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Green Industrial Policy in Emerging Markets

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Abstract

In this review, we discuss the challenges and opportunities associated with implementing green industrial policy in developing countries. These policies promote industries that produce green technologies and encourage traditional industries to produce goods and services in greener ways. We describe the experience in some emerging markets of voluntary programs to reduce emissions. Contrasting India and China's efforts to promote their solar photovoltaic industries, we also discuss the relative efficiency of promoting deployment versus promoting R&D. We also warn against expecting too much from policies that encourage renewables while governments simultaneously subsidize fossil fuels. The review discusses the potential of hybrid policies that combine command-and-control regulations targeted at the intensive margin for the largest polluters with market-based incentives that widen the reach of environmental regulations. We conclude with a discussion of how dismantling tariffs and facilitating foreign direct investment, ostensibly for nonenvironmental reasons, can have important environmental consequences.

1. INTRODUCTION

The set of instruments used by governments to shift incentives vis-à-vis trade, foreign investment, and resource allocation across industries is often referred to as industrial policy.[1] The market failure arguments for traditional industrial policy rely on the existence of large positive spillovers across firms and agglomeration externalities. Many skeptics believe that, even if market failures exist in theory, the cure known as industrial policy is worse than living with the disease. But what about *green* industrial policy?

In our review, we define green industrial policy broadly. There are two components. The first describes policies that promote industries that produce green technologies (for example, promoting sectors that produce biofuels, solar panels, or wind turbines).[2] The second describes policies that encourage traditional industries to produce goods and services in greener ways (for example, through the use of solar panels or wind turbines, or through changes in inputs, processes, or technologies that result in lower energy input per unit of output or lower pollutant emissions). This latter set of policies includes both direct environmental regulation and indirect environmental effects from other policies, such as tariff reform or other types of market liberalization. Our broader concept of green industrial policy is consistent with Lütkenhorst et al. (2014, p. 6):

> . . . *green* industrial policy encompasses any policy measure aimed at aligning the structure of a country's economy with the needs of sustainable development within established planetary boundaries—both in terms of the absorption capacity of ecosystems and the availability of natural resources. This definition extends beyond more narrow notions of green industrial policy, which focus on the promotion of low-carbon fossil fuel alternatives (Karp & Stevenson 2012) or the nurturing and promotion of industrial sectors that produce green technologies and goods . . .

In our view, green industrial policies therefore include any policies aimed at mitigating negative externalities from air, water, or land pollution and climate change. The negative externalities from pollution at the local level are increasingly clear in the form of costs to health and quality of life.[3] Global externalities due to climate change are also well documented, and there is increasing consensus both on the dangers of climate change and the need to address it by pricing carbon in a way that reflects true social cost.

Opponents of industrial policies may object to sector-specific interventions when that sector is automobiles or airplane engines, but is there a stronger case to be made when that sector is solar panels? Similarly, is there a stronger case for input-specific interventions when the input in question is coal, rather than locally manufactured textiles?

In making these comparisons, we find it useful to contrast the rationale for industrial policy in general and green industrial policy in particular. Local and global externalities are why many economists and policy makers believe that the case for green industrial policy is stronger than the usual rationale for industrial policy (see, for example, Hallegate et al. 2013, Karp & Stevenson 2012,

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[1] Whereas policies that target a particular sector are sometimes called vertical, there are also so-called horizontal industrial policies. Horizontal policies (see Stein & Crespi 2014) are industrial policies that apply to all sectors, such as measures to encourage industry associations to work with each other and the government in identifying binding constraints to growth.

[2] This is the narrow definition of green industrial policy adopted by Karp & Stevenson (2012) and Rodrik (2014). Karp & Stevenson (2012, p. 1) define green industrial policy as "government attempts to hasten the development of low-carbon alternatives to fossil fuels." For Rodrik (2014, p. 469), the goal of green industrial policy is to "ensure [that] investments in green technologies take place on an appropriate scale."

[3] For recent estimates of the impacts of air pollution on life expectancy in China and India, see Chen et al. (2013) and Greenstone et al. (2015), respectively.

Pegels 2014, Rausser & Zhi 2011, Rausser et al. 2012, Rodrik 2014, Torani et al. 2016). Identifying and measuring the types of market failures involved in traditional industrial policy—positive spillovers across firms and agglomeration externalities—is much more challenging empirically (Harrison & Rodriguez-Clare 2010). Because environmental market failures are often global in nature, but there are political obstacles to imposing cross-national carbon taxes, green industrial policy is also important as a second-best solution to international environmental challenges.

In this article, we review the evidence on the design and implementation of green industrial policies. We focus on emerging markets, where enforcement of environmental regulation is typically more difficult than in developed countries, but where enormous opportunities exist for low-cost emission reductions. We emphasize five lessons for the use of green industrial policy. The first lesson is that, in contrast to traditional industrial policy, the existence of externalities and the consequent need for government intervention are much easier to document. Nevertheless, we also show that effective implementation of green industrial policy remains a challenge.

The second lesson we draw from the evidence is the importance of direct targeting using appropriate instruments. In the case of green industrial policy, one major externality targeted by policy is emissions from burning fossil fuels. In this case, the first-best policy response would be to set a carbon tax or its equivalent, which has been avoided in most countries. Many of the problems that we document with green industrial policy stem from the fact that first-best solutions are not being used. Another example discussed in this review is the solar industry, where the biggest impediment to global adoption is technologies that are not competitive with fossil fuels. As Torani et al. (2016) show, in this case, a first-best policy would be to subsidize R&D to accelerate technological change. Instead, many other instruments, such as feed-in tariffs and consumer subsidies for deployment, have been favored. Second-best solutions, including the use of green subsidies, have generated unintended consequences in addition to enforcement challenges and inefficiency. This, we feel, is the most important lesson from our review of green industrial policy.

The third lesson arising from our review is that effectively designing and enforcing green industrial policies in emerging markets are very challenging. We discuss some guidelines and possible solutions, including the use of satellite images, designing creative solutions such as community involvement, and the application of latent comparative advantage in setting policy priorities. The fourth lesson is that many pitfalls of green industrial policy can be solved by promoting competition. Finally, our review of the literature suggests that local industrial and environmental policies are likely to have global, interconnected consequences.

Section 2 briefly summarizes the types of instruments available to pursue green industrial policy, using the broad definition described in this introduction. Section 3 provides an overview of the main challenges and opportunities associated with implementing green industrial policy in developing countries. In Section 4, we present three sets of case studies that highlight some of these challenges and opportunities. Section 5 concludes by summarizing the lessons learned from reviewing green industrial policy in various contexts worldwide.

2. THE INSTRUMENTS OF GREEN INDUSTRIAL POLICY

Policy makers have used a wide range of policy instruments to implement green industrial policies. The longest-standing of these policies, aimed at encouraging industries to produce goods and services with fewer pollutant emissions, are environmental regulations that take the form of nontradable technology or performance standards. There is an increasing trend toward the use of market-based mechanisms, such as taxes and tradable permits, to limit pollutant emissions to air and water. With respect to global carbon emissions, the most straightforward of these market-based options is a carbon tax. An almost equivalent market-based quantity instrument is a cap-and-trade system that limits the overall level of emissions, allocates or auctions permits to emit, and allows firms to trade permits. In renewable energy, the equivalent to cap-and-trade is a renewable portfolio standard (RPS), where regions set a renewable energy target (for example, India's target to produce 15% of all generation from renewables by 2020) and then allow generators to trade renewable energy certificates with each other to meet their obligations.

In practice, however, many countries have opted against taxing dirty energy in favor of rewarding clean energy. One common subsidy tool is a feed-in tariff, which guarantees generators a fixed price for their renewable production, often regardless of when it takes place or what it displaces.

Other tools for green industrial policy include R&D support, investment tax credits, guaranteed or subsidized credit or debt, local content requirements (LCRs), subsidies for final product demand, and priority treatment in government procurement. Policy makers often use a combination of these incentives to promote renewable energy (see, for example, Rausser & Zhi 2011 and Rausser et al. 2012).

As an illustration, a range of government support measures has been used to promote the development of the renewables industry in the United States. The first use of solar power originated when the United States was seeking indefinite energy for satellites launched as part of its space program. The role of the government in creating the preconditions for the current shale revolution is documented by Heck & Rogers (2014, p. 48):

> The federal government had conducted considerable research on shale in response to the energy crisis . . . a government/industry partnership had produced detailed maps for most of the shale geology in the US. The Department of Energy had also built on industry efforts in 3-D seismic imaging, which is important for working a drill through a shale formation, and the Bureau of Economic Geology had provided images that helped show how porous the rock was. In addition, the federal government provided tax credits for unconventional oil and gas wells, such as Mitchell's, creating an incentive to experiment.

Emerging markets also use a wide range of green industrial policies. Zheng & Kahn (2017) review the tools used by China to reduce particulate matter (PM) in its largest cities, where air pollution has steadily declined (as measured by PM10 concentrations) since the early 2000s. Zheng and Kahn show that the gradual decline in PM10 was achieved using a combination of command-and-control (CAC) policies, fostering competition to improve environmental quality among local officials, reducing subsidies to water and energy, and investing in pollution abatement. Similar to industrial countries, emerging market governments also provide direct funding or subsidies for R&D and make investments in complementary infrastructure, such as charging stations for electric vehicles.

Well-known instances of specific developing-country programs that combine several different policy tools include China's and India's wide-ranging support for domestic solar industries (Ganesan et al. 2014, Zhang et al. 2014) and Brazil's support for biofuel production (Sorda et al. 2010). In this review, we discuss how India has promoted the local solar photovoltaic (PV) industry by mandating that solar modules be manufactured locally. Although there is a large literature and extensive experience with most of these policies in developed countries, implementing them in emerging markets brings a unique set of challenges and opportunities.

3. CHALLENGES AND OPPORTUNITIES: IMPLEMENTING GREEN INDUSTRIAL POLICY IN EMERGING MARKETS

On the one hand, recent experience with implementing policies to reduce industrial pollution in developing countries has identified a number of obstacles. On the other hand, the potential benefits from improved environmental outcomes—and the possibility of spurring innovation in terms of both technology and policy—may be particularly large in emerging markets. In this section, we provide an overview of both the challenges and opportunities associated with implementing green industrial policy in developing countries.

3.1. Challenges

A key challenge in implementing green industrial policy in developing countries is the potential lack of demand for environmental improvement. Greenstone & Jack (2015) survey the literature and conclude that the willingness to pay for environmental quality in developing countries is low, although this may be due in part to imperfect markets for land and labor that make it difficult to elicit willingness to pay based on observed market outcomes.

Even when there is public demand for improved environmental quality, developing countries may lack the institutions and resources needed to effectively implement existing regulations. Setting and enforcing limits on industrial air, land, and water pollution require knowing the locations of polluting factories, being able to monitor emissions or to inspect and verify the installation of specific technologies or the use of specific processes, and having the ability to enforce penalties on noncompliant factories. A number of factors, including low levels of fiscal resources and trained staff at regulatory agencies, corruption, and a lack of political will to enforce environmental regulations, may hamper the regulatory process (Blackman & Harrington 2000, Duflo et al. 2013).

Even if a regulatory program can be successfully developed, a key challenge lies in extending such a program to the vast number of small, often informal firms that dominate the landscape in developing countries, including in the manufacturing sector. In a country such as India, for example, estimates suggest that as much as 80% of employment in manufacturing is in the informal sector (Nataraj 2011). Whereas large firms may be the largest individual emitters of air, water, and land pollution, groups of informal firms can contribute a substantial share of emissions (Blackman 2000). Many such firms operate without registering with the government, so even identifying them can be a challenge; and given their small size and large numbers, inspection and enforcement would likely be very costly.

In situations where it is difficult to inspect and enforce environmental regulations, regulatory agencies may find it more feasible to charge taxes on inputs such as pesticides or coal. Taxes on pesticides or coal affect the production decisions of even the smallest-scale producers. However, such taxes are likely to create lower incentives for pollution reduction than do fees or cap-and-trade systems, as they do not directly target emissions (Blackman & Harrington 2000).

A related challenge is that small, informal firms often provide livelihoods for very poor households, and the markets in which they compete are often highly competitive, so that the firms are unable to pass on costs of compliance or upgrading technology to customers (Blackman 2000, Kathuria 2006). These firms are often operated close to the owner's residence and serve local customers. This proximity creates a potentially high health burden for poor residents who live in the vicinity of small, polluting firms, and it also makes relocation difficult.

3.2. Opportunities

Although it is more difficult to implement green industrial policy in developing countries than in developed countries, doing so may also provide a greater scope for benefits. The most polluted cities in the world are located in rapidly growing economies: Bahrain, Cameroon, China, India, Iran, Nigeria, Pakistan, and Saudi Arabia (**http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/**). Of these, China and India have multiple cities that make the top 20 list for emitting different pollutants. Greenstone et al. (2015) estimate that achieving India's National Ambient Air Quality Standard for fine PM pollution would save 2.1 billion life years.

In addition to health-related benefits from environmental regulations, some authors have made the case—often known as the Porter Hypothesis after it was proposed by Porter (1991)—that strict but flexible environmental regulations could induce efficiency and encourage innovation. The Porter Hypothesis ran against the idea that being constrained to reallocate inputs to pollution reduction could only reduce productivity for a profit-maximizing firm. The economic arguments in favor of the Porter Hypothesis lie in the premise that environmental regulation provides missing information about efficiency improvements, reduces uncertainty around the payoffs of efficiency-enhancing investments, encourages socially optimal levels of R&D in clean technologies, and circumvents first-mover disadvantages in implementing unfamiliar technologies. Ambec et al. (2013) cast these arguments in terms of market failures: market power, asymmetric information, R&D spillovers, and behavioral and organizational failures.

Developing countries can also potentially benefit from the input use-efficiency embodied in imported technologies, in other words, from the ability to leapfrog to the latest, cleanest technologies. Technology transfer can be viewed in one of two forms. First, there is knowledge transfer, such as information or technical assistance from a foreign partner or a foreign aid donor. There is also equipment transfer or direct imports of goods, such as solar panels or boilers, from foreign suppliers. Encouraging foreign direct investment (FDI) is likely to promote the former, whereas reducing tariffs on capital imports could foster the latter.

One alternative to mandatory regulation that has potential in the developing country context is the promotion of voluntary programs. Such programs include payments for good environmental outcomes, public disclosure of environmental performance, and the signing of negotiated voluntary agreements between regulators and large industrial players. Voluntary programs avoid the imposition of disproportionate cost on small, informal sector firms and may reduce costs associated with enforcement. Ideally, they can be set up in ways that reduce emissions without penalizing growth. They do not, however, obviate the need to monitor emissions. In fact, a number of voluntary programs rely on a baseline-and-credit system to determine the level of benefits received, which creates a separate system of administrative requirements, namely the need to correctly identify counterfactual emissions trajectories.

The clean development mechanism (CDM) is one of the most famous examples of opt-in environmental regulation available to manufacturing firms in industrializing countries. It is one of three "flexibility mechanisms" in the United Nations Framework Convention on Climate Change Kyoto Protocol, an international treaty that set binding limits on greenhouse gas emissions for industrialized countries. Countries and firms can meet part of their Kyoto Protocol commitments in the EU Emissions Trading Scheme using Certified Emission Reductions generated by CDM projects in poor and industrializing countries. CDM credits fund not only renewable energy generation projects but also industrial projects, such as industrial energy efficiency, cogeneration, input substitution, and fuel switching.

One key goal of the CDM is to provide global access to low-cost emission reduction opportunities. The marginal cost of reducing global emissions in developing countries may be significantly less than in wealthier countries for two reasons. First, these countries are growing rapidly, and emissions reductions are substantially cheaper to achieve when opting for cleaner versions of new technologies than when retrofitting existing technologies. This effect is particularly salient in countries such as India and China where large investments in new power generation go online daily. Second, many emerging markets have a sizable base of very old capital stock. Replacing old, low-efficiency vintages is a very cost-effective way of reducing emissions.

Although there are concerns that the CDM has been either crediting projects that would have happened anyway or overcrediting the emission reductions obtained by projects (Colmer et al. 2016, Liu & Martin 2016), the program has led to an acceleration of technology transfer. According to Dechezleprêtre et al. (2008), who examine an early sample of CDM projects, almost half of the projects and more than three-fourths of the expected annual reductions in carbon dioxide emissions involved knowledge transfer. Tang & Popp (2016) evaluate almost 500 wind projects in China funded in part through the CDM. They find evidence of technology transfer through international collaboration at the project level. Specifically, they reveal that costs of wind power decrease (or wind farm productivity increases) after repeated collaboration between the project developer and a particular foreign turbine manufacturer. They also find evidence of industry-wide spillovers; specifically, they show that project costs fall after other similar projects are implemented in the industry.

The following section looks at several case studies that illustrate some of these challenges and opportunities in more detail.

4. CASE STUDIES

We begin with case studies of policies aimed at reducing pollutant emissions from manufacturing firms in different emerging markets. These case studies highlight the challenges in enforcement and implementation discussed in Section 3. We then move to a case study of the solar PV sector, which has been heavily promoted in both emerging and industrial country markets. Our particular focus is on the contrasting cases of India and China. We conclude with a discussion of how conventional trade and foreign investment promotion policies interact with green industrial policy in unexpected ways. One of the important themes from the green industrial policy literature for twenty-first century policy makers is that national decisions have significant impacts on the global market, as local actions now have global repercussions.

4.1. Policies Aimed at Regulating Emissions from Manufacturing

In this section, we review recent papers evaluating policies that target pollutant emissions from manufacturing firms in Asia (China, India, and Malaysia), Latin America (Colombia and Mexico), and Eastern Europe (Poland).

We begin with two studies by Duflo and colleagues in the Indian state of Gujarat. These studies highlight the challenge of enforcing environmental regulations that are on the books. India has a vast array of environmental regulations; typically, the Central Pollution Control Board sets national environmental standards, and state-level boards are responsible for implementation.

In one study, Duflo et al. (2013) collaborated with the Gujarat Pollution Control Board (GPCB) to test the effectiveness of a third-party auditing system for polluting firms. Since 1996, firms classified as "most polluting" or "highly, but somewhat less polluting" have been subject to independent, third-party audits. In the case of "highly, but somewhat less polluting" firms, the firm must hire a private audit firm from an approved list. The auditors submit reports to the plants that hired them and to the GPCB, documenting plant emissions and recommending specific pollution control measures.

In theory, the audit system should provide independent verification of emissions to the GPCB. However, the authors show that the specific implementation of the audit system led to underreporting of pollution. Auditors were randomly assigned to approximately half of 473 plants on the "highly, but somewhat less polluting" list. In this "treatment" group, the auditors were paid a flat rate from a central resource pool, and a random subsample of reported emissions was verified by staff from an engineering college. In the control group, firms could continue to select and negotiate payment with private audit firms from the approved list, although toward the end of the experiment, a subsample of reported emissions was also verified.

The study found clear evidence of underreporting of emissions in the control group, including reports indicating emissions below the regulatory standard, when they were in fact above, in 29% of cases. The reports showed considerable bunching of results just below the regulatory standard, whereas the independent verification by engineering college staff did not. Results from the treatment group suggest that removing the choice of audit firm from the plant's domain improved reporting, reducing by 80% the number of reports that incorrectly stated that emissions were below the standard and lessening the observed bunching. The random assignment of auditors also led to a decrease in pollutant emissions, which was driven almost entirely by the most polluting plants.

A companion study (Duflo et al. 2014) randomly allocated additional inspections by GPCB inspectors to treatment plants in a sample of 960 plants in Gujarat. Although the treatment did result in increased inspections and increased numbers of violations, it did not increase identification of the number of "extreme polluters": plants with emissions five times or more above the standard. The authors argue that inspectors were already targeting plants with the highest emissions, so the marginal returns to additional, randomly assigned inspections were relatively low. Administrative data from the sample of plants in the audit experiment (Duflo et al. 2013) also suggest that regulators were attempting to do their jobs: Approximately 25% of those plants had received a citation for violating an environmental regulation, and the likelihood and severity of the penalty were higher for more polluting firms.

Taken together, these cases demonstrate the difficulty in designing and enforcing environmental regulations. Gujarat's High Court initially called for the audit system "to remedy the perceived failure of inspections in enforcing pollution standards" (Duflo et al. 2013, p. 1505). Yet, even though the GPCB appears willing to hand out citations when it identifies violations and to target the most severe polluters, the design of the third-party audit system allowed underreporting of emissions, thus blunting the regulator's enforcement ability. Although such challenges are not unique to developing countries, they are exacerbated by the regulator's lack of resources in these settings.

Another study from India highlights the importance of public demand for environmental quality improvements. Greenstone & Hanna (2014) examine the effects of three major environmental initiatives in India: (*a*) the Supreme Court Action Plan (SCAP), in which the Supreme Court mandated that 16 cities develop plans to address air pollution; (*b*) a separate set of actions by the Supreme Court requiring the use of catalytic converters; and (*c*) the National River Conservation Plan (NRCP), aimed at mitigating pollutant discharges into waterways. The authors exploit the extent and differential timing of each policy and compare air pollution and water quality outcomes in cities that were and were not affected. Overall, they find that the policies aimed at combating air pollution were relatively successful: The catalytic converter policy reduced ambient levels of PM, sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), while the SCAP policy was also associated with a reduction in NO_2. In contrast, the NRCP was associated with, if anything, worse outcomes for water pollution. The authors suggest that this contrast may have been driven by higher public demand for improved air quality, due to higher disease costs, higher avoidance costs, greater public discourse, and the fact that India's Supreme Court drove the air quality policies.

Harrison et al. (2015) perform a more detailed analysis of the SCAP policy to examine whether it impacted individual plant behavior. Many of the specific regulations included in city SCAPs were aimed at reducing pollutant emissions from manufacturing plants, through measures mandating relocation, installation of pollution control equipment, or bans on the use of dirty fuels. Many of these policies were specifically aimed at plants operating in 17 highly polluting industries (HPIs). Using panel data on formal manufacturing plants from 1998 through 2009, the authors show that in cities subject to the SCAP, the share of large HPI plants investing in pollution control equipment increased. In contrast, there was some observed backsliding among smaller, non-HPI plants that were not typically the targets of SCAP regulations. This finding suggests that the SCAP focused regulatory efforts on the largest, most polluting factories. The authors also find evidence that the SCAP policy is associated with a reduction in total factor productivity, especially among large HPI plants, and with a decreased probability of entry.

Harrison et al. (2015) also exploit the geographic and temporal variation in coal prices to compare the effects of higher input prices, with the CAC regulations of the SCAP. They find that higher district-level coal prices are associated with lower coal use; the price elasticity of demand for coal use, which suggests that a 10% increase in coal price yields a 6–10% reduction in coal use, is in line with estimates from the United States. The authors confirm Greenstone & Hanna's (2014) findings that the SCAP may have decreased NO_2 pollution to some extent. Importantly, they also find that higher coal prices are consistently linked with a reduction in ground-level monitor reports of SO_2 pollution.

Although the variation in coal prices examined by Harrison et al. (2015) was not explicitly brought about by environmental taxes, comparing the effects of the SCAP policies and coal prices suggests that both CAC policies and market-based instruments had some impact on abatement, albeit through different channels and for different pollutants. The responsiveness of firm behavior to coal prices in particular suggests that the coal tax introduced by India in 2010 could play an important role in reducing coal use. In fact, Borenstein (2012) has argued that taxing dirty energy sources may be more effective than subsidizing clean energy sources. A tax is more likely to reduce overall energy consumption, to more directly target the sources of emissions and to ensure that the benefits from emissions reductions occur in the local areas that enact the policies.

Similar to India, China has also enacted a variety of policies to combat air pollution, including SO_2 emissions. Just as in Harrison et al.'s (2015) study of SCAP policies, Tanaka et al.'s (2014) study of China's Two Control Zone (TCZ) policy sheds light on the potential channels through which CAC regulations operate. As of 1998, prefectures were required to comply with TCZ regulations if average annual or daily ambient SO_2 concentrations exceeded threshold levels, if average annual pH values for precipitation fell below a threshold, or if sulfate deposition was greater than a critical load. Firms located in TCZ zones were required to either shift away from high-sulfur coal to low-sulfur coal or to install scrubbers. TCZ status also restricted the construction of new coal-burning thermal power plants.

In contrast with Harrison et al. (2015), who document productivity declines following the implementation of India's SCAP policy, Tanaka et al. (2014) find that TCZ regulation led to firm-level increases in productivity and competitiveness. Specifically, they show that after flexibly controlling for industry- and city-specific trends and holding energy expenditures constant, firms in pollution-intensive industries in TCZ cities had higher revenues than same-industry firms in unregulated cities. They also demonstrate that the regulation acted in part on the extensive margin: The introduction of TCZ policies induced entry of more productive firms and exit of less productive ones.

The case studies from India and China demonstrate that CAC policies can have different impacts on firm behavior, including impacts on productivity and selection (via entry and exit) under different circumstances. They also suggest that both CAC policies and market-based incentives may be effective in reducing industrial pollutant emissions. In this vein, Kathuria (2006) argues that a combination of CAC policies and market-based incentives, coupled with improved enforcement, drove the success of initiatives to address water pollution in Malaysia, Poland, and Colombia. In the case of Malaysia, the Department of Environment (DOE) originally set a standard for biochemical oxygen demand (BOD)—a proxy for the level of organic compounds in water—in discharges from palm oil mills. Mills were required to apply for an operating license; they were also charged a fee per ton of BOD discharges up to the standard and an excess charge of up to 10 times the license fee amount for discharges above the standard. Although mills did initially reduce their discharges to some extent, many chose to pay the excess fee, resulting in smaller discharge reductions than the DOE had anticipated. To address this shortcoming, the DOE therefore threatened to close any mill that discharged BOD above the standard, and it did in fact suspend the operating licenses of 27 mills within a three-year period.

Similarly, Kathuria (2006) reports that Poland also required facilities to obtain permits for sewage disposal, with fees charged up to the permitted levels, and fines (up to 10 times the fee rate) above those levels. Kathuria argues that a combination of permits, fees, and fines, a campaign to target the highest polluters, and increased enforcement drove improvements in environmental quality. Blackman & Harrington (2000) study a similar charge and fine system for air pollutants in Poland and note that although the charges were likely too low to incentivize reduced emissions, the fines do appear to have done so. Both Kathuria and Blackman and Harrington emphasize that monitoring and enforcement were limited by a lack of resources. Some facilities, notably small and medium enterprises (SMEs), may not have obtained permits, and underreporting was likely, as facilities could self-report emissions. Another major challenge in the Polish case was that the charges were not effective for some major polluters, namely, state-owned enterprises, because of their soft budget constraints (Blackman & Harrington 2000, Kathuria 2006). Though this challenge was mitigated when many state-owned enterprises were privatized starting in 1989, Blackman and Harrington argue that it remains a concern. Despite these and other challenges with policy design, the combination of permits, fees, and fines does appear to have improved environmental quality in Poland.

Empirical work to date has most commonly evaluated the effects of either market-based incentives or CAC regulations in isolation. However, the evidence from Blackman & Harrington (2000), Harrison et al. (2015), and Kathuria (2006) suggests that the question of whether CAC regulations or market-based incentives are more effective may not be relevant in some contexts. Rather, a combination of the two may be required to effect change. A potentially fruitful area for future research would be to investigate how firm-level responses differ for the two types of instruments. As Harrison et al. show, higher coal prices affected the intensive margin of firms' coal use in India, but they did not affect the fraction of firms using coal. In contrast, CAC regulations affected the fraction of firms with pollution control equipment but did not increase the average amount of investment among firms with pollution control equipment. In addition, whereas coal prices had similar effects on coal use for firms of different sizes and in different industries, the CAC regulations clearly affected large, HPI firms the most. These findings, coupled with the work by Duflo et al. (2013, 2014), suggest that CAC regulations may be more effective at targeting the largest polluters, whereas market-based incentives may be more effective at widening the reach of environmental regulations. Future research could also focus on cases where market-based incentives and CAC regulations are jointly used to achieve the same environmental goals. This research would shed light on conditions under which the two types of policy instruments are likely to be complementary versus those under which one type of instrument may undermine the other's effectiveness.

Blackman (2009) and Kathuria (2006) also study the case of Colombia's system for wastewater discharges. As in the Polish case, Blackman (2009) notes that certain major dischargers—municipal sewage treatment plants—were not viewed as sufficiently compliant, only paying 40% of invoiced charges from 1997 to 2002. Although this recovery rate was higher than that for other polluters, industrial and agricultural groups used the low rate to argue that they should not be expected to pay fees. This focus on major polluters is a recurring theme in several case studies. As Duflo et al. (2014) show, there is value in targeting major polluters, especially in settings where regulators have low levels of staff and fiscal resources. The Colombian case also highlights that compliance among major polluters may be needed to develop a culture of compliance (Blackman 2009). This strong focus explains Harrison et al.'s (2015) findings that India's SCAP appears to have targeted regulatory effort at large factories in the most polluting industries.

Colombia's wastewater discharge system also raised the issue of distributional impacts, which can be an even more prominent challenge in developing countries than in developed countries. In this case, some argued that the fee system affected the poor disproportionately. If the municipalities passed on the discharge fees proportionally to customers, then poor customers whose basic use was subsidized would face greater percentage increases (Blackman 2009).

The issues of potentially greater harm to the poor and the lack of coverage of SMEs are also prominent in Blackman's (2000) study of four clusters of informal brick kilns in Mexico. Each cluster included between 60 and 500 small brick kiln operations, typically fired with scrap wood, used tires, manure, used motor oil, and other dirty fuels. In each case, several policy initiatives were used to attempt to switch the kilns to propane. Policy tools included subsidies for new technology, bans on the use of specific fuels, boycotts of bricks made with dirty fuels, public awareness campaigns, R&D investments, and price floors for bricks. The effort to switch to propane—particularly for the Ciudad Juárez cluster, which was the earliest to attempt the switch—was helped by national subsidies on propane fuel. However, as these subsidies were phased out in the early 1990s, efforts in all four clusters faltered. Ultimately, the clusters have had more lasting success with bans on the use of very dirty fuels, such as plastics, motor oil, and battery cases.

A key lesson learned from Blackman's (2000, 2009) case studies is that, given the high regulatory cost of monitoring numerous small firms, monitoring by peers or community members, which depends in turn on buy-in from the regulated firms and from the community, was crucial to even the partial success of these initiatives. Peer pressure is likely to be particularly important in developing countries where, as noted above, the capacity for formal monitoring and enforcement may be weak.

Blackman (2000) also notes that the political power of the regulated firms constrained the specific policies that regulators could enforce. In three of the four clusters, the brick makers were politically organized, and in these clusters, regulators generally focused on policies that would not yield large compliance costs or that provided subsidies to offset costly requirements. In contrast, in the fourth cluster, brick makers were not well organized. In that fourth cluster, Blackman (2000, p. 2075) reports that the city forced 19 kilns to move from their location near the city entrance "in a far more draconian manner than originally planned"; financing was planned but not ultimately offered for the purchase of new land, and only six brick makers relocated, whereas the remainder changed jobs.

The cases of informal kilns also highlight the conflict between the goals of economic development, poverty reduction, and environmental improvement. In the Ciudad Juárez cluster, for example, Blackman (2000) notes that the 350 kilns employed 2,000 people, who were largely poor, and they supported another 150 jobs in transportation and wholesaling. Given the competitive nature of the industry, any policies that increased the cost of operation would likely lead to a loss of income or potentially lost livelihoods for brick makers. At a more macroeconomic level, the phasing out of propane subsidies that took place in the 1990s was driven by a broader push toward economic liberalization, which aimed at improving economic outcomes throughout Mexico. One unintended consequence of this rise in propane prices was a reversal in the early success of shifting brick makers in Ciudad Juárez to the use of propane and a stalling of efforts in the other cities. More broadly, Blackman notes that the overall volatility of input prices in developing countries is a key factor to consider when crafting appropriate policy tools.

4.2. The Solar Photovoltaic and Wind Sectors

We now turn from the examination of regulations that encourage many manufacturing sectors to produce their output with fewer emissions to evaluate efforts to promote a specific industry: the solar PV industry. We primarily compare and contrast the cases of China and India.

The evolution of China's solar PV industry has been nothing short of spectacular. Huang et al. (2016) document the remarkable rise of this sector in China, from essentially nonexistent to a global leader in the space of 10 years. Although China had essentially no solar PV industry when it began to grow in the early 2000s, by 2012, it had overtaken Europe in installed capacity. Huang et al. identify a number of factors external to the industry itself as critical in the sector's rise, including (*a*) China's move toward privatization in the late 1980s and membership in the World Trade Organization (WTO) in late 2001, (*b*) easy access to technology transfer in this sector from the West, including the ease of importing turnkey production facilities from Europe and support from foreign firms, and (*c*) a large potential market in the form of Europe. Internal factors identified as critical for catch-up include the fact that the Chinese central government highlighted renewable energy as critical for China's future. This legitimized the solar PV sector for local governments, which in turn provided low-cost loans, infrastructure, and cheap energy to further support sectoral development.

Two interesting outcomes pointed out by Huang et al. (2016) are the eventual use of antidumping provisions by Europe and the United States to counter China's solar PV sector and the bankruptcy of a number of prominent Western solar PV manufacturers, including Solyndra. In 2002, the industry was led by Japanese producers, but by 2012, seven of the ten top global solar PV manufacturers were Chinese, and the Japanese and Germans were no longer in that group.

Another noteworthy aspect of the role of industrial policy in solar PV is the interaction with global markets. Whereas Rodrik (1999, 2007) has emphasized the negative aspects to global WTO rules that now prohibit the types of subsidies used in previous decades by industrial countries, Huang et al. (2016) suggest that WTO membership had a strong positive impact on the emergence of China's solar PV industry. Executives in China were motivated to enter the solar PV sector precisely when China joined the WTO because suddenly they had access to global markets without the previously onerous transaction costs—including actual or potentially crippling tariffs levied by trade partners. Given that the local demand in China for solar power was and is lower than foreign demand, this remains an important consideration. Several of the articles reviewed below suggest that US and European support for renewable energy, which boosted their internal demand and consequently promoted China's exports, has effectively subsidized the growth of the Chinese solar sector.

Groba & Cao (2013) test some of these hypotheses about the rise of China's renewables sector using a gravity model for 43 countries with annual bilateral trade flows between 1996 and 2008. They start with the observation that China's solar PV panel industry rose from negligible to accounting for 45% of world production in 2010. Their wind turbine industry also grew rapidly, accounting for 41% of the global market in 2011. Groba and Cao compare and contrast the two markets, noting that the solar PV panel industry growth in China was primarily driven by opportunities in high-income export markets, with limited demand at home. In the wind energy technology components (WETC) market, however, China has achieved limited export growth but much more significant domestic market growth.

Groba & Cao (2013) combine the information on policy incentives from the International Energy Agency/ International Renewable Energy Agency Global Renewable Energy Policies and Measures Database with their bilateral trade flows; they also consider country size and R&D. Their results suggest that China has benefited from access to high-income country markets and that lower import tariffs abroad significantly affected their exports of solar PV panels but not WETC products. They also find that price incentives in rich country markets, such as feed-in tariffs and price floors, significantly encouraged Chinese exports. Finally, they find that national R&D policies in China did not significantly affect the solar PV industry but that provincial R&D spending did have significant effects. Their results on the limited role of knowledge investments in basic research are consistent with the anecdotal evidence presented by Huang et al. (2016) suggesting that China's significant support of research in renewables at the university level did not quickly translate into renewables manufacturing, which relied more on knowledge transferred through turnkey plants, foreign investment, and foreign technical experts.

India's less successful efforts to promote the solar PV industry are also instructive. The contrast with China is interesting because both nations have large domestic markets, which could have allowed them to exploit scale economies and scope in their home markets. Johnson (2013) argues that, in contrast to China's meteoric rise, India's (later) efforts to foster the local solar PV industry have resulted in failure. When economists warn against the dangers of industrial policy, they could very well have in mind India's experience, as described by Johnson. The Indian government, in part to encourage local employment and the acquisition of local capabilities, promoted the domestic solar PV industry primarily through a policy of mandating LCRs. However, only solar PV producers using crystalline silicon technology were required to source their modules locally; the law exempted solar producers who used thin film technology, which in any case was already preferred in India and was lower in cost. As a result, firms avoided the LCRs by importing modules that used thin film technology, thus undermining the very sector that the policy was designed to promote. In addition, solar panel producers faced negative effective protection, as tariffs on their imported inputs exceeded the tariffs on their own final goods, making it difficult to be profitable. Feed-in tariffs promoting the adoption of solar panels were too weak to compensate for these disadvantages, which were exacerbated by the glut of global capacity in Europe, the United States, and China. Johnson also points to other problems associated with the LCRs introduced in India, including US conditions for US EXIM Bank financing tied to use of the thin film technology and additional policy uncertainty due to the fact that LCRs are in violation of WTO international law.

Grau et al. (2012) compare and contrast Germany's and China's support of the solar PV industry. They make a number of important points that were not emphasized by the previous studies. First, they emphasize that, although system prices fell 50% between 2006 and 2011 due to technological change, virtually all new investments in the PV sector continue to require government support to remain competitive. This is because solar technology is still expensive relative to standard energy sources such as coal. They argue that, for the PV sector to become sustainable without support over the long term, costs would need to fall by at least another 50%. Of course, part of the problem is that countries do not price carbon to reflect global negative externalities.

Grau et al. (2012) trace the rise and dominance of China's and Germany's solar industry firms. They identify feed-in tariffs as Germany's primary means of promoting the industry, with the consequence that German consumers have indirectly promoted China's solar industry emergence. On the Chinese side, support took many forms, including tax holidays, value-added tax rebates, low-cost loans, and infrastructure provision. The authors make the important point that the critical binding constraint going forward is the need to reduce costs, and consequently, to focus on R&D. However, a very small share of industrial policy support has historically been devoted to R&D, with the bulk of support going to manufacturing and deployment. In 2012, the authors estimate that R&D support accounted for only 3% of deployment support in Germany and 1% in China. They recommend that direct support for R&D in both countries be increased. They also warn that German consumers are wary of continuing to indirectly subsidize the Chinese solar industry through feed-in tariffs, and that in China, there are concerns that the industry is growing without sufficient technology transfer on the part of Western manufacturers.

Most of the literature to date analyzing the effectiveness of green industrial policy in solar and wind energy provides a partial analysis of outcomes. Probably the most comprehensive article is the recent evaluation of Pegels & Lütkenhorst (2014) comparing Germany's wind and solar energy sectors. They evaluate the success of green industrial policy along five dimensions: competitiveness, innovation, job creation, climate change mitigation, and cost. They measure competitiveness using revealed comparative advantage and global export shares and measure innovation using patents granted. Cost is primarily calculated using Germany's key industrial policy tool: feed-in tariffs paid to providers of renewable energy.

Pegels & Lütkenhorst (2014), consistent with other researchers, find that Germany's wind energy sector has been more successful than its solar energy sector. They begin by estimating the costs of sectoral promotion policies and then estimate the benefits. The costs can primarily be traced to the feed-in tariffs applicable for both wind and solar energy in Germany; for 2013, they estimate that feed-in tariffs accounted for €12 billion. Two thirds of the amount was spent on solar PV, whereas the remaining one-third went to wind energy. One contentious aspect of the program is that these feed-in tariffs are paid for by both residential and industrial consumers, with estimated energy costs 22% higher for households and 35% higher for industrial consumers as a result.

On the benefit side, Pegels & Lütkenhorst (2014) analyze the competitiveness, innovation performance, pollution mitigation, and employment creation aspects of the wind and solar PV programs in Germany. They show that the German wind converter industry has surged to the leading exporter position, accounting for a 50% global market share in 2013, whereas the solar PV industry has stagnated or declined. As indicated in other aforementioned articles, much of the relatively poorer global performance of Germany's solar sector is due to China's export surge. However, Germany's PV system component manufacturers and equipment suppliers have maintained their competitive edge, accounting for half of the global market.

On the innovation front, Germany's wind sector has also performed better than other sectors. In terms of job creation, the authors find that, of the 380,000 total jobs created by renewable energies in 2012, wind energy accounts for one-third of those, and solar PV accounts for approximately one-quarter. Based on superior global performance, higher rates of innovation, and lower costs, Pegels & Lütkenhorst (2014) conclude that Germany's green industrial policy has been more successful for wind power than for the solar PV industry. However, two important factors need to be taken into account. First, China as an external competitor likely accounts for a large share of the solar sector's decline in Germany. Second, in the wind energy sector, innovation is more closely tied with output expansions than in solar PV. This means that the expansion of solar without the technological edge was easier in China, which then allowed it to take advantage of scale.

Despite a growing body of work, none of the researchers evaluating the effectiveness of industrial policy in the solar and wind industries measure the net welfare gains from the policies. Because these technologies are still evolving and are not yet competitive with traditional energy sources, measuring the overall welfare effect is challenging.

Torani et al. (2016) analyze which policy instruments could be most effective in improving the price competitiveness of solar energy relative to nonrenewables, as this is the major impediment to large-scale adoption globally. Their findings suggest that the most effective policy would be to subsidize R&D to accelerate technological change. They also show that carbon taxes and consumer subsidies in this case are not likely to be effective in accelerating the transition over the next 30 years. This is because the key constraint in this industry is a lack of a cost-effective technology. The key lesson from this study is that the appropriate instrument must address the market constraint directly instead of indirectly, such as through the use of feed-in tariffs and consumer subsidies for deployment. Their conclusions are supported by other research, such as a 2015 study by a team of researchers at the Massachusetts Institute of Technology (MIT 2015).

The MIT (2015) study identifies a number of important challenges to massive deployment of solar energy, including the need to solve the intermittency problem (i.e., solar energy is not always available, and long run storage solutions have not yet been found) and the need to lower costs so that solar can be competitive with conventional energy. The authors also point out that, in contrast to many other countries in Europe and Latin America, the United States does not promote solar energy through the use of feed-in tariffs but through investment tax credits and accelerated depreciation. They see this as an inefficient and expensive approach.

The MIT (2015) study also suggests that policy support should increase for R&D, in line with the recommendations of the aforementioned articles. The study concludes that investment tax credits, accelerated depreciation allowances, and output quotas, which in the United States are referred to as RPSs, are not effective policy tools. They recommend that the United States move to some sort of price-based system such as feed-in tariffs. MIT (2015) also echoes Torani et al. (2016) in suggesting that government support for breakthrough basic research in R&D would be effective in lowering the long run costs of solar.

This section on promotion of the renewables sectors in emerging and developed markets illustrates two important themes of our review. First, we argue that designing instruments to directly address the market failure or externality significantly improves the likely success of green industrial policy. In India, domestic content requirements failed to directly support the promotion of the domestic solar PV industry. Across all countries, consumer and producer subsidies to solar do not directly promote the R&D necessary to make solar competitive with fossil fuels over the long run.

Second, successful implementation of green policies takes into account latent comparative advantage. Germany is well known for its advanced machinery sector but is a less likely candidate for successfully harnessing the sun's energy. Not surprisingly, Germany has fared well in exporting its machinery for the manufacture of solar PV panels, but it is not as successful in deploying the panels domestically. Although its location makes it difficult to take full advantage of solar energy, Germany has nonetheless been more successful with its wind farms. In India, incentives provided through feed-in tariffs and LCRs were insufficient to compensate for the lack of comparative advantage faced by Indian solar panel producers using crystalline silicon technology. Finally, Torani et al. (2016) and other authors argue that consumer and producer subsidies will not be able to compensate for the fact that, in the short run, solar energy is not cost competitive with nonrenewables. Creating a comparative advantage in solar through R&D support could therefore be a smart strategy for the United States and other countries in the longer term.

4.3. The Impact of Trade and Other Policy on Environmental Outcomes

In the traditional industrial policy literature, two key instruments include (*a*) setting and dismantling of tariffs and (*b*) facilitation of FDI. Although these measures are rarely taken specifically for environmental reasons, they can have important environmental consequences.

4.3.1. Theory. The theory behind the impact of tariffs on environmental outcomes was initially based on the Heckscher-Ohlin-Samuelson (HOS) model, in which countries have a comparative advantage in goods produced with endowed factors that are in relative abundance.[4] According to the HOS model, countries with abundant labor specialize in labor-intensive industries such as textiles, whereas countries with abundant capital specialize in capital-intensive industries such as automobiles. Theorists then inferred environmental outcomes by positing that capital-intensive industries are dirty, labor-intensive industries are clean, and developing countries have an abundance of cheap labor. By extension, pollution-intensive industries should locate in capital-abundant rich countries. For a developing country, all else equal, the implication was that if tariffs were reduced, the country would see a decrease in pollution due to a relative expansion of labor-intensive industries. Of course, if a poor country's abundant factor is cheap coal, then the HOS model would predict that a decrease in tariffs would lead instead to a reallocation toward coal-intensive industries.

The theory of comparative advantage led to the theory of pollution havens, namely that some developing countries have a comparative advantage in weak environmental regulation. The fear was that strict environmental policies in developed countries, coupled with low barriers to trade, would lead to industrial flight: Pollution-intensive industries would locate in countries with weak regulation. This reallocation would not only mean lost jobs and tax revenues but could lead, in the case of global pollutants, to worse environmental outcomes if the recipient poor countries also had old, high-polluting capital stock. Another concern, one for which there is little if any evidence, is that the desire to attract industry would drive some countries to further lower their environmental standards, like cities competing to attract large companies with increasingly generous tax breaks, possibly triggering a race to the bottom.

The new trade theory focuses on a different angle. In the Melitz (2003) model, the most productive firms benefit and grow the most from trade liberalization, whereas the least productive firms are unable to afford the fixed costs of production and hence drop out of the market, thereby raising aggregate productivity. Bustos (2014) provides a further extension, in which lowering tariffs gives high-productivity firms additional incentives to upgrade technology. If one of two assumptions holds, then the new trade models can have environmental implications. Namely, there are implications if energy or fuel efficiency moves hand in hand with overall input efficiency (i.e., total factor productivity) or if new technologies have embodied environmental improvements from countries in which they were designed. In that case, lowering tariffs would benefit the environment by reallocating production to cleaner firms within each industry while driving out inefficient firms through increased competition. At the same time, lowering tariffs would give high-productivity firms additional incentives to adopt cleaner technologies.

Copeland & Taylor (1994) provide a canonical framework for the relationship between trade and the environment. They decompose the effect of globalization on the environment into three components: scale (overall scale of the economy), composition (relative importance of each industry in the economy), and technique (pollution intensity of each industry). The HOS model makes predictions about the composition effect, whereas the new trade theory makes predictions about the technique effect. The technique effect includes not only shifts in production toward potentially cleaner firms and adoption of new technologies or improvements in process efficiency, as discussed above, but also any effects of changes in product mix, capacity utilization, or choice of fuels.

[4]See Copeland & Taylor (1994) and reviews by Copeland & Taylor (2004) and Karp (2011).

4.3.2. Empirical evidence. With some caveats, the empirical evidence supports the hypothesis that, although the overall level of pollution worsens with growth, decreases in trade tariffs and many decades of increasing global integration have improved the pollution intensity of growth. Antweiler et al. (2001) study the evolution of SO_2 concentrations at the city level. They regress SO_2 levels on city gross domestic product (GDP)/km^2 (scale), national capital-to-labor ratio (endowments), lagged GDP, trade intensity, and values of capital to labor and GDP relative to world averages. They find that, although a 1%-increase in the scale of economic activity raises pollution concentrations by 0.25–0.5% for the average country, the accompanying increase in income drives concentrations down by 1.25–1.5% via the technique effect.

There is some empirical evidence of a pollution haven effect on the side of the country enforcing stricter environmental regulations. Levinson & Taylor (2008) show that sectors with the greatest increases in the abatement costs in the United States experienced the largest increases in net imports from Canada, and to a lesser extent, Mexico. Similarly, Hering & Poncet (2014) show that, in China, the exports of private firms that became subject to TCZ SO_2 regulation grew less than those of firms located in cities unaffected by the environmental regulations.

There is also some empirical work on pollution havens that uses data from FDI-recipient countries. Eskeland & Harrison (2003) study FDI inflows to Mexico, Venezuela, Morocco, and Côte d'Ivoire and find only weak evidence that foreign investors locate in sectors with high levels of air pollution. Similarly, Dean et al. (2009) study the location-citing decisions of equity joint venture projects in China in the 1990s. In China, water pollution concentration standards are set at both the national and provincial levels, with levies collected from each firm whose wastewater pollutant concentrations exceed the local threshold. Measuring environmental stringency with data on collected water levies, Dean et al. find no evidence of a pollution haven effect from projects from high-income source countries. However, they do find some evidence of a pollution haven effect in high-polluting industries from Hong Kong, Macao, and Taiwan. Finally, Cai et al. (2016) show that China's TCZ policies reduced FDI inflows to treated cities from countries with worse environmental protections than China, where the level of environmental protection is proxied by when they signed the Kyoto Protocol.

A few recent papers also focus on the impact of trade liberalization on firm-level environmental outcomes within developing countries. Martin (2012) studies India's massive trade liberalization in 1991 and shows that it led to within-firm improvements in energy efficiency. She further shows that liberalization of FDI led to reallocations of market share to more fuel-efficient firms. She identifies two mechanisms, however, that led to increases in emissions intensity: increasing generator use and decreasing tariffs on intermediate material inputs, which helped firms using inputs inefficiently to retain market share. Studying the same liberalization episode, Barrows & Ollivier (2016) provide evidence that part of the observed improvement in within-firm energy efficiency comes from changes in product mix.

Martin (2012) also documents the effects of other Indian industrial regulations on energy efficiency. In particular, she studies the dismantling of the industrial licensing system, under which firms were required to obtain licenses to open new facilities, relocate or expand existing facilities, or launch new products. The licensing system was progressively dismantled in the 1980s and 1990s, leading to important increases in output in liberalized industries (Aghion et al. 2008). Martin finds that the removal of this policy resulted in some of the largest effects on the reallocation of market share to more energy-efficient firms and reduction of market share for energy-inefficient firms.

Gutierrez & Teshima (2016) focus on Mexico's free trade agreements (FTAs), notably the North American Free Trade Agreement and its FTA with the European Union. These authors demonstrate that the FTAs induced reductions in plant-level fuel use in Mexico, and plants in industries that experienced the most trade-induced import competition made the greatest investments in efficient energy. They also use satellite data to document relative improvements in local air pollution.

In China, Bombardini & Li (2016) estimate the extent to which the export boom generated additional pollution that affected health outcomes at the city level. They evaluate the local pollution cost of export expansion due to increased demand from countries that imposed lower tariffs on goods coming from China. They translate national, industry-level trade shocks to city-level shocks by using the city-level distributions of labor across industries. They construct two measures of the export shock: The first captures the income effect via the value in dollars per worker of the export expansion, and the second represents the change in pollution intensity of that expansion. They measure air quality using both ground and satellite data. They demonstrate that export shocks decrease infant mortality, while all else equal, pollution-intensive export shocks increase it. In contrast to the studies described above, which often showed a link between decreased tariffs and improved environmental outcomes, the authors find that the average city experienced net increases in infant mortality, albeit with strong heterogeneity across cities.

5. CONCLUSION: FIVE LESSONS FOR GREEN INDUSTRIAL POLICY

We conclude this review of green industrial policy with some lessons learned. The first lesson from our review is that it is much easier to make the case for green industrial policy than for traditional industrial policy. There is conclusive evidence that climate change and local environmental degradation create negative externalities that may justify interventions that deviate from policy-neutrality. The twin externalities of market failure and environmental failure provide a powerful justification for green industrial policies.

Despite the strong theoretical arguments, however, there is also accumulating evidence that successfully implementing green industrial policies is not easy. Green industrial policies, similar to industrial policies in general, often come up short. Rodrik (2014, p. 470) sums up the case for green industrial policy as "strong in theory, ambiguous in practice."

One reason why successful implementation of green industrial policies has been challenging is that policy responses have been indirect. This leads to our second lesson from reviewing green industrial policy: Using the most direct instrument to address the externality is more important than ever. Many of the shortcomings or unintended consequences of green industrial policy stem from failing to heed this very old lesson (see Pigou 1920, and more recently, Borenstein 2012). India's efforts to promote the solar PV industry through domestic content requirements significantly undermined the sector's growth. Our own research suggests that coal taxes are a potentially effective and underused policy in the Indian context. Many studies, including the MIT (2015) study on renewable energy, have suggested that existing global policies to promote renewables have focused too much on deployment and not enough on promoting the R&D necessary to ensure that alternative energy becomes a low-cost, scalable option in the near future. Governments have for the most part avoided putting a tax on carbon, which would be the first-best solution to address negative environmental externalities. Even worse, many governments continue to subsidize fossil fuels, doing the exact opposite of what is suggested by green industrial policy.

In light of the fact that direct targeting is often not possible, our third lesson is that effective green industrial policies require strong implementing institutions and strategies for inducing accountability. Rodrik (2014, p. 481) defines good institutional design as including "clear benchmarks for success, close monitoring, and explicit mechanisms for reversing course." Several authors have noted that, when governments attempt to combine multiple goals, such as employment creation, domestic competitiveness, and technological breakthroughs, outcomes are neither well defined nor achievable. Combining environmental goals with other industrial policy goals, such as employment creation, undermines accountability. An alternative solution, advocated by Cimoli et al. (2009), is that only governments with strong capabilities should tackle extensive intervention. Researchers at the Inter-American Development Bank, in their recent book on industrial policy (Stein & Crespi 2014), suggest that even capable governments should only intervene through what they refer to as horizontal industrial policies, which means policies that apply widely across many sectors and do not target individual sectors.

Although monitoring can be particularly challenging in developing countries, especially given the prevalence of small firms, improved on-the-ground tests and the use of satellite imagery, coupled with creative solutions such as community involvement, create the potential for much better monitoring. These advances also mean that we should be able to measure the gains from sustainable strategies in increasingly precise ways, particularly relative to the gains from traditional industrial policy or infant industry protection.

A fourth lesson is the importance of fostering competition. Previous literature on industrial policy emphasized that countries that used it best subjected their firms and industries to the test of global competition. Amsden (1992) showed that South Korea's government disciplined the firms it promoted by rewarding them for success in export markets. Research on emerging markets following the collapse of the Soviet Union similarly emphasized the need for industrial policies to have as their benchmark the test of global competition (see Clague & Rausser 1992). More recently, Aghion et al. (2015) show that China's industrial policies have been most successful when they reinforce competition. One way to do this is to encourage entry; another approach is to spread policy support widely. The evidence in the area of green industrial policy is no different. China's most successful case of green industrial policy is the solar PV industry, where firms were forced to go global from inception because domestic demand was limited.

Another way to ensure that competition goes hand in hand with green industrial policy is to set high performance standards but refrain from picking specific winners or technologies. Heck & Rogers (2014, p. 229) suggest that governments should set ambitious performance standards and incentives without picking winners because it is difficult to predict which revolutionary technologies are likely to succeed:

> It is possible to invest government spending, provide incentives, and even apply mandates—as controversial as they are in the US—to boost economic performance without picking specific companies or products as winners. Setting an aggressive vehicle mileage standard or tightening efficiency standards for appliances, lightbulbs, buildings, and the like allows multiple technologies and business models to compete, allows private capital to invest in innovation over years, and yields savings for companies and households.

Fifth, in a globalized world, local policies have international consequences. Green industrial policy needs to take into account the interaction between domestic environmental policies and global rules. Whereas the early literature on the use of green industrial policy in global settings suggested an environmental race to the bottom, new work suggests that lowering trade barriers has brought unexpected benefits in some (but not all) cases. China's membership in the WTO helped its solar PV industry to take off. Micro evidence in India suggests that its sweeping reforms have brought environmental benefits to firms. However, there is some evidence that increased exports from pollution-intensive industries in China led to higher infant mortality.

There is much we do not know about the effective use of green industrial policy. Governments use a wide range of green industrial policies successfully (and unsuccessfully). Policies must be tailored to the administrative and institutional strength of the government. A CAC program that might work in a country with strong, well-funded regulatory institutions is likely to fail where there is weak enforcement capacity. Research on green industrial policy is still in its infancy; studies that carefully tally up the gains and losses to provide summary conclusions on the welfare consequences of intervention would be a welcome addition to this young field.

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