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GREEN INDUSTRIAL POLICY:

CONCEPT, POLICIES, COUNTRY EXPERIENCES

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CHAPTER 1

GREEN INDUSTRIAL POLICY: ACCELERATING STRUCTURAL CHANGE TOWARDS WEALTHY GREEN ECONOMIES

Tilman Altenburg, Dani Rodrik

1. INTRODUCTION

There are two major reasons for governments and societies to accelerate structural change in their economies and proactively shape the direction of the change. First, there is the challenge of creating wealth. Structural change, that is, the reallocation of capital and labour from low- to high-productivity activities, is a key driver of productivity growth and higher incomes. This is particularly important for developing countries where incomes are low and poverty is pervasive. According to the latest available estimates, 767 million people lived on less than US$ 1.90 a day, and 1.9 billion people in the developing world still had less than US$ 3.10 a day in 2013–a clear indication that the current structural composition of national economies does not provide a sufficient number of productive jobs (World Bank 2016). Second, economic development has so far been achieved at the cost of severe overexploitation of natural resources. Humanity is approaching various ecological tipping points beyond which abrupt and irreversible environmental change at large geographical scales is likely to happen (Rockström et al. 2009). Radically new techno-institutional systems are needed to decouple economic development and human well-being from resource depletion and waste production. While many of the required technologies are already available, the incentives guiding resource allocation need to change profoundly to disrupt current unsustainable technological pathways and change some economic subsystems entirely, such as those for energy provision and transport (IPCC 2014).

This chapter explores the policy options for managing structural change that accounts for both the productivity and the environmental challenges in a harmonised way.[2] This is a challenge for all countries. Yet we put developing economies at the centre of our analysis because this is where the need to accelerate wealth creation is greatest, and many stakeholders perceive this as incompatible with environmental conservation. Governments typically put economic growth above environmental objectives, arguing that part of the income generated can be used to clean up at a later stage. Also, the policy discourse has often been biased towards specific objectives: Industrialists have mainly sought solutions modeled after the successful cases of early industrialising countries with whom developing countries should catch up, ignoring the limits of our planet's carrying capacity. Environmentalists have tended to put conservation first and downplay the challenge of creating wealth for billions of people who aspire for a better material life. In this chapter we make an effort to bring these perspectives together and suggest ways of balancing the inherent trade-offs.

Industrial policy is our analytical angle. Industrial policy refers to government actions to alter the structure of an economy, encouraging resources to move into particular sectors that are perceived as desirable for future development. Traditionally, industrial policy has focused on productivity enhancement as the key mechanism that would ensure rising returns to capital and labour and thus enable economic growth and prosperity. Increasingly, however, the goals of industrial policy have been broadened. In practice, industrial policy agencies undertake measures to influence structural change such that regional disparities are reduced, labour-intensive industries or small enterprises are encouraged and/or the economy becomes environmentally more sustainable (Altenburg and Lütkenhorst 2015). The main objective of this chapter is to show how industrial policies can be designed to deal with the dual challenge of shifting economic structures in a way that prosperity is increased while at the same time replacing environmentally unsustainable activities with sustainable ones. The rationale for industrial policy rests on the idea that market prices are not always the best guide to allocating investments. We shall argue in the chapter that this idea applies with much greater force where climate change and green technologies are concerned.

A quick word about the term 'industrial policy': We use this term because it has a well-recognised meaning and a long history. But the range of policies we shall cover goes much beyond industry itself. In view of this, some terms that have recently come into use, such as structural transformation policies or productive development policies, would perhaps have been more appropriate. We stick with the traditional term; though we caution the reader that the kind of issues we cover here concern entire economies and not just manufacturing industries.

2 While this chapter puts the dual challenge of creating wealth and greening economies at the centre of its analysis, industrial policy should in fact be assessed against a wider range of societal objectives, as laid down in the 2030 Agenda for Sustainable Development (UN 2015). Increasing employment opportunities for youth, reducing regional disparities or supporting women's entrepreneurship are all legitimate goals. Ultimately, industrial policy has a normative content that depends on what societies define as desirable future courses for social and economic development (Altenburg and Lütkenhorst 2015).

We proceed in three steps. Section 2 analyses the dual challenge in greater detail. It first summarizes what we know about the link between structural change and wealth creation; it then addresses the need to decouple human development from non-renewable resource consumption and pollution, and it shows how this translates into a structural transformation of economies, including those of developing countries. The section ends with a discussion of synergies and trade-offs between the two objectives. Sections 3 and 4 then deal with the design of industrial policy. In section 3 we extract the main lessons from various decades of controversial debate on industrial policy and bring out three key principles of smart policymaking that maximise the governments' ability to overcome market failures while keeping the inherent risks of misallocation and political capture to the minimum. Section 4 takes this debate one step further, exploring the extra challenges of a green transformation and in what ways green industrial policy must go beyond the common practice of industrial policy in a business-as-usual setting. Section 5 concludes.

2. THE DUAL CHALLENGE: CREATING WEALTH FOR A GROWING POPULATION WHILE STAYING WITHIN PLANETARY BOUNDARIES

2.1. CREATING WEALTH: THE NEED FOR STRUCTURAL CHANGE

Productivity growth is a precondition for improving living standards and maintaining competitiveness in the globalized economy. Low total-factor productivity is one of the main reasons for persistent poverty in developing countries. Low income and lower-middle income countries in particular need to boost productivity growth to reduce poverty. This implies the pursuit of more productive ways of doing business within each existing sector as well as to accelerate the structural transformation across sectors, reallocating resources from low productivity activities in agriculture, small trade and simple services to new activities that are knowledge-intensive and exploit the advantages of inter-firm specialisation.

Countries get richer as they diversify their pools of knowledge and create institutions that facilitate continuous recombination of this knowledge for the improvement of existing or creation of new and better goods and services. Empirically, the link between increasing diversification of production and employment and rising incomes is very clear, at least at early stages of development (Imbs and Wacziarg 2003). Except for some natural resource exporting countries, the countries that achieve the highest incomes are the ones that are able to combine diversified knowledge pools in ways that are difficult to emulate by others (Hausmann et al 2014).[3]

Manufacturing plays an important role in the process of diversification. The manufacturing sector is particularly well-suited for serial production allowing for enormous economies of scale. On average, it supplies highly productive and well-paid jobs; it is where most private sector research and development and commercial innovation take place and where most royalties are generated. It generates demand for jobs in upstream and downstream activities from mining to distribution as well as production-oriented engineering, information technology and financial services. Due to this innovativeness, manufacturing creates particularly large knowledge spillovers which enhance productivity in non-manufacturing activities (Cohen and Zysman 1987; Helper et al. 2012). Also, productivity convergence—that is, sectors that are further away from the technological frontier increase productivity faster than the more advanced ones—appears to be especially rapid in manufacturing (Rodrik 2013). Last but not least, most manufacturing goods are easily tradable and can therefore be exported to world markets almost without demand restrictions;[4] this allows countries to reap economies of scale even when their internal market is constrained by low purchasing power and small population size. Historically, there is a clear correlation between phases of economic growth and expansion of the manufacturing sector (Rodrik 2006). Looking at the post-WWII performance of developing countries, the most

3 This dynamic is captured in the Economic Complexity Index developed by Hausmann and others. In their Atlas of Economic Complexity, the authors show how strong the correlation is when natural resource exporters are excluded (Hausmann et al. 2014).

4 By comparison, "an expansion of non-tradables is self-limiting, as the domestic terms of trade eventually turns against non-tradables, choking off further investment and growth" (Rodrik 2006).

impressive growth stories were based on export-led growth in manufactures, particularly in East Asia (Stiglitz and Yusuf 2001; Commission on Growth and Development 2008).

However, the share of manufacturing value added in GDP tends to have a historical maximum, beyond which it starts to decline. This transition towards post-industrial economies happens due to three factors. First, technological progress in manufacturing reduces demand for workers and shifts employment to services, where the potential for automation is not as big. Second, as incomes rise, demand shifts away from food and manufactures to increasingly differentiated services. Third, manufacturing industries become more and more knowledge-intensive and therefore create demand for specialised production-oriented services in areas such as engineering, information technology and finance. It should be noted that the boundaries between manufacturing and services are increasingly blurred and the interdependency of manufacturing and services increases. This is reflected in an increasing share of value added from services embodied in manufacturing products (OECD 2015).

The problem of today's developing economies is that, with the exception of some East Asian countries, manufacturing value added and employment tend to stagnate at very low levels. Most developing countries are moving from agriculture or mining as their main economic drivers to services without going through a proper process of industrial development, a process known as premature deindustrialisation (Rodrik 2016). In Latin America, manufacturing industry`s contribution to GDP and employment has peaked early at a much lower level than one would have expected from the patterns of today's industrialised countries and is now shrinking. In Africa, manufacturing industries are stagnating at a low level (Diao et al. 2016). The same study finds that labour productivity is stagnant or even declining in the modern sectors. Given the importance of manufacturing and modern services as drivers of diversification and productivity growth these trends cast doubts on Latin America's and Africa's prospects for future economic growth and welfare.

Two factors are particularly important to understand these trends: labour-saving technological progress and globalization (Rodrik 2014). New technologies are reducing demand significantly for routine labour activities in manufacturing and services (Brynjolfsson and McAfee 2014). For the US, Frey and Osborne (2013) calculate that about 47 per cent of jobs are susceptible to computerization in the next few decades. Applying the same methodology to developing countries, the World Development Report 2016 finds even higher automation potentials–two thirds of today's jobs in developing countries could be lost to automation, for instance–but assumes that automation will proceed more slowly due to time lags in technology adoption (World Bank 2016:219).

In the past, reallocating workers from low productivity agriculture to export-oriented light manufacturing activities was a powerful driver of industrialisation and productivity growth. East Asian economies especially benefited from this shift, from Korea and Taiwan in the 1970s to more recent industrialisation experiences in China, Vietnam and Cambodia. Progress in labour-saving technologies, however, is now likely to radically reduce the opportunities for boosting productivity through the attraction of investment in labour-intensive export industries. At the same time, globalization creates new opportunities for industrial development as it facilitates access to hitherto inaccessible technologies and markets. However, it can also accelerate premature deindustrialisation as it puts newly emerging small industries in direct competition with highly competitive global corporations that have accumulated knowledge and network externalities over decades and, on top of that, exploit the economies of scale associated with globalized markets. Even in the latecomer countries' own domestic markets, imports often stifle local industry development. While a number of highly competitive firms and regional clusters in developing countries have been able to reap the opportunities of global markets, such successes have been the exception rather than the rule. This explains why since the 1950s, "very few [countries] have become high-income economies. Most developing countries have become caught in what has been called a middle-income trap, characterized by a sharp deceleration in growth and in the pace of productivity increases" (Agénor et al. 2012).

The few successful upgraders include oil exporters and Eastern European countries benefiting from EU accession, as well as East Asian countries. The latter in particular placed emphasis on technological learning and capacity building, especially in manufacturing. They had institutions in place to manage structural change, providing coordination for the emergence of new economic activities, nurturing entrepreneurship and investing in education and skills development to ensure that human capital adapts to changes in the productive structure (Amsden 1989; Wade 1990). The lesson from their success is clear: the creation of wealthy economies is strongly correlated with the ability to manage structural change in a way that enhances productivity in a socially inclusive way.

2.2. TAKING ECOLOGICAL BOUNDARIES INTO ACCOUNT: A GAME-CHANGER FOR STRUCTURAL CHANGE

The global economy is on an unsustainable path. Since the industrial revolution, the world economy has grown at the expense of the environment. Natural resources have been exploited without allowing stocks to regenerate, pollutants have accumulated in the biosphere, ecosystems have been degraded severely and biodiversity has been lost at an alarming rate. Already in the early 2000s, the Millennium Ecosystems Assessment, a UN-led global assessment of the Earth's ecosystems, concluded that about 60 per cent of the ecosystem services examined had been degraded or were used in ways that cannot be sustained (MEA 2005). Similarly, UNEP (2011) summarises a series of reports showing severe overexploitation of fish stocks, increasing water scarcity, decreasing soil quality and unsustainable rates of deforestation.

Through product and process innovations, resource efficiency is increasing worldwide. Put differently, fewer natural resources are needed to produce the same unit of output; but this increase in efficiency has been quite modest, with the effect that GDP growth globally has more than outweighed the efficiency gains (Jackson 2016; Wiedmann et al. 2015). This led to a situation where "global material extraction more than doubled in the past 30 years, from around 36 billion tonnes in 1980 to almost 85 billion tonnes in 2013, an overall growth of 132 per cent" (Vienna University of Economics and Business 2016). Environmental contamination also increased. In the case of anthropogenic greenhouse gases, emissions rose from 33 to 49 Gt CO_2e per year from 1980 to 2010 (IPCC 2014). Due to continued growth of the global population and increased per capita consumption, particularly since the turn of the century, "anthropogenic pressures on the Earth System have reached a scale where abrupt global environmental change can no longer be excluded" (Rockström et al. 2009). Research on environmental systems highlights the existence of tipping points at which environmental change accelerates due to self-reinforcing mechanisms and systems are unable to restore their previous equilibrium (Lenton et al. 2008).

Global warming is the most pronounced threat to human development and the environment. The International Panel on Climate Change predicts that if we continue to manage our economies in the same way, global mean surface temperature will increase by 3.7°C to 4.8°C by 2100 compared to the average for 1850 to 1900 (IPCC 2014). Melting of polar ice and thawing of permafrost soils are two dangerous accelerators of global environmental change. But there are other big threats to the Earth System calling for urgent action including loss of biodiversity, ozone depletion, ocean acidification, water shortage, soil degradation, accumulation of nitrogen in aquatic ecosystems and the accumulation of chemical waste and plastics (Rockström et al. 2009; WBGU 2014).

These fundamental threats to humanity need to be taken into account when thinking about further growth and structural change of economies. The way economic transactions are currently organized largely ignores the social cost of resource depletion and pollution. Natural capital embodied in fertile soils, fresh water, clean air and productive ecosystems is being wasted. This waste undermines the basis for future economic development and jeopardizes the progress made on social welfare (Fay et al. 2015). Therefore, we need to recognise environmental sustainability as fundamental to the production process.

In essence, human well-being and economic progress need to be decoupled from non-renewable resource consumption and emissions (UNEP 2011). To make economic development sustainable, resource efficiency needs to increase at least at the same rate as economic output. The largest challenge is how to achieve the steep decline in GHG emissions needed to keep global temperature rise well below 2°C. To achieve this, global carbon intensity would have to be reduced by 6.3 per cent every year to 2100, much faster than the modest annual decline of 1.3 per cent achieved between 2000 and 2014 (PwC 2015).

So far, none of the major economies has achieved this. However, 'absolute decoupling' is not impossible. Enormous resource efficiency jumps are technologically feasible: with the shift to renewable energy, the use of smart information and communication technology systems, the use of energy-saving technologies and, last but not least, changes in consumer behaviour. To accelerate the required technological and business model innovations, however, economic incentives need to be set very differently. Above all, environmental costs need to be much better reflected in prices, regulations must be tightened and subsidies for fossil fuels and other unsustainable goods and practices need to be phased out.

Doing so will invariably have deep and system-wide implications, comparable to those observed during the first industrial revolution or the rise of information technology (Pérez 2002). It will change the way we farm our land and manufacture goods, where we source our energy, how we transport things and how we build our infrastructure and design our cities. Among the various environmental challenges, mitigating climate change will have arguably the deepest implications for structural change because it affects the energy and transport sectors that so far have fuelled economic development, literally. According to the Intergovernmental Panel on Climate Change, global annual CO_2 emissions will need to be reduced 42 to 57 per cent by 2050, relative to 2010, and 73 to 107 per cent by 2100 (IPCC 2014). To achieve such levels of decarbonisation, major systemic changes are indispensable: Electricity generation needs to shift fully from fossil to renewable sources; as power generation is decarbonised, transport, heating and other energy using sectors need to be electrified, including road traffic; and resource efficiency needs to be increased radically across all industries, including the shift to circular economies where waste is reduced, reused or recycled (Fay et al. 2015).

Some of these changes are already in full swing, others yet to come. Global energy systems–and all the related manufacturing and service activities related to power generation, transmission and storage–are already undergoing a fast and radical change. Renewable energy technologies have been adopted widely around the world. Electricity from hydro, geothermal and certain biomasses can now compete with fossil fuel-based electricity, as do wind and solar power in good locations, and further cost reductions are expected. While 15 years ago renewable energy power installations played a negligible role in global electricity generation, "the world now adds more renewable power capacity annually than it adds in net new capacity from all fossil fuels combined" (REN21 2016; REN21 2017).

Firms continuing to invest in unsustainable technologies run the risk of having to write off major investments. According to McGlade and Ekins (2015), climate research suggests that "to have at least a 50 per cent chance of keeping warming below 2°C throughout the twenty-first century, the cumulative carbon emissions between 2011 and 2050 need to be limited to around 1,100 gigatonnes of carbon dioxide." As a consequence, about one third of oil reserves, one half of gas reserves and at least 80 per cent of known coal reserves cannot be burnt and need to be kept in the ground if catastrophic climate change is to be avoided (McGlade and Ekins 2015). Fossil fuel reserves as well as assets that depend on transforming and trading fossil fuel, such as refineries, power plants and petrol distribution networks, may therefore be overvalued. Rapid technological progress in low-carbon technologies and/or more ambitious decarbonisation policies may force the holders of carbon assets to adjust their values, which in turn may cause a carbon bubble shock with deep repercussions for banks, pension funds and insurance companies (Weyzig et al. 2014). The Economist Intelligence Unit estimates that within the global stock of manageable assets the value at risk due to climate change ranges from US$ 4.2 trillion to US$ 43 trillion between now and the end of the century (EIU 2015). The Financial Stability Board recognises such asset stranding related to climate change to be a relevant risk to the global financial system and therefore put a reporting system in place, the Task Force on Climate-related Financial Disclosure (TCFD 2017). In fact, some institutional investors have started to withdraw from carbon assets (Schwartz 2015). Hence there are market mechanisms at work that accelerate the structural change towards a low-carbon economy.

While mining and power supply industries are most affected, structural change in other industries is following. Regulators in all main automotive markets including the European Union, USA, Japan and China, have defined roadmaps for reducing average CO_2 emission levels of new cars. Within a few years, these levels can no longer be achieved by efficiency gains in fuel-driven cars alone, forcing manufacturers to incorporate electric and hybrid cars into their product range and to rapidly increase their share in overall sales. The private sector is in fact responding. Electric vehicle deployment has recently taken off with exponential growth rates, albeit from a low basis. In 2016, the global stock of electric cars exceeded two million, up from a few hundred ten years earlier (OECD and IEA 2017). With rapidly falling battery prices and increasing battery performance, electric cars will soon be fully competitive with fuel-driven cars (Altenburg et al. 2017, this volume). Early movers such as Tesla and Toyota are taking market shares from established carmakers that have been slower to adapt. Similar changes can be observed in other product categories: reflected in growing markets for organic food, biodegradable packaging and renewable building materials, for example.

Not only products will change, but also production processes and business models. Circular economy models are being developed to minimise material and energy flows through industrial systems and make sure residuals of one production process are used as input for another (Ellen MacArthur Foundation 2012). In energy systems, new technologies enable the development of decentralized mini grids where customers can flexibly respond to price signals, supplying power or reducing demand when the price on the grid is high and consuming power when it is low (Nathaney et al. 2016). Worldwide, new business models are flourishing, models based on sharing rather than owning assets, in most cases facilitated via online marketplaces. These include sharing of cars, accommodation or taxi services. Last but not least, the certification and accreditation industry is receiving a boost, as economic actors are increasingly obliged to prove that their production processes comply with various environmental requirements.

In sum, the recognition of ecological system boundaries has already become a game-changer for economic development. Incentive systems are changing—still too slow from an environmental perspective—and a lot of experimentation is happening in terms of new products and processes.

2.3. CHANGE WILL AFFECT DEVELOPING COUNTRIES

How relevant are these changes for developing countries, taking into account that "many are unable to keep up with the investments to satisfy the basic needs of their citizens, let alone the efficient cities, roads, housing, schools, and health systems they aspire to create" (Fay et al. 2015:2)? In fact, many people in developing countries, including government officials, regard environmental protection a luxury their countries should deal with at later stages of development, once the more pressing problems of human development have been solved.

Still, even when governments put their own national social and economic objectives first, there are strong arguments for not delaying the transition to a green economy (Padilla 2017 and Ambec 2017, this volume). First, environmental degradation undermines the ecological foundations for economic growth and human well-being, most obviously in countries that depend on economic activities in agriculture, forestry or fisheries. Second, pollution and waste typically reflect inefficiencies in production, and resource-saving techniques tend to amortize very quickly even without consideration of positive externalities. Third, sticking to traditional products and processes as the worlds' dominant economic actors shift to greener goods and production techniques will drive a wedge between local and global practices. This makes it more difficult to compete in the future, considering that trade and investment treaties increasingly regulate environmental issues and that lead firms in global value chains impose progressively higher environmental standards. Fourth, countries should avoid getting locked into unsustainable infrastructure and business practices because the costs of switching in the future will likely be disproportionally high. Therefore, today's investments in high-carbon energy infrastructure may turn into financial burdens soon, as renewable energy becomes cheaper and commitments to decarbonise become binding and costly. Developing countries are in an advantageous position in the sense that most of their energy and urban infrastructure is yet to be built, so they can avoid costly misdirected investments in unsustainable infrastructure. Fifth, many new green technologies come with co-benefits. For example, investing in clean air greatly improves health conditions and reduces health-related expenditures; and communities can be electrified at lower cost when new technologies make it easier to use local sources of renewable energy at small scales. Sixth, green industrial policies drive innovation. While new-to-the-world types of innovation will mostly likely be developed in a relatively small number of countries with strong national innovation systems, certain innovations may also be developed in poorer countries and drive local productivity growth and job creation. Table 1.1 provides an illustrative overview of new green product and service opportunities, differentiating between countries by level of income.

Table 1.1: New green product and service opportunities for countries at different income levels

	Higher middle and high income countries	Low and lower-middle income countries
New products	Renewable energy technologies including high-tech components of solar photovoltaics, concentrated solar power, wind turbines and geothermal technologies; energy storage technologies including fuel cells and lithium-ion batteries; electric vehicles; new lightweight materials; bioplastics; carbon capture and storage technologies; high performance building façades.	Low- and medium tech, low cost products such as solar water heaters, solar water pumps, solar driers; drip irrigation systems; rainwater harvesting technologies; LPG, LNG or ethanol cook stoves; LNG-based three-wheeler taxis. Inputs for global green production for which factor endowments exist: such as lithium, rare earths, cellulosic ethanol.
New services	Design and operation of smart grids, closed-cycle eco-industrial parks, intelligent transport systems, advanced energy management systems, electronic road pricing, tracking and tracing systems for environmental performance along value chains.	Simple low-cost services such as for operation and maintenance of decentralized and mini electric grid solutions; labour-intensive waste recycling; low-carbon livestock management; management of rapid transit systems. Labour-intensive tasks in emerging green global value chains, such as assembly of solar panels or lithium-ion cells.

Source: Adapted from ClimateTechWiki (n.d.).

In fact, awareness of the need for green industrial policy is clearly increasing among developing country stakeholders. Governments of countries at very different income levels have enacted green economy strategies, ranging from Ethiopia, Rwanda, Cambodia and Vietnam to Mexico and China. Growing recognition is also reflected by the 197 countries party to the 2015 Paris Agreement under the United Nations Framework Convention on Climate Change, thereby committing to limit the increase in the global average temperature to well below 2°C above pre-industrial levels, to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels and to formulate and communicate long-term low greenhouse gas emission development strategies. So far, the existing commitments, known as Nationally Determined Contributions, are not sufficiently ambitious to stay below the envisaged threshold levels (Climate Action Tracker 2015), and we may expect a gap between political declaration and actual implementation; but the trend towards greener technologies and incentive systems is unlikely to be reversed. Especially in the field of energy generation, renewable energy technologies are becoming much more cost-efficient in many more locations. Developing and emerging economies now account for about half of global renewable energy investments and the market for renewables-based mini-grids is booming (REN21 2017). With regard to air pollution, many developing countries and municipalities have taken drastic measures to regulate transport. These include measures to reduce allowable fleet emissions, to restrict access of high polluting vehicles in inner cities or to oblige taxi fleets to run on ethanol or compressed natural gas.

2.4. THE DUAL CHALLENGE

Governments around the world are thus confronted with a dual challenge: to accelerate structural change towards higher productivity in a way that is socially inclusive and to align economic development with the carrying capacity of our planet. Recognizing the need to harmonise both objectives and to make industrial policy environmentally sound is essential. In this regard, the unanimous global agreement on the 2030 Agenda for Sustainable Development has been a major achievement (UN 2015).

However, not a single country has been able, so far, to enhance the welfare of its citizens without increasingly depleting its resource base. In this regard, governments in search of a welfare-enhancing sustainable economy are entering uncharted territory. There are obvious trade-offs between the welfare and environmental sustainability objectives, at least in the short and medium term. Ostensibly, internalizing environmental costs that have been externalized in the past increases the apparent cost of production and reduces cost-competitiveness if competitors do not have to bear these costs. Moreover, green investments have opportunity costs: governments need to find a good balance between the necessary investments in environmental improvements and other outlays, such as those for health, education and infrastructure. But there are multiple synergies as well. The search for green technologies will create many opportunities for economic development, health benefits, improved efficiencies and better living conditions. Governments must understand these synergies and trade-offs to be able to design green industrial policies while Maximising gains and minimizing costs. This will be challenging, given that optimal solutions depend on situation-specific factors–from resource endowments and techno-institutional capabilities to the distribution of power between the polluting incumbents and green newcomers.

3. THE ROLE OF INDUSTRIAL POLICY

Unfettered market-based allocation of resources is unlikely to foster structural change in a socially optimal manner, one that allows for high productivity, broad-based societal inclusion, generalized wealth and increasing environmental sustainability. In many instances, markets do not send out the right price signals. This is the case when an initial investment that would have triggered many knowledge spillovers is not carried out because the investment in itself does not immediately pay off in a way the individual financier could appropriate the profits stemming from all the resulting secondary technological developments and market opportunities. In other words, the social or public returns are larger than the individual or private returns, which is a very common phenomenon given the cumulative character of technological development. Market-based resource allocation also has its limitations in the presence of coordination failures. These occur when the viability of a new business depends on simultaneous investments in related fields, with the effect that no firm risks an investment unless someone guarantees the necessary complementary investments. Similarly, markets do not facilitate the socially optimal level of entrepreneurial 'discovery' of cost: When an investor undertakes a new activity, he or she discovers the underlying costs, as well as the benefits (Hausmann and Rodrik 2003). However, this knowledge, especially the likelihood of high returns, quickly becomes public and other investors will copy the business model. This is good for the overall economy, but bad for the pioneering investor who bore the full risk of failure but sees his innovation profits dissipate. Put differently, the social value of discovering the cost of a new activity exceeds the private gains. This is another important market failure. Similar market failures occur, for example, when markets do not reflect the full environmental costs of an investment or when market actors lack relevant information.

This is where industrial policy enters the scene. It has important roles in encouraging industries with potential knowledge spillovers, coordinating interdependent investments, subsidizing early entrepreneurial search processes, promoting cleaner industries and facilitating market transparency and information flows. Generally speaking, industrial policy aims to reinforce or counteract the allocative effects of markets with the objective of restructuring economies towards a better societal outcome (Rodrik 2004). It should be noted that industrial policy is about promoting desirable structural change in general and not limited to industry or even to manufacturing.

Here, an important qualification is in order to avoid a common misinterpretation of industrial policy. Proponents of modern industrial policy do not think policymakers are better than entrepreneurs in anticipating market opportunities. They know the market mechanism is a smart institutional arrangement. In many regards, markets reflect what people want and how much they are willing to pay for alternative options. Also, markets encourage the creativity of individuals who take personal risks in the pursuit of profits. Ideally, competition among firms with different business concepts will reward efficient entrepreneurs and force less efficient ones out of the market. It is this process of entry, innovation and exit in a competitive environment that drives productivity growth and determines where firms, regions, or countries have relative advantages. The role of industrial policy is not to replace this creative process with top-down bureaucratic planning, but to embed it within broader social welfare processes to improve the outcomes for society at large.

Beyond externalities and coordination failures, societies tend to have different preferences, many of which cannot be fully expressed in market prices–often because they imply ethical considerations or touch upon entrenched societal values. For example, people have different preferences when it comes to attaching economic values to cultural norms or to biodiversity. This affects how people strike their personal balance between economic opportunities and the related risks of, for instance, genetic engineering, global warming or nuclear energy. People also differ with regard to the degree of social inequality or employment insecurity they are willing to accept. Also, they have different views on where, how much and with which measures the state should interfere to regulate such issues. Against this background, industrial policy is about facilitating stakeholder dialogues on the direction of structural change, moderating different viewpoints, finding compromises and creating consensus on broadly defined development pathways. As well, it is about adapting regulatory frameworks and incentive schemes in such a way that creative entrepreneurial search processes are encouraged and channelled towards the achievement of agreed goals. This again implies strategic collaboration between the private sector and governments to jointly identify barriers that need public-private coordination for their removal.

In essence, industrial policy aims to complement the market mechanism. Given the pervasiveness of market imperfections and the legitimacy of investment criteria that go beyond microeconomic efficiency, the question is not whether to apply industrial policy or not, but how to do it (Rodrik 2004).[5]

Critics point to various ways in which industrial policy is frequently being abused by interest groups. Industry lobbyists demand specific subsidies and orchestrate resistance when subsidies shall be withdrawn. As there are usually substantial information asymmetries between the lobbyists and the public sector it is often easy to develop a storyline justifying subsidies. Similarly, politicians may claim and allocate funds to satisfy electorates and protect firms in their jurisdictions rather than to maximise public welfare on the basis of scientific evidence. Keeping such political capture to a minimum is indeed a major challenge.

To cope with this challenge, three basic principles of effective industrial policymaking should be applied when designing and implementing industrial policy (Rodrik 2014; Altenburg et al. 2008):

1. **Embeddedness**. Policymakers need to maintain close relationships with the private sector and other stakeholders to get a deep understanding of how specific economic sectors function, what the business rationale of relevant private actors is and where bottlenecks exist that hold back improvements. To what extent government intervention is necessary and what instruments are best suited to overcome market failures depends on the gap between what self-organized private actors would achieve and the optimal outcomes in the public interest. This is likely to be very context-specific and to change over time. Industrial policy should thus be conceived as a collaborative process of discovery in which public and private actors closely interact and continuously negotiate and adapt their contributions to the development of the respective industry.
2. **Discipline**. Such embeddedness obviously entails risks of collusion and capture by private interests. To minimise these risks, governments need to maintain full autonomy in decision-making and be able to use disciplining devices against abuse (Evans 1995). Governments need to draw a clear line between collaboration in the public interest and favouritism. This presupposes clearly defined objectives that are broken down into measurable performance indicators. Furthermore, it requires monitoring and evaluation routines to continuously check the performance of firms and support programmes against existing benchmarks. Governments need to have the independence to adjust or even withdraw incentive packages without falling prey to lobbyists. Unbundling the roles of policy formulation, funding, implementation and evaluation can be helpful to insulate such performance-based systems against political interference. Putting implementation out to tender, encouraging competition among service providers and monitoring their performance through independent agencies further enhances effectiveness. Clear and transparent rules as well as conditionality and sunset clauses are also helpful to keep rent-seeking behaviour in check.
3. **Accountability**. Policymakers and implementing agencies should be held accountable for their industrial policies. This can be achieved using various reporting requirements and obligations to disclosure as well as more general democratic checks and balances by central auditing authorities, political parties, independent courts and a free press. Accountability serves not only to prevent corruption, favouritism and other forms of collusive behaviour but also helps to legitimize appropriate industrial policies.

5 Countries that managed to close the technological and income gap vis-à-vis more advanced economies invariably employed a range of carrots and sticks to protect and nurture their national industries. Empirical evidence shows this for the early catching-up experiences of Germany, the United States and Japan as well as for the more recent post-World War II examples, from the early "Asian Tigers" of Korea and Taiwan to the current emergence of China. None of the countries that strictly followed the Washington Consensus, in contrast, has achieved comparable success in terms of technological upgrading, economic growth, and poverty reduction (Rodrik 2005; Chang 2009).

4. GREEN INDUSTRIAL POLICY: HOW IT IS DIFFERENT

Industrial policy is about anticipating relevant long-term trends of technology and market development and providing incentives to adapt the structure of a national economy in such a way that it can take advantage of the change. As climate change mitigation and other ecological challenges increasingly influence the future direction of economic development, environmental considerations need to become a key part of industrial policymaking. This is what green industrial policy is about (World Bank 2012; Hallegatte et al. 2013; Lütkenhorst et al. 2014; Pegels 2014).

The boundaries between green industrial policy and environmental policy are not clear-cut. Environmental policies aim at protecting and sustainably using our natural environment. Intentionally or not, some of these policies drive structural change. For example, carbon prices shift investments from fossil fuels to renewable energy; ambitious automobile emissions standards accelerate the substitution of traditional fuel with electric vehicles that in turn requires different types of supplier industries; environmental fiscal reforms that tax environmental consumption instead of labour may reduce the international competitiveness of resource-intensive industries while making labour-intensive activities more competitive. Other environmental policies mainly induce process innovations and thereby have only little effect on structural change, such as new pollution control technology upgrades in existing industries. In this volume, environmental and energy policies that deliberately push structural change into the desired direction are considered part of green industrial policy. In addition, it encompasses policies that enhance the national benefits of the green transformation in terms of higher incomes and better employment opportunities. Hence, we define green industrial policy as including any government measure aimed to accelerate the structural transformation towards a low-carbon, resource-efficient economy in ways that also enable productivity enhancements in the economy.

How is green industrial policy different from industrial policies that do not systematically integrate the perspective of environmental constraints? In many ways, steering investment towards a green economy is not that different from steering them towards conventional industrial policy objectives, such as higher value added and enhanced productivity. As Schwarzer (2013:vi) puts it, "…green industries are essentially infant industries, with all the characteristics of conventional infant industries and subject to the same opportunities and challenges of promoting them." Various information and coordination failures call for facilitation. Policymakers as well as entrepreneurs take decisions without knowing what the future will look like; therefore, policies carry risks of misallocation and political capture, which need to be kept to a minimum. Also the available instruments are very similar, including information and coordination platforms, regulations, standards and labels, differential taxes and credit subsidies. And the three basic principles of effective policymaking apply. Finally, as in conventional industrial policy, shifting to new green industries requires public support and therefore needs to find ways for dealing with the 'losers' and smoothing the adaptation of firms and workforce (Fay et al. 2015). This is why the researchers and practitioners concerned with green transformation can learn many lessons from the conceptual discussions about industrial policy and its successes and failures of implementation.

Yet, green industrial policy is also different. It goes beyond the traditional notion of industrial policies in at least six important ways (Altenburg and Pegels 2012; Lütkenhorst et al. 2014):

1. the focus on environmental externalities as an additional and particularly damaging market failure
2. a clear predictable distinction between 'good' and 'bad' technologies, based on their environmental impacts, and therefore systematic steering of investment behaviour in a socially agreed direction

3. the urgency to achieve structural change within a short period of time, to preclude the risk of catastrophic environmental tipping points
4. enhanced uncertainty due to long time horizons of some transformations as well as dependence on policy changes
5. additional policy interfaces and therefore the need for particularly encompassing policy coordination
6. a motivation to manage global commons, such as the atmosphere and oceans, for long term sustainability, which may not always be aligned with immediate national interests.

In what follows, we will address each of these defining features one by one.

4.1. THE IMPORTANCE OF ENVIRONMENTAL EXTERNALITIES

The most obvious specificity of green industrial policy is that it aims to correct the failure of markets to reflect the social costs of environmentally harmful production. For companies investing in green technologies, the private return lies significantly below the social return, resulting in underinvestment. Quoted in The Guardian Newspaper, regarding his report for the UK government, Stern tells us "Climate change is a result of the greatest market failure the world has seen" (Benjamin 2007; Stern 2007). Hence the theoretical case for applying industrial policies to accelerate and upscale investments in green technologies is even stronger than it would be for other technologies.

To close the gap between private and social returns the first-best solution would be to price the use of environmental goods, such as water or clean air. This has a big advantage: market actors can use their ingenuity to find the most cost-effective way to consume less of these goods. There are basically two ways that governments can attach prices to environmental goods: cap-and-trade systems and environmental taxes on resource consumption or emissions. In cap-and-trade systems, governments define an upper limit for the use of a resource or emissions and then distribute or auction use rights among economic actors, which can then be traded. This encourages all participants to explore and implement the most cost-effective solutions[6]. Defining the cap and allocating use rights, however, is not easy for political reasons. Polluter lobbies typically claim that ambitious caps would threaten their international competitiveness in order to keep the cap high and the price of use rights low; and they ask for assignment of free use rights. As governments do not want to harm their national industries, cap-and-trade systems so far have often failed to set ambitious caps (Helm 2010; IPCC 2014). Environmental taxes, in contrast, do not guarantee an upper limit to resource use or pollution because industry's readiness to pay taxes defines how much they will reduce that resource use or pollution. But taxes have several advantages. As they are directly set by a government authority, the additional cost for firms is more predictable. Also, taxes create a double dividend as they not only reduce environmental impacts but also raise revenues for the government. These can be used to reduce other taxes or increase government spending, both of which help to build societal support for environmental tax reforms. Finally, taxes are easier to implement than cap-and-trade systems, making them particularly attractive for developing countries (Schlegelmilch et al. 2017, this volume).

As market instruments that encourage entrepreneurial search and cost-effective allocation, both cap-and-trade and environmental taxes are increasingly being applied internationally. For several reasons, however, pricing environmental goods is not sufficient (Fay et al. 2015). One limitation is that there may be other market failures hampering green transformations—for example those related to incomplete information, lack of coordination or inadequate appropriability of research and development investments. Another limitation consists in ethical concerns about pricing. Not everyone would agree with the basic idea that everything nature provides can be expressed in monetary values. These critics hold, for example, that the preferences of future generations cannot be fully reflected in market prices. In addition, first-best policy instruments may not be available for political or administrative reasons.

Hence policy mixes are usually required that combine market-based instruments, regulations, capacity building, subsidies and other components in various ways. The right combination depends on country conditions, such as what degree of policy complexity can be handled and how well the government is insulated from lobbying pressure. Also, governments need to anticipate the trade-offs between pricing

6 For the case of climate change mitigation, Cramton et al. (2017) convincingly argue why a global carbon price would be much more effective than the current practice of individual pledges with weak review mechanisms. Rather than depending on altruism it would create a reciprocal common commitment, whereby "each country would commit to placing charges on carbon emissions sufficient to match an agreed global price formula."

environmental goods and competitiveness. Polluting industries will intentionally face higher costs and may therefore lose any advantage over competitors from other jurisdictions where the same industries are not taxed. At the same time, pushing industries early on to develop clean technologies may result in early mover advantages if other jurisdictions impose similar conditions with a time lag (Porter and van der Linde 1995; Ambec 2017, this volume).

4.2. SYSTEMATICALLY STEERING INVESTMENT BEHAVIOUR

The overarching objective of bringing the economy back into a 'safe operating space for humanity' necessarily gives structural change a direction (Rockström et al. 2009). First and foremost, traditional industrial policy aims at enhancing productivity growth and incomes but, in most cases, leaves it to market forces to find the most lucrative technologies and business models. Green industrial policy, by comparison, is driven by scientific evidence of environmental threats. This implies a much clearer picture of which technologies and business models are good or bad. Underlying green industrial policy is the Pigouvian idea of steering investment behaviour systematically and permanently towards what governments conceive as environmentally sustainable (Spratt 2013:12).

This leads us to four peculiarities of green industrial policy when it comes to issues of technology choice and promotion: First, there needs to be agreement on which technologies are good for a sustainable future. This is far from trivial because alternative solutions may exist, all with some trade-offs that imply difficult value judgments. For example, from a decarbonisation perspective, biofuels are desirable substitutes for fossil fuels, but their commercial production may lead to monocultures, loss of biodiversity, higher food prices and increased pressure on unutilized vulnerable land. In a similar vein, nuclear energy and large-scale carbon capture and storage are advocated by some as necessary elements of decarbonisation strategies but rejected by others for their inherent risk of large-scale contamination. What is desirable thus depends on value judgments, and political deals are needed to define what merits support.

Second, there is a case for subsidizing deployment of clean technologies, even beyond the point where they break even with harmful technologies. Traditional industrial policy would foster technologies only at their infant stage and withdraw support as soon as they start competing in the market place. In contrast, the logic of green transformations implies that where environmentally sustainable solutions compete with harmful ones it is in the public interest to accelerate the substitution rather than waiting for markets to reward commercially superior alternatives. Never and Kemp (2017, this volume) discuss how standards can be used to accelerate the diffusion of green technologies.

Third, an important part of green industrial policy is to proactively phase out harmful technologies. In some cases, such as when substances that deplete the ozone layer or greenhouse gases are concerned, it is not enough to promote the development and deployment of sustainable alternatives. Green industrial policy defines road maps and sets incentives to phase unsustainable technologies out. Cosbey at al. (2017, this volume) show how this can be done in practice.

Fourth, while conventional industrial policy rarely tries to affect consumer behaviour, influencing purchase decisions is an important element of green industrial policy. Mandatory labelling programmes may help to make markets transparent and enable consumers to distinguish products with different environmental effects. Educational programmes can encourage people to reuse and recycle things. However, it should be noted that consumers do not respond perfectly to price signals. Even when new products exist that are better in many ways and cheaper, many consumers stick to the bad old alternatives because they do not understand the situation well, because their neighbours have not changed or simply out of force of habit. Green industrial policy can use a wide range of options to encourage green consumption and shift markets using advertisements, nudges and green default options, among other schemes. A rapidly growing literature shows how insights from behavioural science can be used to influence consumers in a pro-environmental way (Sunstein and Reisch 2013; Price 2014).

4.3. URGENCY TO ACT FAST AND UPSCALE EXPERIMENTATION

Some economic activities have strong impacts on specific ecosystems or even on the entire Earth System. These ecosystems have a certain capacity to react to disturbances and return to their previous equilibrium state; but thresholds exist beyond which such return is no longer possible and systems may collapse, in some cases with potentially catastrophic effects for life on Earth (Lenton et al. 2008). It is thus truly vital to avoid such tipping points.

So humankind is approaching, or even transgressing, various thresholds at the global level where irreversible and catastrophic change may happen (Rockström et al. 2009). To stay within a safe operating space, quantum leaps in resource efficiency are needed that in turn require radically different technologies and business models in various fields. Among the various thresholds, global warming is the one for which the most sophisticated models exist to assess: how much carbon can still be emitted to keep warming below tolerable limits, by when the world economy needs to become carbon-neutral, how much the transition would cost and how much the cost would increase if action got delayed. While such calculations necessarily have methodological limitations, they all concur in their assessment that the necessary technology switch needs to happen within the next one or two decades if global warming beyond 2°C is to be avoided. Also, it is widely agreed that delayed implementation of mitigation measures will make it much more difficult and costly, if not impossible, to reach given climate targets. Costs increase–due either to greater environmental damages if targets are not met or to the greater stringency of the necessary mitigation measures if the original target is maintained–and opportunities to act early on low-cost mitigation measures are missed (Executive Office of the President of the United States 2014).

This provides a very strong rationale for green industrial policy that is ambitious and leads to results quickly. More mission-oriented innovation programmes are probably needed to facilitate big coordinated investments and accelerate the development of critical key technologies, such as for energy storage (Foray et al. 2012). In addition, sunset clauses and compensation schemes will be needed to phase out harmful technologies, as well as guarantees and subsidies to accelerate the dissemination of clean substitutes. Many of these policies involve risks of misallocation. Governments cannot know beforehand whether a certain public investment in a new technology or business model will pay off in the future. However, this is not an argument against such investments. If there are good reasons to assume that experimentation creates knowledge spillovers to society that are large compared to the private return on investment, supporting such experimentation makes sense. While this holds for industrial policy in general, it is particularly relevant for policy areas where solutions are needed urgently and quickly, because any delay leads to an escalation of costs. In the presence of tipping points in the Earth System, industrial policy support for sustainable technologies can hardly be overestimated. Also, it should be noted that there are ways to limit the risks of misallocation and share them with private investors, through competitive bidding processes and other means.

4.4. DEALING WITH ENHANCED UNCERTAINTY

Many of the objectives of a green transformation cannot be achieved in the short term. Decision-makers need to define long-term targets—such as the European Commission's target to cut the EU's greenhouse gas emissions to 80 per cent below 1990 levels by 2050—and then define intermediate milestones and derive technology and policy road maps for achieving the target (European Commission 2011).

With longer time horizons, uncertainty increases. Three types of uncertainty compound here. First, there is uncertainty about technologies and markets. These are always difficult to predict, but predictions become even more uncertain when systemic change is envisaged that stretches out over various decades. Moreover, considering that so far not a single country has succeeded in systematically decoupling economic welfare and growth from resource consumption, there are no role models for a green economy. Governments of developing countries are no longer well advised to emulate technologies and institutions from rich economies but rather need to find their own pathways.

Second, there is policy uncertainty. Green industrial policy is strongly driven by politically defined objectives, rather than by new technologies and market opportunities, which makes it essential to have predictable and stable long-term policy frameworks in place. Political factors–such as the level of ambition of policies to phase out coal or fuel-driven automobiles, the political will to implement carbon taxes or the willingness and ability to sustain preferential tariffs for renewable energy– strongly affect the profitability of investments (Karp and Stevenson 2012). At the same time, these political factors are often contested and they change when new administrations take office or public pressure mounts for or against certain measures.

Third, there is uncertainty about ecosystem dynamics. Policy frameworks need to respond to environmental changes that are difficult to predict because the effects of environmental disturbances are non-linear. If disturbances are minor and time-bound, systems tend to return to their previous equilibrium state; but thresholds exist beyond which systems may collapse (Scheffer

2009). Natural science research is thus needed to understand the inherent economic risks in ecosystems' dynamics and inform policymakers and investors.

Overall, uncertainty tends to be larger in green transformations than in ordinary market-driven transformations. Governments thus have a particularly important role in reducing uncertainties and related investment risks. They can do so by drafting roadmaps to augment investors' confidence in long-term policy targets. The EU's energy targets and its reduction targets for automotive fleet emissions are cases in point. Governments can also provide guarantees. Renewable energy laws in many countries combine guaranteed purchases from independent power producers with guaranteed minimum prices, known as feed-in tariffs. Also, they can anchor certain long-term targets in international treaties. All these measures help to lock polices in, shielding them from political cycles and increasing investment security.

On the other hand, given technological uncertainties, policy frameworks also need a certain degree of flexibility to respond to changing circumstances, such as new environmental risk assessments, emerging technological options or changing prices. The challenge is thus to find a good balance between providing 'directionality' and encouraging entrepreneurial experimentation (Mazzucato 2013).

4.5. ADDITIONAL POLICY INTERFACES AND NEED FOR POLICY COORDINATION

Often the green transformation goes far beyond the replacement of individual technologies. What is pursued is a transformative change of entire production systems, such as the energy system or the transport system. This requires simultaneous changes on several fronts including the development of various interdependent technologies and business models and the related adjustments of regulations and support systems. Such systemic change is unlikely to proceed smoothly without a proactively coordinating public agency. For example, no company would dare to invest in offshore wind parks unless other investors ensure the synchronized establishment of a grid that allows to bring electricity to the shore and further on to the main centers of demand. That, in turn, requires complex plan approval procedures involving affected communities as well as regulatory provisions for electricity transmission through various systems. Likewise, carmakers are unlikely to shift from fuel-driven to electric cars unless other specialised firms make parallel investments in batteries and charging infrastructure, and new technical standards are developed as well as credible policy road maps that signal the phase-out of fuel engines. Well-managed coordination processes with strong political backing are needed to bring such change about.

While the failure of markets to bring about simultaneous large-scale investments in complementary fields is one of the key reasons for adopting industrial policy in general, such coordination failure is particularly problematic when change is system-wide and transformative, as it is the case in the greening of economies. As economic subsystems tend to be interlocked, transformative change in one subsystem tends to have repercussions on others. When energy systems shift from fossil to renewable biofuel, it has unintended consequences on land and food prices; if dams are built to create hydropower, it affects water supply for agriculture; if agriculture shifts to organic, markets change for producers of fertilisers and agrochemicals.

Hence, new policy interfaces become relevant to understand the interdependencies and optimise the outcomes for all sectors of a society, especially civil society. Political decision-makers need to take various stakeholder interests into account when designing policies. This, again, is not a unique feature of green industrial policy, but it is a particularly relevant element of it, because stakeholders lobbying for the preservation of jobs provided by polluting industries are often better organized than environmental groups or social activists, for instance. The political feasibility of green economic reform therefore often depends on compromises among these interests, even though some compromises may reduce the policies' effectiveness in terms of environmental performance. Hence policies need to be co-designed by participants with strictly environmental interests and those helping to maximise social welfare, as well as those supporting economic or industrial interests.

4.6. THE MOTIVATION TO PROTECT NOT ONLY NATIONAL INTERESTS BUT ALSO GLOBAL COMMONS

The agenda of green industrial policy is partly driven by international agreements, such as the Paris Agreement, where governments have committed to decarbonise their economies; the Montreal Protocol on the protection of the ozone layer; and other treaties concerning fisheries management, marine and air pollution control, proper management of hazardous materials or genetic diversity of crops. All these agreements have a differential effect on industries: restricting the expansion of resource-using industries and/or forcing them to use product substitutes or to develop different technologies and business models, for example. They all serve to solve collective action problems at an international, often global, scale.

This is another important difference vis-à-vis traditional industrial policy. Normally, governments will try to implement the required policies in such a way that they enhance the productivity, competitiveness and employment potential of its domestic industries. Thus "…the benefits vest almost exclusively in the implementing country, and the costs are borne by foreign producers–a traditional mercantilist outcome" (Cosbey 2017, this volume). When it comes to green industrial policy, there are likely to be positive externalities for the global environment and for other countries. As pioneering countries develop solutions for environmental pressures, their industries will allow other countries to solve their domestic problems at a lower cost (Fankhauser et al. 2012). These spillover effects have important implications for the way we judge public subsidies. While in normal conditions, industrial policy should not enter into a competition on the basis of subsidies; a 'subsidy race' among nation states can be a good thing as it accelerates the development and global dissemination of green technologies (Rodrik 2014:471).

Hence, policymakers need to ponder the effects on domestic industry and global commons. Ideally, green industrial policy improves both in tandem, but outcomes differ in practice. Germany's solar policy was temporarily seen as a successful industrial policy in the traditional, national sense. A fairly high guaranteed feed-in tariff contributed to the diffusion of solar panels in the German market, and local companies reaped early mover advantages, becoming world market leaders and creating thousands of manufacturing jobs. But after a few years, Chinese low cost competitors started to crowd out the German industry, and many German solar panel manufacturers went bankrupt (Lütkenhorst and Pegels 2014). This led observers to criticise German solar policy as one that created a market but failed to build an industry (Paris Tech Review 2012). From a global perspective, however, Germany's support for the industry enabled the first large-scale photovoltaic module production that in turn brought unit prices down–by 80 per cent in the period 2009–2015 (IRENA 2016). The supply triggered worldwide deployment of this green technology. In terms of national industry, China was the main beneficiary (Pegels 2017, this volume).

More recently, a similar story is happening with electric vehicles, where China is the pioneer that accelerates the global diffusion of greener technologies. Here, the government heavily subsidises the shift from internal combustion to electric engines, thereby making China the lead market where new models are developed, tested and rolled out in mass production (Altenburg et al. 2017, this volume). Given that China is the world's largest automobile market and served largely by multinational carmakers, China's industrial policy is accelerating the cost degression of electric cars and batteries to the benefit of the rest of the world.

Currently, such positive spillovers from national policies to global green technology diffusion have mainly happened unintentionally. To accelerate the worldwide diffusion of technological solutions for managing global commons, more international technology cooperation is needed. This requires expansion of mechanisms that fund international research and development, knowledge sharing and technical assistance to developing countries, such as the Global Environmental Facility and the UNFCCC's Technology Mechanism.

5. CONCLUSIONS

Governments, those of developing countries in particular, are facing a dual challenge: they need to advance structural change towards higher productivity while at the same time decoupling human well-being and economic progress from resource consumption and emissions. This implies the need to better integrate industrial and environmental policies–rethinking the former from an environmental perspective and exploring how the latter can contribute to greater competitiveness and more and better jobs. This chapter shed some light on the policy options.

In the long term, there is no trade-off among social, economic and environmental objectives: there is no human development or economic success on an uninhabitable planet. In the short term, however, there are trade-offs to be considered. For example, pricing environmental goods puts an additional, but appropriate, burden on producers who have been able to externalize these costs in the past and may jeopardize their competitiveness and employment capacity. At the same time, moving to greener economies holds many benefits even from a purely economic perspective, as greater resource efficiency lowers costs, early movers may develop new markets, asset-stranding is avoided and new job opportunities open.

Governments need to understand the opportunities and pitfalls to minimise the costs and maximise the gains, striking a fine balance between environmental objectives and competitiveness, industrial development and job agendas. It should be noted that this is a classic political transformation project rather than a technocratic exercise. First, because finding the right balance of competing objectives and deciding among various alternative techno-institutional pathways implies value judgments; and second, because transformations always create winners and losers. Governments need to create consensus on the direction of change and facilitate compromises among stakeholders. This in turn presupposes a thorough understanding of interest groups and their power resources. When some elements of the transformation encounter strong resistance from interest groups, governments need to identify less contested no-regret options, such as resource efficiency programmes with quick economic returns or pollution control programmes with benefits for large parts of the society, to propel the transformation forward. Fortunately, there are already strong forces driving the green transformation, such as the decreasing price of renewable energy generation, an increasing number of environmentally conscious citizens ready to wield their voices and their buying power, lead firms in global value chains pushing for greener supplies, international treaties demanding greener standards and institutional investors pulling out of carbon assets.

Accelerating structural change always requires a proactive public sector. The case for industrial policies is theoretically very strong and backed by evidence. Public policies have a role in supporting research and development, subsidizing entrepreneurial cost discovery, coordinating complementary investments that need to be undertaken simultaneously and facilitating information sharing and technological learning. In these areas, social benefits tend to be much higher than returns to private investors, so that markets alone cannot provide socially optimal solutions.

When it comes to the urgent need to decouple human development from non-renewable resource consumption and pollution, market signals alone are even less effective. First, environmental costs are not sufficiently reflected in market prices, and second, the green transformation requires system-wide changes–such as radical redesign of the predominant energy systems–that cannot take place without well-coordinated interventions to deal with multiple coordination failures. As a consequence, green industrial policy is in many aspects similar to traditional industrial policy, but it has to come to grips with additional layers of complexity: The need to avoid negative environmental externalities requires specific policy instruments, such as cap-and-trade systems and environmental taxes. The urgency to phase out polluting technologies and replace them with green substitutes within short time frames calls for more comprehensive and aggressive research and development and technology diffusion programmes. The necessary restructuring of entire economic sub-systems presupposes long-term strategies spanning several decades that offer clearly defined interim targets and, where necessary, credible long-term subsidy schemes and financial guarantees. Furthermore, particularly comprehensive policy coordination and consensus-building mechanisms are needed to manage radical systemic changes at the interface of industrial and environmental policies. Thus as a rule, green industrial policy is more ambitious than most industrial policies of the past. This increases the risks of misallocation and political capture. We argue, however, that the long-term costs of not taking, or of delaying, action are much larger than the risks of losing part of the industrial policy funds to non-performing programmes and that there are proven policy design principles that greatly reduce the risks of ineffectiveness and capture.

Countries are likely to reap multiple benefits when they take a proactive stance and accelerate their green transformation in a way that combines social, economic and environmental objectives and when they design their policies according to the three basic principles of effective industrial policymaking. Well-designed green industrial policies are crucial not only for bringing economic development back into the safe operating space for humanity; they can also serve as an investment programme for long-term productivity gains.

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