Chapter 5

ECONOMICS OF CHANGE

Main points

- The next fundamental transformation of the global economy can deliver strong economic growth and poverty reduction, and at the same time reduce the growing potential risks of climate change.
- Many of the perceived short- to medium-term trade-offs between economic growth and climate action disappear when policy is examined in a dynamic context of change, and when existing economic inefficiencies and the multiple benefits of action are taken into account.
- The multiple benefits of low-carbon policies, such as health benefits from reduced fossil fuel use and increased fiscal efficiency through recycling of revenues from carbon pricing, could offset the costs of climate action. Agile labour markets and just transition policies for workers can also reduce the economic costs, including limiting the impact on aggregate employment.
- Many model-based assessments do not consider these multiple benefits and market dynamics. Notwithstanding these limitations, recent modelling suggests economic costs of climate action for a 2°C path are likely to be small, at around 1.7% (median) of baseline global GDP in 2030. This is equivalent to reaching the same level of baseline GDP around 6 to12 months later.
- Delay raises costs, potentially cutting global consumption growth by around 0.3% per year in the decade 2030 to 2040, compared to less than 0.1% per year over the same period if we act now. Delay may also lead to greater climate damage in the long-term, which could impact the drivers of growth and hit sovereign credit ratings of vulnerable countries.
- To manage change and realise growth opportunities, clear and credible policies are needed to align expectations, guide investors, stimulate innovation, and avoid locking in to carbon intensive infrastructure and behaviour. Policy frameworks will differ by country but should aim to include a price on carbon as part of wider fiscal reform and phase out of fossil fuel subsidies, estimated at around US$600 billion per year.

1. Introduction

Throughout history economies have constantly had to adapt to changing preferences, politics and technologies. Such shifts have driven changes in investment in energy, cities, land use and transport. Public institutions and financial services have had to innovate to adapt. Over the past few decades economies and technologies have changed rapidly and profoundly, and the next few decades will see continuing transformation. Countries now face radical choices that will shape their economies, including their cities, energy systems and land use, in decisive ways for decades to come. This chapter is about these choices.

Some change is more predictable and this knowledge can help governments plan. Coming changes are likely to include: a continued, strong rise in the share of output from emerging markets and developing economies; a world population that may increase by an estimated one billion or more people by 2030; rising pressure on resources as the world industrialises; continuing, rapid urbanisation; population aging and a decline in the working-age population in many countries; and the building and rebuilding of energy systems. At the same time the world has seen and will see increasing risks from global climate change. Some change is less predictable, however, for example as a result of technological or other innovation breakthroughs, resource price shocks or geopolitical conflict.

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The structural transformations that will take place may be handled well or badly. If they are handled well they will be less costly and stimulate more innovation and opportunity. Lessons from economic history are helpful here. We have the advantage of learning from several transformations since the industrial revolution, including from a rich Schumpeterian tradition of analysis, discussed in Section 5.3. The opportunities and risks from the structural changes different countries face are highlighted in Chapter 1: Strategic Context.

Institutions and policies are central to transition. Economies with accountable institutions and responsive policy frameworks will be better placed to adapt, evolve, embrace and manage change, to reallocate resources more efficiently, and to foster growth opportunities. They will have the flexibility to tap new markets and adopt new innovations. The alternative – of resisting change, protecting vested interests, propping up declining industries and delaying action – risks locking in less productive growth and leaving investors, firms and households vulnerable to shocks. Resisting change may enable economies to squeeze a little more out of their existing structure in the short-term, but it is unlikely to benefit them in the medium- to long-term.[1]

This chapter outlines the policies that governments could implement over the next 15 years to steer the next transformation of the world economy in a low-carbon direction.

The view that there is a rigid trade-off between low-carbon policy and growth is partly due to a misconception in many model-based assessments that economies are static, unchanging and perfectly efficient. Any reform or policy which forces an economy to deviate from this hypothetical counter-factual baseline incurs a trade-off or cost. In fact, there are a number of reform opportunities that can reduce market failures and rigidities that lead to the inefficient allocation of resources and hold back growth, including excessive greenhouse gas emissions. Indeed, once market inefficiencies and the multiple benefits of reducing greenhouse gas emissions, including the potential health benefits of reduced air pollution, are taken into consideration, the perceived net economic costs are reduced or eliminated. But tackling market failures and taking advantage of these multiple benefits requires ambitious and coherent policy.

This chapter focuses its analysis on the three key drivers of growth: resource efficiency; better infrastructure investment; and innovation. These will be critical for determining the pace and shape of change. It illustrates this through reference to the three critical systems highlighted throughout the report – energy, cities and land use – which are at the heart of structural change. Governments can provide clear and credible policy incentives to stimulate these drivers of growth in a way that guides a structural shift to a low-carbon economy.

It should be viewed alongside the rest of the report. For example, Chapter 1: Strategic Context, describes the story of structural change in different economies and explains how this motivates the analytical bases of this report. Chapter 6: Finance describes how to drive low-carbon investment, taking forward analysis here of a low-carbon policy framework. Policies to tackle market failures are discussed further in Chapter 7: Innovation, regarding research and development.

The chapter starts by outlining the key elements of a strategy for low-carbon growth. Section 3 discusses the broad policy mix, focussing on fiscal reform including carbon pricing and fossil fuel subsidies. Section 4 discusses policies to ease the transition for the poorest and most vulnerable. Section 5 analyses how to achieve clear and credible policy signals, including better metrics and models, to guide expectations, and provides lessons from history. Section 6 concludes with recommendations for policy-makers.

2. A framework for economic growth that also tackles climate risk

2.1 The framework

This chapter and report discusses how to achieve "better growth" that increases quality of life across key dimensions, including incomes, social stability, equality, and better health, while also achieving a "better climate". By "better climate" we mean reducing the risk of dangerous climate change by cutting greenhouse gas emissions.

The economic framework presented in this chapter for "better growth" and a "better climate" recognises that economies are not "static" but are dynamic and constantly changing. As such the economic analysis and tools deployed must be appropriate for this context.

The framework has four main building blocks:

- The short-run opportunities to tackle market imperfections that hurt economic performance and increase climate risk;
- Investment, growth and structural change in different country contexts;
- Flexible approaches to managing transition, especially given political economy challenges, and distributional issues that need to be tackled; and
- The development and deployment of improved measurement and modelling tools that can improve economic decision-making and lead to better policy choices.

Tackling market imperfections and steering innovation

Economic principles inform us that there are opportunities to pursue strong economic growth today that are also good for climate because a range of market failures persist with immediate social, economic and environmental costs.

Greenhouse gases are a market failure as the emitter does not bear the costs of the damage and disruption from their activities. Some have suggested that greenhouse gases may be the largest market failure of all.[2] Beyond the long-run impact of greenhouse gases on the climate and thus the economy, emissions from burning of fossil fuels cause severe local air pollution today which damages the health and productivity of millions of people, particularly in urban areas in rapidly developing countries. Outdoor air pollution caused 3.7 million premature deaths in 2012, according to the World Health Organization (WHO). Emissions from transport, industry and power generation are a major source of this pollution.[3]

Other market failures include imperfections in risk and capital markets, for example a failure to consider the full range of investment costs and benefits. Such market failures misprice risk; limit access to finance; and reduce investment in infrastructure. Another failure is in early stage research and development (R&D), where technical knowledge "spills over" to others. This prevents the innovator from capturing the rewards of their efforts and deters investment in innovation. Market failures around the provision of information and networks are also crucial. For example, poor awareness of the potential for long-term energy savings would result in under-investment in energy efficiency (see Section 3.3).

These combined market failures imply that policy reforms are possible today that can effectively and efficiently boost productivity and growth. Policy to reduce fiscal distortions from unpriced greenhouse gases will enhance resource efficiency and deliver multiple other benefits including reduced local air pollution. Policy to tackle market failures in capital markets will boost productive infrastructure investment. And policy to tackle the spillover problem can stimulate innovation, the benefits from which can often come through more quickly than expected. In economic terms, policy to tackle market failures can give rise to the possibility of a Pareto improvement, where at least one person is made better off with nobody worse off.[4]

The cost-effectiveness and efficiency of such a strategy will be enhanced further if it is well-coordinated and complemented with policies to promote economic flexibility, including more responsive labour markets; a better educated workforce; and open and free trade. Strong and trusted institutions that align expectations on the direction of change and which reduce policy risk are also important.

But this framework goes far beyond an exercise in "comparative statics", where the limitations of the existing economic system are stated and the policies that can correct market failures are described. This approach is about the dynamics of change: recognising that the transformation is likely to be non-marginal, and embracing this change through a broad suite of social and economic policies to steer the economy onto a low-carbon path. In other words, this is about combining the economics of market failures with the economics of change and transformation.

Investment, growth and structural change in different country contexts

Policies to foster low-carbon growth and realise the multiple benefits discussed throughout this report may require additional investment in the next 15 years, above what would be required without climate action (see Section 4.3). The appropriate way to consider these additional investment costs is the "dynamic net economic cost".

The dynamic net economic cost includes the additional up-front investment, for example, the cost of upgrading and constructing new networks and new low-carbon energy infrastructure. These are monetary costs and must be financed (see Section 3.3 and Chapter 6: Finance).

The additional investment may also impose a resource cost if it ties up additional inputs to produce the same amount of output, e.g. an off-shore wind farm may require more skilled labour and more physical resources than a fossil fuel plant to produce a megawatt of electricity. This would reduce total output as it uses up existing productive resources.

However, this resource cost does not reflect the final economic cost. For example, climate policies are likely to incentivise substitution away from more to less carbon-intensive goods, often with attractive fuel savings. The more substitution opportunities available in the short-term, and as innovation makes more substitutes available, the lower the economic cost.

But calculating the final dynamic net economic cost requires us to consider the full range of costs and benefits, including the returns to the up-front investments. These include a reduction in long-run climate risk but also short- and medium-run benefits such as health, congestion, security and innovation (see Section 3.1). In fact, there is evidence that low-carbon investments may have greater scope for learning- and innovation-driven cost reductions than high-carbon alternatives, and also greater scope for spillover into other sectors.[5]

Where political and institutional realities are difficult to overcome, countries have adopted pragmatic "second-best" approaches

The full dynamic net economic cost must also reflect net economic benefits that will be forgone if action is delayed. Taking action later to derive the same economic returns will require a larger investment, and with high-carbon infrastructure, technologies and behaviours further locked-in, the dynamic costs will rise.

Therefore this is not a "free lunch" - some additional upfront investment is needed to pay for the attractive benefits and this may have an economic cost in terms of additional resources. But after considering the net benefits it is a "lunch worth paying for" - these investments have attractive economic returns and could quickly pay for themselves. Delay raises the dynamic net economic cost.

The precise policy framework required to drive investment for low-carbon growth will differ from country to country, depending on their individual contexts. For example, industrial policies have often been favoured in the past by countries, such as South Korea, trying to progress rapidly from middle- to high-income. When well-targeted, such policies have helped to foster investment in new and productive low-carbon industries. Another approach is tax reform to boost demand for environmental goods and services. Vietnam adjusted tax rates on polluting goods and services, such as fuels and chemicals, to reflect their environmental damage. This reform boosted investment and domestic demand for goods and services, but better recycling of the additional tax revenues could have reduced the costs of the reforms for particular groups.[6] China has incorporated growth and low-carbon objectives into its 5-year plans, with the 12th plan containing a range of measures to reduce emissions growth and promote investment in strategic high-tech, low-carbon industries.[7] The shape of its 13th plan (2016-2020) is likely to strengthen this transformation.

This chapter has many relevant lessons for least developed countries. However, their special circumstances demand additional analysis and focus. For example, a study prepared for the Commission examines the role that agriculture can play in addressing poverty reduction in Africa. It discusses how transformative adaptation in agriculture could present opportunities for "triple-win" outcomes with benefits for economic growth, poverty reduction and environmental sustainability. Crop intensification, minimum tillage, agroforestry coupled with designation and maintenance of protected for¬ests, support for social protection and development of insurance markets, are examples of techniques and policies that can deliver these outcomes. Such adaptation also presents an opportunity to tackle long-standing barriers holding back productivity gains in agriculture, including restrictions on regional trade, under-investment in infrastructure and limited provision of social protection.[8]

Managing the challenges of transition

In practice, governments have found it difficult to implement the most cost-effective and efficient policies for growth and reducing climate risk, such as legislating an explicit carbon price coupled with productive use of the resulting auction or tax revenues. This difficulty is partly a result of political economy pressures, including powerful vested interests in a fossil fuel-based economy, concerns around competitiveness, and concerns around any regressive impact of these policies on households. In a low-carbon transition, the specific costs, trade-offs and benefits that affect particular groups need to be carefully analysed. Dedicated, transparent measures are likely to be needed to reduce the costs and trade-offs for workers and firms. Managing change also requires strong institutions that can set clear and credible policies to guide expectations on the direction of change. Weaknesses in institutions and policy uncertainty raise the costs of change and slow the transition.

In cases where political and institutional realities are difficult to overcome, many countries have adopted pragmatic “second-best” approaches where the alternative may be no policy at all. Governments may need to take a step-by step approach, to discover the right combination of instruments and institutions to advance overall welfare. Where possible, governments could maintain flexibility in these policy frameworks, so that they can move towards more efficient and effective approaches over time - second best policy is only useful if it moves policy in the right direction. To ensure a continuing transition towards more optimal policy design, governments can legislate provisions to review the effectiveness and efficiency of policies.

Metrics and models for better policy

The appropriate metric for judging an economic policy intervention is its impact on overall welfare. If the policy creates a net welfare gain, it will still be important to consider the possible negative impacts on different groups, and whether some mechanism for redistributing the benefits of the policy is needed, e.g. assistance for some groups towards adjustment costs. Sometimes a policy may appear costly because not all its benefits are included in the balance of costs and benefits or are not easily identified. It is also of great importance to consider the counter-factual baseline with which a new policy is compared. In the case of low-carbon policies, the usual baseline assumption of “business as usual” growth may not hold due to the transformation that is coming anyway and the risks from future climate impacts. An appropriate counter-factual for comparison should reflect the economic costs of climate change and other impacts of continued growth in fossil fuel combustion, such as worsening air pollution.

Ministries of Finance need to tackle such shortcomings in their decision-making by adding several steps to routine policy evaluation. First, they could take an economy-wide view of costs and benefits. Second, they could recognise classes of costs and benefits not traditionally included in cost-benefit analysis, such as health costs from air pollution. Third, they could provide guidelines for how to incorporate these wider costs and benefits into planning and cost-benefit analysis tools.[9] Fourth, they could consider longer term returns rather than focus solely on up-front costs, as is standard practice when assessing investments in education or infrastructure. Governments can formalise this wider consideration of costs and benefits in economic policy-making through better use of metrics and models for monitoring and assessing the impacts of policy and change on quality of life, as discussed in Section 5.

Welfare must be approximated and gross domestic product (GDP) is often used. But GDP remains just one indicator among many attempting to measure changes in welfare. Supporting indicators are also necessary. For example, measuring the risk of overuse and damage to the natural world requires metrics beyond GDP. Governments and firms can incorporate such risks into decision-making by monitoring cumulative human impacts on various types of natural capital, including, water, ecosystems, species, minerals, the atmosphere and oceans. Monitoring would require governments and firms to include natural capital in national and corporate accounts (see Section 5). A failure to measure and manage natural capital is likely to result instead in its depreciation and possible destruction, with direct impacts on productivity, growth and output.[10] On the other hand, in recognising and measuring the value of natural capital, efficient environmental management can become a productive investment that is comparable with investments in physical or human capital. In this way there is a real opportunity to boost medium- to long-term growth through policies that increase the productivity of natural capital, including the atmosphere. Chapter 3: Land Use illustrates how this can happen in practice, through better management of degraded agricultural lands and by curbing deforestation.

To conclude, with economies constantly changing and transformation of the world economy likely over the coming decades, it makes sense to start to manage this change now. The framework for growth presented is a realistic one that can be implemented over the coming 15 years. The proposed approach would tackle the factors impeding economic growth today, while also accelerating a low-carbon transition. It will help to avoid the lock-in of long-lived high-carbon infrastructure, promote resource efficiency, reduce fiscal distortions, tackle pollution-related health issues, enhance energy security, drive low-carbon innovation, and increase the momentum for more effective and ambitious mitigation measures in the future.

The policy decisions taken in the next 15 years will be crucial for both long-term growth and the climate. There are huge opportunities for human welfare if change is managed well, and huge risks if managed badly. Sustained policy efforts will be needed beyond 2030 to ensure that these short- to medium-term reforms achieve the long-term, internationally agreed goal of reducing greenhouse gases to levels consistent with keeping global average temperature rise to below 2°C compared with pre-industrial levels.

2.2 The broad policy mix and institutions to enable change

Countries which anticipate and plan for change are likely to perform better. Various policy instruments will be needed to manage change. This does not mean more or unnecessary regulation, rather better policies and institutions for more efficient markets and for managing the type of change that countries will likely experience over the coming decades. The main types of policies and tools examined in this chapter are: fiscal policies such as carbon pricing and subsidies; policies to complement carbon pricing, such as standards; adjustment policies to ease the transition for households, workers and businesses; and models and metrics to manage change better.

Putting a price on greenhouse gas emissions is perhaps the most important policy, in particular to keep the costs of action low. Efforts should be focused on getting the design of such carbon pricing policies right, including applying the price across a wide base of different sectors, establishing a reasonable and robust price that rises over time, and using the revenues raised in productive ways, for example for fiscal reforms which make the broader tax system more efficient. But, carbon pricing is one among several instruments, to tackle a range of market failures, including in innovation, which should play an important role in the policy mix (see Section 3.3).

Additional policies to create a more flexible and responsive economy can also help to facilitate change more cost-effectively and efficiently. They will cover a broad range of areas including competition and product market policy, trade and investment policy, labour market policy, and human capital and education policy, among others. These additional policies will increase the flexibility with which resources are deployed and support the conditions for growth. Campaigns against corruption, graft and fraud will ensure more responsive policy-making. More rigid economies, for example with inflexible labour and capital markets, will face higher costs of adjustment to structural changes, including those needed for a transition to a low-carbon economy.

A competitive product market is essential for a more responsive economy. This will lower entry barriers for new, more efficient and cleaner firms and products that can challenge incumbents. It will also allow inefficient firms to decline and exit. To encourage enterprise and boost productivity, product market regulation should be set in a way that does not hamper competition and is combined with a clear and effective antitrust framework to ensure a fair, level playing field among firms.[11] Openness to trade also makes economies more agile and adaptable, by making them less constrained by the limits of domestic markets.[12]

Progressive labour market policies similarly enhance economic flexibility, providing firms with the ability to adapt to ever-changing market conditions, on the one hand, and workers with adequate employment rights, on the other (see Section 4 below). Providing adjustment assistance for workers in declining industries will be an important task of transition policies. An affordable and flexible housing market facilitates labour mobility so that workers can move from regions with declining industries to expanding ones, aiding cost-effective economic transformation. Human capital and education policies ensure that workers have the right education and skills to benefit from structural change. Without training and re-skilling opportunities, some workers may find their existing skills are mismatched to those demanded in new growth industries.[13]

Finally, any discussion of efficient and effective policies must take into account the nature of existing institutional frameworks and governance structures of individual countries. Effective and supportive institutions are crucial as they can help to shape expectations, strengthen policy co-ordination, and manage and resolve political economy challenges.

Carbon pricing is one among several instruments which should play an important role in the policy mix.

Political institutions that are trusted by citizens to execute policies in the public interest will perform better, as they better guide public expectations, and will be held accountable for their successes and failures. To take one example, governments in Scandinavia have long been expected to invest in long-run issues relating to childcare, education and the environment, and will be held electorally liable if they do not. By contrast, institutions which are not trusted, for example because they are subject to corruption and graft or because they fail to innovate and are not responsive to a changing economy and society, will not be trusted to deliver policies in the public interest. Opposition even to policy reforms in the public interest may arise on the assumption that the benefits will not reach citizens. This expectation itself reduces incentives for policymakers to implement reforms in their country's long-run interest, especially when the costs to upsetting the beneficiaries of a corrupt system are high, and so the spiral continues.

Strong, trusted and responsive institutions can align expectations and reduce the costs of change by sending clear and credible policy signals across the economy on the direction of change. This will give the private sector the confidence to deliver the necessary efficiency gains, infrastructure and innovation that will drive productivity of all forms of capital and growth. Box 1 describes institutional structures that can reinforce policy credibility. Clear policy signals lower the risk of premature stranding of infrastructure investments, while helping to accelerate and scale investments in more efficient products, new business models, new markets, new skills and jobs, and more productive ways of working and operating. Policies that send weak, absent or muddled signals slow or hinder change and increase costs.

Box 1
Institutions for policy stability and credibility

Given that governments are often in power only a few years, it is important to consider how longer term commitments to policies for managing change could be made more credible, recognising that total certainty can never be guaranteed.

Some institutional and legal structures can provide policy stability and credibility, and lower uncertainty. For example, Britain's statutory climate adviser, the Climate Change Committee, recommends decarbonisation targets 15 years or more ahead, under legislation which has a 40-year horizon. Similarly, Australia's statutory adviser on infrastructure investment, Infrastructure Australia, recommends long-term investment strategies to state and federal government. The National Institute for Health and Clinical Excellence (NICE) in the UK helps government to design health policy more effectively by providing evidence-based guidance and advice, quality standards and performance metrics, and information services.[14] National development banks can also help to reduce policy risk and give credibility (see Section 4.3).

Policies to tackle market failures do, however, create their own risk of government interventions that are poorly designed or lock us into the wrong path. The story of path-dependency amplifies the potential size and duration of any such policy failure. This makes the need for accountable, trusted institutions, and credible, cost-effective and transparent policies, designed to make markets work well and achieve well-specified (emissions reduction) goals, all the more important.

3. Policy and coordination

3.1 Fiscal reform – carbon prices

Greenhouse gas emissions cause long-term climate change and economic damage. The most economically efficient way to tackle the greenhouse gas market failure is by requiring polluters to pay a price per tonne emitted.[15] This approach discourages emissions and incentivises investment in low-carbon infrastructure, efficiency and innovation. Carbon pricing should also be part of a broader fiscal reform package, where taxes are shifted away from things we want to encourage such as labour and business activities, towards taxing "bads" such as pollution and resource use. This will help markets to guide resources away from declining and less productive activities, toward growing, more flexible and productive activities, leaving economies better able to prosper and absorb shocks.

The primary tool to tackle the damage from greenhouse gas emissions is an explicit carbon pricing instrument: a

Box 2
What price for greenhouse gas emissions?

The social cost of carbon (SCC) is a theoretical measure which attempts to value the full social cost of damage from an additional tonne of greenhouse gas emissions. Theoretically, it is the appropriate welfare-based measure of greenhouse gas externalities, and should ideally be applied as a carbon price across all greenhouse gas emissions sources and countries, with international finance provided to ensure equity.[16] It signals what society should, in theory, be willing to pay now to avoid the future damage caused by incremental greenhouse gas emissions.[17]

There is ongoing debate and uncertainty around how to calibrate the factors that determine the SCC. These factors include climate sensitivity, climate damages and discount rates. Recent discussions have recommended a declining discount rate, which would see carbon costs rise over time.[18] Some studies have emphasised the need for two discount rates: a social and private discount rate.[19] Estimates of SCC values range anywhere from a few dollars per tonne of greenhouse gas emissions, measured in carbon dioxide equivalent (CO_2e), to several hundred dollars.[20]

In practice, a global carbon price is unlikely to be agreed in the near term. Individual countries and regions will decide a price (in the case of a carbon tax) or an emissions cap (in the case of an emissions trading system) which reflects their climate ambition, other climate and energy policies, and a range of other political and economic factors. The key is that the price sends a clear, credible signal that aligns expectations, and so shifts investment toward low-carbon infrastructure and activities over time.

In the absence of more universal carbon pricing, but in the expectation that this may one day arrive, a number of government agencies, companies and organisations have applied "internal" or shadow carbon prices to their critical investment decisions. For example, the US government has established a SCC of around US$35 today, rising to around US$50 in 2030, and recommends that US government agencies use this price in cost-benefit analysis of regulatory actions that impact emissions.[21] (See Section 5.2 for a discussion on the models that produce these estimates). More than 100 major businesses worldwide have disclosed that they use an internal carbon price in their operations.[22] In the United States, around 30 companies indicated that they used an internal carbon price ranging from US$6 to US$60 per tonne of CO_2e. Most of these were energy-intensive firms such as BP and Exxon-Mobil, but also included were Google, Microsoft, Disney, Walmart, and Delta Airlines.[23]

Box 3
Multiple benefits from carbon pricing

Local environmental benefits

Carbon pricing reduces greenhouse gas emissions and local air pollution from the burning of fossil fuels. This generates significant benefits for health, quality of human life and labour productivity. The health benefits arise because burning fossil fuels produces pollutants including ozone, a result of the reaction of organic compounds in sunlight, and fine smoke particles called particulate matter, both of which contribute to lung and heart disease. These potentially large benefits accrue mainly to the country taking action, and are realised in the short-term.

There is extensive literature assessing the value of these non-climate benefits. In total, outdoor air pollution in cities and rural areas was responsible for 3.7 million premature deaths annually in 2012, according to the World Health Organization.[27] Much of this pollution was particulate matter emitted from burning fossil fuels in transport, industry and power generation. A review of 37 studies, published in 2010, found the value of air quality benefits from climate change mitigation ranged from US$2-128 (average US$44) per tonne of abatement of greenhouse gas emissions in developed countries, and US$27-196 (average US$81) in developing countries.[28] Developing countries tend to have high emission rates (including less use of emissions control technologies) and greater population exposure.

In its latest review of climate science, the Intergovernmental Panel on Climate Change (IPCC) reported an estimate for the global benefits of avoided mortality from less burning of fossil fuels, which uses new relationships between mortality and exposure to ozone and particulate matter, at US$50-380 per tonne of CO_2e abatement.[29] Another study by the International Monetary Fund has estimated the value of the benefits by country, accounting for externalities including air pollution and traffic congestion, net of any pre-existing fuel taxes and subsidies. The total value of such un-priced, local externalities associated with burning fossil fuels was around US$58 per tonne of CO_2, on average, across the top 20 global greenhouse gas emitters.[30] All these indicative estimates show potentially very large multiple, monetised benefits from reducing greenhouse gas emissions.

While it may be possible to tackle local air pollution and vehicle congestion more cheaply directly, this approach would not necessarily help reduce climate risk. For example, coal plants may be required to fit equipment which reduces emissions of sulphur dioxide, but this would not reduce CO_2 emissions. Recent studies show that doing the two together is best, meaning that the net total benefits of a combined policy are larger than either of the separate policies.[31] (See Chapter 1: Strategic Context).

Reduced local air pollution also has significant benefits for ecosystems which have been impacted for decades by pollution: sulphur dioxide and nitrogen oxides acidify soil and waterways and reduce tree health and productivity; ground-level ozone reduces crop and forest productivity; mercury decreases reproductive success and changes fish and wildlife behaviours.[32] The Economics of Ecosystems and Biodiversity (TEEB) study published in 2010 analysed approaches for the valuation of ecosystem services and biodiversity.[33]

Enhanced energy security in fossil fuel importing countries

A stable and affordable energy supply is critical for economic development. In the short- to medium-term, carbon taxes can drive a switch from imported fossil fuels, such as coal, oil and gas, to domestic, lower carbon sources such as wind, solar, hydro and geothermal power. In such cases, energy security can be enhanced and the risk of supply disruption reduced. In the longer term, an increasing share of low-carbon energy in the domestic mix will result in less volatile energy prices. Carbon prices and efficiency standards can also incentivise investments in energy efficiency, reducing total energy consumption and thus demand for imports.

carbon tax or emissions trading system.[24] Our focus here is on explicit carbon pricing, but it is also possible to ensure that prices of fossil fuels reflect their full costs to society through the extension of existing fuel taxes, with the tax rate adjusted to reflect the carbon and pollution content of the particular fuel. Many developing countries may find this an attractive alternative, while they develop the necessary institutions to support explicit carbon pricing, because such taxes are already in place and are easily administered.[25]

New work from the International Monetary Fund (IMF) calculates "corrective" tax estimates by fuel across 156 countries, and shows large differences between "efficient" fuel taxes that would reflect their carbon, environmental and other impacts, and the actual, current tax levels. Their research also provides some rough estimates of the fiscal, environmental, and health benefits that "efficient" prices could bring.[26] Some of the multiple benefits from carbon pricing are outlined in Box 3.

Carbon pricing also provides dynamic efficiency benefits in the short-, medium- and long-term. These include motivating continued emissions reductions by providing incentives for innovation, and increasing macroeconomic efficiency through the recycling of carbon tax revenues. These are briefly summarised.

- *Incentives for innovation*

  Carbon prices provide incentives for innovation toward less emission-intensive products and processes, because companies are motivated to innovate continuously to reduce their carbon tax liability. For example, a case study analysis of the United Kindom's Climate Change Levy found that firms subject to the full rate of the levy submitted more technology patents than firms subject to a reduced rate.[34] Expectations of high future carbon prices are an important factor affecting innovation, as reflected in patenting activity.[35] The benefits from innovation in one sector can also spill over and benefit other sectors. This is a key reason why carbon pricing is an extremely cost-effective instrument, particularly in the medium- to long-term.

- *Revenue-raising for government*

  If developed countries used carbon pricing to implement emissions cuts as pledged in Cancun under the United Nations Framework Convention on Climate Change, they could raise more than US$400 billion annually by 2020.[36] Many countries are already moving to higher rates of auctioning of permits in cap-and-trade systems. For example, about 40% of permits were auctioned in the European Union Emissions Trading System (EU ETS) in 2013, compared to very little auctioning in the second phase of the scheme from 2008-2012. Around 90% of allowances are auctioned in the Regional Greenhouse Gas Initiative (RGGI) in the north-eastern United States, and a growing share are auctioned in California.

  However, as carbon prices rise, they are likely to incentivise consumers and businesses to shift their behaviour to avoid the tax, through adopting low-carbon products and practices. As this happens, the net revenues from carbon prices can be expected to fall.

- *Macroeconomic efficiency through the recycling of carbon revenues, under wider fiscal reforms*

  Carbon tax or auction revenues can be recycled through the economy. Such uses can reduce the economic costs associated with a carbon price and potentially lead to increased employment, thus increasing political acceptability of the policy. In practice, the potential for reducing the economic cost of carbon pricing will depend on the nature of pre-existing distortions or inefficiencies in a country's tax system and the nature of the revenue recycling (Box 4).

  The best use of carbon tax or auction revenues should be guided by good principles of public finance, including efficiency, distribution, and incidence. Some potential uses include: reducing existing distortionary taxes; funding innovation; financing international climate action; and public support for infrastructure investment, for example by capitalising green investment banks. A share of the revenues will also be needed to compensate vulnerable households and businesses, for example for higher energy prices.

Carbon prices provide incentives for innovation toward less emission-intensive products and processes, because companies are motivated to innovate continuously to reduce their carbon tax liability.

  A well-established literature has examined the pre-existing distortions and the most effective revenue recycling options.[37] A clear message from the literature is that revenues must be put to good use, e.g. to reduce existing distortionary taxes rather than giving out emissions permits for free, as their use has a large impact on the cost-effectiveness of carbon pricing. In this way, the appropriate way for most countries to view carbon pricing is not as a choice between policy and no policy, but between different ways of raising and returning revenues.

Explicit carbon prices in practice

The use of carbon pricing as a policy instrument is already widespread, both nationally and regionally. About 40 national and over 20 sub-national jurisdictions have implemented or have scheduled a price on carbon[40] (Figure 1). The use of carbon pricing also appears to be expanding. Twenty national and six sub-national jurisdictions are considering a price on carbon.[41]

Together, the actual, scheduled and considered schemes cover around 12% of global greenhouse gas emissions.[42] The highest carbon prices are found in Sweden. These were introduced in 1991 at a relatively low rate, but are currently as high as US$168 per tonne of CO_2e in some sectors.[43] The Swedish scheme raises annual tax revenues of almost US$3.7 billion.

There are several technical lessons that can be learned from countries with experience of emissions trading systems or carbon taxes. These examples show that carbon pricing has indeed created incentives to reduce emissions. In the Australian National Electricity Market (NEM), carbon dioxide (CO_2) emissions reductions attributable to the carbon price, implemented on 1 July 2012 and repealed in July 2014, were between 5 to 8 million tonnes of CO_2 in the fiscal year 2012-13, and between 6 and 9 million tonnes in 2013-14.

Box 4

Recycling carbon tax revenues

A range of modelling studies, including new analysis for the Commission as well as empirical evidence, suggest that smart revenue recycling can reduce or eliminate the short-run costs of carbon pricing.

New analysis prepared for the Commission simulates fiscal reform for 35 developed and developing countries, with revenues raised from carbon prices recycled through either lump sum transfers, deficit reduction, cuts in labour taxes or increased government investment.[38] The results show that recycling options that influence the supply-side of the economy, such as government investment that increases the capital stock or personal income tax cuts that increase the supply of labour, reduce the impact of carbon pricing on short-run growth, and in some countries, e.g. Brazil, could offset any impact and boost short-run growth. Using carbon tax revenues to pay down government debt had the most negative impact on short-run growth. A country's economic structure and sources of energy also influence the results.

Over the medium- to long-term, modelling evidence suggests that the economic cost of efficient climate policies is likely to be small; for example, in the range of about 0.5–2% of a country's gross domestic product (GDP) in 2030 (compared with baseline) in most studies, with costs varying in part based on how tax or auctioning revenues are recycled.[39]

These modelling exercises are useful tools but their results must be interpreted carefully as they are likely to overstate the costs to GDP for a range of reasons. For example, they are unable to capture the full range of economic distortions in the existing tax system. In real life, therefore, greater welfare gains are likely from revenue recycling to reduce existing taxes. They also largely ignore the value of the other benefits from carbon pricing. And GDP impacts only reflect part of overall welfare impacts. Some of the modelling results cited in this report overcome some of the reasons models tend to overstate costs, for example by allowing for capacity gaps and unemployment, but all models face some limitations (see Section 5.2).

The reductions represent 3 to 6% of total emissions in the NEM in each of those years.[45] See also the example of British Columbia in Box 5.

However, their effectiveness has been limited in a number of cases, for example because prices were too low, a lack of credibility around the future of the policy, or key energy-intensive industries were either exempted or given overly generous compensation. For example, some of the recent emissions reductions in the European Union Emissions Trading System (EU ETS) were achieved primarily through other policy instruments or the economic downturn, rather than the carbon price. Experience also shows the importance of considering the potential overlap and interaction with other policies, such as feed-in tariffs for renewable power and energy efficiency regulations, as this has the potential to reduce the efficiency and effectiveness of carbon pricing (see Section 3.4).

Regarding emissions trading, market surprises may call for adjustments to emissions caps. Examples include EU provisions for setting aside some permits, to remove a surplus generated during the financial crisis, and a proposed "market stability reserve". The north-eastern US Regional Greenhouse Gas Initiative (RGGI) scheme used cap tightening to achieve an objective of faster emissions reductions.

Emissions trading systems can also be designed as "hybrid" schemes, in some ways mimicking a bounded carbon tax. Price floors can ensure a minimum level of effectiveness in emissions trading, as is the case in California and in seven Chinese pilot schemes. Price ceilings can limit the costs of permits, which can be important in terms of ensuring industry acceptability.

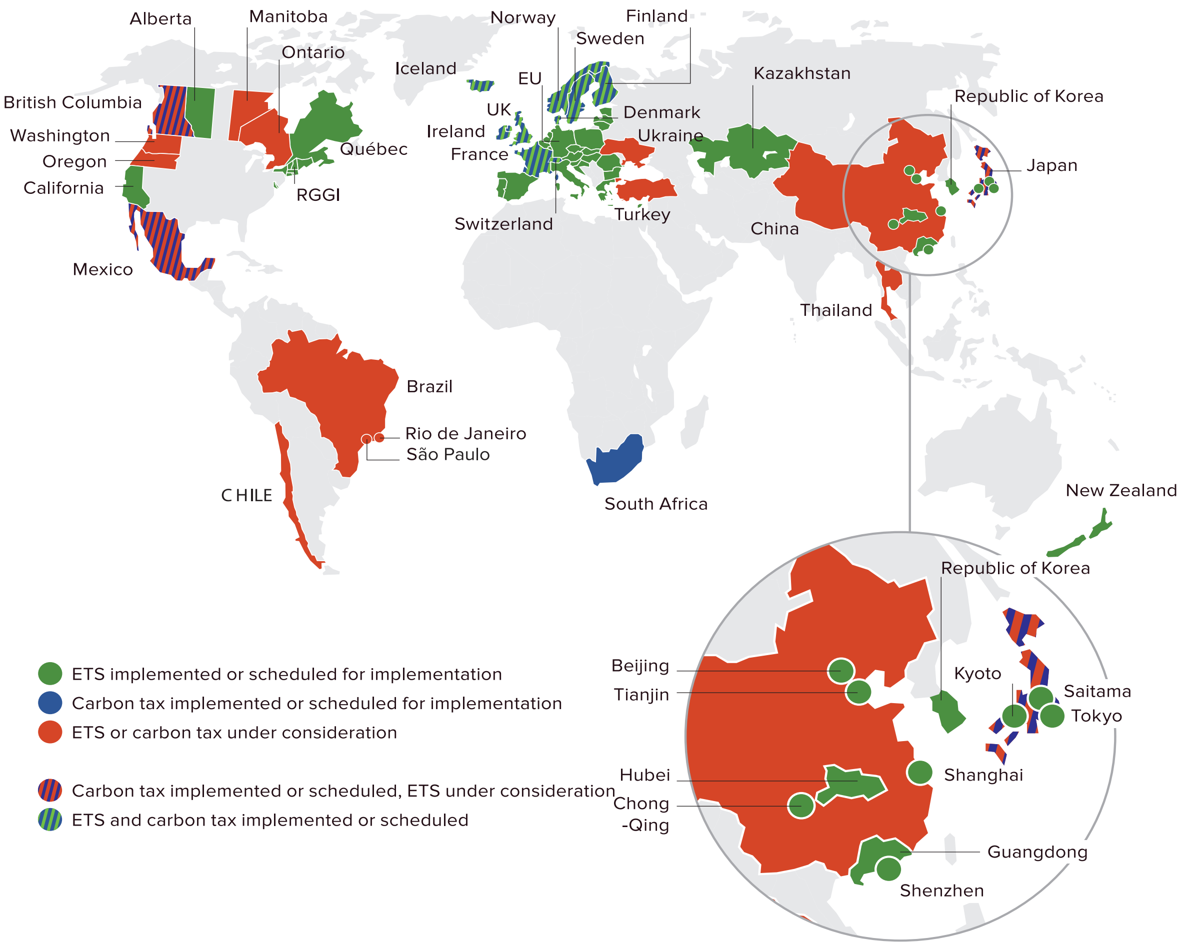
Among governments which are auctioning or selling a significant amount of allowances, or applying a carbon tax, some are using the revenues to cut income taxes for low income earners or corporate taxes, with evidence that these fiscal reforms can achieve distributional objectives and economic efficiency gains (for example British Columbia). Other governments are recycling the revenue into emissions reductions programmes (California and RGGI), innovation programmes (EU), or for international climate action (Germany, in the EU ETS).

It is common practice that permits are allocated for free to industry. This increases the costs of carbon pricing as it fails to realise the efficiency benefits from the recycling of revenues, but may increase political acceptability in the short-run. However, this practice is increasingly confined to shielding trade-exposed and emissions-intensive industries from adverse effects on their international competitiveness, as in the EU. Free permits to the power industry are now largely confined to situations where power producers cannot pass on carbon costs (as in China) or to support large and politically influential coal-fired generators (in Eastern Europe).[46]

3.2 Fiscal reform - subsidies.

Just as it is efficient to price negative externalities, or "bads", it is inefficient to subsidise them. Many countries start from a position of negative carbon prices because of subsidies for fossil fuels. But subsidies go beyond fossil fuels: they are likely to total over US$1 trillion globally per year in energy, water, steel and food alone.[49] Any serious attempt by a country to get fiscal policy right for both growth and climate change should start with a reassessment of these distortions.

Figure 1
Carbon pricing around the world



Source: © 2014 International Bank for Reconstruction and Development - The World Bank.[44]

> *Any serious attempt by a country to get fiscal policy right for both growth and climate change should start with a reassessment of subsidies to fossil fuels*

The International Energy Agency (IEA), International Monetary Fund (IMF) and the Organisation for Economic Co-operation and Development (OECD) have estimated and reported on various fossil fuel subsidies over a number of years, and assessed the impacts of their phase-out.[50] The group of 20 leading global economies (G20) has been discussing the removal of fossil fuel subsidies for the past five years.

The OECD has estimated the value of support for fossil fuel production and consumption in OECD countries at around US$55-90 billion per year over the period 2005 to 2011, with most of this in the form of tax breaks for consumption.[51] Even countries which are now re-evaluating their support for renewable energy still have fossil fuel subsidies in place. For example, Germany provided €1.9 billion in subsidies to its hard coal sector in 2011.[52] The IEA estimated fossil fuel consumption subsidies in emerging and developing countries at around US$540 billion in 2012.[53] The majority of these were for energy consumption in net fossil fuel exporting countries (Figure 2).[54]

Countries subsidise fossil fuel consumption in various ways. Governments may keep local energy prices below international market prices, or provide grants or vouchers to make energy more affordable. Such subsidies are

Box 5
British Columbia, Canada: an example of a well-designed carbon tax[47]

An explicit carbon tax was introduced in British Columbia on 1 July 2008 at C$10 per tonne of carbon dioxide equivalent (CO_2e), rising by C$5 per year until it reached C$30 in 2012. The tax applies to nearly all fossil fuels, including petrol, propane, natural gas, and coal. It covers nearly 80% of the province's greenhouse gas emissions from residential, commercial and industrial sources. It is designed to be revenue neutral; all revenues raised are recycled to reduce other existing taxes, with a focus on corporate and labour taxes, and tax relief for vulnerable households.

In the 2012-2013 fiscal year, the scheme raised revenues of around C$1.2 billion, from a tax rate of C$30 per tonne. That is equivalent to 0.7% of 2012 nominal GDP. After 5 years of operation, the government has delivered C$500 million more in tax cuts than total carbon tax revenues raised. Petrol prices rose around 7 cents per litre over the period 2008-2012; this price rise has cut per capita consumption of petroleum fuels subject to the tax by around 17%, compared to a 1.5% increase in the rest of Canada. From vvzzemissions fell by 10%, compared to a 1.1% drop in the rest of Canada. Over the same period, GDP per capita declined by 0.15% in British Columbia, compared to a 0.23% fall for the rest of Canada.

As the tax rate has increased, however, evidence has emerged that the tax is becoming more regressive.[48] Such an outcome would call for higher compensation for vulnerable groups.

particularly popular in developing countries, for example as a way to distribute the benefits of a country's natural resource wealth to the general population. This is particularly important in countries without social safety nets or other means of delivering support for their populations. These motives are powerful and make reform politically difficult. It is therefore important to understand the costs of these subsidies and the benefits of reform, as this may help to identify more efficient ways of achieving the same social objectives.

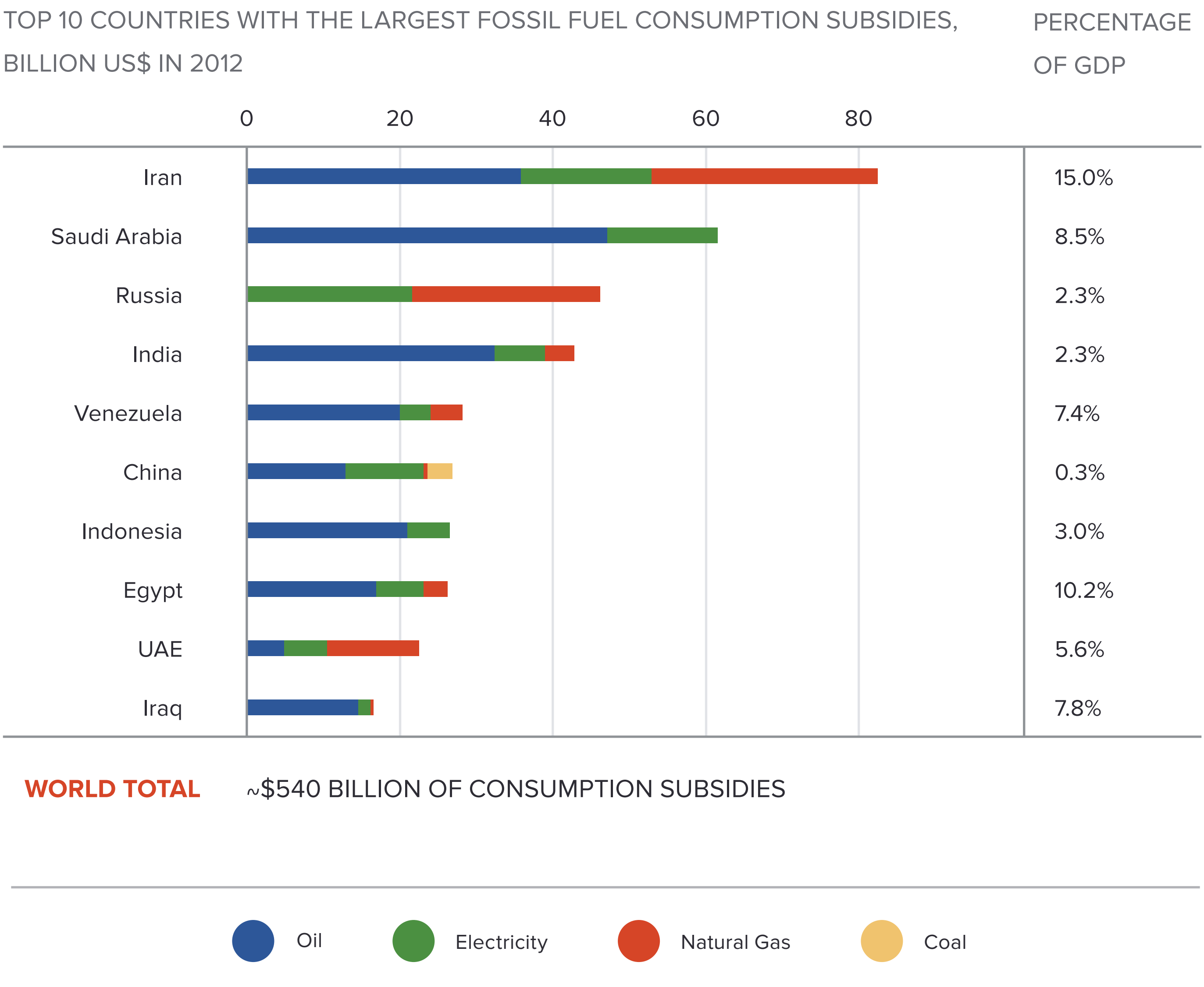
The limitations and costs of fossil fuel consumption subsidies fall into five key categories.

- Inefficient - They are often economically inefficient. Subsidies artificially incentivise greater use or production of fossil fuels than is economically efficient for a given welfare level.
- Budget impact - There is an opportunity cost from selling energy domestically below its international price, assuming there are further international market opportunities in the case of oil exporters. There is a real cost for a country which taxes fossil fuel energy at a lower rate. These foregone revenues represent 5% or more of GDP in some countries.[56] By this measure, Indonesia and Mexico have spent more on energy subsidies than on health or education in recent years.
- Environmental impact - Increased consumption of fossil fuels, in response to subsidies, increases air pollution, including indoor air pollution where fossil fuels are used for cooking and heating. Lower energy prices can also lead to excessive pumping of groundwater, as for example in India. And subsidies accelerate climate change by increasing carbon emissions.
- Lock-in - Subsidies promote fossil fuel dependence and long-term lock-in to a high-carbon economy, for example they encourage greater reliance on private vehicles and urban sprawl.
- Regressive - Subsidies tend to favour well-off urban middle classes, who can afford large cars and multiple electric appliances, at the expense of taxpayers or the poor who would benefit more from targeted pro-poor public spending. An example is Mexico where 80% of electricity subsidies for irrigation water pumping accrued to the richest 10% of farmers.[57] The poorest 20% in Mexico capture only 11% of residential electricity subsidies and less than 8% of transport fuel subsidies. Price controls can also undermine electric grid investment, and therefore energy access for vulnerable people, as utilities have less incentive to invest and fewer financial resources.

Subsidy reform reduces an economic distortion and increases fiscal revenues, which leads to gains in real incomes and GDP from more efficient resource allocation. Reform also leads to higher energy prices and stronger incentives to invest in energy access and renewable energy. Higher energy prices also encourage investment in energy efficiency and conservation, cut carbon emissions from fossil fuel combustion, and yield other, related benefits including lower air pollution. The impact of subsidy removal on global greenhouse gas emissions is uncertain, but some estimates exist. One study reports that if all 37 countries covered by the IEA fossil fuel subsidy database removed their subsidies by 2020, global greenhouse gas emissions could be around 8% lower in 2050, compared with a baseline projection.[58]

It is vital to tackle equity issues arising from fossil fuel subsidy reform, such as the impact of rising energy prices on vulnerable people, who may be below or just above a defined poverty line. Such problems can be tackled through cash transfer payments, funded by a share of the savings from reduced subsidies. However, in some countries administrative challenges could prevent these payments being made effectively, suggesting fossil fuel subsidy reforms will need to be accompanied by institutional reforms. Also, given the lack of trust in the political process in many countries, governance reforms

Figure 2
Fossil fuel consumption subsidies in emerging and developing countries, 2012



Source: IEA, 2013.[55]

that increase fiscal transparency and trust in government institutions will be a vital. To build trust, some support may need to be provided for vulnerable people through up-front financing before implementing the reforms. Reductions in subsidies are unlikely to be supported if there is no expectation of receiving compensation, if revenue savings are expected to line the pockets of elite groups, or if they are simply returned to the public coffers.

Experience in reducing fossil fuel subsidies

Many countries have experimented with reforms to reduce subsidies. These have often proved politically challenging and there are many barriers, but reform is possible and some useful lessons emerge.

International organisations have proposed a range of measures that can support successful subsidy reform. The components for successful fossil fuel subsidy reform include: a comprehensive reform plan integrated with broader fiscal reforms; credible and targeted measures to protect the poor; a clear communications strategy; appropriately phased and sequenced price increases; and improvements in the efficiency of state owned enterprises.[59] Box 6 provides some further lessons from five countries that have undertaken subsidy reform.

Innovative ideas are also emerging that may help governments overcome some of the barriers to reducing fossil fuel subsidies. A recent example is the idea of a "subsidy phase-out and reform catalyst" (SPARC) bond. Such bonds would enable governments to raise money from private investors, with only a small contribution from government to cover some of the risk. The proceeds would provide the up-front finance necessary to demonstrate

Box 6
Lessons learned from reform of fossil fuel consumption subsidies

The examples of Ghana, Tunisia, Bolivia, Nigeria and Indonesia provide useful lessons from fossil fuel subsidy reform in practice.[60]

Ghana – an example of a successful reduction in the overall level of subsidies. Ghana carried out an impact assessment prior to the reform, and a widespread advertising campaign. The government increased fuel prices by around 50% in 2006, followed by several more increases to bring prices in line with the international market price. The revenues saved were partly used to compensate the poor for energy price increases. A new petroleum authority (NPA) was introduced to depoliticise the price-setting process.[61] This was not a structural policy reform in isolation. Ghana has implemented a comprehensive fiscal reform package that is transforming its economy.

Tunisia – an example of countering the impacts of fossil fuel subsidies with support for renewable energy. Tunisia implemented an innovative reform programme from 2005 that encouraged households to shift away from water heaters run on subsidised fossil fuels, to solar water heaters. The scheme tackled the key local challenges hindering the shift. First, it provided subsidies to reduce the upfront costs of the solar system. Second, it developed the supply chain, such as training installers and creating accreditation and quality certification programmes. Third, it raised community awareness and confidence in the alternative technology. And fourth, it used the state utility to act as debt collector, guarantor and enforcer, overcoming credit market weaknesses.[62]

Bolivia - an example of unsuccessful reform. In 2010, the Bolivian government announced a dramatic 70% increase in prices for fossil fuels. This quickly led to riots and civil unrest and the reform was abandoned. [63]

Nigeria – another example of poor communication. The Nigerian government had to scale back initial price increases of 117% for gasoline in 2012, to around 50%.[64] Concerns in Nigeria included fear of loss of competitiveness, loss of income for low and middle income households and job losses.

Indonesia – an example of public opposition, despite a compensation scheme. The Indonesian government doubled the price of diesel and nearly tripled the price of kerosene in 2005, while offering compensation in the form of an unconditional cash transfer programme and cash payments to low-income individuals. Despite the compensation programme, subsequent attempts to phase out energy subsidies and provide compensation have faced strong public opposition.[65]

the benefits of reform and build public acceptance. The future savings from reduced fossil fuel use would repay the bond over time. The World Bank or other international financial institutions could potentially act as guarantor and intermediary for the bonds.[66]

3.3 Policies to tackle other market failures and political economy barriers

A well-coordinated portfolio of different policies is needed to tackle different market failures, boost productivity and growth, and to lower the costs of emissions reductions.[67] We now discuss targeted policies to tackle the market failures beyond greenhouse gases. The failures are categorised into three broad areas: innovation; infrastructure investment; and networks.

It should be noted that other chapters in this report provide further detail on these market failures and policies to tackle them, for example in Chapter 6: Finance and Chapter 7: Innovation. They are introduced here.

Policy for market failures in innovation, investment and networks

Innovation is crucial for productivity and growth.[68] But there are market failures throughout the innovation chain, in particular in the early stages of R&D, which hold back investment in low-carbon innovation. When a firm invests in early stage R&D, it produces technical knowledge that can be replicated across many firms at very low cost. This knowledge spills over from one firm to another through imitation and learning.[69] Knowledge spillovers cause firms to under-invest in R&D compared with the public optimum, because innovators do not fully appropriate the returns to their investment.[70] Policies that can help to remedy this include direct government investments in R&D, innovation prizes, patenting systems, and carefully targeted tax breaks and subsidies.[71]

Analysis for the Commission finds innovation is generally path-dependent, meaning that the type of innovation path we follow will depend on our expectations of future technologies and the initial conditions of the innovation process.[72] Government thus has an important role not only to tackle market failures, but also to help set the initial conditions that can shift innovation from high- to low-carbon. Direct subsidies for low-carbon R&D can be an effective tool to deal with the spillover externality, and in combination with carbon prices, can shift expectations for the innovation process to low-carbon.

Support for early-stage R&D for renewable energy and energy efficiency has risen rapidly in recent years and is starting to overcome a long legacy of government R&D support for fossil fuels. In 19 countries in the OECD, renewable energy and energy efficiency R&D increased from around 15% of total government energy R&D spending in 1990 to nearly 50% in 2011.[73] Government R&D spending on fossil fuels fell from 20% to 12% of total energy R&D over the same period.[74]

A second market failure concerns investment in the deployment of clean energy infrastructure. In this case, market failures include a failure to price risk properly, including some important social costs and benefits, and policy uncertainty, which together raise risk premiums and deter clean energy investment. Experience across most countries shows that a mix of economic, fiscal and financial incentives are needed to tackle these failures in a way that reduces the costs of debt and equity and unlocks investment in deployment of low-carbon technologies. Specific policies will differ depending on individual country risk characteristics and the type of technology. Two complementary instruments that can be used to support low-carbon deployment are feed-in tariffs and concessional debt. Chapter 6: Finance provides more detail on the types of policies to boost low-carbon investment, according to national income characteristics.

Concessional debt is particularly useful in countries where governments are unable to provide clear and credible policy signals. However, such credit may not always provide investors with the level of risk reduction necessary. In such cases feed-in tariffs (FITs) can provide renewable energy generators with a fixed long-term price, and so can reduce market risks further. FITs can function simultaneously as a policy de-risking instrument (through guaranteed grid access and "must-take" requirements) and a financial de-risking instrument (through a guaranteed price over a period of years). Much has been learned over recent years on how to design FITs better.[75] But problems remain. For example, they are still more costly compared to a carbon price (Box 8). And as a form of subsidy, they should be limited in their use, and time-bound with transparent and pre-announced plans for how they will be phased out over time as more efficient options become feasible. Many countries, such as China and Saudi Arabia, are starting to use auctions to ensure that price incentives are economically efficient and to avoid excessive subsidies. In some countries, these economic incentives may need to be supplemented by other fiscal and financial incentives, to tackle remaining investment risks, as discussed in Chapter 6: Finance.

A third market failure is around networks. Lack of suitable networks or access to them can provide a barrier to new technology uptake by would-be adopters, and prevent new technologies from competing on a level basis with incumbent technologies.[76] For example, the widespread uptake of the current generation of electric vehicles is dependent on access to a reliable network of charging stations. Policies to tackle network-related market barriers include public investment in smart electricity grids, public transport and broadband, and to open existing networks, for example to allow local renewable energy generators to sell electricity into existing grids.

The importance of networks is pervasive and crucial for fostering innovation and the transition to a low-carbon economy.[77]

The challenge with support for low-carbon technologies and systems is therefore one of designing the optimal policy package that includes the appropriate combination of economic, fiscal and financial incentives to ensure effectiveness at the lowest cost.

The role of regulations and standards in tackling market failures

Regulations such as standards (see Box 7) can tackle a range of market failures and provide confidence and clear signals. If designed well, they can help to make carbon pricing schemes more effective and efficient.

A market failure that regulation can help tackle is that of split incentives. One example is in the rented building sector. In this case, landlords may not reap the benefits of investing in better insulation, because they do not pay the electricity bills, while tenants are reluctant to make such long-term investments, as they do not own the property. As a result, energy efficiency investments are missed, even when the returns are high. Examples of relevant regulations include a requirement that tenants qualify for subsidised insulation, or the introduction of minimum building efficiency standards in buildings. Split incentives apply in other sectors such as in shipping, where owners of fleets often have little incentive to improve efficiency, because customers pay fuel costs. Regulations can mandate shipping fuel efficiency standards.

Regulations can also help to tackle existing restrictions and barriers that reduce competitiveness, such as barriers that prevent new products from accessing established markets, and which can hinder innovation. These barriers are already proving powerful in the case of electric vehicles, with, for example, car dealerships in many US States blocking Tesla from bypassing the dealer network and selling their electric vehicles directly to the public.[79]

Regulations are particularly useful where there are systematic behavioural biases and preferences that can reduce the effectiveness of explicit carbon prices.[80] Understanding consumer and household behaviour is central to cost-effectively reducing the demand for energy, which helps limit emissions, lower resource costs and enhance energy security. Such behavioural biases include an excessive focus on the short-term among consumers in their purchase decisions, which can undervalue the benefits of energy efficiency. Regulation can tackle such behavioural bias, for example through standards which draw attention to energy savings, and so emphasise long-term benefits. Mandatory or voluntary energy efficiency labelling on appliances has proved a particularly effective way to shift consumer behaviour.[81] A review of energy demand reduction experiments around the world finds that providing additional information on electricity bills - such as advice on energy efficiency, feedback on energy usage, information on potential cost savings and social comparison -can be effective at motivating energy

Box 7
Standards

Standards can provide clear signals and policy certainty for the private sector. If they are announced sufficiently in advance, they can drive private investments in R&D and innovation in low-carbon technologies. They can influence the design of new products and R&D strategies, as seen in the car industry. They have also been found to positively affect consumer preferences and social norms.

Performance standards may also have greater political acceptability compared with policies such as carbon pricing, for a variety of reasons:

1. In most sectors, standards do not immediately affect existing industries and equipment, only new investments, so incumbents are less likely to object to their introduction.

2. Many countries already have performance standards, and these may only need strengthening and better enforcement to reduce emissions further. Thus governments can avoid the trouble of creating entirely new policy tools.

3. Performance standards achieve measurable results more rapidly than carbon prices, and their benefits can thus be observed over shorter timescales.

4. Performance standards convey a positive message and focus on achievements and progress, for example contributing to development goals such as moving domestic manufacturing toward higher value-added products, rather than focusing on limits and constraints.

There is criticism of the cost-effectiveness of standards, particularly in the auto industry. The literature evaluating Corporate Average Fuel Efficiency (CAFE) Standards in the United States suggests that increased fuel duties and taxes would be a more cost-effective way of reducing emissions.[78] However, standards can be designed to overcome some of these concerns through incorporating price ceilings and floors. The price ceilings can contain compliance costs, while the price floors provide ongoing incentives for improvement in periods when the costs of meeting the standard falls.

savings.[82] One of the most powerful forms of information on bills is social comparison. Comparing household energy bills to energy uses of neighbours can "activate" social norms and pro-environmental attitudes and "nudge" households towards lower energy use.[83]

The role of regulations and positive subsidies in tackling political economy and institutional barriers

Regulations including standards can be useful where political realities and institutional factors prevent the implementation of explicit carbon pricing. Such hard-nosed realities which can obstruct the legislation of carbon pricing include resistance from powerful pressure groups, more obvious short-run consumer costs compared with relatively opaque costs of standards and rebate schemes, a lack of institutional capacity domestically, and a particular difficulty agreeing carbon pricing schemes internationally.

Pressures from powerful vested interests have been particularly effective in delaying the wider use of explicit carbon pricing, even in countries like the United States, Canada and Australia where carbon pricing at the regional level has proved successful. The resistance is generally based on competitiveness and equity concerns, as discussed in Section 4 of this chapter. Pressure groups that resist pricing are often well-mobilised, well-resourced and influential.

Standards may offer an easier alternative, especially where governments already have the legislative authority to use these; the use of vehicle standards in the US is one example. And standards may pave the way to carbon pricing in the future; proposed US regulation of emissions from power plants allows states to use some form of carbon pricing.

Regulations including standards can be useful where political realities and institutional factors prevent the implementation of explicit carbon pricing.

Other policy instruments, besides standards, may attract less political resistance than carbon pricing. For example, "feebates", which have proved popular with consumers. They impose a fee on a dirty product and offer a rebate on a clean substitute. The "feebate" can be closely aligned with the market failure that they are tackling and, unlike standards, they provide a constant incentive to improve efficiency.[84] They have proved effective in driving the switch to more efficient vehicles. Investment subsidies, for example for home insulation or purchase of energy efficient equipment, are also popular. Many governments also provide subsidies to clean energy.

It is noted that while policies such as standards and subsidies may, in certain cases, attract less political and public resistance than carbon pricing, this may be because the costs associated with these instruments are often diffused or hidden in the detail of income tax regulation, general fund expenditure, utility financial regulation,cost-pass through arrangements and energy bill levies. As a result, these advantages may disappear over time, as the costs become more obvious. The result could then be a political backlash. Examples include the opposition to the costs of subsidising offshore wind farms in many EU countries.

Policy-makers can make the real cost of standards more transparent using the concept of an implicit or "effective" carbon price. Box 8 presents estimates of "effective" carbon prices for different policy instruments. Economic costs may be reduced over time by leaving flexibility in the system to move toward a more cost-effective mix of policies as the political and institutional barriers to implementing such measures are overcome. This could involve, for example, conditions that any new type of subsidy needs to be well targeted and gradually phased out over time. Failure to ensure such a condition could see policy become less efficient over time and distortive, for example where the subsidy fails to fall in line with technology costs.

Besides industry opposition, carbon pricing may also be obstructed by weaknesses in institutional capacity. Regulations can be useful in countries without the capacity to support and administer carbon prices, including some developing and emerging economies. China is an example of a country that uses regulations extensively, but is now experimenting with carbon pricing and starting to build the necessary institutions to support this. The World Bank Partnership for Market Readiness is helping in this regard, providing support for countries preparing for fiscal reforms that include carbon pricing and reducing fossil fuel subsidies.[86]

Regulations may also be easier to agree nationally and internationally. The "en.lighten" initiative is one example of an international approach to efficiency standards. Some 55 countries have committed to implement policies and measures that will reduce inefficient lighting by 2016. The initiative aims to eliminate inefficient lighting by 2030, a goal which could save about 1,000 terawatt hours (TWh) per year in electricity consumption; cut carbon emissions by some 500 million tonnes of CO_2 annually in 2030; and shave more than US$100 billion from electricity bills. Another example is the Global Fuel Economy Initiative (GFEI), which is working to help 20 countries increase their vehicle fleet efficiency. If these countries committed to doubling the fuel efficiency of passenger vehicles by 2030, they could avoid at least one billion tonnes of CO_2 per year in 2030, achieve fuel savings worth up to US$2 trillion, and secure large health benefits from reduced air pollution in cities.[87] Chapter 8: International Cooperation provides more detail of multilateral initiatives to drive cuts in greenhouse gas emissions.

3.4 Coordination across the policy mix

The policies discussed above, and indeed throughout this report, will be most effective and efficient when carefully integrated in a well-coordinated policy mix. They will be better at driving short- medium-run growth and reducing greenhouse gas emissions.

Planning policies in cities provide a clear example of coordination benefits. For example, carbon or petrol taxes are much more effective at reducing emissions when an effective, reliable public transport system is in place.[88] Carbon taxes would have to be higher to achieve the same level of emissions reductions if there is no suitable public transport alternative.

While policies such as standards and subsidies may, in certain cases, attract less political and public resistance than carbon pricing, this may be because the costs associated with these instruments are often diffused or hidden.

In the power sector, emissions reductions are more cost effective when coupled with strong investment in energy efficiency, with evidence of this relationship in the Regional Greenhouse Gas Initiative (RGGI) in the north-eastern United States.[89] Adequate grid capacity will ensure low-carbon electricity can be utilised when the wind blows strongly.

An uncoordinated approach to policy can potentially lead to overlap and negative interactions between policies.[90] The coexistence of the European Union Emissions Trading System (EU ETS) and its renewable targets is often given as an example of overlap. The EU-wide renewable energy target, underpinned by subsidies, aims to reduce emissions in the energy sector, rather than allowing the EU ETS to allocate emission reductions where they are cheapest.

The EU made a choice to structure its policies in this way in order to incentivise early investment in the deployment of renewables, as they are central to decarbonisation of the energy system and investments now will bring down their cost, potentially enabling greater ambition in future years. In addition, the carbon price required to incentivise sufficient renewables deployment to meet EU emissions targets without these supporting policies and targets may be too high politically.

As the emissions cap in the EU ETS is fixed, driving emissions reductions in the energy sector in this way may reduce demand for permits elsewhere, reducing permit prices and creating space for other sectors to emit more. One solution to this perceived problem would be to adjust the cap downwards, but attempts to do this have proved politically difficult. However, recent evidence finds that this overlap is not the main cause of low EU ETS carbon prices. This research shows that the recession, which has led to emissions below the level of the cap, renewable support policies, and international credits, can only explain around 10% of the EU ETS price decline from almost €30 in 2008 to less than €5 in 2013.[91] A lack of long-term

Box 8

The cost of carbon abatement according to policy instrument, using the example of the electricity sector[85]

The OECD has analysed the cost-effectiveness of various approaches for cutting carbon emissions in the electricity sector, and found wide variation. For each policy approach, the study calculated the total cost per tonne of CO_2 abatement, or the so-called "effective" carbon price. These estimates have several limitations: they do not account for the value of additional benefits from these policies, such as improved air quality; and they don't compare different approaches to energy taxes. This is also a static analysis; it doesn't consider the dynamic incentives of each approach for inducing innovation over time. Nevertheless, the estimates are still informative.

1. Carbon trading systems and broad-based taxes have so far proved to be the most cost-effective and economically efficient policy tools.

2. Taxes on fossil fuels are also cost-effective in reducing greenhouse gas emissions. Vietnam is an example of an emerging country that has taken this route. Fuel duties can be a fairly good proxy for explicit carbon pricing and have been shown to be effective. For example, they can have a high impact on reducing emissions in the transport sector.

3. Regulations are more costly, with an average cost of around €50 per tonne, including considerable variation around this average. Feed-in tariffs and investment subsidy instruments are the most commonly used instruments in practice, and some of the most expensive, costing an average of over €150 per tonne of avoided CO_2. They are often the easiest policy instruments to put in place, due to political constraints on carbon pricing and their popularity with those who benefit from the subsidy payments. A greater understanding of their implied and often hidden costs could inform more efficient policy mixes.

This discussion should not imply that only the "cheapest" policy option should or can be used in all cases; for example, regulations are likely to be needed to tackle other market failures beyond greenhouse gas emissions. But, in general, using regulations and subsidies as the main tool to tackle the greenhouse gas market failure is likely to be more expensive than a well-designed mix of policies, with regulations and other measures used to support explicit carbon pricing, and where carbon pricing revenues are recycled to productive uses.

A key point from the OECD analysis is that these policies are often applied in a piecemeal fashion within countries today. As a result, effective carbon prices vary widely across countries. For example, for the electricity sector, the average effective carbon price in Korea is around €200 per tonne of CO_2 abated, around €100 per tonne in the UK and Germany, and below €50 for Australia, the US, Chile and China. Policies could be coordinated in more effective and efficient ways to better tackle the market failures.

credibility around the future of European climate and energy policy appears the likely explanation of most of the decline.[92]

More research is required into the most effective and credible coordination of policies across a wide-range of areas relating to energy, climate, competition, fiscal management, innovation, development cooperation, agriculture, investment policies, competition policy and trade policy.[93] It is clear that coordination is best applied across sectors, such as cities, transport, energy and land use. Poor coordination, coupled with an incomplete range of policy instruments to tackle the relevant market failures, will raise costs, impact credibility, and lower the effectiveness of policies. For example, the presence of fossil fuel subsidies raises the carbon price needed to achieve a certain level of emissions reductions. Another example of competing policies is trade rules, which are not always compatible with support for low-carbon energy. This is discussed in Chapter 8: International Cooperation.

Better coordination of policy could transform efficiency and accelerate the pace of change. In May 2014, Ministers of Finance and Economy requested the OECD and the IEA to provide recommendations on how to align policies to achieve a low-carbon transition. Such work will be an important follow-up to this report.

4. Managing and monitoring change and learning from experience

4.1 Policies to ease the transition

Policies can help firms and households manage and adapt to the structural change associated with a low-carbon transition. This will minimise the economic and social costs. Countries that have a record of proactively managing change and easing the costs of transition will do better and experience less resistance to reforms.

Managing change requires recognising where there will be winners and losers, and smoothing the transition for affected groups. Some workers and firms may face higher costs or dislocation. Some firms and industries will decline. Governments have a role to identify the most effective policies to reduce these costs without impeding change. Phasing in policy reforms according to a pre-announced schedule, after public consultation, can provide time and clarity for businesses and workers to adapt or identify new opportunities.

Three key challenges are identified, related to the structural shifts associated with policies to boost growth and reduce climate risk:

- Equity, to distribute the benefits and burdens of change fairly;
- Employment, to help workers re-skill and retrain; and,
- Competitiveness, to help firms benefit from change, and not be put at a disadvantage relative to competitors.

Each is examined in turn below.

Equity

Carbon taxes and fossil fuel subsidy reforms can have regressive impacts when they raise domestic energy prices. Poorer households may take a relatively bigger hit than others.[94] Targeted compensation policies can alleviate these costs for households, for example, through cash transfers or social security payments, or by reducing marginal income tax rates for households.[95]

Poorer households may not have benefited so much from fossil fuel subsidies. While energy consumption subsidies are often intended to help the poor, they are often proportionate to the level of energy consumption, which is generally higher for rich households, who then capture most of the benefit. The subsidies also tie households to purchasing fuel or electricity if they wish to benefit. By contrast, poor households can use direct income support, rather than subsidies, for other needed spending, such as on clothing, food and education.[96] These support packages can be adjusted over time as the carbon price level and the structure of the economy changes.

One policy challenge in making compensation transfers is to devise appropriate mechanisms, given the lack of social safety nets in many developing countries. A lack of such mechanisms and institutions is often part of the reason why such countries relied on fuel or electricity subsidies in the first place. Much experience has been gained in recent years with the introduction of cash payment schemes, and the World Bank is assisting a number of countries to introduce these. The introduction of the "Aadhaar" proof of identity and address scheme in India has enabled better targeted support to poor households and has been an essential factor in recent energy subsidy reforms, despite implementation issues that have reduced public trust in the scheme. In countries that have social safety nets, governments must be careful to ensure additional support is in fact required. For example, social security payments often adjust automatically to price levels, including the impact of higher energy prices.

Jobs and unemployment

Workers are at the centre of economies, and will be directly affected by any form of structural change. As economies develop and grow, labour will continually transition from declining sectors to more profitable and productive activities.

> *Policies can help firms and households manage and adapt to the structural change associated with a low-carbon transition. This will minimise the economic and social costs.*

Various policies can ensure a just transition for workers. They can take many forms but should minimise unemployment, promote job creation in growing sectors and tackle labour market distortions efficiently, while also providing protection for the most vulnerable. They should tackle the wide range of factors related to the risk of job loss and impacts on the communities in which workers live.[97] Such measures are a central part of the integrated framework for managing change described in this chapter. These policies can increase the responsiveness of the workforce to change and new opportunities in a way that benefits both employees and employers: it is not about making it easier for employers to hire and fire workers. They include:

- Pro-active training to equip people for change by acquiring new skills. Sweden, the Netherlands and Germany have demonstrated successful training and re-skilling policies to prevent long-term unemployment. Singapore actively promotes structural change through public policy to encourage knowledge-intensive skills and activities.
- Unemployment benefits must be designed to motivate workers to re-enter the workforce, in particular because learning on-the-job remains an effective way to prevent skill atrophy. This means finding the right level for benefits that incentivise re-entry into the labour market without creating financial distress for the unemployed, and provision of in-work credits or wage subsidies to get people back to work. It may also be more efficient to promote job creation in new sectors rather than protecting old jobs.[98]
- Assisting workers is harder where job losses are concentrated in particular geographical regions, such as a remote coal mining town, or where losses hit older or less skilled workers. Recent experience shows that these workers can end up among the long-term unemployed for many years, or drop out of the labour force

altogether. In these cases, the government may need to provide unemployment benefits, resources for job search, relocation assistance, improve the flexibility of the housing market, and provide geographic mobility programmes to get people back to work. In cases where long-term workers are unlikely to be able to retrain or relocate, the provision of social protection mechanisms to ensure workers receive adequate pensions and health insurance is key to a just transition and to overcome resistance to change.

- Reforms to ensure strong labour market institutions, to protect the most vulnerable workers, such as minimum wages and collective bargaining, are also important for a well-managed transition.

Experience has shown a range of risks that governments should be aware of when implementing such policies. For example, severance payments or loans need to be linked to suitable training that improves employability. Poorly designed training programmes and work creation schemes can develop the wrong skills and fail to increase employability of workers. Inadequate schemes can send negative signals to employers, who then avoid employing these workers. Multiple training programmes can reduce the motivation of workers to search for new jobs, and so these should be limited and well-targeted. And retrained workers can end up displacing existing workers.

Despite the complexities and pitfalls of such transition programmes, experience has shown that propping up declining sectors rather than actively managing structural change is counterproductive. Following are some brief examples from around the world.

- The **UK** experience of trying to shield its ailing ship-building, steel and car-making industries from adjustment in the 1970s illustrates the risks, including the heavy social cost of subsequent rapid restructuring of the economy

- **Germany** has in the past managed structural change by welcoming an appreciating exchange rate, which has put less productive firms under increasing pressure to innovate, as part of a process of "Schumpeterian" or continual change.

- **Japan** provides a good example of actively managing structural change in industries that are in decline. From 1987, the government provided long-term support to smooth the decline of what it called "structurally depressed" industries, including textiles and ship-building. This support reallocated resources within and outside the depressed industries; provided financial assistance to troubled firms; and mitigated negative impacts on the labour force.[99]

- In **Poland**, starting in 1990, the government restructured its loss-making mining sector through debt restructuring, mine closures and a radical reduction in employment. Initial reforms were resisted as they did not provide adequate support for miners. From 1998 the employment reduction programme was accompanied by incentives for firms to hire ex-miners; free retraining programmes financed by the European Commission; social benefits and severance payments, which were effective but very costly for government; loans and credits for ex-miners, which were mainly used for household consumption; job guarantees for miners close to retirement; and benefits for miners with long tenure, such as five-year voluntary vacations at 75% pay. These measures were designed in cooperation with the unions, which helped overcome resistance to the reforms. From 1998 to 2002 alone, some 53,000 workers left the industry and 33,000 received some form of support (total coal mining employment in Poland fell from around 390,000 in 1990 to 120, 000 in 2006).[100] The total cost of the 1998 programme was around €1 billion, which was probably far less costly than propping up the ailing industry for years to come. In 1998 the industry made a net financial loss of around US$ 1.5 billion but by 2004 had returned to profitability with a net financial profit of around US$730 million.[101]

- The **United States** instituted the US Trade Adjustment Assistance (TAA) programme several decades ago to help workers adjust to trade liberalisation. The programme provides: income support for over 100 weeks; training expenses; health coverage tax credit; wage insurance that "tops up" a potential lower income in a new occupation for up to two years for workers over 50 years of age; and costs associated with job search and relocation. This assistance package is designed to be targeted and calibrated to worker needs. However, recent assessment of its effectiveness finds mixed results.[102]

Evidence from the OECD suggests that a combination of a carbon price with revenue recycling to productive uses, and fair transition policies which help workers adjust to change, could help offset the employment impacts of a low-carbon transition.[103] They model the economic costs of a carbon price across OECD countries, assuming a moderate carbon price in 2030 with lump-sum transfers, and find that markets with just transition policies and more responsive labour markets as a result, could see as little as a 0.78% fall in the level of GDP and a 0.32% fall in employment. In one scenario with revenue recycling through reduced labour taxes, there was a small but net positive impact on employment. In contrast, rigid labour markets could see a 2% fall in GDP and a 2% fall in employment in 2030 compared with the baseline. The modelling suggests that ensuring a just transition for workers could significantly reduce the economic costs of transition.

A number of reports suggest that policies can boost the gross number of jobs in new and less polluting sectors. A recent study commissioned by the International Trade Union Confederation (ITUC) suggests that investing 2% of GDP in the green economy could create up to 48 million jobs in five years.[104] Bottom-up analyses, for example a recent study by the World Bank, finds that if Brazil sent all solid waste to sanitary landfills, with methane and biogas produced for electricity, it could create 44,000 new jobs and increase national GDP by over US$13 billion, and if India built 1,000 kilometres of new bus rapid transit lanes, it could create 128,000 new jobs and save 27,000 lives from lower air pollution and accidents.[105]

However, many such studies focus only on gross job gains in green sectors, and do not consider economy-wide impacts such as job losses in other, declining industries, or consider skill or location mismatch that could prevent workers filling these new jobs. Studies that do account for economy-wide effects, and take a general equilibrium approach, tend to confirm that the net employment impacts from a low-carbon transition would likely be small over the medium- to long-term. For example, a major survey of the literature for the European Commission in 2013, regarding a shift to low-carbon energy in 2050, concluded that there was no clear consensus about whether the overall net impact on employment would be positive or negative, but in almost all cases the impacts were small at the macroeconomic level. As indicated above, depending on how the revenues from carbon taxes are recycled back, fiscal reform could lead to a small net employment gain.[106]

That net effects are found to be small should not be surprising, given that the policy framework presented here is likely to induce a substitution between different types of production and consumption, away from more polluting and toward less polluting activities. Overall net employment gains or losses from such policies should be small. However, there will be changes in the numbers and types of jobs across and within economic sectors and, as is the case with all industrial change, workers will need to move from declining to expanding sectors, firms and job types. This gives rise to the need for policies to support workers in their transition.

Risks to competitiveness for early movers

Many governments and individuals are concerned that taking early or ambitious action to reduce greenhouse gas emissions will increase energy costs and leave an economy, sector or firm at a relative economic disadvantage, compared with peers in jurisdictions with less strict carbon regulation.

This concern needs careful consideration. Carbon pricing and investments in energy efficiency and renewable energy will raise costs for certain sectors. In response to climate legislation, firms and sectors producing carbon-intensive, globally traded goods and services could reduce their cost base by relocating production to countries with more relaxed environmental regimes. This is known as carbon leakage and it will limit the effectiveness of climate action as emissions do not fall but are merely displaced.

There is substantial evidence suggesting that the direct competitiveness impacts are small for a country which is an early mover in legislating climate policy.[107] Other factors, such as labour costs and access to materials and markets, are the primary drivers of firms' investment and location decisions, rather than climate change policy. In addition, relocation of physical plants or investment will make sense only if investors expect the asymmetric application of climate policies across trade competing countries to endure long enough to cover a sufficient part of the lifespan of the new capital. Otherwise, future policy changes might render such relocation decisions costly and unnecessary.

Many governments and individuals are concerned that taking early or ambitious action to reduce greenhouse gas emissions will increase energy costs and leave an economy, sector or firm at a relative economic disadvantage.

However, there is general agreement that a few carbon-intensive globally traded sectors and sub-sectors, which account for less than 5% of GDP in most countries, may see competitiveness impacts if stringent climate policy is enacted in one country but not in trade partners. These sectors include metals, cement, paper, and chemicals. Even for these carbon-intensive sectors, however, most studies fail to find evidence that current policies as applied, for example in the European Union or California, have had a significant effect on business competitiveness.[108]

Generally, ex-post econometric studies using empirical data from actual policies have found a smaller competiveness impact than was predicted by ex-ante models.[109] This is partly because carbon pricing and other environmental policies introduced so far have not been very stringent, as for example in the EU ETS, and partly because a large swathe of compensatory measures or preferential treatment was provided to energy-intensive industries to limit competitiveness impacts. In the European cement industry, for example, the EU ETS has not forced carbon emissions cuts in addition to those the sector would have made anyway as a result of general gains in best practice, because of the allocation of free

Box 9
Border carbon adjustments

Border Carbon Tax Adjustments (BCA) or Border Adjustment Measures (BAMs) are measures that would apply a tax on the carbon embedded in traded products and services, based on the CO_2 emitted in their production. Some commentators and governments have promoted them as a way to level the playing field and tackle competitiveness concerns given the lack of climate policies in some countries. They have also been suggested as a means to spur countries towards more comprehensive global climate action. But such BCAs are very controversial, especially where they are seen as discriminating against developing countries.

In economic theory, applying a BCA could internalise the costs of greenhouse gas emissions in their production, enhancing the efficiency of unilateral climate policy.[113] However, some modelling studies have found that carbon leakage would in any case be low, except under scenarios where very few countries took climate action. BCAs may therefore have a limited impact in reducing carbon leakage.[114] A recent cross-model comparison under the Energy Modelling Forum found that full BCAs could reduce leakage rates on average only by one-third.[115] Given growing climate action worldwide, even if patchy and uneven, it is increasingly unlikely that BCAs would have much
effect in protecting energy-intensive industries or reducing global emissions.[116]

There is extensive discussion in the literature on whether and how BCAs could be designed in a way that is compatible with international trade rules, for being non-discriminatory in their application and applying a consistent measurement of "comparable effort". A number of approaches to ensure WTO compatibility have been suggested, but such amendments may further limit the effectiveness or efficiency of the measure.

Recent guidance on how a BCA could be applied in practice highlights a number of significant technical challenges, in particular measuring production-related emissions and in setting the right tax levels.[117] Establishing an appropriate BCA would require identifying a carbon tax level commensurate with the local tax in the importing country, and accurate measurement or benchmarking of the production-related greenhouse gas emissions in the exporting country. The latter can be complicated. For example, regarding steel production, a basic oxygen furnace technology emits over four times as much CO_2 per unit of steel produced than standard electric arc furnace technology. One resolution could be to base the BCA on the carbon intensity of best available technology.[118] This may be seen as fairer, as it does not require discrimination among like products according to production processes.[119]

Ideally, a BCA would discount any explicit or implicit carbon "price" that may already be applied in the producing country, via regulations or other policies, but this would be incredibly difficult given the number and variety of different policies affecting greenhouse gas emissions. Recent analysis of "effective" carbon prices of various policy instruments has found the average costs of some regulations are over €400 per tonne of CO_2 abated.[120] Such uncertainty about the implicit carbon price in exporting countries, coupled with uncertainties about the exact emissions associated with production processes in countries without extensive emissions monitoring, may make the practical challenges and administrative costs of applying even a very narrow BCA prohibitive.

permits and a low-carbon price.[110] Also, as a result of this compensation, the scheme has not yet prompted relocation of cement production abroad. Indeed, energy- and carbon-intensive industry may have profited from the scheme as a result of large opportunities for firms to make windfall profits from carbon trading.[111] This compensation may have served to achieve early buy-in from industry, but it makes for a wasteful use of public funds in the long-run. A recent study of competiveness impacts on the European Chemicals Industry found that there are significant opportunities to reduce emissions by 80-95% in the sector by 2050, while at the same time maintaining or enhancing competitiveness.[112]

Concerns about the potential competitiveness impacts of climate policies remain, however, and governments must tackle them. The best option, from an efficiency point of view, is to apply climate policies across more countries, so that significant trade effects do not arise.

Another option, where international coordination does not exist, is the application of so-called border carbon tax adjustments, as described in Box 9. Given the absence of strong international coordination currently, it is inevitable that these are being discussed and examined. But they are "second" or "third-best" instruments, and the primary policy effort should be on achieving internationally coordinated policymaking, or targeted measures to mitigate impacts in the small number of sectors where differential carbon regulation makes a genuine difference.

Compensation schemes to smooth the low-carbon transition for truly vulnerable sectors can help to level the playing field and mitigate the impacts of asymmetric policy application across countries. Lessons from recent experience and economic theory include:

- This protection should not be provided through exemptions from carbon pricing, as this would reduce the incentives to reduce emissions, improve efficiency, and shift consumption toward lower carbon alternatives. Indeed, even energy intensive sectors are likely to become more productive in the long-run as a result of incentives to improve efficiency. Instead, some of the revenues raised through carbon pricing could be recycled back to companies in proportion to output. One study suggests that recycling approximately 15% of revenues to carbon-intensive, tradable sectors in the United States might be sufficient to eliminate any negative impact on profits.[121]

- Compensation to affected industry reduces the revenues available for other productive recycling purposes, such as cuts in distortionary taxes. Therefore, it is important that compensation mechanisms are well-designed and well-targeted, to avoid encouraging rent-seeking. Failure to recycle revenues in the most productive manner, for example by allocating allowances for free, will raise costs.

- In the case of cap and trade, most countries have opted for some free allocation of permits in emissions trading systems, given the relative simplicity and political popularity of such measures to level the playing field and protect against competiveness impacts for carbon intensive tradable products. In the EU, RGGI, and other schemes, there is now a shift towards decreasing the percentage of permits that are allocated for free.

- In the case of carbon taxes, compensation to selected affected industries could take the form of lump sum rebates. Other support could include grants to re-skill and retool production, especially for smaller firms, or support investment in low-carbon and energy efficient technologies.

- Industry compensation should be transparent, temporary and avoid overcompensation and rent-seeking. It can be designed in ways that enable industries and investors to adjust proactively, for example by consulting in advance with stakeholders, pre-announcing the policy and starting with low levels of carbon pricing but with agreed ratcheting up. This allows firms to plan investments accordingly, including investments in clean solutions, without prematurely scrapping carbon-intensive capital and shifting production to other areas.

In summary, how carbon pricing policies change comparative advantage will depend on skill levels, innovation and flexibility to respond to structural change and reallocate resources toward new markets. The impacts also depend on expectations: if others are expected to also take climate action soon, the competitiveness opportunities for early movers will be larger than if they are not. China and other countries have realised that a low-carbon economy can provide new business opportunities and help tackle growing resource challenges. This should encourage other countries to adopt stronger policy as both the expectations of costs of waiting and of opportunities rise.

Managing structural change requires strong institutional frameworks that are able to set clear and credible polices to guide expectations on the direction of change.

4.2 Strong institutions for clear and credible policy signals to align expectations around future growth

As introduced in Sections 2 and 3, managing structural change requires strong institutional frameworks that are able to set clear and credible polices to guide expectations on the direction of change. This is a prerequisite for cost-effective, low-carbon investment across the economy. Countries such as the UK and Mexico have legally enshrined climate change acts which provide a credible underpinning to the legislative process, tying the hands of future governments to the extent that they must accede to amend or repeal legislation if they are to renege on climate policy targets. Such institutions set clearer signals that align expectations on the future direction of growth and development.

Clear signals are especially important because of the long-lived nature of physical networks and infrastructures, in particular in energy generation, transport and the urban form. Because such infrastructure becomes entrenched in an economy and society, the pattern of development of infrastructure therefore builds on what went before, or becomes locked-in. Such "path dependence" is a common phenomenon in behaviours, technologies and networks. For example, some major road and rail networks in England were determined by choices made by the Romans two thousand years ago. Path dependence is also relevant to innovation, where new technologies tend to be based on existing networks. Path dependence can lead to positive synergies, through the development of new systems and networks. For example, the creation of cycling and walking paths and the presence of good public transport can, in time, drive a modal shift: politicians will then invest more in cycling and walking paths and public transport infrastructure, because there are more users, as shown in Amsterdam and Copenhagen.

The degree to which populations embrace a shift from historical norms will depend on their expectations. For example, people are more likely to embrace a shift towards low-carbon growth if they understand its virtues, policies are clear and credible and they expect others to move in tandem. They will see the benefits of supplying new markets; expect technology costs to fall; and anticipate easier access to finance for a sector that is no longer considered niche. Once enough decision-makers act in this way, the expectations become self-fulfilling: technology and business costs come down as a result of experience, learning and deployment. Political institutions and groups not making the transition can then find themselves at a competitive disadvantage. For example, China's significant investments in renewables in recent years have helped drive down technology costs and this has opened large new markets. The scale of other similar developments may be sufficient to start a domino effect, where by a critical mass of countries move, prompting all the others to move in an unstoppable transition.[122]

By contrast, if businesses expect no one else to move, they are less likely to be proactive. They will see high risks in the prospect of new markets, and the costs of acting are higher and the decision to hold back looks sensible. Many business leaders are calling for governments to provide this signal and adopt a clear, credible and predictable long-term price on carbon, against which they can plan investment.

Expectations determine which path countries take, whether they move quickly to innovate and take advantage of the opportunities of a low-carbon and resource efficient transition, or remain stuck in a hedging or waiting game. Both paths can look rational to individual agents, depending on expectations, although as the risks of climate change mount with time and new technologies emerge, the incentive to tip toward action will increase.

The degree to which populations embrace a shift from historical norms will depend on their expectations.

4.3 Policy risk and muddled expectations delay investment

As highlighted in Chapter 6: Finance, the infrastructure investment requirements for growth will be large over the coming decades. Global infrastructure investment required to achieve a broad-based, low-carbon transition is likely to be in the region of US$93 trillion (constant $2010) over the period 2015 to 2030. The estimated infrastructure investment required under a business as usual, high-carbon path is around US$89 trillion over the same period. Therefore an extra US$4 trillion will need to be invested over the next 15 years to shift the world onto a low-carbon path. The appropriate way to consider these additional investment costs is in the wider context of the dynamic net economic cost, as discussed in Section 2.1.

Government induced policy uncertainty from vacillation, inconsistency, sudden shifts in policies, or a belief that there may be such shifts in the future, can prevent or delay financing for these investments. Along with market failures and the risk of government failure, this is one of the biggest barriers to investment. Some European countries, notably Spain, have dramatically reduced renewable energy support recently, sometimes retroactively. Investors are confronting the risk that policy changes will render some investments less profitable or even loss-making. This policy risk is likely to reduce investments in renewable energy compared to what would otherwise be the case. It should be noted, however, that many of these European countries have faced extraordinary budgetary pressures in the wake of the financial crisis, and there is an argument that renewable energy developers should share some of the burden of austerity.

Chapter 6: Finance explores in detail how governments and international finance institutions can take some share of the financial and regulatory risk of developing low-carbon technologies. Such assistance can provide a signal of the government's commitment to the policy: if the policy were reversed or failed to deliver, the public sector would stand to lose. Government-backed infrastructure banks and green investment banks have a particular role. As well as increasing a government's financial commitment to the policy, such banks can develop dedicated expertise in clean infrastructure finance, something that is often lacking in the more traditional private finance sector. They can draw on strong networks to convene different coalitions and sources of finance. And their capital structure allows them to take a long-term view. If they are combined with well-coordinated, clear and credible policies, and strong institutional governance, they can foster rapid change.[123]

Government induced policy risk can prevent or delay financing for low-carbon investments. Along with market failures and the risk of government failure, this is one of the biggest barriers to investment.

For much of the world, now is a good time to support resource-efficient investment. There is no lack of private money seeking positive returns, with real, risk free interest rates at record lows, or even negative. There is, however, a perceived lack of opportunity, and developing a bankable pipeline of viable projects is always a challenge. The World Bank Energy Group is helping countries identify upstream renewable investment opportunities.

With many economies forecast to operate below capacity for the foreseeable future,[124] the potential to crowd-out alternative investment and employment is much smaller now than when the economy was operating close to full capacity.[125] Clear and credible structural policies now could restore confidence and generate growth, and accelerate the transition to a low-carbon economy.

4.4 Overcoming barriers to change

Political economy and institutional barriers

Political economy and institutional barriers prevent reforms and hamper efficient long-term decisions. Entrenched networks and technologies, as well as behaviours, institutions and lobbies work to resist change, even where it is in the economic interests of society. Powerful vested interests, with political influence, actively seek to prevent or delay these changes. Distributional impacts, a feature of any transition on this scale, create often vocal losers in the short-term, even when the long-term aggregate impact of the transition is largely positive. So-called entanglement with the existing high-carbon economy, for example where governments derive a large share of their fiscal revenues from fossil fuels, can also stand in the way of reforms (Box 10).

These types of barriers have been present throughout history. In the case of low-carbon change, the losers are generally concentrated and well-defined, and include carbon intensive fossil fuel industries and particular entangled governments, while the beneficiaries are dispersed and unorganised or cannot yet easily understand the gains. This is particularly true given that most of the gains from climate action now will be to the benefit of future generations, in the avoidance of costly climate damage.

Box 10
Carbon entanglement

For some governments royalty payments, taxes, and other revenue streams from upstream oil and natural gas rents are a major source of income. This can represent as much as 90% of total government revenues in some oil-producing countries, such as Saudi Arabia, Iraq, and Libya.[126]

In such countries, the structure of the economy and the government revenue base is highly dependent on continued fossil fuel production. Even in countries where fossil fuel revenues are much smaller, such as in Australia, Canada, and the Netherlands, where they represent under 4% of total government revenues, there are often policies in place to actively discover and exploit new fossil fuel reserves. This is likely to increase dependence on this source of revenue.

In that this affects policy decisions it is the institutions and politics which are the key barriers to aligning expectations and embracing change. Many politicians and commentators have ruled out the most efficient market-based policies, in particular explicit carbon pricing, based on judgments of what might be politically feasible, without those judgements being made explicit and their validity examined. Some of the underlying assumptions are being challenged, however, in countries that are forging ahead and learning how to compensate losers and manage existing vested interests effectively. Such lessons include designing transitory support with a pre-announced phase-out to avoid creating a new class of vested interests. In the future, the barriers countries face today may be viewed in the same light as other reforms once perceived as politically impossible, such as public bans on smoking.

Behavioural psychology provides broad and high level lessons and ideas for how to overcome political economy barriers to change.[127] A combination of the following may be needed, beyond evidence that this is good policy:

- Trusted leaders across society, including community leaders, Heads of Government and Ministers, and labour, military and religious leaders, telling a convincing story that appeals to the public intuition, thereby empowering and inspiring people to take action;
- Key countries (and businesses) taking the lead and acting strongly, encouraging others to act through the power of example, with leaders recognising "moments of power", where people are more willing to listen, consider the arguments, and commit;
- Smaller communities, cities and regions setting strong examples and providing social proof for others, through experimentation, learning and discovery, of the benefits of more locally controlled networks for distributed energy, food production, waste management, transport coordination and stewardship of natural capital. Some relatively poor regions may turn out to be pioneers of this new, more ecological economy;[128]
- Involvement and actions by key decision-makers who have a reputation for "getting things done";
- Engagement of the young, including their power to pressure leaders to do more. Examples include the UN Major Group for Children and Youth;
- Encouraging public discussion and reasoning on policy and standards of behaviour, including a better understanding of social and personal responsibility and values. This includes discussion on the multiple benefits of policy and transparency on the short-run adjustment costs and on our willingness to confront the challenges.

- Social compacts between governments and community organisations, labour unions, civil society groups, to ensure an inclusive and just transition.

Government liability risk, as insurer of last resort

Overcoming barriers may require a greater awareness of the risk of the alternative from inaction or delay, including large contingent liabilities for governments. Private insurance covers only a fraction of the possible climate-related or severe weather event losses. Governments would end up bearing the residual risk, as insurers of last resort. That residual risk is often hidden, but it is likely to grow, for example as homes and other infrastructure lose their value as a result of climate impacts including rising sea levels and more frequent floods and storms.

There is a related risk that the long-run impacts of climate risk could hit government credit ratings in some countries. Downgrades are likely to manifest through lower economic growth, weaker external performance, and increased burdens on public finances. This is likely to be most damaging for low-income countries, particularly in Africa and Asia, in part because of their higher exposure to climate risk, and also because of their inherently more fragile credit ratings. A measure has been devised to assess potential sovereign vulnerability. The measure is composed of three variables: share of population living in coastal areas below 5 meters of altitude; the share of agriculture in national GDP; and a vulnerability index measuring susceptibility to adverse climate impacts, based on exposure, sensitivity and adaptive capacity. The 10 most vulnerable nations are Cambodia, Vietnam, Bangladesh, Senegal, Mozambique, Fiji, Philippines, Nigeria, Papua New Guinea and Indonesia.[129]

Overcoming barriers to low-carbon change may require a greater awareness of the risk of the alternative from inaction or delay, including large contingent liabilities for governments.

A recent study attempted to quantify local and national US government costs from climate change.[130] The "Risky Business Project" focused on the impacts of storm surges, heat waves and sea level rise on particular regions and sectors, such as agriculture in the Mid-West, and coastal infrastructure in the Gulf of Mexico. One of the main conclusions was that climate change would put government budgets at risk, as the insurer of last resort, in the same way that countries were forced to use government balance sheets to bail out the banks in the financial crisis of 2007-2008. Illustrating the scale of potential risk, the report estimated that current trends in global greenhouse gas emissions would see stronger storms that could result in an additional US$2 billion to US$3.5 billion in property losses per year by 2030, along US eastern and Gulf coasts.

5. Better metrics and models for better macroeconomic management

Better metrics and models are necessary to steer a low-carbon transition. Regarding metrics, as is often stated, we cannot manage what we cannot measure. Regarding models, we cannot assess the likely impacts of what we struggle to predict.

5.1 GDP is a limited measure of changes in welfare

There is a growing realisation that macro-economic statistics, such as those based on GDP, are useful but do not provide policy-makers with a sufficiently detailed picture of economic and societal well-being. For example, an overreliance on the GDP statistic can promote an excessive focus on increasing this measure, potentially at the expense of other important aspects of welfare and development.

The GDP measure has advantages and disadvantages, here briefly described.

GDP has merit as a key indicator of living standards. Shrinking GDP implies lower incomes, and possibly idle factories and rising unemployment. Furthermore, GDP is a well-known indicator and is consistently measured. It also correlates fairly well with many elements pertinent to social welfare such as happiness, poverty reduction, gender equality and social mobility. On the other hand, GDP is a measure only of the flow of production, income and expenditure, not the stock of assets or wealth. As a result, it will fail to register deterioration in a country's natural resources. Furthermore, some services derived from these assets as flows are not adequately valued or priced, and so are not registered or are under-represented in the income accounts. Such flows include environmental goods and ecosystem services. Nevertheless, as relative prices change and appropriate policies such as carbon pricing are implemented, the value of environmental services will begin to rise, increasing their price weight in the measure of real GDP.

Even where market prices are absent, statistical agencies can value non-marketed activities and bring them formally within the national accounts. For example, until recently there were few direct estimates of the output of the public sector activities that were not generally sold on the market, including for example police output or education. As a proxy, inputs were used to estimate output, with no explicit measure of productivity change. Since then, statistical agencies have developed a range of measures from educational attainment, medical results and crime statistics, to capture public sector value. Similar improvements can be expected to evolve to measuring environmental services, and include these within GDP.

However, GDP remains just one indicator among many attempting to quantify the variables that society cares about, and its limitations make it important to develop and use other, complementary indicators. A number of countries and organisations have been making progress in establishing a more representative set of indicators to measure progress, building on the recommendations made in 2009 by the Commission on the Measurement of Economic Performance and Social Progress, also known as the Stiglitz-Sen-Fitoussi Commission. Those recommendations recognised that no informative assessment of welfare can be reduced to a single dimension. A practical and informative alternative would be to monitor several indicators, in addition to GDP.

There are many suggestions on how to expand and improve the range of metrics for better decision-making. Some are being implemented.

- Studies by the OECD have proposed broad frameworks of indicators, to assist decision-makers manage growth while at the same time considering social and environmental dimensions.[131]

Macro-economic statistics, such as those based on GDP, are useful but do not provide policy-makers with a sufficiently detailed picture of economic and societal well-being.

- The World Bank has developed an adjusted net savings (ANS) metric, which measures the net rate of saving after taking into account investments in human capital, depletion of natural resources and damages caused by pollution.[132] The indicator provides an assessment of an economy's sustainability based on the System of National Accounts (SNA), a framework finance ministries use on a regular basis.

- Countries have established through the United Nations a System of Environmental-Economic Accounting (SEEA), which contains internationally agreed concepts, definitions, classifications, and accounting rules for producing internationally comparable statistics on the environment and its relationship with the economy.[133] A multi-year process to revise the SEEA is underway, with the participation of various international organisations. The first element, a Central Framework, was adopted by the UN Statistical Committee in 2012.

- The US states of Vermont and Maryland have adopted the "genuine progress indicator" (GPI), an adjusted economic measure, to monitor welfare, and are using it to inform legislative and budgetary decisions.[134] The GPI uses personal consumption expenditures, which is a measure of all spending by individuals, as its baseline and makes more than 20 additions and subtractions to account for factors such as the value of volunteer work, and the costs of divorce, crime and pollution.[135]

The choice of metrics needs to reflect the specific demands of decision-makers. In the case of change over the coming decades, various specific indicators will be needed to allow decision-makers to evaluate progress in transitioning toward a low-carbon economy. For example, an indicator such as environmental tax revenue as a share of GDP could be useful to monitor progress in internalising environmental externalities.[136] A list of specific indicators could span carbon and energy intensity, share of renewables, pollution and environment indicators, as well as economic indicators linked to low-carbon policies, to provide a comprehensive picture.

Some countries are starting to measure natural capital. England's Natural Capital Committee (NCC) is tasked with advising on how to integrate natural capital into the English economy and the UK Office of National Statistics (ONS) has released some preliminary work valuing part of the UK's natural capital assets.[137] The valuation of natural capital in government accounts would enable a more comprehensive assessment of the total wealth of a country, and better identify where policy is needed to improve the quality and quantity of natural capital.[138] In parallel, better measures of exposure to climate and other environmental risks are also needed, covering intrinsic vulnerability, system resilience, and contingent liabilities affecting the public balance sheet.

The private sector can also be involved, through the development of corporate natural capital accounts that document an organisation's ownership and extended reliance on natural capital, together with related assets and liabilities. This would allow for a more comprehensive assessment of the value of corporate assets and enable better management of business operations.[139]

The financial statements produced by firms also fail to provide all the information investors need so they can assess risks and opportunities and allocate their capital efficiently. For example, there is no standardised system of sustainability accounting that provides an interested investor with reliable information on an automobile company's investments in fuel efficiency and electric vehicles. This is not disclosed in a standardised way, and may not be disclosed at all.[140] Cities face a similar but currently much greater problem, given the lack of standardised accounting frameworks to measure economic and environmental impacts at the urban level.

5.2 Economic modelling can significantly undervalue the net benefits of climate action

Researchers working in academia, policy institutes, and Finance Ministries use a range of economic models to provide economic forecasts, and to simulate the effects of policy or other developments. Relevant questions that they seek answers to include, how would the economy change if a policy was introduced, relative to some counter-factual, for example with the introduction of a carbon price? Or how might the economy respond to an energy price spike?

There are many different types of applied economic models with different strengths and weaknesses. Applied economic models are essentially simplified frameworks to describe the workings of an economy. They are an essential tool to help us formulate, examine and understand interactive relationships.

Economic modelling can help to shed light on what types of policy measures are likely to be lower cost, or more effective. Cross-model comparison exercises such as those undertaken for the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), or through Stanford University's Energy Modelling Forum, can provide insights about, for example, the driving forces behind different cost estimates of climate change policies, as well as about the range and nature of the uncertainties involved. However, economic models also have a number of limitations, and when used inappropriately or without a proper understanding of their assumptions and relevant caveats, can lead to poorly informed policy decisions.

Climate modelling involves the use of Integrated Assessment Models (IAMs). They are "integrated" because they bring together science (climate and impact) and economics models. In this way their aim is to utilise information from diverse fields of study including climate science, economics and technology in order to assess the impact of actions such as policies on human welfare through time. But there is no rigid specification for an IAM; the term describes a whole array of diverse heterogeneous models developed by different groups in different ways that try and capture features pertinent to the climate story. Increasingly, decision-makers are turning to IAMs to inform options for tackling climate change.

Two main kinds of economic models have traditionally been deployed in IAMs when they are used to assess the impact of energy and environment polices on the economy. These are commonly referred to as "top-down" and "bottom-up" economic models. More recently, a number of "hybrid" models have also been developed, combining features from top-down and bottom-up models. Most economic models used in IAMs have reduced form equations to characterise the drivers of key variables such as greenhouse gas emissions, global mean temperatures, the damages caused by temperature changes and their impact on social welfare, as well as the costs of abating emissions.

Bottom-up models contain a detailed, technological treatment of the energy system. The models aim to minimise the costs of a policy goal by choosing the cheapest technologies to meet final energy demand for a given level of energy services under certain greenhouse gas emissions constraints. They do not contain a behavioural component, and often ignore partial as well as general equilibrium costs and trade effects.

Top down models attempt to characterise overall economic activity by applying a theoretically consistent description of the general economy. Because they try to represent the entire economy, by simulating selected representative households and the production and sale of goods and services, they are by necessity less detailed than bottom-up models when it comes to individual components, and tend to aggregate technologies into a simple production function. Three types of top-down models dominate estimates of climate policy costs: computable general equilibrium (CGE) models; macro-econometric models; and neoclassical growth models, including so-called overlapping generation models. They all provide simplifications of reality by condensing complex relationships into a few equations that are easily understood and manipulated. This helps simulate key relationships, but means they often miss the full array of dynamic substitution options available in the transition to a low-carbon economy.[141]

Economic models have a number of limitations, and when used inappropriately or without a proper understanding of their assumptions and relevant caveats, can lead to poorly informed policy decisions.

Most CGE models start from the assumption of an economy where resources are already efficiently allocated, for the good reason that it is not easy to model properly the real and dynamic world of multiple imperfections and numerous market failures. The effects of policy reforms are thus judged against the assumed starting point of an efficient economy. Such results, while interesting, need to be used cautiously as a guide to policy when one is judging the results of reform versus non-reform in a highly imperfect and inefficient world.

Notwithstanding the limitations of models, GDP costs of climate action look like "background noise" when compared with the strong underlying growth that the global economy is likely to experience over the coming 15 years.

Such shortcomings have been examined, regarding the use of UK Treasury's CGE model to assess the short-run cost of UK climate policies. This analysis illustrated the limiting assumptions of the model. It showed that including the values of health benefits from reduced air pollution and the value of carbon emissions that are not traded in the European Emissions Trading System (EU ETS), would reverse the model results - the benefits of the policy would exceed the costs.[142]

Notwithstanding these limitations, the most recent modelling, highlighted in the Intergovernmental Panel on Climate Change 5th Assessment Report, finds the economic costs from taking ambitious climate action consistent with a 2°C path are in the order of 1-4% of global GDP (median: 1.7%) in 2030, relative to a baseline without climate policy.[143] GDP costs of this magnitude look like "background noise" when compared with the strong underlying growth that the global economy is likely to experience. For example, the next 15 years could see the size of the global economy increase by around 50%. And when the benefits of acting are factored in, including variables such as better local air quality, the net costs are likely to fall further.

While the costs of climate action are small, they will vary by country. They are also likely to rise sharply with delay. If global action to reduce emissions is delayed until 2030, global CO_2 emissions would have to decrease by 6-7% per year between 2030 and 2050 in order to have a reasonable chance of staying on a 2°C path.[144] Such rates of reduction are unprecedented historically and are likely to be expensive (estimates of delay suggest an average annual consumption growth loss of around 0.3% in the decade 2030 to 2040, compared to a loss of less than 0.1% over the same period if we act now).[145] In addition, many of the modelling scenarios assume the immediate implementation of an efficient, globally co-ordinated policy response, for example they assume a uniform global carbon price is implemented simultaneously across all countries and all technologies specified in the model assumptions are available. Delay in immediate implementation of a single global carbon price or technology constraints raises the economic costs, as does misguided, inconsistent or poorly designed policy, including poor coordination with the wider policy framework for managing change. In contrast, providing a clear, well-coordinated and early policy-direction can help build investor confidence and encourage innovation, which should bring economic costs down in the long-run.

A number of recent modelling efforts have started to make progress in better reflecting the benefits of climate action, including the multiple benefits of reduced air pollution and related health costs, which are usually ignored in such modelling. Others have made progress in recent years in better modelling endogenous technical change, a critical factor in understanding the potential economic growth and greenhouse gas impacts of long-term climate policies. But significant data limitations and technical challenges remain (Box 11).

As further progress is made to improve and enhance the modelling frameworks, they will be able to capture better the net economic benefits of efficient and ambitious climate action. Even so, no single model will ever tell the full story of how an economy could transition dynamically to a low-carbon economy. These models adjust at the margins based on our current understanding of the economy. As a result they tend to over-estimate costs. Ex post analysis of the costs of environmental policies tend to find that they are significantly cheaper than ex ante analyses suggest, because models fail to capture the broad range of innovations in technologies, behaviours and institutions that may occur as a result of strong and coherent policies. Models therefore need to be seen as just one input to inform analyses and discussions about policy reforms; they do not constitute a fully comprehensive assessment.

5.3 The history of change

Quantitative models are one part of the tool-kit required to understand the relationship between growth and climate policy. History can also help to better understand the long-run transformation story described in this chapter and report, providing valuable insights on managing change. We have the advantage of learning from several transformations since the industrial revolution,[152] including the current information and communications technology (ICT) revolution, and there is a rich Schumpeterian tradition of analysis on medium- to long-run technological transformations.[153] This tradition argues that capitalism develops through innovations by entrepreneurs, namely, the creation of new production technologies, new products and new markets, with new and innovative firms and progressive ideas displacing existing firms and ideas from the previous period.[154]

Box 11
Challenges and progress in modelling the net economic benefits of climate action.

There is an extensive literature on modelling the costs of policy action and the avoided damage costs from reduced climate impacts, most notably the quantification of costs and benefits of policy action outlined in the 2007 Stern Review.[146] Much less has been done to analyse how climate impacts and mitigation might affect economic growth in specific sectors.

Regarding climate risks, difficulties encountered when integrating an appropriate assessment of impacts into economic models include continued uncertainty regarding the magnitude of and probability distribution of climate impacts, especially at the regional level, and challenges in converting the impacts to monetary values. The traditional approach of valuing static damages from climate change fails to account for the impacts of these damages on the drivers of future economic growth. For simplicity, growth is usually, and implausibly, assumed to carry on at some predetermined baseline rate. This leads standard modelling to systematically underestimate the case for urgent action.[147] A recent study found that reflecting some of the potential impacts of climate change in a dynamic CGE model incurred global GDP losses (damages) of 0.7% to 2.5% by 2060, and with much larger sectoral and regional variations.[148]

Regarding the net costs of mitigation, another set of challenges emerge. One problem is that many standard Integrated Assessment Models (IAMs) do not adequately model the drivers of innovation.[149] Many recent climate economic models have attempted to incorporate innovation.[150] However, these models usually treat innovation as an economy-wide, aggregate phenomenon rather than firm-level and sector-specific process with complex spillovers and interactions across sectors, institutions and behaviours. These could lead to a number of complementarities and scale economies which enhance the low-carbon impact of innovation. Hence, predictions of IAMs are biased towards innovations that seem more likely from the point of view of today, thus underestimating their likely impact on costs.

Properly accounting for path dependencies makes early intervention in the innovation system more desirable, even under the higher discount rate assumptions made by some economists. This is because if we delay intervention, then as time progresses, conventional technologies will become more entrenched and making a low-carbon transition more expensive. Inadequate modelling of innovation has the potential to significantly over-estimate the cost of future low-carbon technologies. See the discussion in Chapter 4: Energy on the underestimation of the recent large declines in renewable energy costs.

The empirical literature on how changes in climate variables affect economic activity is slowly growing, and will help further improve future modelling exercises. The OECD is presently undertaking a multi-year exercise to incorporate climate change and environmental degradation including air pollution, water scarcity and biodiversity loss into an in-house dynamic CGE model. The aim of the CIRCLE project (Cost of Inaction and Resource Scarcity; Consequences for Long-term Economic Growth) is to identify the impacts of environmental degradation and resource scarcity on long-term economic growth. The adjusted baseline projections for GDP, reflecting the impacts of climate damage, have been already included in the OECD@100 project, which informs the OECD Economic Department growth projections.[151]

Box 12 provides an informative neo-Schumpeterian interpretation offered by Carlota Perez, a member of the Global Commission's Economics Advisory Panel (EAP). Today the world is likely to be mid-way along an economic transformation driven by the ICT revolution, blending digitisation with distributed energy and more circular business models.

Overcoming barriers to low-carbon change may require a greater awareness of the risk of the alternative from inaction or delay, including large contingent liabilities for governments.

As described in Chapter 7: Innovation, the present ICT transformation has significant implications for the shape of future economic growth and development, and for opportunities to tackle climate change. This is of profound significance for all countries, in particular for emerging nations such as China, which is keenly aware of this moment in history, is thinking systematically about engineering a low-carbon transition, and is starting to reflect this objective clearly through its 5-year plans and other institutional mechanisms.

Box 12
Lessons from economic history: a neo-Schumpeterian view

In the middle of the depression in the 1930s it was difficult to recognise the vast range of viable innovations connected with plastics, energy intensive materials, energy using devices and the new mass production methods that were capable of creating a consumerist way of life that could fuel economic expansion for decades. Today an equivalent, perhaps even greater, technological potential resulting from advances in information and communications technology (ICT) is yet to be unleashed and its consequences are equally difficult to prefigure. The potential of ICT to transform industries and activities has barely been realised.

Historically, every technological revolution has led to a radical change in consumption patterns, reflecting the range of products shaped by new technologies. However, as with every other aspect of paradigm shifts brought by each technological revolution, the processes of change are slow and uneven and only intensify when society in general assimilates the new possibilities and gives a clear impulse to the transformation. What is lacking today is a policy direction that will tilt the playing field, in a manner similar to the way in which policy for suburbanisation did in the post-war boom. It is not easy to steer such change. It requires deep understanding and bold leadership. Both businesses and politicians need to be persuaded that it is in everybody's interest – medium and long-term – to build a new positive-sum game. It was not any easier to set up the conditions for the flourishing of the previous mass production, suburban revolution. But measures taken then, such as public roads, mortgage guarantees, subsidies, new taxes, official labour unions, expansion of public services, incomes policies and unemployment security, created the demand conditions for mass consumption as well as for tax-funded military innovation. Structural change in a low-carbon direction globally needs systematically important countries to take policy action that tilts the playing field decisively. With clear, credible and stable policies stimulating energy and resource saving, a massive wave of mutually reinforcing low-carbon innovations driven by ICT could be stimulated across all industries. Unleashing the transformative power of ICT to bring a sustainable global boom could do for the world population what the post-war golden age did for Western democracies.

6. Concluding remarks and recommendations

This is a story about embracing and managing the next transformation of the world economy, in a way that both fosters growth and development, and reduces the risk of dangerous climate change by reducing greenhouse gas emissions.

Achieving this outcome will require policy and institutional reforms to tackle market failures, particularly around greenhouse gases and innovation, align expectations and drive a more efficient and productive economy.

In the past, countries that have overcome the barriers and political constraints to implement clear and credible structural reform policy have outperformed those that resisted or failed to embrace change. The framework presented here is in the economic interests of countries seeking to prosper over the coming decades.

The Commission accordingly makes the following recommendations:

- National, sub-national and city governments, businesses, investors, financial institutions and civil society organisations should integrate this framework for change and climate risk into their core economic strategies and decision-making processes. This includes decision-making tools and practices, such as economic and business models, policy and project assessment methods, performance indicators, and reporting requirements.
- Governments should design clear, credible and well-coordinated reform packages centred on fiscal reform, including carbon pricing and subsidy reform, to align expectations and send signals throughout the economy on the direction of change.

More specifically, the Commission recommends that countries:

- Develop comprehensive plans for phasing out existing fossil fuel subsidies, essentially negative carbon prices. These should include enhanced transparency and communication and targeted support for poor people and affected workers. Developed countries could accelerate efforts to remove subsidies to fossil fuel exploration and production. Developing countries could explore innovative approaches with multilateral and national development banks on how to finance the up-front costs of reducing adverse effects on low-income households. Governments should build trust in the reforms by enhancing the delivery of services while subsidies are being phased out.
- Apply a clear and credible carbon price signal across the economy.

- Where political pressures for certain countries or sectors demand a lower price initially, ideally implement a predictable price escalator.
- Revenues from carbon pricing should be recycled to productive uses, for example cutting distortionary or poorly structured taxes. A share of the revenues should be prioritised to offset impacts on low-income households.
- Regulations, standards, "feebates", and other approaches should be used to complement carbon pricing. These can also help foster low-carbon change in countries for which even a low level of carbon pricing is politically or institutionally difficult, preferably with flexibility built in to facilitate the introduction of carbon pricing later.

- Governments should plan to put initial policies in place over the coming 5-10 years, and increase their ambition and efficiency as quickly as possible thereafter. The exact package of policies used in any country will need to reflect its specific realities and context.
- Major companies worldwide should apply a "shadow" carbon price to their investment decisions and look to cascade this shadow price through their supply chains.
- Countries should recognise and tackle the social and economic costs of the transition. Change on this scale will require policy to ease adjustment for vulnerable workers; in particular enhancing their ability to participate in faster-growing low-carbon sectors.
- Together with technical support from public international institutions such as the OECD, the World Bank and the IMF, national governments should accelerate the deployment of metrics and models that provide a more comprehensive, reliable analysis of potential climate risks to natural and societal capital, as well as the costs and benefits of climate action.

Endnotes

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To build momentum and demonstrate broad support for carbon pricing at the UN Summit on Climate Change in New York in September 2014, the

World Bank has issued a call on those countries, regions, companies and organisations that are applying some form of carbon pricing or that support carbon pricing to sign a statement to this effect.

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