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Climate Change and Industrial Policy

Wim Naudé*

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Abstract

This paper explores the implications of climate change for industrial policy (IP). Five implications are discussed, namely the need for international coordination of IPs; for putting human development, and not emission targets, as the overriding objective of low-carbon IP; of stimulating innovation for energy efficiency, energy diversification, and carbon capture and storage; and for aligning IP with trade policies. Finally the funding needs of low-carbon IPs are discussed, and the importance of private sector funding emphasized.

Keywords: climate change, sustainable development, industrialization, industrial policy, low-carbon growth

JEL classification: L60, O25, Q54, Q55,

*Maastricht School of Management, MGSoG (University of Maastricht), and UNU-MERIT, email: naude@msm.nl

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UNU World Institute for Development Economics Research (UNU-WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

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1 Introduction

Industrial Policy (IP) is vital for sustainability in its broadest sense: both environmental as well as societal sustainability will depend on IP. In a world characterized by growing inter-and intra-country inequality, industrialization offers scope for providing job opportunities, incomes, and the chance for industrially lagging countries (ILCs) to catch up. In a world facing the specter of climate change, low-carbon industrialization, and green growth paths have become imperatives. Altenburg (2009) describes climate change as one of the most important challenges facing IP. Naudé and Alcorta (2010) stress that achieving low-carbon industrialization

> … is going to require selective government intervention… neutrality towards all products and processes cannot be maintained. It has got to be driven by governments as coordination, subsidization, protection, information and large scale investments are at the core of the responses towards limiting the human impact on climate change. The need for making the right choices will become even more apparent as the world's population increases to more than 9 billion people by 2050. A growing population with increasing purchasing power will demand new and more products and ways of making them that will not only have a heavy toll on the environment but will also put heavy pressure on the availability of natural resources to produce them (ibid.: 1)

Moreover, promoting low-carbon industrialization and obtaining its accompanying development benefits (Szirmai 2009) will itself improve the ability of currently poor countries to adapt to climate change. It is the case that 'the best defence against climate change is economic development' (Schelling 2009: 16).

Although the Earth's climate has always been changing there is now wide agreement that the climate is warming and that human emission of greenhouse gases[1] (GHGs)—anthropogenic global warming (AGW)—is a contributing factor. 'Every company, every farm, every household emits some greenhouse gases' (Tol 2010: 29). One of the most significant levels stems from industrial activity. Industry demands around 30 per cent of global final energy demand and is responsible for around 40 per cent of all energy-related emissions, with iron and steel, cement, chemicals and petrochemicals, pulp and paper, and aluminum production being the most carbon intensive (IEA2009b). The human-emitted component of GHGs in the atmosphere has risen considerably since the first Industrial Revolution. It poses a challenge for human well-being as warmer climate is expected to have many negative (although also positive) impacts on society.

When the current industrially advanced countries underwent their rapid industrialization process starting in the eighteenth and nineteenth centuries, and even when China started its economic reform in 1978, the potential threat of climate change, and in particular by AGW, was unknown. Over the past two decades, however, it has become one of the most talkedabout global challenges of our times.

1 Including carbon dioxide, CO_2, and methane, CH_4.

Climate change is predicted to have particular economic and social impacts through various channels; moreover these are expected to differ geographically, and as the next section will detail, developing countries are expected to be worst affected. These impacts and consequences will require *adaptation* to climate change as well as actions to *mitigate* AGW.It means that active and selective IP will have to be used by both advanced as well as developing countries to achieve the balancing act of reducing GHG emissions and ensuring that industry (manufacturing in particular) remains an engine of growth and employment.

Adaptation and mitigation will have costs and opportunities for industrial development, but differing across the globe. Generally, the challenge is to ensure that industrial development and the prospects for industrial development is not adversely affected by climate change and that industrial development takes place without worsening AGW—ideally contributing towards moving global production, distribution, and consumption towards a low-carbon and eventually decarbonized economy. Moreover industrialization itself could mitigate climate change and facilitate adaptation through providing the means to accelerate the transfer of employment from agriculture to industry—this could potentially reduce pressures on deforestation and clearing of land for agriculture, two important sources of GHG emissions.[2]

The purpose of this paper is to further explore the need or rationale for IP due to climate change, and to determine what it implies for the how of IP. To achieve these objectives the remainder of the paper will discuss the challenges facing both industrialized and ILCs in contributing towards a low-carbon economy. The central argument of the paper is that a low-carbon economy will require mitigation, explicit recognition of the relationship between adaptation and industrialization, and should be undergirded by international coordination. For the *how* of IP it requires at a minimum a threefold approach, consisting of (i) appropriate innovation and technological change, (ii) trade policy alignment, and (iii) the prioritization of sustainable human development.

Before discussing the elements of this threefold approach, the basics of climate change economics as it pertains to industrialization and IP is discussed in Section 2. This is to provide an adequate frame of reference and stress the daunting obstacles in the path of low-carbon industrialization. Then in Sections 3 the three implications for the howof IP (innovation, trade, and sustainable human development) with respect to mitigation and adaption and industrialization are discussed. Section 4 concludes.

2 Climate change and industrialization

2.1 Greenhouse gas emissions and industrialization

Before proceeding it may be necessary to deal briefly with the question: how does AGW occur? The answer, as alluded to in the introduction is that human activity give rise to GHGs (especially carbon dioxide, CO_2, and methane, CH_4). The so-called Kaya Identity (see Girod et al. 2009) is used to depict the main links between human activity and GHG emission:

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2 According to estimates deforestation in developing countries is currently the source of up to 25 per cent of all GHG emissions (Martin 2010).

$$GHGemissions = population \times \{\left(\frac{GDP}{Population}\right) + \left(\frac{EnergyUse}{GDP}\right) + \left(\frac{GHGemissions}{EnergyUse}\right)\}$$

The Kaya identity shows that GHG emissions arise from human activity through increases in incomes, and energy and carbon intensity, all which rise with population growth. Industrialization therefore contribute towards GHG emissions through (i) contributing to general GDP growth, (ii) having a dramatic overall impact on energy demand and use, and (iii) using carbon-intense production methods.

Based on the Kaya identity, given forecasts of economic development, population growth, and given assumptions on energy demand and carbon intensity of production and consumption, it is possible to predict GHG emissions caused by human activity. Such predictions are provided by the Intergovernmental Panel on Climate Change (IPCC)[3] and the International Energy Agency (IEA). According to the IEA's recent estimates, CO_2 emissions are currently increasing by about 1.5 per cent annually. As a result it predicts emissions to rise from 28.8 Gt (gigaton) in 2007 to 40.2 Gt by 2030 (IEA 2009a). Faster industrialization in the developing world will, ceteris paribus, raise these emissions and contribute to further AGW.

2.2 Economic impacts of global warming

What are the consequences of global warming, and hence the consequences of industrialization? The overall assessment is that global warming will be detrimental to economic development and contribute to greater poverty (Ojha 2008). Various studies, using quantitative modelling techniques including computable general equilibrium models, have since the early 1990s been used to estimate the economic impact of global warming. Most studies have assumed an increase in global mean temperature of either 1 ^{0}C or 2.5 ^{0}C—which is assumed would occur if the amount of GHGs in the atmosphere doubles. Table 1, adapted from Tol(2010), summarizes the key peer reviewed studies in this regard.

Table 1 indicates that most peer reviewed estimates of the economic impacts of climate change ranges between -11.4 and 2.3 per cent of global GDP. It can also been seen that some regions are net losers—in many cases Africa or Asia—and some net winners—mostly Russia and the countries of the former Soviet Union.

One of the quoted (and criticized) estimates on the impacts and costs of climate change and its mitigation comes from the Stern Review (Stern 2006). The Stern Review estimated that climate change's economic damages would amount to around 12per cent of global GDP, and that the costs of mitigation—moving to a low-carbon economy—would be much lower, around 1 per cent of global GDP. Hence the key message of the Stern Review was that the impact of climate change is likely to be severe but the costs of avoiding this relatively small, if the world acts without delay.

3 For a discussion of the criticisms against the IPCC's scenarios see Girod et al. (2009).

Key criticisms against the Stern Review were that too low a discount rate was used to value future damages, thereby overstating future damages, and that mitigation costs were underestimated (see e.g. Tol and Yohe 2006; Nordhaus 2007).

The World Bank's 2010 World Development Report (WDR) focused on climate change. According to the World Bank (2010) global climate change will have disproportionate negative impact on developing countries, in particular on agricultural productivity in Africa, South Asia, and parts of Latin America. The World Bank also expects that Russia and Canada and parts of Western Europe may benefit through improving agricultural productivity. The potential out-migration of people from agriculture in Africa, South Asia, and Latin America has accordingly been raised as a concern (Martin 2010), and emphasizes the importance for structural change—industrialization—to assist in providing alternative employment to out-migrants from agriculture.

Predicting the economic impacts of global warming is however, a contentious issue—as is the case generally with climate modelling or weather forecasting—with Prins et al. (2010:18) complaining that assumptions and simplifications used in such models can 'undergird just about any view of the future that one prefers', and Tol (2010:30) stating that 'the uncertainties about climate change are vastindeed, so vast that the standard tools of decision-making under uncertainty and learning may not be applicable'. He provides a discussion of some of the methodological challenges in estimating the economic impacts of climate change such as (i) the difficulty of assigning uncertainties (i.e. discount rates), (ii) the difficulty of modelling adaptation, of (iii) putting values on environmental services, and of (iv) estimating the marginal costs of GHG emissions.

Given the acknowledgement that, despite uncertainties in estimating the impact of climate change, it remains a significant threat and that reducing GHG emissions are warranted, economists have asked what the social costs of GHG emissions are, with a view of establishing a price on carbon (through taxes, emission trading, or regulation). This is based on the economic view that the cost of a negative externality, such as a carbon emission, need to be internalized by the party responsible.

Tol (2010: 41) considered estimates from 232 published scientific studies and concluded that 'the uncertainty about the social costs of climate change is very large'. The mean estimate from these studies is US$105 per ton of carbon, with the modal estimate around US$13 per ton and the median US$29 per ton.

Industrialization, given its high contribution to emissions, thus clearly carries a price. Although the extent of the ultimate price is still subject to uncertainty, what is certain is that poorer countries will be worst affected, and that unless industrialization can proceed in a way that reduces GHG emissions, the eventual price will be higher, both in terms of damages to GDP and the social costs of emissions. Indeed, as the IEA (2009b:21) notes 'total industrial energy consumption and CO_2 emissions are rising and progress in industrial efficiency and CO_2 intensity has been more than offset by growing industrial production'.

3 Implications for industrial policy

Achieving low-carbon industrialization has a number ofinterrelated implications for IP. These will be discussed in the following sub-sections.

3.1 International coordination of industrial policy

A piecemeal, country-by-country approach is likely to be sub-optimal. In the past IP was very much nationally-oriented with little cooperation and coordination between countries. Now however, a transition to a low-carbon economy will require global cooperation and coordination. This raises issues of the appropriate and effective institutional mechanisms to achieve such coordination. Is it through the UN, the G20, regional initiatives like the EU, or perhaps some other sovereign, non-state actor? And how will compliance be ensured and monitored?Before coming to these issues, the case for international coordination of IPs needs to be stressed.

It has been estimated that in order to limit average global warming to 2 ^{0}C by 2100, with a 50 per cent probability, that concentrations of CO_2 should be stabilized at450 ppm (parts per million) by 2030 (IEA 2009a)—it is at the time of writing (2010) around 389 ppm and rising by 2 ppm per year—growing at around 1.5 per cent annually (Prins et al. 2010; IEA 2009a).

The challenge in achieving this reduction in CO_2 seems almost too incredible to achieve. Barrett (2009) reports that CO_2 should be reduced not to 450 ppm but to 350 ppm to limit global warming—a level already exceeded. He refers to the need therefore for a 'global climate-technology revolution' to aim at this target, while the IEA (2009a:8) calls for a 'low-carbon revolution'. Nothing less than a low-carbon 'revolution' iscalled for, as the IEA (2009a) expects that at current rates, CO_2 emissions would continue to rise from 28.8 Gt (gigatonnes) in 2007 to 40.2 Gt in 2030. This is estimated to push average global temperatures up by 6 ^{0}C and result in CO_2 levels of more than 1,000 ppm.

Currently, and to date since the first industrial revolution, most developing countries are not major GHG emitters—even large emerging economies like China, Brazil, and India emit relatively little in per capita terms—although due to the size of their populations and economies their total emissions are significant (Ojha 2008).However as far as the future is concerned, the IEA (2009a) expects that *all*of the projected increase in CO_2 emissions between now and 2030 will come from developing countries—mainly China, India, and the Middle East. Around 75 per cent of the predicted 12 Gt increase in annual emissions is set to come from China alone, with the country expected to become the world's largest importer of oil by 2025 (IEA 2009a). The growth in CO_2 will be driven not only by the growing prosperity and rising demand from rising industrial giants such as China and India, but also from the need to meet the, still as yet unmet, demand of around 1.5 billion people around the world who lack access to electricity. The majority of these live in Sub-Saharan Africa (SSA) (IEA2009a).

Developing countries will, however, in many cases also be the worst affected by climate change, as was discussed in Section 2. And most of the current industrially-generated stock of carbon in the atmosphere has been caused by advanced economies, where most of the technological capability, know-how, human skills, and financial resources reside to mitigate climate change and adapt to its impacts.

This suggests that a low-carbon revolution requires global coordination. Many questions have arisen and remain relevant. How can this do be accomplished? Is it possible? What will be the costs? Is globally coordinated action towards a low-carbon economy possible? There are currently no clear answers. What is clear at the time of writing is that the multilateral (UN-mediated) negotiationsroute, which has characterized global coordination attempts for almost two decades, has not yet resulted in definitive success. The process, which started with the Rio Declaration and includes the flawed Kyoto Protocol, has not been a total failure as some would suggest. There have been in fact hugely important milestones—but they have not yet brought the world significantly closer towards containing global warming.

The 'Hartwell Paper' (see Prins et al. 2010) is particularly critical of the multilateral UN-mediated route to achieve a reduction in CO_2 emissions, claiming that it is putting carbon reductions before human development, that it is being overly top-down in its approach of working through 'set-piece conferences', and that it obscures varying 'interests and agendas within utopian talk of global and universal solutions' (ibid.: 12).

What bedevils global coordination with respect to achieving a low-carbon economy are a number of conflicting incentives arising out of the nature of the climate change challenge. The first is that developing countries have potentially much to gain from carbon-intensive industrialization. This issue will be discussed in greater depth in the next section, as it has a bearing on the objectives of IP.

The second problem is that climate change and the move to a low-carbon economy creates both potential losers and winners—it has unequal benefits and costs so that countries face an incentive structure that 'resembles a multiplayer prisoner's dilemma game' (Brandt and Svendsen 2003:10). These create potential benefits for countries with low-carbon technologies and/or the knowledge to be a producer and exporter of such technologies—indeed they could corner the market. In other words a first-mover advantage in low-carbon technology and products could be valuable. How should countries with such an advantage exploit it? The answer is through IPs that ensure that a sufficiently large number of countries would want to adopt such technologies—for instance through committing to binding agreements on CO_2reductions and increasing the share of non-renewable energy. Such a country-level strategy could, however, be counter-productive from the point of view of obtaining binding agreements on CO_2reductions if there are countries who do not want, for competitiveness reasons, to allow others to exploit their first-mover advantage.

This is according to Brandt and Svendsen (2003) exactly, however, the position the EU and USA find themselves in, and that could explain part of the USA's reluctance to commit to the Kyoto Protocol. Their thesis is that the EU has a first-mover advantage in some renewable energy technologies, for instance windmills,[4] and is therefore quite keen to push for wide international agreements that will see a rise in the price of carbon

[4] Brandt and Svendsen (2003) discuss the case of Denmark, where government subsidization of the wind turbine industry (following the oil crisis of 1973) has resulted in the country gaining a lead in the production of windmills.

and targeted share of renewable energies in future energy consumption.[5] See also Helm (2009) who states that the EU is projecting a leadership role for itself in setting GHG emissions targets. However, for countries without this advantage, such agreements will result in them having to spend more on importing such renewable energy technologies from the EU. Brandt and Svendsen (2003) argue that this may be a reason why countries such as the USA have been reluctant to commit to such globally-binding agreements, and may perhaps also explain why the EU's climate policy over the past two decades has 'probably not made as much as one part per million difference …the rhetoric, the plethora of initiatives, directives, and interventions has not been matched by outcomes' (Helm 2009:1).

International coordination of IP is thus needed for low-carbon industrialization, but faces daunting challenges in dealing with strategic and opportunistic national behaviour.

3.2 Objectives of low-carbonindustrial policy

A second implication of the need for low-carbon industrialization for IP is for the fundamental objective of a low-carbon IP and the cooperation and coordination to underpin it. Should it be first and foremost (as has been the case in current global climate negotiations) be on carbon reduction, or on human development (as growing numbers of commentators have been arguing)?

However such coordination is done, it might mean that industrial policies will face certain (more) international constraints (policy space for supporting carbon-intensive manufactured goods may for instance increasingly shrink), but will have to balance global pressures for climate change mitigation against national pressures for job creation and infrastructure.

In Section 3.1 the difficulty of reaching a substantial international agreement on climate change was discussed. There was noted that many developing countries have potentially much to gain from carbon-intensive industrialization, particularly asthey face for job creation and provision of basic services, including electricity.

The IEA (2009a) estimates that more than 1.5 billion people worldwide lack access to electricity. High unemployment is critical in emerging regions such as Africa and Latin America, and industrial development remains one of the engines of job creation. As put by Ojha (2008:324) for most developing countries 'the more pressing need obviously is achieving poverty reduction rather than controlling carbon emissions'. This should be seen against the fact that coal is still one of the most abundant, and cheapest, sources of energy in developing countries. For instance, in India it accounted for over 47 per cent of energy demand in 2005 (Ojha 2008). And South Africa started the construction of a huge coal-fired power station only months after it became a party to the Copenhagen Accord of December 2009 (which is, however, not legally binding).

It is not that these countries are not concerned with the impacts of climate change. Rather it isa question of addressing the challenge without compromising on

5 The EU's 20-20-20 Climate Change Package adopted in January 2008 aims to reduce EU emissions to 20 per cent below 1990 levels by 2020 and raise the proportion of energy from renewable to 20 per cent by 2020 (Helm 2009).

development and rising living standards. And the latter is likely to win in any ‘contest’. As recognized by Helm (2009:6)

> The key challenge for climate-change policy is how the developing world can raise its standards of living towards those of the developed countries and at the same time global carbon emissions, and other environmental damage, can be reduced.

With this in mind many have criticized the United Nations Framework Convention on Climate Change (UNFCCC) multilateral-type of approach of putting carbon reductions ahead of people’s development, and see the failure ofCOP15 at Copenhagen in December 2009 as a result of this misplaced emphasis. As was put forcefully by the Hartwell Paper

> Climate change is better understood as a persistent condition that must be coped with and can only be partially managed more-or-less well…it is not straightforwardly an environmental problem either. It is axiomatically as much an energy problem, or a land-use problem, and may be better approached through these avenues than as a problem of managing the behaviour of the Earth’s climate (Prins et al. 2010: 16).

Similarly, Bondre (2010:16) saw the failure of the COP15 meeting as due to the singular focus on GHG reduction, stating that climate change is a ‘multipronged challenged’ and should not just have ‘a singular focus on global warming’ as it would drive polarization. Tol (2010, 2002a,2002b) and others have argued that, because poverty is a fundamental cause of climate change, that the best strategy is to speed up economic growth and development—it is seen in these quarters as even better than emissions reduction. Also, has been argued that developed countries may find it ‘cheaper to compensate poorer countries for the climate change damages caused, rather than to pay for reducing their own greenhouse gas emissions’ (Tol 2010:36).

Some have also asked about the effectiveness of advanced regions, such as the EU, trying to adopt expensive measures to reduce their GHG emissions. According to Helm (2009:6) ‘…there may be much cheaper ways, for example by preserving tropical rainforests or decarbonizing China and India’s rapid coal-based economic growth’.

The implication is that once the objective of low-carbon IP is to promote sustainable human development, issues such as these raised above become important, and start to shift to centre stage in the debate, resulting in not only different approaches to IP (more internationally coordinated), but also containing different IP content (such as compensation and transfers from advanced to emerging countries).

3.3 Innovation-driven industrial policy

Achievement of a low-carbon revolution is clearly impossible without innovation and technological change. Innovation is a complex process, and requires a systems approach—as is seen on a country-basis in governments’ efforts to enhance their national systems of innovation and on an international level by the promoting of Research, Development, and Demonstration (RD&D) by the UNFCCC, the Major

Economies Forum (MEF)[6] and IEA. It is also a process wherein entrepreneurship plays a leading role. Entrepreneurship is vital for innovation (Schumpeter 1911) and entrepreneurial innovation has played already an important role in reducing CO_2 emissions. The Soviet Union and Maoist China are examples of large economies that had little prospect of declining emissions—indeed these countries saw very rapid CO_2 emissions characterizing their industrialization during the twentieth century.

Innovation can be a gradual progress, and as far as low-carbon IPs are concerned, this will have to be taken into consideration. It poses, however, difficult questions in terms of capital investments and returns on these. For instance, as discussed by Prins et al. (2010), moving to a low-carbon economy will require IP measures towards innovation and technological change that have different outcomes over the short, medium, and long term. Over the shortterm the emphasis needs to be on improving energy efficiency, over the mediumterm to phase in the greater use of renewable energy and energy diversification, and over the longer term to introduce more path-breaking technologies for low-carbon production. The remainder of this sub-section discusses energy efficiency, renewable energy, and energy diversification, and low-carbon production technologies.

3.3.1 Energy efficiency

Energy efficiency entails using less energy in production and consumption. Examples include development of ‘smart grids’, improvements in building energy efficiency, industrial energy efficiency and vehicle efficiency, including the promotion of electric/hybrid, and hydrogen based vehicles (IEA, 2009b). Energy efficiency in industrial process can contribute significantly to reduced GHG emissions—Trudeau and Tam (2009) estimate that energy savings in the industry could contribute to a reduction of up to 5.7 Gt in CO_2 emissions by 2050.Globally coordinated IP and cooperation in IP is required since developing countries can reduce their industrial emissions significantly over the short to medium term through adoption of currently existing best available technologies (BAT). Prins et al. (2010) for instance report that BAT in the steel industry is globally diffused; it would reduce CO_2 emissions annually by around 340 million tons. Similarly significant reductions may be obtained if coal-powered plants would adopt best available practice (IEA2009). IPs facilitating learning, copying, adopting, and experimentation on a sector by sector basis (the nature, needs, and requirements for improving energy efficiency differs substantially between industrial sectors) will be needed (Trudeau and Tam 2009).

It should be noted that though improvement in industrial energy efficiency can make an important short-term contribution, it may not necessarily lead to significantly lower energy demand or reduced GHG emissions. This is because of the income—effect of energy savings—people may channel their energy savings into increased consumption on other, more carbon-intensive goods. This means that carbon taxes may be needed as an IP measure to facilitate longer terms reductions in GHGs from energy efficiency (Helm 2009). And industries may expand faster than the savings they establish.

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6 An objective of the MEF is to double expenditures on RD&D for low carbon technologies by 2015 (IEA 2009b).

3.3.2 Energy diversification

Energy diversification requires clear IP initiatives to increase the share of non-fossil fuels in energy demand. Energy diversification would mean greater use of nuclear and renewable energy sources—clean energy. Such diversification is enjoying high priority in many countries, not just based on concerns about climate change, but also about energy security and the possible opportunities it may hold for industrialization and job creation. For instance, in the latter regard the South African government estimates that 300,000 new jobs could be created in the country through renewable energy production over a period of ten years. The country's Industrial Development Corporation envisages a US$10 billion investment in renewable energies between 2010 and 2015 (Creamer 2010). Diversifications of energy towards renewable and nuclear sources are therefore set to continue for these reasons.

The main sources[7] of renewable energy include wind, solar, bio-energy, geothermal, and wave (marine) energy, although at present most RD&D into renewable energy are going into solar power (see Table 2). Marine and hydroelectricity is relatively neglected, also in the IEA (2009b) reports on renewable energy initiatives.

According to Barrett (2009) the main task is to reduce the relative cost of these sources—currently they are much more expensive than carbon sources of energy and thus uneconomical. He points out that lowering their costs will involve not only technological innovation in the energy generation process itself, but also in complementary technologies in the transmission and storage—especially of wind and solar energy, where the resource is often located at some distance from where the energy is demanded. It will also require a high and rising price of carbon. Carbon can be priced through putting a taxon it or using a market-based mechanism such as a permits or trading scheme. A large literature has arisen discussion about the pros and cons of various ways of pricing carbon. Many argued that taxes are better than permits or trading schemes (e.g. Nordhaus 2009; Helm 2009).

The major trading schemes that have so far been created for pricing carbon include the Regional Greenhouse Gas Initiative in the north eastern USA and the European Union's Emission Trading Scheme (ETS). Carbon pricing mechanisms, in particular cap and trade proposals and carbon taxes have generated substantial criticism. (Prins et al.2010:9).claim that

> The huge efforts that have been invested in elaborating complex top-down regulatory regimes and in particular the ambitions for regional—let alone global—cap and trade regimes to regulate carbon by price can now be seen to have been barren in their stated aims although profitable for some in unexpected and unwelcome ways.

There have also been concerns that energy demand is highly inelastic so that a higher price for carbon will have little impact—apart from hurting the poor.

7 Nuclear power is not a renewable source of energy because it is dependent on uranium supplies. However, it can provide substantial non-carbon energy over the mediumterm, subject to risks (Barrett 2009).

Other criticisms concern the difficulties in establishing a price for carbon (see Helm 2009), reflected in the fact that governments have so far been unsuccessful in cooperating to increase the price of carbon (Barrett 2009). Indeed many have pointed to the volatility of carbon prices in the ETS as creating uncertainty. Helm (2009) provides extensive criticism against the EU's ETS, arguing that it is has been a failure due to political compromises and lobbying by polluters—a typically old problem of any IP. As he describes, 'a tradable permits regime creates new markets, which in turn create rents for participants. There is now a rapidly growing set of vested financial interests with every incentive to lobby for the retention and development of the EU ETS' (ibid.: 9).

The challenge for low-carbon IPs is how the incentive problem for getting entrepreneurial investment into developing and rolling out low-carbon technologies can be successfully overcome. Fundamentally, there may be substantial entrepreneurial opportunities in low-carbon industrialization for developing countries. Many are already looking at China's example to provide the lead, and create further incentives and opportunities for ILCs to use low-carbon technologies as a way to catchup—similar to the way that it provided opportunities for catching up in conventional manufacturing. China, the world's largest energy consumer, is already a world leader in wind power and solar energy, and is making strides in expanding nuclear energy generation.

3.3.3 Carbon capture, storage, and sequestration

Over the longer term more path-breaking technologies for low-carbon production and energy diversification are needed. How can IP promote these? One answer is that IP should invest in mechanisms for directly removing, storing, and sequestering carbon from the atmosphere (Barrett 2009). As put by Helm (2009:21) 'unless coal can be burnt in a less harmful way…there will be little or no progress in abating global emissions'. Such carbon capture and storage (CCS) mechanisms are currently expensive, ranging from US$25 per ton of CO_2 to US$90 per ton of CO_2 (Barrett 2009). Stimulating further investment in these will also require, as in the case of energy efficiency measures, that a positive and increasing price of carbon be established to underpin IP for a low-carbon economy.

But carbon pricing will in itself not be sufficient to stimulate investment in CSS. In addition, subsidies to low-carbon technologies and goods will be required (greater spending on research, development and dissemination—RD&D), as well as IP measures to reduce carbon leakage.

Consider RD&D: IEA (2009b) provides a discussion of current RD&D expenditures of mainly OECD countries and the aims of these expenditures across ten categories of RD&D in low-carbon technologies[8].These expenditures are summarized in Table 2.

Table 2 indicates that, based on available data, by far the most significant bulk of RD&D expenditures to promotelow-carbon economy takes place in the area of

8 There are a number of efforts to globally coordinate RD&D efforts. These include initiatives by the MEF, the UFCCC, and the IEA The MEF aims to double expenditures on RD&D for low carbon technologies by 2015. Other major initiatives for low carbon technological RD&D include the Carbon Sequestration Leadership Forum, the International Partnership for the Hydrogen Economy, and the International Thermonuclear Experimental Reactor.

advanced vehicle technologies—almost twice as much as on the second most sizeable area, CCS.

According to the IEA (2009b) advanced vehicle technology RD&D is particularly focused at the development of plug-in vehicles, hybrid-electric vehicles, lightweight materials, energy storage systems, hydrogen fuel cell vehicles, and low rolling resistance tires. These can be seen as energy-saving technologies.

The second largest category in terms of RD&D spending is on CCS. According to the IEA (2009b) here most research is focusing on direct capture of CO_2 from the air, on development of CO_2 storage facilities, on CO_2 pipeline transport, and on using CO_2 in enhanced oil recovery methods and cement production. This is followed by RD&D expenditure on solar energy with the USA, Italy, and Germany leading the field. Most solar energy applications aim at providing electricity through photovoltaic or concentrated solar power (IEA2009b). Solar energy is seen by many to provide particular opportunities for green growth to developing countries, particularly those in Africa.

IP for innovation-driven low-carbon industrialization will, in addition to carbon pricing, and subsidized RD&D also have to deal with carbon leakage. Carbon leakage refers to the practicewhereby firms and factories can migrate to countries where carbon prices are lower. To deal with carbon leakage will require IP, but also trade policy and an alignment of trade and IPs. This is discussed again in detail below in Section 3.5.For now, it may be mentioned that IP may deal with carbon leakage through industry-level agreements on the global scale—hence again requiring coordination IP. In this regard sector approaches, agreements and mechanisms have been called on to support low-carbon industrialization. These would entail sector-level agreements—for instance in the steel industry—to move towards particular emission standards, work towards adopting and spreading the best available technologies in this regard, and police the agreement (Wooders 2010; Prins et al. 2010).

3.4 Aligning industrial policy with trade

IPs to foster a low-carbon economy will have important repercussions for trade and foreign direct investment (FDI)—and hence trade policies. Hence a paper on IP and climate change cannot omit a discussion of the foremost trade issues that may arise. Note, however, that a comprehensive discussion of the relationship between climate change and trade falls outside the scope of this paper—the interested reader is referred to Hufbauer, Charnovitz, and Kim (2009) for a recent overview.

One of the central global issues that has spilled over from the industrial low-carbon debate onto the trade arena, is related to concerns about ‘carbon leakage’, as was already mentioned in Section 3.3.3. The fear is that regions that take the lead in moving to a low-carbon industrial base could become competitively disadvantaged. Some have even added to this the fear that the overall impact of such carbon leakages could be that global emissions increase, as it may create huge incentives for carbon-production in other regions (Helm 2009). UNCTAD (2010:36) stresses the incentive this would create for many developing countries, stating that ‘for poor countries in dire need of expanding their productive capacities such foreign investment could potentially generate large development gains’.

In the absence of globally binding agreements on low-carbon regulations and a global price of carbon, two alternative mechanisms have been mooted to deal with this potential problem. The one is border tax adjustments (BTAs)—tariffs on the carbon content of imported goods. The other is the development of emission trading schemes requiring importers to buy emission rights domestically to offset imported emissions.

BTAs currently appear to be the most favoured approach, at least politically. It boils down to getting industrial and trade policies consistent. But can it be effective? While there are proponents, a growing number of economists have in recent times cast doubt about the desirability and feasibility of BTAs.

Dong and Whalley (2008) discuss some of the difficulties with using BTAs to affect emissions. First, they note that it is growth rather than trade that is the major contributor to emissions. Second, emissions differ more substantially between countries than products, posing the problem of whether trade policy should discriminate against products, or countries—and conflict with the non-discrimination clauses of the WTO. Third, WTO-based tariff measures are likely to have a small impact on emissions because most are in a small number of sectors where output is not directly traded, such as electricity generation and transport. Fourth, it is difficult to define and agree on what could be regarded as 'environmentally sensitive' goods and services to treat separately in trade. Moreover as UNCTAD (2010) also indicates, it is difficult to measure or agree to measure the carbon-intensity of individual goods. Fifth, the administration of BTAs based on the carbon-content of imports will be a very costly process and difficult to implement.Finally, Dong and Whalley (2008) also point to the danger that once BTAs are used that government may want to engage in further 'strategic' trade policies to try and offset other perceived sources of competitive disadvantage, which could herald a new era of retreating from freer global trade to protectionism. In other words BTAs could be misused for protectionism—or 'old' IPs.

Hence, in the context of climate change IPs should guard against being usurped by strategic trade policies due to misuse of BTA. Careful alignment with trade is needed; moreover, the pitfall yet again emphasizes the importance of globally coordinated IPs.

3.5 Funding industrial policies for a low-carbon economy

There is recognition that all of the above will require huge amounts of investment—by both private and public sector. Financial resources would need to be made available for developing countries. From whom and how such funds should be channeled, remain largely unresolved global questions. Proposals include the reform of the Clean Development Mechanism (CDM) and the establishment of international funding pools. More FDI into low-carbon projects in developing countries are needed (UNCTAD2010).

At COP15 member states agreed (as part of the Copenhagen Accord) to create a funding mechanism to support mitigation of climate change in developing countries. It has subsequently been estimated that in order to achieve the targets in GHG reductions contained in the Copenhagen Accord, that at least US$440 billion in additional annual investment will be needed between 2010 and 2015, and that this would rise to US$1.2 trillion per year by 2030 (Creamer 2010). Other estimates of the investment required for climate change mitigation has come from the IEA. According to the IEA (2009a) in order to limit CO_2 levels to 450 ppm by 2030 will require additional investment in energy infrastructure and capital to the amount of US$10.5 trillion. Half of this would be in transport and around US$1.5 trillion would be specifically needed in industrial and bio-fuels (second-generation) production. Developing countries are estimated to require around US$197 billion in extra investment by 2020 (IEA 2009a).

For developing countries international transfers will be a key source of funding a low-carbon economy, as well as for adaptation. However, taxation of CO_2—broadening the resource base and providing incentives for switching from carbon at the same will also be important. And developing countries seem to be taking such taxes seriously—e.g. South Africa introduced in 2010 a carbon tax on vehicles (Van der Merwe 2010a, 2010b).

Generally though, especially coming after the financial crisis, many developing (and advanced) countries will find it hard to scrape together substantial funds for supporting mitigation efforts and particularly low-carbon industrialization. Here the entrepreneurial perspective comes into play again. As UNCTAD (2010:24) stress 'the financial contribution of the private sector is essential for achieving progress in making economies worldwide more climate-friendly, particularly in view of the huge public deficits worldwide'.

These will need on a global level to be supported by much more FDI into low-carbon production in developing countries. Such FDI is seen as an important channel for transferring knowledge about low-carbon technology and for limiting carbon leakage (UNCTAD 2010) According to UNCTAD (2010) the estimated FDI in 2009 into renewable, recycling, and low-carbon manufacturing was around US$90 billion, with around 40 per cent of this going to developing countries. Private funding will thus be an important source of funds for mitigating climate change in developing counties. There are some encouraging signs of such funding already emerging in SSA. For instance private investors have established, at the time of writing, at least two funds for developing and rolling out low-carbon technologies on the continent, including a technology development fund and a technology deployment fund (Van der Merwe 2010b).With aid to developing countries shrinking, and aid perhaps being diverted to climate change funds, and in view of the many practical difficulties in operationalizing the planned global funds for addressing climate change, the need for IP to engage with the private sector, and elicit private funding, is likely to be crucial in getting low-carbon industrialization efforts financially supported.

4 Concluding remarks

More than fifty years ago Raul Prebisch pointed out that 'industrialization of the periphery has always been a controversial subject, not only in the centers, but also in the peripheral countries themselves' (Prebisch 1959:251). Given rising global inequalities, the failure of industrialization in the poorest countries, particularly in SSA, and given the challenges of climate change, the industrialization of the periphery will undoubtedly become an even more controversial subject in times to come.

This paper started out by pointing to industry as a major emitter of GHG—contributing to global climate change. It is also a major driver of economic growth and development.The benefits of industrialization are sorely needed in a very unequal world where more than a billion people still live in absolute poverty. But in light of the likely economic impact of climate change, industrialization needs to take place so that it mitigates climate change and facilitates adaptation.

Industrialization in the coming decades will face clear costs and benefits. This paper made the case why selected policies needed to deal with such industrialization in the midst of the climate change challenge. The costs implied by climate change will be incurred because countries' entrepreneurs need to shift their firm onto a different production technology frontier—changing the way goods are produced. Investment in new techniques processes as well as shifts to lower carbon energy sources are required. These all imply costs, and hence the guidance of IPs to minimize costs. Carbon itself will have to be priced, and will have to become gradually more expensive. This will result in more costly production, at least over the mediumterm.

But a transition to a lower carbon industrialization process also offers benefits and opportunities. These include opportunities for producing low-carbon products. Many developing countries could benefit from this green growth, if they could marshal the adequate and timely responses through IPs. These could also generate substantial savings in the cost of using fossil fuels, if successful. In addition to these direct benefits, achieving a sustainable low-carbon industrialization path would result in indirect spillover benefits such as a cleaner environment and health improvements.

There are many pitfalls in applying IP. From past debates about IP most of these are known—they revolve around the imperfect information possessed by governments and the potential for IPs to be captured by special interest groups. Such potential government failures remain important to avoid. In the context of climate change however, perhaps the most important prerequisite for avoiding pitfalls is that IPs need greater international coordination and cooperation than ever before. This has been the central argument of this paper. Achieving such international coordination is perhaps, given the possible adverse impacts of climate change, one of the greatest challenges facing global development. This paper noticed a number of stumbling blocks, including the fact that developing and advanced economies face different objectives and challenges in low-carbon industrialization. For developing countries, job creation and the extension of energy to their populations are key issues; for advanced economies it is job creation and energy security. IPs for low-carbon industrialization need to be designed and coordinated around these imperatives.

The most likely path forward for low-carbon industrialization that will be consistent with the needs of human development may be one supported that makes use of nuclear power, that also uses coal, but that uses CSS technologies as far as possible to reduce carbon in the atmosphere. These need to be accompanied by a diversification into renewable energy sources over the medium to longer term. Hence IPs needs to have different short- and long-term goals. Cooperation between the big emerging powers, China and India on the one hand, and the USA and EU on the other in reducing carbon emission would afford ILCs some leeway to achieve growth from cheaper supplies of coal, while moving at an appropriate tempo to a carbon-free economy. Of course, this leeway should be supported by the large emerging powers and advanced countries by transfers of technology and climate funding.

For SSA, and large parts of Latin America, the fundamental challenge is not to make a short-or medium-term contribution to the mitigation of global warming, but to adapt industrialization to the consequences of global warming. In SSA industrial development can as such not be divorced from agriculture. More research is needed to draw out the implications for IPs in Africa where the base will be agriculture. The latter, the source of livelihoods to a majority of the population, will according to most estimates be severely affected by global warming. Hence the best response in Africa could be to promote job-intensive growth, the rolling out of social security nets, the encouragement of entrepreneurship—in other words generally increase the resilience of the population to adapt to climate changes and climate shocks. For this, socio-political stability and continued improvements in governance will be required from African governments. Advanced countries should support and rewards such improvements, inter alia by coordination of their own policies (such as scrapping expensive subsidies for farmers in advanced economies) with that of developing countries. Ultimately what will be required if the climate change challenge is to be credibly shouldered, is that international coordination of IPs will lead to a change in the nature of development cooperation—moving it from donor-driven aid towards partnerships. Partnerships that are consistent with local needs, conditions, and abilities, and that give developing country policymakers, through their IPs, a driving-seat role in their countries' development.

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Table1: The global economic impact of climate change—estimates from the literature

Authors	Impact on global GDP (%)	Worst affected region	Bestoff region
Frankhauser (1995)	-1.4%	China	Eastern Europe and former Soviet Union
Tol (1995)	-1.9%	Africa	Eastern Europe and former Soviet Union
Nordhaus and Yang (1996)	-1.7%	Developing Countries	Former Soviet Union
Plambeck and Hope (1996)	-0.5% to -11.4%	Asia	Eastern Europe and former Soviet Union
Mendelsohn, Schlesinger, and Williams (2000)	0.0 % to 0.1%	Africa	Eastern Europe and former Soviet Union
Nordhaus and Boyer (2000)	-1.5%	Africa	Russia
Tol (2002)*	2.3%	Africa	Western Europe
Maddison (2003)	-0.1%	South America	Western Europe
Rehdanz and Maddison (2005)	-0.4%	Africa	South Asia
Hope (2006)	0.9%	Asia	Eastern Europe and former Soviet Union

Note: * Assumes a 1 ^{0}C warming only.

Source: Adapted from Tol (2010: 31).

Table 2: Estimated RD&D expenditure on low-carbon industrialization in selected countries,2009 (in US$million)

Country	Advanced vehicles	Bio-energy	CCS	Building energy	Industrial energy	Lower coal emissions	Smart grids	Solar energy	Wind energy
USA	539.4	287.6	594.0	85.4	79.9	217.2	60.2	190.3	31.7
Japan	319.6	18.7	36.8	139.0	143.9	78.9	94.4	1.0	1.9
Australia	189.9	6.9	123.5	22.7	26.4	100.2	20.8	39.0	5.7
France	135.8	40.2	38.8	32.8	16.7		12.2	47.9	2.5
EC	94.0	19.2	31.9	-	-	43.0	18.9	44.4	15.9
Korea	73.4	4.7	12.2	8.0	81.9	16.9	27.7	58.3	18.4
Italy	62.9	17.5	11.7	83.3	13.2	16.1	90.6	93.6	4.4
Germany	57.4	34.7	8.3	31.6	11.0	47.2	57.4	79.0	49.9
Canada	36.1	43.2	19.0	19.2	12.6	17.1	12.2	13.6	8.3
UK	19.0	24.8	6.5	8.2	1.8	2.0	15.6	40.0	30.9
Russia	15.2	14.5	0.9	22.6	23.4	5.0	9.6	6.9	
Brazil		62.8							
India		10.5						20.6	4.3
China		5.1						29.3	11.7
Totals	1542.7	590.4	883.6	452.8	410.8	543.6	419.6	663.9	185.6

Source: Compiled from IEA data (2009b).