

# 'Green growth' and the new Industrial Revolution

Alex Bowen, Chris Duffy and Sam Fankhauser

Policy brief  
January 2016



Grantham Research Institute on  
Climate Change and  
the Environment



Global  
Green Growth  
Institute



Grantham Research Institute on  
Climate Change and  
the Environment

The Grantham Research Institute on Climate Change and the Environment was established in 2008 at the London School of Economics and Political Science. The Institute brings together international expertise on economics, as well as finance, geography, the environment, international development and political economy to establish a world-leading centre for policy-relevant research, teaching and training in climate change and the environment. It is funded by the Grantham Foundation for the Protection of the Environment, which also funds the Grantham Institute for Climate Change at Imperial College London. It is also supported by the Global Green Growth Institute through a grant for US\$2.16 million (£1.35 million) to fund several research project areas from 2012 to 2014. More information about the Grantham Research Institute can be found at: <http://www.lse.ac.uk/grantham/>



Global  
Green Growth  
Institute

Based in Seoul, Global Green Growth Institute (GGGI) is an intergovernmental organisation founded to support and promote a new model of economic growth known as 'green growth'. The organisation partners with countries to help them build economies that grow strongly and are more efficient and sustainable in the use of natural resources, less carbon intensive, socially inclusive and more resilient to climate change. GGGI's experts are working with governments around the world, building their capacity and working collaboratively on green growth policies that can impact the lives of millions. More information about the Global Green Growth Institute can be found at: <http://gggi.org/>



THE LONDON SCHOOL  
OF ECONOMICS AND  
POLITICAL SCIENCE ■

# Contents

Executive summary	3
1. Introduction	5
2. Climate-resilient development	6
3. Carbon pricing and revenues	9
4. Green jobs	12
5. Competitiveness and innovation	16
References	20

### The authors

Dr Alex Bowen joined the Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, in 2008 as a Principal Research Fellow, after many years at the Bank of England, most recently as Senior Policy Adviser. He first became involved in climate change issues when seconded as lead economist to the Stern Review of the economics of climate change. His research interests include the design of public policies to reduce greenhouse gas emissions, 'green' growth and the macroeconomic and labour-market aspects of climate change policies. He has been a consultant to the EBRD, OECD, World Bank, ADBI, DFID and DECC among others. Dr Bowen has a BA in Economics from University of Cambridge and a PhD in Economics from the Massachusetts Institute of Technology, where he studied on a Kennedy Scholarship.

Chris Duffy is Policy Communications Manager at the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science. Previously he held roles at the Carbon Trust, the Environment Agency, and in the climate change team at the Greater London Authority. He has also worked as a PR consultant for clients including supermarket chains, construction firms and local authorities. Chris has a degree in History and a Public Affairs Diploma from the Chartered Institute of Public Relations (CIPR).

Professor Sam Fankhauser is Co-Director at the Grantham Research Institute on Climate Change and the Environment and Deputy Director of the Centre for Climate Change Economics and Policy, both at the London School of Economics and Political Science. He is also a member of the Committee on Climate Change, an independent public body that advises the UK government on its greenhouse gas targets. Previously, Sam has worked at the European Bank for Reconstruction and Development (EBRD), the World Bank and the Global Environment Facility. Sam studied economics at the University of Berne, the London School of Economics and University College London.

### Acknowledgements

Financial support has come from the Global Green Growth Institute, the Grantham Foundation for the Protection of the Environment, as well as the UK Economic and Social Research Council through the Centre for Climate Change Economics and Policy. The views expressed in this paper represent those of the authors and do not necessarily represent those of the host institutions or funders.

# Executive summary

The green growth transition will be large, system-wide and structural. In other words, a new industrial revolution. This will require new green growth policies that foster economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies (OECD, 2011). More and better evidence is needed to support the design of effective green growth policies and to understand their impact on the economy. This policy brief summarises the main policy implications of a two-year research programme, sponsored by the Global Green Growth Institute (GGGI), which aimed to contribute to the growing evidence base.

The research programme focused on a number of important aspects of green growth, primarily as related to climate change, namely climate-resilient development, the economics of internalising the carbon externality via carbon pricing and the impact of green growth policies on jobs and innovation. The key findings can be summarised as follows.

## 1) Climate-resilient development

Some climate change is now unavoidable. In response governments are developing plans to adapt their economies and infrastructure to future changes in climate and weather patterns. This presents a particular challenge for developing countries because they are forced to think about future climate impacts at the same time as undergoing rapid economic development, creating the risk that adaptation plans are out of sync with rapid changes to the economy. This gets to the heart of the need for climate-resilient development.

To facilitate climate-resilient development the following should be considered:

- Economic development plans must become more climate-aware and acknowledge future climate risks.
- Adaptation plans must acknowledge the dynamism of modern economies. Badly designed adaptation plans may hinder development by focusing too much on the status quo instead of embracing more transformative forms of adaptation.
- Perhaps most importantly, development planners and adaptation planners need to work more closely together. This will force economic planners to consider sectoral growth dynamics in light of climate risks and adaptation planners to factor the evolving economic system into their planning.
- Opportunities where proactive adaptation can be factored into development strategies, spatial planning and long-term investment decisions – the ‘entry points’ for adaptation – should be identified systematically. Economic growth offers an opportunity to build climate resilience into decisions from the outset and to alter for the long term the risk profile of countries with respect to climate change.

## 2) Carbon pricing and revenues

Economists widely agree that introducing a carbon price is the single most effective way for countries to reduce their carbon emissions. Carbon pricing policies – either a carbon tax or cap-and-trade – are therefore a key plank of any green growth policy framework.

A key lesson from the 2008 financial crisis has been that carbon pricing policies must be designed to respond to macroeconomic shocks and fluctuations. Two recommendations are forthcoming:

- In order to cushion the impact of economic fluctuations on the carbon price, it is preferable that the policy – whether it is a tax or cap-and-trade – covers as large a group of emitters as possible.
- The instrument should allow for the stringency of regulation to respond to economic fluctuations according to a transparent and predictable rule.

Building this type of flexibility into carbon pricing policies is particularly important in developing countries because their economic and emissions cycles are typically more volatile.

Analysis suggests that carbon taxes allow economies and the stringency of climate change policies to respond more appropriately to economic shocks than do cap-and-trade systems (Grodecka and Kuralbayeva, 2015), but whichever policy is chosen, the potential revenues from carbon pricing are considerable. How revenues are spent fall under three headings: spending on complementary green policies; cushioning any adverse impacts of carbon pricing; and improving the tax-benefit system as a whole. Revenues could also be used to reduce outstanding public debt or increase spending on unrelated objectives. Strict earmarking, or ‘hypothecation’, of carbon pricing revenues is unlikely to be a good idea in the long run, given their uncertainty and time-varying spending needs.

## 3) Green jobs

Green growth policies have an impact on the sectoral composition of economies and therefore labour markets and jobs. However, a sophisticated assessment of the impacts on jobs is currently hampered by the need for better statistics, an agreement on common definitions and the further study of methods to estimate the number of green jobs. In the light of these observations, it would be helpful for policy-makers to do the following:

- Accelerate international efforts to establish common statistical standards for measuring the number of existing green jobs.
- Restore the momentum behind the compilation of national green jobs statistics in countries where it has slackened, notably the US and the UK.
- Consider ways in which international agencies, such as Eurostat and the OECD, and countries that already report regularly can help developing countries improve their statistics on green jobs.
- Assess regularly the pace at which the demand for workers in environmental and resource management services is changing.
- Assess the likely labour market impacts of economy-wide green growth using an appropriate macroeconomic framework.
- Develop strategies for coping with employment losses in the sectors that will suffer from green growth policies (such as electricity, aluminium and cement).

#### 4) Competitiveness and innovation

The structural transition to green growth raises questions about how the businesses of today will be hit by the green growth policies that will drive the transition.

There is an ongoing debate about the impact that 'green' policies have on firms. On one side, it is argued they add costs and slow down productivity growth and therefore affect the competitiveness of domestic industry if the stringency of policies differs across countries. An alternative view is that green policies may foster innovation in environmentally friendly technologies, help regulated firms achieve technological leadership and boost broader economic growth.

A review of the available evidence suggests that environmental regulation, including climate change policies, are unlikely to harm economic growth and competitiveness unless there are large differences in policy stringency between countries. Conversely, these policies drive innovation in new, high value, clean technologies that have broad application across economic sectors. As a result, environmental regulations can be a source of economic growth and future prosperity.

Polluting sectors will require support to make the transition to a low-carbon economy and this should be a key area for future research and development activities.

## 1. Introduction

There is no single agreed definition of the term 'green growth'. A range of other definitions exists, informed by different philosophical, analytical and operational perspectives (Bowen, 2014; Jacobs, 2013). A useful operational definition is GDP growth that preserves aggregate natural capital (Bowen and Hepburn, 2014). Achieving this goal presents societies with major challenges. The composition of GDP is likely to have to change significantly, with more emphasis on new ideas and less on increased material throughputs.

Public policy will be crucial to the transition to 'green growth' and will have to go beyond internalising externalities to 'get prices right'. The necessary transformation will be large, system-wide, and structural, and this will require, at the least, overall strategic direction. In other words, a new Industrial Revolution is required, but one driven by concerted long-term collective action. State intervention has played a part in many past industrial transformations, as noted by Hippe and Fouquet (2015). One reason why persistent and pervasive policies are required is the inertia in energy and industrial systems once built. This is a key issue facing many low-income countries at the moment. As they begin to industrialise they face key decisions about technology, infrastructure and behaviour that, once made, bind their economy into a long-term trajectory. Without guidance and incentives from the state, private decisions in periods of rapid economic development can lock consumers into high energy service prices in the long run and, similarly, bind economies onto a high energy intensity trajectory with major long run impacts (Fouquet, 2015).

Delivering this new industrial revolution will require new green growth policies that foster economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies (OECD, 2011). More and better evidence is needed to support the design of effective green growth policies and to understand their impact on the economy. This policy brief summarises the results of a two-year research programme, sponsored by the Global Green Growth Institute, which has aimed to fill important research gaps on green growth.

Green growth is about prosperous economies that are low-carbon, climate-resilient, resource-efficient, clean, biodiverse and sustainable. The research programme focused on a number of important aspects of green growth, namely climate-resilient development, the economics of internalising the carbon externality via carbon pricing and the impact of green growth policies on jobs and innovation. The policy implications of this research were explored in a series of policy briefs: 'Climate change adaptation in dynamic economies: the cases of Colombia and West Bengal' (Kocornik-Mina and Fankhauser, 2015), 'Green agricultural policies and poverty reduction' (Lovo et al., 2015), 'Carbon pricing in good times... and bad' (Doda, 2014), 'Carbon pricing: how best to use the revenue?' (Bowen, 2015), 'Looking for green jobs: the impact of green growth on employment' (Bowen and Kuralbayeva, 2015), 'The impacts of environmental regulations on competitiveness' (Dechezleprêtre and Sato, 2014), and 'Climate change policy, innovation and growth' (Dechezleprêtre et al., 2015).

This policy brief summarises the key findings from these studies. A more detailed analysis can be found in the individual papers and related academic research on the website of the Grantham Research Institute.<sup>1</sup>

## 2. Climate-resilient development

Whatever success there will be on reducing greenhouse gas emissions, a certain amount of climate change is now unavoidable (IPCC, 2014). Managing the risks of climate change is therefore an essential part of green growth.

This is a particular challenge in developing countries because they are forced to plan for potentially severe changes to their climate and weather patterns at the same time as undergoing rapid economic development and change. This creates a risk that adaptation plans focus too much on sectors that will become less important over time and too little on sectors that will be important in the future. It could also mean that adaptation plans fail to take account of changing land use, for example rapidly growing cities and more intensive agriculture. This gets to the heart of the need for climate-resilient development, but these issues are often overlooked or underappreciated by policymakers.

To remedy this, the links between sustainable economic development and vulnerability to climate change should be acknowledged. In doing this, first, its needs to be recognised that climate change may affect basic development outcomes. Second, it should be appreciated that the development choices of today will shape the climate risks of the future. Third, more awareness is required of the synergies between climate-resilient development and green growth more broadly. The pursuit of climate-resilient development offers many opportunities to advance wider economic, social and environmental objectives at the same time. These issues were explored in 'Climate change adaptation in dynamic economies: the cases of Colombia and West Bengal' (Kocornik-Mina and Fankhauser, 2015) and 'Green agricultural policies and poverty reduction' (Lovo et al., 2015). The key findings are summarised below.

### 2.1 Climate change affects development

The World Bank (2013a) warns that climate change will put recent development achievements at risk, unless they can be safe-guarded through effective adaptation. Development strategies must be designed to be resilient to future climate change. Timely action is particularly important in areas where lead times are long (e.g. the development of new crop varieties), where there are win-win opportunities (that is where adaptation yields wider benefits) and where today's decisions lock in vulnerability profiles for the long term (Fankhauser et al., 2013).

---

1 Visit <http://www.lse.ac.uk/GranthamInstitute/publications/?sthm=all&styp=435&cdir=all>



The integration of adaptation and development is beginning to happen, but not yet in a systematic way. A review of 250 development projects in three countries found that a third of them were at medium to high risk from climate change. Of the projects at risk, up to half required proactive adaptation measures at the outset, given that they had long-lived outcomes that would be difficult to alter over time (Ranger and Garbett-Shiels, 2014).

## 2.2 Development choices affect future climate risk

Economic growth and socio-economic development can fundamentally alter vulnerability to climate events – either for better or for worse. Hansen et al. (2011) calculate that coastal development in South East Asia is likely to put at least as many additional people at risk from coastal flooding as climate change. In mitigation, the associated wealth creation and growth will ensure that they are better able than today to invest in coastal defences – but even so the vulnerability profile of coastlines will have radically changed.

Economic growth and development affect climate risks in several ways. First, economic growth is associated with changes in production processes and the sectoral composition of an economy, including a structural shift from agriculture into manufacturing and ultimately services. This changes the sensitivity of the economy to climate events. Second, socio-economic trends like urbanisation change the geographic location of population centres and economic activity. This changes their exposure to climate risks. Third, economic development alters people's income and wealth, which is a key driver of climate vulnerability. It increases adaptive capacity and people's willingness to pay for climate protection, but also the stock of assets that might potentially be at risk (Fankhauser and McDermott, 2014).

Policymakers must be aware of the vulnerability consequences of development choices, and identify 'entry points' for adaptation action, that is, opportunities in growth strategies to move development in a safer, more climate-resilient direction. Kocornik-Mina and Fankhauser (2015) explore the implications of dynamic economic development for adaptation to climate change in two case studies, the country of Colombia and the Indian state of West Bengal. The two cases offer important policy lessons about combining adaptation and development planning into a coherent climate resilient development strategy.

## 2.3 There are synergies with other green growth objectives

Like all green growth programmes, climate-resilient development projects have to take into account all relevant economic, social and cultural factors. This is likely to reveal trade-offs – for example between urban growth and climate vulnerability (Hansen et al., 2011) – but well-designed projects will also be able to exploit synergies between climate resilience, green growth and poverty alleviation.

Lovo et al. (2015) study the scope for win-win solutions in green agriculture. Agriculture remains a dominant sector in terms of employment and output in many low-income countries. It is also one of the most vulnerable activities to climate change. They argue that green agricultural policies should be complemented with initiatives that tackle local market imperfections. Policymakers need to consider factors such as: the availability of credit; property rights and land ownership arrangements; labour market conditions; the strength of local institutions and legal context; and social and cultural norms. Interventions work best where good information is available about local socio-economic and institutional conditions. When gathering information is too costly, participants in green agricultural initiatives should be allowed to choose appropriate interventions from a menu of options. This makes the best use of their local knowledge and enables them to best match the options to their individual circumstances.

However, the search for synergies has to go beyond agriculture. While the agricultural sector remains dominant today and productivity improvements can make a material difference to rural income, it is rarely an engine for sustained future growth. Climate-resilient development strategies also need to safeguard the core drivers of future growth, including sectors such as manufacturing, services and exports (Kocornik-Mina and Fankhauser, 2015).

### 2.4 Conclusion

The need to adapt to the residual impacts of climate change, which cannot be avoided through emission reductions, is now well understood. The close link between adaptation and development is also widely acknowledged (Bowen et al., 2012; OECD, 2014). However, in practice the two are still often treated as separate activities. Instead of a series of bespoke activities that respond to a particular risk (e.g. flood defences, drought plans, etc.); adaptation has to become an integral part of economic development planning. This is the practical meaning of climate-resilient development.

Combining adaptation and development planning into a coherent climate-resilient development strategy has intuitive appeal. Institutionally, it shifts the responsibility for adaptation from environment departments and hydro-meteorological offices to planning and economic ministries, which are often more powerful and better able to instigate the necessary reforms (Fankhauser and Schmidt-Traub, 2011).

Climate-resilient development puts development at the centre of the analysis. It acknowledges that in practical terms adaptation and development often overlap (McGray et al., 2007). It is extremely difficult, for example, to make a credible distinction between measures that deal with existing climate variability (i.e. vulnerability to current weather extremes) and adaptation to future climate change.

Climate-resilient development turns adaptation from a static into a dynamic concept. Adaptation often seeks to preserve current structures, for example by protecting agricultural output, and neither acknowledges nor takes advantage of the fact that the status quo is evolving. In contrast, climate-resilient development is inherently dynamic. Development objectives are set with current and future climate risks in mind whilst reflecting the vibrant nature of modern economies (OECD, 2014; World Bank, 2013b).

Moving from adaptation to climate-resilient development has a number of practical implications for policy makers (Kocornik-Mina and Fankhauser, 2015).

- First, economic development plans must become more climate-aware and acknowledge future climate risks. Current development plans often promote development models or set development objectives that are impractical or risky in the light of climate change, particularly for agriculture.
- Second, adaptation plans cannot ignore the dynamism of modern economies. It reduces their relevance and effectiveness. Because they are more vulnerable, adaptation efforts often focus on stagnant sectors and regions, rather than the growth areas of the economy, where avoidable future climate risks might lie. Badly designed adaptation plans may hinder development by focusing too much on the status quo instead of embracing more transformative forms of adaptation.

- Third, and perhaps most importantly, development planners and adaptation planners need to work more closely together. This will force economic planners to consider sectoral growth dynamics in light of climate risks and adaptation planners to factor the evolving economic system into their planning. It will make it easier to identify potential synergies and manage development trade-offs. One such trade-off is productivity, where some improvements may come at the expense of higher climate risk..
- Finally, policymakers need to systematically identify opportunities where proactive adaptation can be factored into development strategies, spatial planning and long-term investment decisions – the ‘entry points’ for adaptation. Economic growth offers an opportunity to build climate resilience into decisions from the outset and to alter for the long term the risk profile of countries with respect of climate change.

The practical challenge of making these lessons actionable in actual planning processes should not be underestimated. The solutions will be situation-specific and depend on the institutional and political economy context. There are likely to be barriers to achieving a closer integration between climate adaptation and development planning, and the need to be studied and addressed case by case. However, without closer integration, both adaptation planning and development planning could become increasingly ineffective.

## 3. Carbon pricing and revenues

Green growth must be low-carbon. Economists widely agree that introducing a carbon price is the single most effective way for countries to reduce their carbon emissions. Carbon pricing policies – either a carbon tax or cap-and-trade – are therefore a key component of any green growth policy framework.

A key lesson from the 2008 financial crisis has been that carbon pricing policies must be designed to respond to macroeconomic shocks and fluctuations. Carbon pricing policies also have the potential to raise significant revenues for government, which raises the question of how they should be spent. These issues are explored respectively in ‘How to price carbon in good times... and bad’ (Doda, 2014) and ‘Carbon pricing: how best to use the revenue?’ (Bowen, 2015). The key findings are summarised below.

### 3.1 Carbon pricing and business cycles

As the 2008 financial crisis showed, business cycles and economic shocks can have a major impact on carbon pricing mechanisms. In part due to a huge drop in demand for emissions permits in the European Union Emissions Trading System (EU ETS), triggered by the global financial crisis, the price of permits collapsed and has remained low, undermining the long-term effectiveness and credibility of the carbon price signal the system is designed to generate.

This experience highlighted the need for carbon pricing instruments to be flexible and able to respond appropriately to economic fluctuations and business cycles. Analysis by Doda (2014) provides two clear policy recommendations. First, whatever instrument is chosen to price carbon, it is preferable to apply it to as large a group of emitters as feasible. Economic fluctuations impact countries differently so, by applying the carbon pricing scheme to as many as possible, governments can cushion the impact of economic fluctuations on the carbon price their countries face.

Second, the instrument should allow the stringency of regulation to respond to economic fluctuations according to a transparent and predictable rule. Making the stringency of regulation responsive to economic fluctuations can decrease the overall burden of regulation. In the context of emissions trading, this means that the cap on the quantity of greenhouse gas emissions should be relaxed during economic expansions and tightened during recessions. In the case of a carbon tax, the tax should be increased during booms and reduced during recessions. Policymakers can trade off slightly higher annual emissions during economic booms against slightly lower emissions during recessions. Doing so makes the instrument responsive to the business cycle without compromising the long-term target of reducing emissions.

An effective responsiveness mechanism should take into account country-specific factors, be rules-based rather than at the discretion of the government, transparent and hard to manipulate. Preferably, it should be built in at the outset rather than retrofitted later.

Fluctuations in developing countries are typically more volatile, more persistent and less predictable, so the gains from having carbon pricing instruments that respond appropriately to economic fluctuations are likely to be greater in developing countries (Doda, 2014). However, Grodecka and Kuralbayeva (2015) argue that where macroeconomic fluctuations are driven by productivity shocks (as typically assumed in the ‘real business cycle’ literature), the degree of responsiveness of the carbon price that is desirable is small. As a consequence, if one had to choose between a carbon tax and an emissions trading scheme, the former would be preferable.

### 3.2 Carbon pricing: how best to use the revenue?

The potential level of revenues from pricing carbon, whether by taxation or cap-and-trade, is considerable. In the longer term, with carbon pricing applied more widely around the world and the price of carbon rising, the revenues are likely to rise higher still, reaching several percentage points of global income – well above the total receipts from all environmental taxes today (Bowen, 2015). How should these revenues be used?

Suggestions for how to use carbon revenues have tended to cluster under three headings: spending on complementary green policies; cushioning any adverse impacts of carbon pricing; and improving the tax-benefit system as a whole (Bowen, 2015). However, revenues could also be used to reduce outstanding public debt or increase spending on unrelated objectives. Each is explored in more detail in the following sections.

#### 3.2.1 Spending on complementary green policies

As far as complementary green policies are concerned, governments may want to use some of the carbon pricing revenues to put in place a more comprehensive set of such policies. They might, for example, want to invest in new low-carbon public infrastructure and low-carbon R&D. Climate change mitigation is impeded by a range of market failures and as many policy instruments are required as there are market failures to be corrected. Using all the tools in the policy tool-box should make climate change mitigation more cost-effective, as illustrated, for example, by Fischer and Newell (2007) for the US electricity supply industry. The extra spending appropriate for any particular nation and its direction will depend on how each country’s environmental policies have evolved so far. However, there is a strong case for all countries to consider increasing spending on low-carbon research, development and deployment, particularly in nations with a comparative advantage in research activities – largely advanced industrial economies. Fortunately, it appears that ‘green’ innovations have bigger positive spill-over effects on other innovations than does the typical innovation (Dechezleprêtre et al., 2013). Rich countries may also want to take the opportunity to use the revenues from carbon pricing policies to increase the flow of finance to developing countries to help them

mitigate and adapt, as they have promised under the aegis of the UNFCCC. The warranted sums are likely to be large (Bowen et al., 2014). There is also an awkward question about to what extent, if at all, fossil fuel exporting countries should receive finance on the grounds of equity or pragmatism.

### 3.2.2 Cushioning any adverse impacts of carbon pricing

Carbon pricing hits some people's real incomes, some businesses' profits and some rents, notably those received by fossil fuel owners. It may be therefore be necessary to cushion adverse side effects of carbon pricing by making financial transfers.

Governments need to consider who, if anyone, ought to be compensated on the grounds of equity or political pragmatism. This can also help to 'buy off' political lobbies that would otherwise obstruct climate policies). Some firms, particularly those that are energy intensive and trade exposed, may require financial support to make the transition to the low-carbon economy, either by using carbon pricing revenues to reduce their energy costs or to help them develop new energy efficient technologies.

The impact of carbon pricing across income groups depends on particular characteristics of households' energy consumption and the existing tax-benefit system. What happens to wages and the return on capital as a result of carbon pricing also matters. However, in many countries, there is a danger that carbon pricing will hit poor households proportionally harder. For them, there is a strong case for focusing extra help on the poor, for example via increased cash grants to low-income families and direct provision of low-carbon technologies for the home. This is particularly important in low-income countries with rudimentary social security arrangements. But the degree of regressivity in a particular country needs to be assessed, not assumed.

### 3.2.3 Improving the tax-benefit system as a whole

Carbon pricing revenues can also be used to reduce the economic inefficiencies inherent in tax-benefit systems. This can give rise to a 'double dividend' – the environmental benefit and the reduction in deadweight economic losses from other taxes or benefits – which can be weighed against the deadweight losses from carbon pricing itself. However, governments need to consider carefully where the greatest distortions arise in the rest of their tax-benefit systems and why they are present in the first place. This issue arises regardless of the existence and level of carbon pricing and is really a separate question about the system's efficiency. For example, a reduction in payroll taxes, designed to reduce labour supply disincentives from carbon pricing, is widely advocated. But pre-existing distortions from the structure of capital taxation may be worse. At the same time, governments need to distinguish between the merits of reducing some forms of capital taxation on the grounds of efficiency and the merits of compensating firms hit by carbon pricing for pragmatic political reasons. International competition in a world of uneven carbon pricing complicates the picture.

Countries with a pressing need to reduce the ratio of public debt to GDP may want to use carbon pricing revenues primarily to reduce their budget deficits. There is, however, debate about the level at which a high ratio becomes a threat to economic performance and how fast budget consolidation should take place. At some point, governments are likely to want to increase public spending, including on objectives unrelated to the environment, and will seek to use new revenue sources to relax the budget constraint to which they are subject. And governments need to consider what signal this approach would send to taxpayers about why they raised carbon prices in the first place – there is a danger of cynicism about new taxes supposedly to improve economic efficiency.

### 3.3 Conclusion

The 2008 financial crisis showed the need for more sophisticated carbon pricing policies that are able to respond to economic shocks and fluctuations. Two recommendations are forthcoming from this research. First, in order to cushion the impact of economic fluctuations on the carbon price, it is preferable that the policy – whether it is a tax or cap-and-trade – covers as large a group of emitters as possible. Second, the instrument should allow the stringency of regulation to respond appropriately to economic fluctuations through a transparent and predictable rule. Building this flexibility into carbon pricing policies is particularly important in developing countries because their economic cycles are typically more volatile.

Analysis suggests that carbon taxes allow economies and the stringency of climate change policies to respond more appropriately to economic shocks than do cap-and-trade schemes (Grodecka and Kuralbayeva, 2015), but whichever policy is chosen, the potential revenues from carbon pricing are considerable. It is highly unlikely that a single simple rule for using carbon pricing revenues that does not depend on time or place is going to be the best rule. In particular, strict earmarking, or ‘hypothecation’, of carbon pricing revenues is unlikely to be a good idea in the long run, given their uncertainty and time-varying spending needs. Governments ought to assess and re-assess regularly what best to do with new revenues over time. Nevertheless, the potential revenues of carbon pricing do give societies many attractive options for pursuing a range of goals (related to the environment or otherwise) in addition to the environmental benefits of carbon pricing.

## 4. Green jobs

Green growth policies have an impact on the sectoral composition of economies and therefore labour markets and jobs. It has often been argued that job creation is an important benefit of green growth policies. For example, UNEP (2011) claims that the greening of economies is a net generator of decent jobs – good jobs that offer adequate wages, safe working conditions, job security, reasonable career prospects and worker rights.

Yet it has also been claimed that environmental policies may have much less attractive consequences for labour markets. Michaels and Murphy (2009), for example, conclude that it is highly questionable whether a government campaign to spur green jobs would have net economic benefits. Hughes (2011) criticises what he called the ‘myth’ of green jobs, adding that job creation has no merit as a basis for judging policy.

Resolving the debate is problematic due to the lack of a consistent definition of ‘green jobs’ and the associated challenge of counting them; a problem compounded by patchy data collection. As a result, estimates of green job numbers vary depending on the definition applied and method used for counting them. A sophisticated empirical analysis of the broader macro-economic effects of green growth policies on labour markets is currently absent.

Given that climate change and other green growth policies will eventually constitute a large, non-marginal change in the policy environment in all countries, there is an urgent need for improved data collection on green jobs and a more sophisticated assessment of green growth policies on labour markets around the world. This has been investigated in detail in ‘Looking for green jobs: the impact of green growth on employment’ (Bowen and Kuralbayeva, 2015). The key findings are summarised below.

## 4.1 What do we know about green jobs?

The data available suggest that green jobs are a small but non-negligible fraction of the workforce in industrial economies. The European Commission estimates that green jobs constitute a small but significant share of total employment in the EU – 1.7 per cent of total paid employment in Europe (European Commission, 2007). In the UK, the Department for Business Innovation and Skills (2013) estimates that employment in low-carbon and environmental goods and services accounted for almost one million jobs in 2011/12 (approximately 3 per cent of total paid employment).<sup>2</sup> In the US the Bureau of Labor Statistics (2013) estimated that green jobs comprised 2.6 per cent of the US workforce in 2011 (a share that had increased by 0.1 percentage points since 2010).

There is also evidence about the number of jobs created by specific ‘green’ sectors. For example, IRENA (2014) estimated that renewable energy jobs reached 6.5 million in 2013, with the largest employers being, in decreasing order, China, Brazil, the US, India, Germany, Spain and Bangladesh. To put this figure in perspective, this compares with total global employment of just over 3 billion (ILO, 2015). Attempts have also been made to quantify the number of jobs created by renewable energy projects in terms of jobs per megawatt of capacity installed. Estimates vary enormously. For example, according to a study of the European Union (Blanco and Rodrigues, 2009), the estimated number of direct jobs recently created per megawatt of wind capacity installed varied from 0.76 in Austria to 6.97 in Belgium.

Much less is known about numbers of green jobs in developing countries. However, analysis of green growth policies on labour markets in developing countries shows that conflicts can arise between green jobs and poverty reduction. If green growth policies slow down the reallocation of employment towards higher labour productivity industries, they may not be the best way to promote poverty reduction and desirable long-run structural change. In other words, climate change mitigation policies and other green growth initiatives cannot be relied upon to generate enough of the right sort of jobs in the right places to be very effective in poverty reduction. Instead, they may well cause a slow-down in the effectiveness of growth in reducing poverty. The main lesson is that trade-offs are bound to exist. The key challenge is to understand how in a particular setting increased government spending on green objectives and increased environmental taxation is likely to affect wage-setting, migration and unemployment.

The overall message for policymakers is that structural changes in labour markets due to green policies have been relatively small so far. But better statistics, agreement on common definitions and the further study of methods to estimate the number of green jobs are urgently needed, especially if the pace of climate change mitigation is to be ramped up.

## 4.2 The difficulty with defining green jobs

There is as yet no single universally agreed definition of a green job. That makes it hard to compare studies of green job creation (GHK, 2009) and has led some researchers to avoid the term completely.

A consensus is emerging on an appropriate definition that focuses on a subset of industries producing environmentally desirable outputs. Several studies, notably by the European Commission’s Environment Directorate, have used the OECD/Eurostat definition of the environmental goods and services industry (OECD, 1999), comprising “activities which produce goods and services to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems. This includes technologies, products and services that reduce environmental risk and minimize pollution and resources.” That covers pollution management (for example, air pollution control) and resource management (renewable energy plants and water supply).

<sup>2</sup> ONS reported that 29.35 million people were in employment in July 2012 <http://www.ons.gov.uk/ons/rel/lms/labour-market-statistics/july-2012/statistical-bulletin.html>

While this is probably the best definition available for analysts, it is not without flaws. For example, jobs in the nuclear power sector are not included although they are in a low-carbon industry. Also, jobs in the car industry are excluded, even though some may be devoted to developing low-carbon vehicles.

Overall, there has been progress towards standardising a definition of green activities and the jobs associated with them. While the OECD/Eurostat definition is not perfect, it is being integrated into UN System for Integrated Environmental-Economic Accounting and European countries are beginning to collect better data. However, the data remain patchy and methods of counting green jobs are found wanting in a number of respects. These issues are explored in the next sections.

### 4.3 Measuring green jobs and impacts on the broader economy

A fundamental problem with current assessments of green jobs is that they focus too closely on the direct impact of green policies on jobs in green sectors. But green policies also affect labour markets indirectly through supply chains and through changes in overall demand. The destruction of 'brown jobs' in polluting industries should also be taken into account.

The broader macro-economic consequences of green policies for labour markets, such as changes in labour productivity and the costs of employment, are also poorly understood and often overlooked. A more sophisticated understanding of the impact of green policies on labour markets through many channels is urgently needed. Key questions that need to be better understood are the extent to which green jobs crowd out jobs in other sectors or generate sector-specific human capital and job search costs that could slow the shift of workers across sectors or out of long-term structural unemployment. Improving data collection and standardisation will be crucial to achieving this and is discussed in more detail below.

It is also noteworthy that many recent studies that attempt to forecast green job creation do so from a starting point of widespread involuntary unemployment. This is hardly surprising given the context of the recent global economic downturn and resulting focus on green fiscal stimuli, but they do not necessarily provide results that are indicative of long-term green job prospects in moving from one longer-term growth path to another. Analysis of green job creation across a much longer time horizon and a wider range of macroeconomic circumstances is mostly absent at present.

To address these issues national governments should assess regularly – using improved data – the pace at which the demand for workers in environmental and resource management services is changing, comparing this with the normal degree of flux and change in labour markets. They should also assess the likely labour market impacts of economy-wide green growth using an appropriate macroeconomic framework, given that climate change and other green growth policies are likely eventually to constitute a large, non-marginal change in the policy environment for firms and households.

### 4.4 Data issues

Data on green jobs are patchy and the bases for data collection are varied and subject to frequent revision. Its collection has failed to improve over the past five years as a result of reduced public funds in the UK and US, in both of which key statistical studies of the labour market have been cancelled or delayed due to budget cuts.

Given that global action on climate change is likely to accelerate in coming years in the context of a global climate deal, international efforts to establish common statistical standards for measuring the number of existing green jobs should be increased. This should build on the



framework provided by the UN System for Integrated Environmental-Economic Accounting. Efforts should also be made to restore momentum behind the compilation of national green jobs statistics in countries where it has slackened, notably the US and the UK. Policymakers should also consider ways in which international agencies such as Eurostat and the OECD, and countries that already report regularly, can help developing countries improve their statistics on green jobs.

#### 4.5 Conclusion

From the perspective of national policymakers, the net change in total employment (and average job quality) across the economy as a result of green policies is at least as important as the direct gross change in employment in environmental sectors. Much of the green jobs literature focuses on the most direct impacts of policies on employment, with some attention to indirect and induced job creation and to the destruction of ‘brown jobs’ in polluting industries. However, the consequences for labour markets of green growth policies, for example via macroeconomic adjustments to labour productivity and the costs of employment, can be large, are often overlooked, and will need to be better understood.

The message for policymakers is that structural changes in labour markets due to green policies have been relatively small so far, but could increase as national governments develop policies that deliver deeper decarbonisation of the global economy. In this context, better statistics, agreement on common definitions and the further study of methods to estimate the number of green jobs are urgently needed.

In the light of these observations, it would be helpful for policymakers to do the following:

- Accelerate international efforts to establish common statistical standards for measuring the number of existing green jobs, building on the framework provided by the UN System for Integrated Environmental-Economic Accounting and the International Conference of Labour Statisticians (ICLS) recommendations for classifying jobs.
- Restore the momentum behind the compilation of national green jobs statistics in countries where it has slackened, notably the US and the UK.
- Consider ways in which international agencies, such as Eurostat and the OECD, and countries that already report regularly can help developing countries improve their statistics on green jobs.
- Assess regularly – using improved data – the pace at which the demand for workers in environmental and resource management services is changing, comparing this with the normal degree of flux and change in labour markets.
- Assess the likely labour market impacts of economy-wide green growth using an appropriate macroeconomic framework, given that climate change and other green growth policies are likely eventually to constitute a large, non-marginal change in the policy environment for firms and households. The appropriate macroeconomic framework will depend on the nature of each individual country’s labour markets and macroeconomic circumstances.
- Develop strategies for coping with employment losses in the sectors that will suffer from green growth policies, remembering that this may include sectors hit by higher real prices for currently carbon-intensive inputs (such as electricity, aluminium and cement).

# 5. Competitiveness and innovation

The green growth transition will be large, system-wide and structural. In other words a new industrial revolution. This raises questions about how the businesses of today will be hit by the green growth policies that will drive the transition, and how they can respond.

Ever since the first major environmental regulations were enacted in the 1970s, there have been concerns about their potential impacts on businesses. Managing the balance between environmental constraints and economic impacts has been an ongoing dilemma. The recent economic downturn, combined with increased competition from emerging economies, has made the debate even more acute, particularly in relation to climate change policies.

Economists traditionally think environmental regulations add costs to companies and slow down productivity. Environmental regulations may thus affect the competitiveness of the domestic industry if the stringency of policies differs across countries, putting some firms at a disadvantage to their foreign competitors. An alternative view is that environmental regulations may foster innovation in environmentally-friendly technologies, help regulated firms achieve technological leadership and boost broader economic growth. These views have received a great deal of attention from policymakers, particularly in the context of the recent economic downturn.

The growing importance of this debate in policy circles has led to a large number of studies that attempt to quantify the impact of environmental regulations on businesses. These studies have analysed many aspects of the economic performance of regulated businesses, including productivity, innovation, employment, profitability, output and trade. This literature is explored in detail in 'Climate change policy, innovation and growth' (Dechezleprêtre et al., 2015). The following section provides a summary of the key findings.

## 5.1 Productivity and employment

Environmental regulations can reduce employment and productivity by small amounts in the short-term because they divert some resources away from productive activities. This is particularly true for pollution- and energy-intensive sectors. The impact of regulations on productivity seems most noticeable during the transitory period when the economy moves away from polluting activities and towards cleaner production processes (see Kozluk and Zipperer, 2013, for a recent review). The impact in the longer run seems smaller, with some evidence for positive productivity impacts after the initial transition period (Berman and Bui, 2001; Alpay et al., 2002).

Discussions about the impacts of environmental regulations on competitiveness are often framed as 'jobs versus the environment', particularly in the US, where falling employment in manufacturing has been an important political issue. Many observers fear jobs will be lost because of higher costs related to environmental regulation. However, while there could definitely be significant adjustment costs as workers move from declining (polluting) to expanding (clean) sectors, in the long run, environmental regulations might simply induce a substitution between polluting and non-polluting activities. The impact of this substitution on net employment is undetermined (Brahmbhatt, 2014). The evidence so far has been mixed but, if anything, points to statistically insignificant or small effects on employment in regulated sectors.

It should also be noted that the costs of environmental regulations need to be weighed up against the benefits they provide and which justify those regulations in the first place. The benefits are often important and severely underestimated. For example, the estimated health benefits from the Clean Air Act in the US are two orders of magnitude greater than the employment costs of the policy. This indicates that including job losses in cost-benefit analyses for environmental regulations is unlikely to make them unviable. Future research should systematically compare the costs of environmental regulations with their benefits.

## 5.2 International competitiveness

A central focus of the competitiveness debate and research has been on the impacts on international trade, capital flows and industry location. Research in these areas tends to focus on the pollution haven effect, i.e. the hypothesis that countries with relatively lax regulation will specialise in the export of pollution intensive goods and services, which they produce at a lower cost, and countries with stringent policies will lose out in terms of industry and jobs. The pollution haven effect is one of the main arguments used against ambitious environmental regulations. However, the evidence is decidedly mixed and its empirical assessment faces a number of challenges. First, the most desirable test of the pollution haven effect would be to identify the impact environmental of regulations on net imports (holding real wages and exchange rates constant). However, this is almost impossible to assess accurately. Another challenge is the lack of good measures for relative policy stringency. Given these empirical challenges it is not surprising that a strong consensus is yet to emerge.

Nevertheless, the evidence available shows that overall there is little to suggest that strengthening environmental regulations deteriorates international competitiveness. Environmental regulations seem to influence firms' investment and location decisions much less than factors such as market conditions and the quality of the local workforce. However, the impact could increase in the future if efforts to control pollution diverge significantly across countries. Emerging research comparing environmental efforts in different countries will play a key role in being able to assess and prevent adverse impacts on trade and investment in the future.

## 5.3 Environmental regulation and innovation

There is clear evidence that environmental regulation drives greater low-carbon innovation. Aghion et al. (2014) examine innovation activity by around 3,000 firms in the car industry and show that they tend to innovate relatively more in clean technologies when they face higher fuel prices. Therefore, fuel taxes can help break the path dependence in the direction of low-carbon innovation. Calel and Dechezleprêtre (2014) explore the impact of the European Union Emissions Trading System (EU ETS) on innovation by analysing low-carbon patenting activity of regulated firms. They show that the EU ETS has increased innovation activity in low-carbon technologies among regulated companies by 10 per cent.

There is also evidence showing that, at the same time as encouraging increased low-carbon innovation, environmental regulation discourages research and development in conventional (polluting) technologies. Thus environmental regulations can help economies break away from a polluting economic trajectory and move to a 'cleaner' one.

## 5.4 Low-carbon innovation and economic growth

Recent evidence shows that low-carbon innovations induce larger economic benefits, in terms of knowledge spillovers, than the dirty technologies they replace (Dechezleprêtre et al., 2014), offering some support to the argument that costs of environmental regulation are to some extent offset by the benefits delivered via innovation.

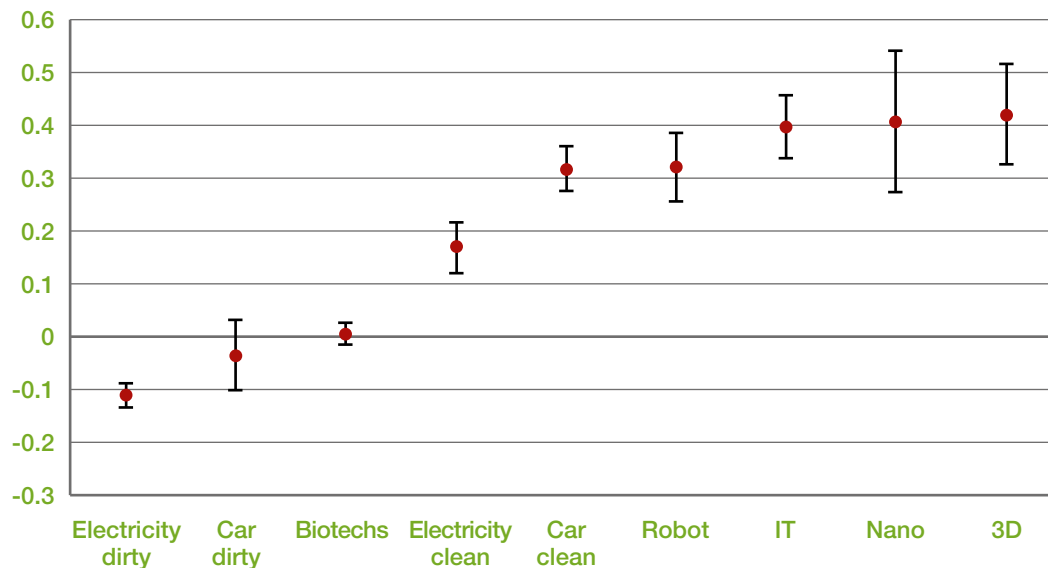
## 5. Competitiveness and innovation

Before going further let's briefly define the term 'knowledge spillover' and explain its importance. A knowledge spillover occurs when knowledge or information gathered for a specific purpose leads to opportunities and applications elsewhere in the economy. The larger the spillover effect (i.e. the more times a patent is cited) the higher the potential for an invention to benefit the broader economy. An obvious example of a knowledge spillover is Android-based smart phones. It was Apple that first launched the now dominant design of smart phones. However, other companies such as Google were also able to benefit from the original research and development investments undertaken by Apple by copying or improving the original design.

Recent analysis of patent data by Dechezleprêtre et al. (2014) enables us to explore the impact of low-carbon innovation on economic growth. It shows that low-carbon innovations tend to have broader application in other areas of the economy than innovations in dirty technologies (i.e. they have a much greater knowledge spillover effect). For example, inventions in the renewable energy sector are also benefiting technologies in the health sector. This greater spillover effect means that green innovations could be a driver of economic growth.

To analyse this further, Dechezleprêtre et al. (2014) analysed changes to firms' stock value as they innovate (measured by patent applications). They found that, all else equal, a firm's value increases by more if they apply for a patent that cites a clean patent rather than a dirty patent. In other words, spillovers from clean technologies are more economically valuable than spillovers from dirty technologies. The analysis also compared spillovers from low-carbon technologies with other new technology fields and found that the intensity of spillovers is comparable to those in ICT and biotechnologies (see figure 1).

Figure 1. Clean and dirty spillovers versus other emerging fields



**Note:** the y-axis: measures the difference in the intensity of knowledge spillovers, as measured by patent citations, between various technologies and the average innovation patented in the economy. For example clean electricity technologies have a 20 per cent higher spillover rate than the average innovations.

These spillover effects are captured mostly within the inventor's country, though this depends on the size and openness of the economy. On average, 52 per cent of spillovers in clean technologies patented since the year 2000 has occurred within the inventor's country. Japan has captured 61 per cent, the US 59 per cent, Germany 44 per cent, France 28 per cent, the UK 15 per cent and the Netherlands 10 per cent.

## 5.5 Conclusion

Taken together, these pieces of evidence suggest that environmental regulation, including climate change policies, are unlikely to harm economic growth and competitiveness unless there are large differences in policy stringency between countries. Conversely, these policies drive innovation in new, high value, clean technologies that have broad application across economic sectors. As a result, environmental regulations can be a source of economic growth and future prosperity.

Polluting sectors will require support to make the transition to a low-carbon economy and this should be a key area for future research and development. For each sector, policies will need to be fine-tuned to balance the policy goals with the multiple impacts of environmental regulations on pollution, employment, trade, productivity and innovation. A key challenge for research will be to understand better the link between policy design and these different dimensions of competitiveness.

Policy design will also need to consider how environmental regulations should be adjusted as other countries' environmental regulations evolve. For this to happen, however, researchers will need better ways to measure the relative stringency of environmental regulations and data from more countries. Currently, almost all of the existing data comes from developed countries, though the lessons can be applied more broadly.

A further key task for future research is to identify where environmental regulations can be strengthened to deliver clear social benefits, in terms of health or new technologies, with little risk of reducing competitiveness. Because policies can affect sectors differently, this should be assessed on a sector-by-sector basis, depending on the abatement opportunities available and the level of competition to which the sector is exposed.

# References

- Alpay, E., Kerkvliet, J. and Buccola, S., 2002. Productivity growth and environmental regulation in Mexican and US food manufacturing. *American Journal of Agricultural Economics*, 84(4), pp.887-901.
- Berman, E. and Bui, L., 2001. Environmental Regulation and Productivity: Evidence from Oil Refineries. *Review of Economics and Statistics*, 83(3), pp.498-510.
- Blanco, M.I., Rodrigues, G., 2009. Employment in the wind energy sector: An EU study. *Energy Policy*, 37, pp.2847-2857.
- Bowen, A., 2011. *The case for carbon pricing*. Policy Brief. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.
- Bowen, A., 2014. Green growth, Ch. 15 in Atkinson, G., Dietz, S., Neumayer, E., and Agarwala, M. (eds.) *Handbook of Sustainable Development* (2nd ed.). Cheltenham, UK, Edward Elgar.
- \*Bowen, A. 2015. *Carbon pricing: how best to use the revenue?* Policy Brief. (forthcoming): Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.
- Bowen, A., Campiglio, E., and Tavoni, M., 2014. A macroeconomic perspective on climate change mitigation: Meeting the financing challenge. *Climate Change Economics* 5(1).
- Bowen, A., Cochrane, S., and Fankhauser, S., 2012. Climate Change, Adaptation and Growth. *Climatic Change* 113(2), pp. 95-106.
- \*Bowen, A., and Hepburn, C., 2014. Green growth: an assessment. *Oxford Review of Economic Policy* 30(3), pp. 407-422.
- \*Bowen A., and Kuralbayeva, K., 2015. *Looking for green jobs: the impact of green growth on employment*. Policy Brief. Grantham Research Institute on Climate Change, London School of Economics.
- Bowen, A., Cochrane, S., and Fankhauser, S., 2012. Climate Change, Adaptation and Growth. *Climatic Change*, 113(2) pp. 95-106.
- Brahmbhatt, M., 2014. *New Climate Economy Report: Background Note on Climate Mitigation and Jobs*. London: New Climate Economy.
- Bureau of Labor Statistics, 2013. Green Goods and Services (GGS) news release. [online] Available at: <http://www.bls.gov/news.release/pdf/ggqcew.pdf>
- \*Dechezleprêtre, A., Martin, R., and Bassi, S., 2015. *Climate change policy, innovation and growth*. Policy brief. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.
- Dechezleprêtre, A., Martin, R., and Mohnen, M., 2014. *Knowledge spillovers from clean technologies: A patent citation analysis*. Working Paper 135, London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, and Centre for Climate Change Economics and Policy.
- Dechezleprêtre, A., and Sato, M., 2014. *The impacts of environmental regulations on competitiveness*. Policy brief. Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.
- Department for Business, Innovation and Skills (BIS), 2013. *Low carbon environmental goods and services (lcegs) – Report 2011/12*. [online] Available at: [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/224068/bis-13-p143-low-carbon-and-environmental-goods-and-services-report-2011-12.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224068/bis-13-p143-low-carbon-and-environmental-goods-and-services-report-2011-12.pdf)
- \*Doda, B. 2014. Evidence on business cycles and CO<sub>2</sub> emissions. *Journal of Macroeconomics*, 40, pp.214–227
- \*Doda, B. 2014. *How to price carbon in good times... and bad*. Policy Brief. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.
- European Commission, 2007. *Facts and figures: Links between EU's economy and environment*. Luxembourg: Office for Official Publications of the European Communities
- \*Fankhauser, S., McDermott, T., 2014. Understanding the Adaptation Deficit: Why are Poor Countries more Vulnerable to Climate Events than Rich Countries? *Global Environmental Change*, 27, pp. 9-18.
- Fankhauser, S., Ranger, N., Colmer, J., Fisher, S., Surminski, S., Stainforth, D., and Williamson, A. 2013. *An Independent National Adaptation Programme for England*. Policy Brief. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.
- Fankhauser, S., and Schmidt-Traub, G., 2011. From adaptation to climate resilient development. The cost of climate proofing the Millennium Development Goals in Africa. *Climate and Development* 3, pp. 1-20.

Fischer, C., and Newell, R.G., 2007. *Environmental and technology policies for climate mitigation*, RFF Discussion Paper 04-05 (revised). Washington D.C: Resources for the Future.

\*Fouquet, R. 2015. *Lessons from Energy History for Climate Policy*. Working Paper (forthcoming). Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

\*Grodecka, A., and Kuralbayeva, K., 2015. *The Price vs Quantity debate: climate policy and the role of business cycles*. Working Paper No. 177. Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

GHK, 2009. *The impacts of climate change on European employment and skills in the short to medium term: A review of the literature*. Final Report to the European Commission Directorate for Employment, Social Affairs and Inclusion Restructuring Forum, Vol. 2. London: GHK International

Hanson, S., Nicholls, R., Ranger, N., Hallegatte, S., Corfee-Morlot, J., Herweijer, S., Chateau, J., 2011. Global Ranking of Port Cities with High Exposure to Climate Extremes. *Climatic Change* 104, pp. 89-111.

\*Hippe, R., and Fouquet, R., 2015. *The human capital transition and the role of policy*. Working Paper No. 185. Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

Hughes, G., 2011. *The myth of green jobs*. Report No.3. London: The Global Warming Foundation

International Labour Organization (ILO), 2015. *World employment and social outlook – Trends 2015*. Geneva: ILO.

International Renewable Energy Agency (IREA), 2014. *Renewable energy and jobs – Annual review 2014*. Abu Dhabi: IREA.

Jacobs, M., 2013. 'Green Growth', Ch. 12 in R. Falkner (ed.), *The Handbook of Global Climate and Environment Policy*, Oxford, Wiley-Blackwell, pp. 197-214.

Kozluk, T. and Zipperer, V., 2013. *Environmental policies and productivity growth – a critical review of empirical findings*. Working Paper No.1096, Paris: OECD Economic Department.

\*Kocornik-Mina. A., and Fankhauser, S., 2015. *Climate Change Adaptation in Dynamic Economies*. Policy Brief. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

\*Lovo, S., Bezabih, M., and Singer, G., 2015. *Green agricultural policies and poverty reduction*. Policy brief. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

Mayhew, K. 2013. Government and Business: An Introduction. *Oxford Review of Economic Policy* 29(2), pp. 249-60.

McGray, H., Hamill, A., Bradley, R., Schipper, E.L., and Parry, J., 2007. *Weathering the Storm. Options for Framing Adaptation and Development*. Washington DC: World Resources Institute.

Michaels, R., Murphy, R.P., 2009. *Green jobs: fact or fiction?* Houston: Institute for Energy Research.

Organisation for Economic Co-operation and Development (OECD), 1999. *The environmental goods and services industry: Manual for data collection and analysis*. Paris: OECD

Organisation for Economic Co-operation and Development (OECD), 2011. *Towards green growth*. Paris: OECD.

Organisation for Economic Co-operation and Development (OECD), 2014. *Climate Resilience in Development Planning. Experiences in Colombia and Ethiopia*. Paris: OECD

Ranger, N., and Garbett-Shiels, S-L., 2012. Accounting for a Changing and Uncertain Climate in Planning and Policymaking Today: Lessons for Developing Countries. *Climate and Development*, 4(4), pp. 288-300.

Surminski, S., 2016. Insurance Instruments for Climate Resilient Development, in: S. Fankhauser and T. McDermott, eds. *The Economics of Climate Resilient Development*. Cheltenham: Edward Elgar, forthcoming.

United Nations Environmental Programme (UNEP), 2011. *Towards a green economy: pathways to sustainable development and poverty eradication – a synthesis for policy makers*. Geneva: United Nations Environmental Programme.

World Bank. 2013a. *Turn Up the Heat. Climate Extremes, Regional Impacts, and the Case for Resilience*. Washington DC: World Bank.

World Bank. 2013b. *Building Resilience: Integrating climate and disaster risk into development*. Lessons from World Bank Group experience. Washington DC: World Bank.

\*Papers produced as part of the LSE-GGGI research programme on Green Growth and the new Industrial Revolution.



Grantham Research Institute on  
Climate Change and  
the Environment



Global  
Green Growth  
Institute

---