are assessed. If domestic market shares are gained at the expense of more efficient foreign producers, domestic benefits will be larger than global ones. The possibility of retaliation must also be considered in the design of policies that aim to shift rents. The desirability of industrial policies should be evaluated in view of these risks, especially if ambitious policies in a few countries lead to an escalation of support at the global scale, beyond what is justified by market failures.

Scarcity rent shifting may also play a role for green policies, since many commodities, including oil, are a source of rent for producers. The development of renewable energy and improved energy efficiency may reduce the scarcity rent received by oil-exporting countries and benefit oil-importing ones. Also, the reduction in scarcity rent may lead to increased oil production and reduced fossil fuel prices, opposing the desired effect of green policies (the so-called "green paradox", (Sinn, 2008)). Recent analyses accounting for extraction costs show that this effect cannot reverse the effects of green policies, but it can reduce their effectiveness (Fischer and Salant, 2012).

3.3. "Sunset" industrial policies

Industrial policies can support the development of new sectors but, as illustrated by past cases, it can also be used to support declining industries and protect them against foreign competition. Doing so can be justified by distributional consideration or by a desire to smooth a transition that would otherwise have negative impacts on welfare and social stability. In the specific case of green industrial policies, competitiveness concerns may also be invoked to support brown industries if other countries are not implementing comparable environmental policies.

Distributive aspects and political economy

Industrial policies have long been used for regional balance and to create jobs and activity where unemployment is higher or the population poorer. Industrial policies can also be used to smooth economic transitions. Labor markets are seldom very flexible, and structural economic changes or trade liberalization often lead to a rise in unemployment, with skill and institutional issues preventing workers to shift from sunset to sunrise sectors. For instance, (Muendler, 2010) and (Menezes-Filho and Muendler, 2011) show that trade liberalization displaced workers from the de-protected industries in Brazil, and that it took several years for these workers to be absorbed by the growth sectors (see a review in Porto, 2012). The social costs of such a transition may justify transient support to declining industries to allow time for retraining and shifting workers toward growing sectors. This was the approach used by Japan industries to make the transition toward high-productivity high-skill industries more socially acceptable (Peck et al., 1987).

Similarly a green strategy may need to include some transient support to energy-intensive industries. This component of the green growth package can be a requirement for its political acceptability, in spite of its cost. Such support would aim to smooth the transition, helping businesses adjust their production technologies and workers adapt by moving to other sectors. Sometimes, there is also a regional component, when a region is particularly dependent on an energy-intensive sector. The need for such complementary policies depends on the availability of safety nets and retraining programs. Direct support creates a significant risk if policies cannot be progressively phased out, making it preferable to use sector-neutral safety nets when possible.[10]

Porto (2012), in a discussion of the lessons from the trade adjustment cost literature and its lessons for green policies, suggests moreover that it is more efficient to subsidize employment in growing sectors (to help them hire the workers that lose their job in the declining sectors) rather than supporting workers in declining industries. Support can thus be offered to the sunrise sector to enable it to more rapidly absorb workers from declining sector, or more directly to the workers themselves through social safety nets and retraining schemes.

---

[10] Public support has been found difficult to remove (for instance in the agricultural sector) even in industrialized countries with strong institutional capacity, high level of transparence and strong civil society.

These ideas are developed in (Rozenberg et al., 2013b) using a two-sector growth model. They show that a transition toward a low-carbon economy can be triggered by either supporting green investments (e.g., through subsidized loans) to favor green sectors in the absence of a carbon tax, or by complementing a carbon tax with a subsidy to polluting capital to smooth the negative impact on the tax. Both these approaches are found sub-optimal when measured in terms of inter-temporal welfare. However, they result in a lower short-term loss of income and protect the owners of polluting capital and the workers that depend on them. As such, they may be easier to implement. Unsurprisingly, many countries follow this second-best approach to green policies, with subsidies and "feebates" (e.g. for hybrid or electric cars (Anderson et al., 2011)), feed-in tariffs (e.g. for solar and wind electricity), free allowance of carbon permits for energy-intensive sectors, and sectoral regulation (e.g., CAFE standards on cars in the US) creating an incentive for green investments without *directly* penalizing polluting activities.[11]

Competitiveness considerations

It is unrealistic to expect all countries to implement comparable environmental policies. Differences in income levels and socio-political context mean that some countries are moving first and will continue to do so. There is thus a risk of pollution leakage from countries with strict environmental regulations to laxer countries. Fears of deindustrialization and job losses have played a large role in national debates on carbon tax and cap-and-trade system. For instance the European cement industry financed a study that—perhaps unsurprisingly—found that 80% of the European cement market would be captured by importers if a 25 euros per ton of carbon price was introduced.

However, the potential for leakage should not be overestimated. Pollution abatement costs represent only a small fraction of production costs for most industries. According to (Copeland, 2012), "*the evidence suggests that factors such as capital abundance, labor abundance, location, institutions, and agglomeration effects are more important than environmental policy in determining firm location choice and competitiveness*." (Branger and Quirion, 2013) provide a review of existing ex ante and ex post analyses of this problem. Ex ante modeling studies suggest that existing policies should generate a limited leakage at the macro-level, with significant sector-scale effects in heavy industries. In the analysis of 12 different models investigating a 20% emission abatement in all Annex I countries of the UNFCCC, for instance, leakage is estimated between 5 and 19% (with a mean at 12%), with loss of output by 0.5-5% in energy-intensive sectors (Böhringer et al., 2012). Moreover, most of the leakage in these models is not due to competitiveness effects, but to the green paradox (the fact that reduced current and expected demand in countries with climate policies leads to an increase in extraction and a reduction in oil price that increases demand in other countries).

Ex post studies fail to identify a significant impact of existing environmental policies, even in heavy industries (e.g., Sartor, 2013). (Demailly and Quirion, 2008) provide a detailed analysis of the European iron and steel industry, showing that the impact of the European Emission Trading Scheme on the competitiveness of the European industry remains limited, with an impact on marginal cost smaller than inter-annual exchange rates variations. Also, panel data from the UK production census suggest that the introduction of the Climate Change Levy (an energy tax) had a significant impact on energy intensity, but no detectable effects on economic performance or plant exit (Martin et al., 2009). The same conclusion is reached by (Anger and Oberndorfer, 2008) on German firms and the EU ETS system. These conclusions suggest that the impact of current environmental regulation on firm

[11] Polluting capital is however indirectly penalized through the competition with green capital production.

competitiveness remains limited, and that there is little support for the existence of a significant pollution leakage effect from international trade.

Nevertheless, some uncertainty remains: estimates of the effect of environmental policies are based on relatively modest efforts to date and may change should environmental policies become much stricter in some countries but not others. Additional measures may become necessary to maintain a level playing field between stricter and laxer countries—for example through trade policies such as bilateral or multilateral agreement on environmental regulation or border tax adjustments with or without transfer of revenues to the exporting country (Copeland, 2012); or through industrial policies, such as reduced corporate tax or support to energy-efficiency investments in vulnerable sectors.

These measures need however to remain consistent with WTO rules (Monjon and Quirion, 2011a, 2011b). Considering the technical and political difficulty in managing compliance with WTO rules on the topic, Branger and Quirion (2013) suggest that the allocation of free emission allowance to vulnerable energy-intensive industries (i.e., a subsidy to a polluting sector) may be a good second-best option.[12]

4. When and how to effectively deploy green industrial policies?

To be effective, green industrial policies need to target well-identified – and if possible measurable – market failures or distributional issues (Pack and Saggi, 2006). A green industrial policy that aims at developing a new economic sector without targeting the obstacles to such development is unlikely to succeed. This section proposes a typology of these obstacles to help determine whether industrial policies can be useful and how they can best be structured.

4.1. A typology of green industrial policy contexts

A simple analytical framework to identify the relevance of industrial policies in the green policy toolkit can be built along two essential factors:

- Price effectiveness: whether prices are in fact an effective instrument to trigger the needed structural changes – this depends on the price elasticity of the behavior that policy makers are seeking to influence;

- Ability to change prices: whether prices can in fact be changed and raised to levels high enough to trigger a response – this depends on the political or social acceptability of a price change.

These two issues are linked: if price effectiveness is low (i.e. the price elasticity is low), then a change in behavior would require a significant change in price. A large change in price is more likely to have negative consequences on some groups or industry, and is thus more difficult to implement. But even when a change in price is efficient, the acceptability of a price change may be limited (e.g., removing energy subsidies that lead to water overuse). And prices can sometimes be changed without leading to the expected impact on some behaviors (e.g., the EU-ETS introduced a carbon price for electricity supply, but it has little impact on how individuals make decisions on building insulation).

[12] This solution is equivalent to the application of a carbon price with subsidies to energy-intensive vulnerable sectors, similar to the case explored in (Rozenberg et al., 2013b).

In Quadrant 1 in Table 1, prices can be adjusted to an adequate level and they are effective instruments. In such a case, it is possible to implement a price instrument such as a tax or a carbon market, no further policy instrument need be deployed, and industrial policy is not needed.

Quadrant 2 is the classic industrial policy case: prices can be used to internalize the environmental externality but they are not effective at triggering the needed change. For instance, if a carbon tax is sufficient to trigger fuel shifts in the energy sector (e.g. use less coal and more gas power plants) but not enough to generate frontier innovation in the energy or automobile industry. Industrial policies are useful to complement environmental policies and help develop new green sectors or technologies, compensating for market failures such as economies of scale and knowledge spillovers. These policies help create the technologies needed to make price-based instrument efficient (i.e. to move from the right to the left side of the matrix) and respond to a latent demand. The justifications and caveats to these industrial policies are important but no different than those for other industrial policies (see, e.g., (Harrison and Rodríguez-Clare, 2009; Pack and Saggi, 2006; Rodrik, 2005).

Table 1: A framework to determine when and how to deploy green industrial policies.

		Effectiveness of price instruments	
		High	Low
Ability to change prices	High	(1) Price-based policies	(2) Classical temporary (sunrise) industrial policy to help develop new sectors and technologies
	Low	(3) Policies to smooth transition and reduce competitiveness concerns [support to sunset industries, social, and/or trade policies]	(4) Sunrise green industrial policy to help develop green sectors and technologies + efforts to improve acceptability of price changes [sunset industrial policies, social, and/or trade policies]

In Quadrant 3, pricing is an effective instrument to change behaviors but it is not socially or politically acceptable to raise prices to the needed level. In theory, this is a case where environmental policies to "get the price right" – through carbon taxes, carbon markets or payment for environmental services – should be enough. In practice, however, the challenge is less a market failure than a political economy stalemate due to competitiveness or distributional issues. The challenge is to devise policies to smooth the transition.

The appropriate instrument will therefore depend on what the obstacle to implementing the right price is. The issue may be concerns about the impact on the poor, in which case social safety nets or targeted subsidies may be the needed complementary policy. It could be the need to manage powerful lobbies that benefit from a rent and fiercely oppose reform. Experience from fossil fuel subsidies (IMF, 2013) show that successful reforms usually entail using part of the avoided expenditures to help firms and households adjust to the new prices, and sometimes to "buy out" opponents to the reforms.

Industrial policies may also be used to increase the acceptability of the needed price hike, in the same way it has been used in Japan to cope with decreasing demand (Peck et al., 1987). There may be concerns about the loss of competitiveness of a particular industry or the unemployment and societal dislocation that could occur in a region that is heavily dependent on such an industry. In such a case, industrial policies can mitigate negative impact. For instance, a carbon tax can be combined with temporary subsidies directed to the owners of the pre-existing polluting capital (e.g., coal power plants or high-emission vehicles) – that is the polluting capital that has been purchased *before* the price change. Doing so would influence the new investments and thus favor a transition toward a greener economy, without affecting negatively those who are currently dependent on polluting capital. In this case, a challenge is to ensure the support is in fact temporary, given governments' difficulties in cutting subsidies (as illustrated by the pervasiveness of fossil fuel subsidies). As discussed by (Rozenberg et al., 2013b), a solution may be to enact regulations that only apply to new capital, instead of implementing an economy-wide carbon price (as the CAFE standards or "feebates" programs in the automobile sector): this too influences new investment without affecting existing capital.

Quadrant 4 represents what we consider the "classic green industrial" policy case where both environmental and industrial policies are needed, because prices are difficult to adjust and would be insufficient to trigger the needed changes. In such cases, industrial policies may help both address the ineffectiveness of price instruments and facilitate price changes by either reducing the extent of needed price hikes or by providing options to mitigate the losses from higher prices. Policies to increase the fuel efficiency of new vehicles (e.g. CAFE standards) would reduce the impacts on households of a higher gasoline price, making them more socially acceptable; while support to the domestic car industry to help make it competitive in the fuel-efficient vehicle segment would reduce resistance from the car industry.

This matrix should be viewed in a dynamic fashion. The objective of complementary policies is to bring the situation into the left-upper corner of the matrix, where prices are efficient and can be adjusted to internalize the environmental externality. But political economy issues may dictate a sequencing of reforms that goes from Quadrant 4 to Quadrant 3 before reaching Quadrant 1. It may be politically unacceptable to raise prices until a technology exists that easily enables a transition. This could justify support to green technology, through supply- and demand-side industrial policies such as feed-in tariff and access to subsidized loans and capital, even in the absence of appropriate pricing, at least in a transition phase. The support to solar energy in China is an example of industrial policies that supported a green sector in anticipation of the introduction of a carbon price. In such a case however, rebound effects or limited market demand need to be managed (in China's case through an initial reliance on export markets).

Depending on the context, therefore, green industrial policies have up to three parallel and interlinked objectives:

- developing the new technologies and sectors that will make it possible to green the economy and to implement efficient price instrument without large negative economic impacts, and possibly with positive economic impacts (sunrise industrial policies);

- smoothing the transition toward a greener economy, by compensating losers and helping them adjust to the new situation; in that case, they help implement environmental policies and need to be implemented in conjunction with them (sunset industrial policies, social and trade policies);

- generating environmental benefits – both directly even in the absence of other environmental policies) and indirectly through the first two objectives as a complement to environmental policies (e.g., a carbon price).

The context also has consequences on how to evaluate green industrial polices. Classical assessments of industrial policies often rely on the Mill and Bastable tests (Harrison and Rodríguez-Clare, 2009). The Mill test asks whether the supported sector or technology can become competitive in the absence of support, while the Bastable test asks whether the benefit of support exceeds the cost. Many scholar support the idea that an industrial policy should pass these two tests to be justified. But for green industrial policies, the Mill test can be difficult to use if the environmental externality cannot be corrected. In this case, indeed, some green technologies that can be supported by industrial policies will never become profitable in the absence of support. Carbon capture and sequestration (CCS) for example cannot be competitive without a carbon price. It means that CCS will be used only if the environmental externality is corrected or in the presence of a permanent support. In that case, assessments of green industrial policies will have to rely only on the Bastable test. But this test is also difficult to use if the future carbon price is unknown, or depend on future policy choices that are difficult to anticipate.

Table 2 provides concrete examples of the type of policies that can or have been used in different contexts.

4.2. Mitigating implementation risks

Rodrik (2004) claims that where markets do not work well because of institutional weaknesses (e.g., lack of enforcement of property rights and contracts, difficulty in appropriating investment returns), coordination will be particularly difficult and industrial policies represent an interesting alternative. However, this argument is at odds with the idea that industrial policies are more appropriate where transparency and rule of law reduce the risk from capture and rent-seeking-- highlighting the difficulty in identifying the contexts in which industrial policies potential benefits exceed their risks in terms of capture and rent-seeking behaviors.

More generally, the two main criticisms to industrial policies are linked to (i) the risk of being wrong, i.e. to pick and support the wrong technology or sector; (ii) the risk of being captured, i.e. to distribute resources to friends and political allies instead of promising firms.

The risk of being wrong

It is difficult to anticipate the potential of new technology or a country's latent comparative advantage[13], and the cost of being wrong can be large. As mentioned in (Rodrik, 2004), industrial

[13] Using a model of industrial policy as a process of Bayesian experimentation and evaluation by policymakers seeking to discover comparative advantage under incomplete information about the nature of world markets, Klimenko (2004) suggests however that even an optimally designed experimentation strategy may not be able to discover the "right" comparative advantage, leading to specialization in "wrong" or "inferior" activities.

policy aims at discovering and developing the appropriate new technologies and products, and cannot be expected to succeed in all cases. There is thus a real potential for costly failure and waste of scarce public resources, as illustrated by well-known examples (e.g., the large support of Norway to Norsk Data, which went bankrupt in 1993).

Table 2: Situations in which industrial policies can represent a useful complement or alternative to price instruments

	Effectiveness of price instrument	
Ability to change prices	**High** *Market failure*: Only the environmental externality	**Low** *Market failure*: Environmental externality, and economies of scale, learning by doing, knowledge externality, coordination failure, missing markets, or lack of long term credibility of carbon price
High *Political economy failure:* *N*one	*Examples*: -Acid rains caused by sulfur and nitrogen oxides -Power generation reliant on coal while cheap alternatives (e.g. gas) are available. *Challenge/objective:* internalize environmental externality *Policy instruments:* - Classical market-based instruments: environmental tax, allowance market. (e.g. US Acid Rain Program, EU-ETS)	*Example*: Offshore wind power stuck in the "valley of death"* (despite the carbon price given by the EU-ETS) *Challenge/objective:* accelerate technology development and diffusion *Policy instruments: sunrise* industrial policies*:* - R&D subsidies, - Feed-in-tariffs and tenders - Forward contracts and market "making" (e.g. Pilot large-scale offshore wind projects, France 2011-2013)
Low *Political economy failure:* Limited social acceptability of higher prices Competitiveness concerns Lobbying power of losing industries	*Example*: Low energy cost leads to high energy consumption and environmental costs *Objective*: Reform energy subsidies *Challenge:* improve social/political acceptability of higher energy prices *Policy instruments:* complement tariff increases** with: - targeted cash transfer to the poor delinked from energy consumption (e.g. unconditional cash transfers in Indonesia, Iran) - improve social safety nets (e.g. energy subsidy reform in Armenia) - Support to urban mass transit (e.g., subsidized loans for bus purchase in Nigeria) and vulnerable firms (Iran).	*Example*: private transport dependent on energy-inefficient cars *Objective:* increase fuel prices *and* introduce new transport technologies *Challenge:* improve social/political acceptability of higher fuel prices, manage competitiveness issues; trigger R&D into new car technologies & allow for large scale deployment to exploit economies of scale. *Policy instruments:* - CAFE standards to reduce energy intensity of new cars without negatively affecting owners of energy-inefficient vehicles -"feebates" programs and other incentives to subsidize learning by doing in favor of high potential technologies (hybrid and electric vehicles)

(*) The "valley of death" refers to the fact that many technically viable technologies never take off usually due to the inability of their creators to make them commercially viable.
(**) see (IMF, 2013)).

This is why output-based or horizontal approaches are generally considered superior to vertical policies (those that "pick the winner," or at least the preferred technology) because they reduce the risk of capture and rent-seeking by vested interest. The fear is that with technology specific policies, *governments may pick the wrong winner*. However, Azar and Sanden (2011) make the case that absolute technology neutrality is difficult to use as a guiding principle: government can never avoid setting some priorities. As such, the appropriate question is "how much", not "whether", a particular policy is technology-specific.

Further, given knowledge externalities, learning by doing, economies of scale and the "valley of death" that hamper the transition from lab to market, reliance on market instruments (e.g. carbon price) is likely to favor established technologies. This may be optimal if the goal is to encourage the deployment of the cheapest technology available today. However, if the goal is to develop the technology with the greatest potential (in terms of cost reductions or ability to fill needs), then *the market may pick the wrong winner* (Azar and Sanden 2011).

Thus, the fact that the potential of one technology is deemed to be superior to another justifies favoring one technology over another (del Rio Gonzalez 2008). For instance, specific support to solar energy production (as opposed to other carbon-free electricity production technologies like wind power) is justified by the larger potential of this technology to solve the clean energy challenge at low cost (Tour et al., 2013). The current relatively high costs make it unlikely for solar energy to be massively deployed in the presence of horizontal support to carbon-free electricity production. A feed-in tariff that favors solar over wind may therefore be more efficient in the medium to long run than technology neutral feed-in tariffs (designed as a function of GHG emissions of electricity production) that allow the electricity provider to freely chose today's economical low-carbon technology.

And as discussed in Section 3.2, a latent comparative advantage is sometimes visible when countries have a potential to develop hydro, wind or solar power. In that case, the risk of being wrong is reduced.

The information necessary to target green industrial policies is spread across economic actors. Designing an efficient policy therefore requires a process through which the government can learn about technological potentials and production costs. Rodrik (2013) suggests to do so through the *embeddedness* (Evans 1995) of government officials in civil society and business networks. In other terms, collaboration and cooperation is needed between the private sectors and the government agencies that control and support them. This requirement parallels proposals in other domains such that risk management, where stakeholders, experts, and regulators need to collaborate to design cost-effective and legitimate regulation (World Bank, 2013). Also, specific tools can be implemented that not only support an industry but also collect information about technologies, costs, and potentials and avoid relying on information that firms can manipulate. For instance, the Chinese government used tenders to assess solar electricity production costs before it implemented a feed-in tariff, in the hope of collecting enough data to set the tariff at the right level.

More generally, green industrial policies need to target well-identified – and if possible measurable – market failures. Their design is indeed particularly dependent on the market failure that needs to be corrected (Pack and Saggi, 2006). It is particularly important to define a success indicator that allow for objective and predictable decisions regarding the attribution and termination of support to a firm or a technology. A green industrial policy that aims at developing a new economic sector without targeting a specific obstacle to such development is unlikely to succeed.

When countries try to develop a leading industry in a green sector, they have to keep in mind that not everybody can be the leader in green technologies: if many countries try to become major exporters of green goods and services, only a few will succeed, and the others may lose significant resources in the process.

The risk of being captured

Well-targeted industrial policies are more likely to succeed but they still face significant risks of capture and rent-seeking behaviors. This is why Pegels (2014) (and papers within) appropriately frame the debate on green industrial policy as the management of the rent created by industrial policy to incentivize investment in green sectors and technologies. The aim of a green industrial policy is to create the appropriate level of rent from green investment to facilitate the green transition.

Rent-seeking behavior is likely to influence policies, even in countries with high institutional capacity and appropriate "checks and balances" (Anthoff and Hahn, 2010; Helm, 2010). (Neven et al., 2000) identify factors that make such problems more likely: sharply partisan political systems, weak governments, and absence of transparency. But rent-capture remains possible, even in the most efficient, balanced, and transparent economy, because industrial lobbies are powerful actors in any economy.

The risk of capture is particularly important if green industrial policies are implemented in absence of correct price-incentives. Indeed, it is in this case even more difficult to assess them, because the created industries cannot be put through a market test. A "classical" industrial policy aiming at capturing a latent comparative advantage is supposed to be transient and can be tested from the viability of the supported industry when the support is removed. In absence of appropriate pricing (e.g., a carbon tax), green industries (e.g., solar electricity) may remain non-viable in absence of support. Therefore, they cannot be market-tested, and they require a support over the long-term. In that case, green industrial policies have to be permanent, just like the support to some private health or education institutions has to be permanent.

Rodrik (2013) provides some guidance to avoid these potential pitfalls:

- Given the strong incentives of the private sector to game the government, predictable and transparent criteria are needed that determine when public support is terminated. Doing so is much easier for industrial policies that are well-targeted, since the target can more easily be translated into an indicator for success.

- The institutional design faces a trade-off between flexibility (the ability to account for new information regarding technology potentials, for instance) and predictability (the fact that actors have to be able to anticipate the scale of support to incentivize private investments). Evidence suggests that solar feed-in tariffs were adjusted following changes in input prices (Tour and Glachant, 2013). Such responsiveness to new information requires an iterative processes with regular revision based on participatory approaches and consultations (World Bank, 2013). When supported firms and technologies cannot be subjected to a market test– because the relative prices are biased, for example– then other success indicators need to be devised, such a reduction in production costs or performance standards.

- The beneficiaries of green industrial policies should be the public, not the firms receiving support, making transparency and public accountability a major requirement. Allocation of resources should therefore be made public, and some regular auditing process is needed. For example, an independent auditing agency could be created and responsible for an annual analysis of how funds and supports are distributed. Obviously, the power of such an agency is largely dependent on the existence of a free press and an active civil society able to react to mismanagement of funds.

With industrial policies come the risk of capture and rent seeking. But the same is true for major infrastructure development, R&D subsidies, and regulation in all sectors, from finance to household appliances. Because industrial policy implies investing in many risky projects with strong information asymmetry, the risk may be higher in this domain than in many others, and it therefore requires paying careful attention to institutional design. Where it appears impossible to ensure an appropriate level of transparency or discipline, it may be preferable to avoid this approach.

But in the institution design also, an iterative process based on learning is possible, with small initial resources that are growing over time as the skills of government officials improve and the confidence in the resource allocation process improves.

5. Conclusion

Greening our growth processes to the extent and with the speed needed cannot be done without industrial policies, even if prices can be adjusted to reflect environmental objectives. Even if the environmental externalities are internalized in prices, investments that are needed because they are expected to yield large learning-by-doing or knowledge spillovers may not be profitable. In such cases, prices are neither sufficient nor effective. Thus “sunrise” industrial policies that provide targeted support to a promising but currently expensive green technology (e.g. carbon capture and storage), may be warranted given its likely importance and potential for learning by doing and economies of scale.

Temporary “sunset” green industrial policies and trade policies may be needed in conjunction with safety nets and other policy instruments to make carbon pricing less costly in terms of competitiveness, employment and welfare and thus easier to implement. Fossil fuel subsidy reforms have demonstrated that price changes can be made politically acceptable if complemented with appropriate measures to smooth their transitory impacts and help firms and households adjust. Similarly, temporary “sunset” industrial policies and trade policies targeting industries that are vulnerable to carbon pricing can mitigate the negative impacts of the price change and make it possible to internalize the climate change externality without causing unacceptable loss in competitiveness and jobs.

Even in the absence of carbon pricing, “sunrise” green industrial policies that target green sectors may still be usefully deployed –at least in the short term—to reduce emissions and bring down the price of needed alternative technologies. Knowledge creation can be promoted with tax breaks for private universities without creating a price for knowledge. Similarly, green investments can be incentivized through instruments other than a carbon tax, for instance through access to cheaper capital, lower taxes, or regulations. Through their impact on the economic structure and because they lead to innovation and reduce the cost of green options and technologies, these alternative instruments can facilitate the later introduction of price instruments and even make some green technology competitive with fossil fuel technologies (e.g., solar or hydropower). In that case, green industrial policies can be understood as a transitory instrument to prepare the economy to the transition toward a green economy in which prices reflects environmental externalities.

Green industrial policies are best deployed carefully and in concert with other instruments. Green or not, industrial policy requires carefully navigating the twin dangers of market and governance failure. It is a difficult instrument to wield well and one that is best deployed in concert with pricing policies, norms, regulations, and consumer mandates. A careful analysis of the economic and environmental costs and benefits of green industrial policies is needed to assess their desirability. Particular attention must be paid to avoid potential unintended negative effects, such as rebound effects (especially if prices are inappropriate), misallocation of capital, or capture and rent-seeking behaviors. Institutional design needs to ensure that (i) green industrial policies have clear and measurable objectives, (ii) support to non-performing firms or technologies is terminated rapidly, (iii) tools are adjusted regularly to account for changes in technology costs and potentials, (iv) transparency and accountability processes are in place.

Past experience – especially in Asia – provides support for the ability of industrial policies to encourage changes in economic structures, even though it is unclear whether they would have passed a cost-benefit analysis. But even if they fail to provide domestic economic benefits through their employment or GDP impact, green industrial policies can provide global environmental benefits through their impact on emissions and green technology costs. Their proven ability to affect the economic structure makes them good candidates for green policies, since their objective is to eventually transform the economic structure to make it sustainable.

6. References

Acemoglu, D., Aghion, P., Bursztyn, L., Hemous, D., 2012. The Environment and Directed Technical Change. American Economic Review 102, 131–166.

Ades, A., Tella, R.D., 1997. National Champions and Corruption: Some Unpleasant Interventionist Arithmetic*. The Economic Journal 107, 1023–1042.

Anderson, S.T., Parry, I.W.H., Sallee, J.M., Fischer, C., 2011. Automobile Fuel Economy Standards: Impacts, Efficiency, and Alternatives. Rev Environ Econ Policy 5, 89–108.

Anger, N., Oberndorfer, U., 2008. Firm performance and employment in the EU emissions trading scheme: An empirical assessment for Germany. Energy Policy 36, 12–22.

Anthoff, D., Hahn, R., 2010. Government failure and market failure: on the inefficiency of environmental and energy policy. Oxford Review of Economic Policy 26, 197–224.

Baldwin, R., Krugman, P., 1988. Industrial policy and international competition in wide-bodied jet aircraft, in: Trade Policy Issues and Empirical Analysis. University of Chicago Press, pp. 45–78.

Baldwin, R.E., 1969. The Case against Infant-Industry Tariff Protection. Journal of Political Economy 77, 295–305.

Beason, R., Weinstein, D.E., 1996. Growth, Economies of Scale, and Targeting in Japan (1955-1990). The Review of Economics and Statistics 78, 286–295.

Böhringer, C., Balistreri, E.J., Rutherford, T.F., 2012. The role of border carbon adjustment in unilateral climate policy: Overview of an Energy Modeling Forum study (EMF 29). Energy Economics 34, Supplement 2, S97–S110.

Borrus, M., Tyson, L.D., Zysman, J., 1986. Creating advantage: how government policies shape international trade in the semiconductor industry. Strategic Trade Policy and the New International Economics 99–114.

Branger, F., Quirion, P., 2013. Climate policy and the "carbon haven" effect. Wiley Interdisciplinary Reviews: Climate Change. DOI: 10.1002/wcc.245.

Chang, H.J., 2006. Industrial policy in East Asia-lessons for Europe. European Investment Bank, Economic and Financial Studies.

Chang, H.-J., 2010. Industrial Policy: Can We Go Beyond an Unproductive Confrontation? (Working Paper No. 2010/1). Turkish Economic Association.

Copeland, B., 2012. International Trade and Green Growth. Policy Research Working Paper 6235. The World Bank.
Dechezlepretre, A., Martin, R., Mohnen, M., 2013. Knowledge spillovers from clean and dirty technologies: A patent citation analysis.
Del Río González, P., 2009. The empirical analysis of the determinants for environmental technological change: A research agenda. Ecological Economics 68, 861–878.
Demailly, D., Quirion, P., 2008. European Emission Trading Scheme and competitiveness: A case study on the iron and steel industry. Energy Economics 30, 2009–2027.
Dutz, M., Sharma, S., 2012. Green growth, technology and innovation. Policy Research Working Paper 5932. The World Bank.
Evans, P.B., 1995. Embedded autonomy: states and industrial transformation. Cambridge Univ Press.
Fischer, C., Salant, S., 2012. Alternative Climate Policies and Intertemporal Emissions Leakage: Quantifying the Green Paradox (Discussion Paper No. dp-12-16). Resources For the Future.
Fluri, T.P., 2009. The potential of concentrating solar power in South Africa. Energy Policy 37, 5075–5080.
Goodrich, A.C., Powell, D.M., James, T.L., Woodhouse, M., Buonassisi, T., 2013. Assessing the drivers of regional trends in solar photovoltaic manufacturing. Energy & Environmental Science.
Gual, J., 1995. The three common policies: an economic analysis, in: Buigues, P.-A., Jacquemin, A., Sapir, A. (Eds.), European Policies on Competition, Trade and Industry: Conflict and Complementarities. E. Elgar.
Guivarch, C., Hallegatte, S., 2013. 2C or not 2C? Global Environmental Change 23, 179–192.
Hallegatte, S., Heal, G., Fay, M., Treguer, D., 2012. From Growth to Green Growth-a Framework. National Bureau of Economic Research. Working paper 17841.
Harrison, A., Rodríguez-Clare, A., 2009. Trade, foreign investment, and industrial policy for developing countries. National Bureau of Economic Research. Working paper 15261.
Hausmann, R., Rodrik, D., 2003. Economic development as self-discovery. Journal of Development Economics 72, 603–633.
Helm, D., 2010. Government failure, rent-seeking, and capture: the design of climate change policy. Oxf Rev Econ Policy 26, 182–196.
Helpman, E., Krugman, P.R., 1989. Trade policy and market structure. The MIT Press.
IMF, 2013. Energy Subsidy Reform – Lessons and Implications. International Monetary Fund.
Kalkuhl, M., Edenhofer, O., Lessmann, K., 2012. Learning or lock-in: Optimal technology policies to support mitigation. Resource and Energy Economics 34, 1–23.
Klimenko, M.M., 2004. Industrial targeting, experimentation and long-run specialization. Journal of Development Economics 73, 75–105.
Krauss, E.S., 1992. Political economy: policymaking and industrial policy in Japan. PS: Political Science and Politics 25, 44–57.
Krugman, P., 1994. The myth of Asia's miracle. Foreign affairs 62–78.
Laffont, J.-J., 1999. Political economy, information and incentives. European Economic Review 43, 649–669.
Lee, H., Moon, D.-S., 2005. Next Generation of Korea Train Express (KTX): Prospect and Strategies. Proceedings of the Eastern Asia Society for Transportation Studies 5, 255–262.
Lee, J.-W., 1996. Government interventions and productivity growth. J Econ Growth 1, 391–414.
Martin, R., Wagner, U.J., de Preux, L.B., 2009. The Impacts of the Climate Change Levy on business: Evidence from Microdata. CEP Discussion Papers.
Menezes-Filho, N.A., Muendler, M.-A., 2011. Labor Reallocation in Response to Trade Reform. National Bureau of Economic Research. Working Paper No. 17372.
Monjon, S., Quirion, P., 2011a. Addressing leakage in the EU ETS: Border adjustment or output-based allocation? Ecological Economics 70, 1957–1971.
Monjon, S., Quirion, P., 2011b. A border adjustment for the EU ETS: reconciling WTO rules and capacity to tackle carbon leakage. Climate Policy 11, 1212–1225.

Muendler, M.A., 2010. Trade reform, employment allocation and worker flows. Trade Adjustment Costs in Developing Countries: Impacts, Determinants and Policy Responses, World Bank, Washington, DC.
Murphy, K.M., Shleifer, A., Vishny, R.W., 1988. Industrialization and the Big Push (Working Paper No. 2708). National Bureau of Economic Research.
Neven, D.J., Röller, L.H., Wandel, W.B. für S.A.W. und I., 2000. The political economy of industrial policy in Europe and the member states. Edition Sigma.
Noland, M., 1993. The Impact of Industrial Policy on Japan's Trade Specialization. The Review of Economics and Statistics 75, 241–248.
Noland, M., Pack, H., 2003. Industrial policy in an era of globalization: Lessons from Asia. Peterson Institute.
Nunn, N., Trefler, D., 2010. The Structure of Tariffs and Long-Term Growth. American Economic Journal: Macroeconomics 2, 158–194.
Okuno-Fujiwara, M., 1988. Interdependence of industries, coordination failure and strategic promotion of an industry. Journal of International Economics 25, 25–43.
Pack, H., Saggi, K., 2006. Is There a Case for Industrial Policy? A Critical Survey. World Bank Res Obs 21, 267–297.
Pack, H., Westphal, L.E., 1986. Industrial strategy and technological change: Theory versus reality. Journal of Development Economics 22, 87–128.
Peck, M.J., Levin, R.C., Goto, A., 1987. Picking losers: public policy toward declining industries in Japan. Journal of Japanese Studies 13, 79–123.
Pegels, A. (Ed.), 2014. Green Industrial Policy in Emerging Countries, Routledge Studies in Ecological Economics. London: Routledge. 192 pages.
Porto, G.G., 2012. The Cost of Adjustment to Green Growth Policies: Lessons from Trade Adjustment Costs (SSRN Scholarly Paper No. ID 2165675). Social Science Research Network, Rochester, NY.
Richter, W.F., Schneider, K., 2003. Energy taxation: Reasons for discriminating in favor of the production sector. European Economic Review 47, 461–476.
Rodrik, D., 2004. Industrial policy for the twenty-first century. CEPR Discussion Paper No. 4767.
Rodrik, D., 2005. Chapter 14 Growth Strategies, in: Handbook of Economic Growth. Elsevier, pp. 967–1014.
Rodrik, D., 2013. Green Industrial Policies. Presented at the "economics of green growth" workshop. Grantham Reserach Institute and Global Green Growth Institute. October 1, London.
Rosenstein-Rodan, P.N., 1943. Problems of Industrialisation of Eastern and South-Eastern Europe. The Economic Journal 53, 202–211.
Rozenberg, J., Hallegatte, S., Perrissin-Fabert, B., Hourcade, J.-C., 2013a. Funding low-carbon investments in the absence of a carbon tax. Climate Policy 13, 134–141.
Rozenberg, J., Vogt-Schilb, A., Hallegatte, S., 2013b. How capital-based instruments facilitate the transition toward a low-carbon economy : a tradeoff between optimality and acceptability. Policy Research Working Paper Series 6609. The World Bank.
Sinn, H.-W., 2008. Public policies against global warming: a supply side approach. Int Tax Public Finance 15, 360–394.
Smulders, S., Withagen, C., Toman, M., 2013. Green theory and "Green Growth." Presented at the "economics of green growth" workshop. Grantham Reserach Institute and Global Green Growth Institute. October 1, London.
Stern, N., 2006. Stern review report on the economics of climate change.
Tour, A.D.L., Glachant, M., 2013. How do solar photovoltaic feed-in tariffs interact with solar panel and silicon prices? An empirical study.
Tour, A.D.L., Glachant, M., Ménière, Y., 2013. What cost for photovoltaic modules in 2020? Lessons from experience curve models.
Vogt-Schilb, A., Hallegatte, S., 2011. When starting with the most expensive option makes sense. Policy Research Working Paper 5803. The World Bank.

World Bank, 2010. Development and climate change. 2010 World Development Report. The World Bank.
World Bank, 2013. Risk and Opportunity: Managing Risk for Development. 2014 World Development Report. The World Bank.