Carbon pricing: how best to use the revenue?

Alex Bowen

Policy brief
November 2015

Grantham Research Institute on
Climate Change and
the Environment

Global
Green Growth
Institute

Grantham Research Institute on Climate Change and the Environment

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

Global Green Growth Institute

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

The Grantham Foundation for the Protection of the Environment

LSE The London School of Economics and Political Science

Contents

The author

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

Acknowledgements

This Policy Brief draws on research carried out at the Grantham Research Institute on Climate Change and the Environment with the generous financial support of the Global Green Growth Institute. It also draws on work commissioned by the OECD and presented as an Issues Note, 'Inclusive Labour Markets for Green Growth', at the OECD Green Growth and Sustainable Development Forum in November 2014. The author, however, is solely responsible for the analysis and views expressed, the recommendations to policymakers and any errors or omissions.

The author is grateful to Nils Axel, Bob Ward, Chris Duffy and Dimitri Zenghelis for their comments and feedback.

Executive summary

Carbon pricing could raise considerable amounts of new revenue, whether by taxation or emission quota auctioning. The European Union, for example, could raise over €150 billion between 2015 and 2025 – equivalent to 0.1 per cent of the likely cumulative GDP over that period. In the longer term, with carbon pricing applied more widely and the price of carbon rising, the revenues are likely to rise higher still, and could reach several percentage points of global income – well above the total receipts from all environmental taxes today.

This Policy Brief discusses how priorities might be set for spending these revenues. Advocates of particular environmental taxes have often suggested that the tax receipts could be used for spending on complementary green policies and/or cushioning any adverse impacts of the taxes. But they could also be used to help improve the tax-benefit system as a whole, to finance additional spending on other government objectives or to reduce outstanding public debt.

Carbon pricing should be part of a comprehensive policy framework to reduce greenhouse gas emissions. This framework is likely to include new spending commitments, which could be funded, to some extent, by revenues raised from carbon pricing. For example, governments may want to invest in new low-carbon public infrastructure and offer subsidies for energy efficiency improvements. The extra spending appropriate for any particular nation will depend on how its environmental policies have evolved. However, there is a strong case for all countries to increase spending on low-carbon research, development and deployment, particularly in nations with a comparative advantage in research activities – largely advanced industrial economies.

Rich countries could also use carbon pricing revenues to increase the flow of finance to developing countries to help them mitigate greenhouse gas emissions and adapt to climate change impacts, as promised under the UNFCCC.

It may be necessary to cushion adverse side effects of carbon pricing by making financial transfers. Carbon pricing hits some people's real incomes, some businesses' profits and some rents, notably those received by fossil fuel owners. Governments need to consider whom, if anyone, to compensate on the grounds of equity or political pragmatism (in order to 'buy off' political lobbies – at home or abroad – that would otherwise obstruct climate policies).

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

Carbon pricing revenues can also be used to reduce the economic disincentives inherent in tax-benefit systems. This can in principle give rise to a 'double dividend' – the environmental benefit and the reduction in deadweight economic losses from other taxes or benefits – which can be weighed against the deadweight losses from carbon pricing itself.

However, governments need to consider carefully where the greatest distortions arise in the rest of their tax-benefit systems and why they are present in the first place. This issue arises regardless of the existence and level of carbon pricing and presents a separate question about the system's efficiency. For example, a reduction in payroll taxes, designed to reduce labour supply disincentives from carbon pricing, is widely advocated. But pre-existing distortions from the structure of capital taxation may be worse.

At the same time, governments need to distinguish between the merits of reducing some forms of capital taxation on the grounds of efficiency and the merits of compensating firms hit by carbon pricing for pragmatic political reasons. International competition in a world of uneven carbon pricing complicates the picture.

Countries with a pressing need to reduce the ratio of public debt to GDP may want to use carbon pricing revenues to reduce their budget deficits. There is, however, debate about the level at which a high debt ratio becomes a threat to economic performance and how fast budget consolidation should take place. Governments need to consider what signal this approach would send to taxpayers about why they raised carbon taxes in the first place – there is a danger of cynicism about new taxes supposedly to improve economic efficiency. In less indebted countries, new tax revenues, which relax the government's financing constraints, may simply be used to increase spending on desirable public goods.

Following a single, simple rule for carbon pricing revenues – one that does not vary over time or according to circumstance – is unlikely be the optimal approach. In particular, strict earmarking, or 'hypothecation', of carbon pricing revenues is unlikely to be a good idea in the long run, given their uncertainty and time-varying spending needs. For example, there is no reason why finance for low-carbon R&D should be of the same order of magnitude as carbon pricing revenues or follow a similar trajectory over time. Governments should assess and re-assess regularly what best to do with new revenues.

Nevertheless, the potential revenues of carbon pricing give societies many attractive options for pursuing a range of goals (related to the environment or otherwise) in addition to the environmental benefits of carbon pricing.

1. Introduction

Putting a price on greenhouse gas emissions – carbon pricing – is a powerful tool to encourage reductions in emissions and innovations in low-carbon technologies across all sectors of the economy in a market-friendly way (Bowen, 2011). It can also raise considerable amounts of revenue for governments, which in turn raises a crucial question: how should these new revenues be spent?

This question matters because the potential level of revenue from pricing carbon, whether by taxation or emission quota auctioning, is considerable. For example, Point Carbon estimates that, after recent reforms, auctioning emissions quotas in the European Emissions Trading System (EU ETS) will raise over €150 billion for the 28 nations of the European Union between 2015 and 2025 (about 0.1 per cent of likely GDP over that period).[1] In the UK, receipts from auctioning could amount to over £5 billion per year by 2030, well over 10 per cent of the current level of environmental tax receipts (Cambridge Econometrics, 2014) – perhaps around 0.2 per cent of GDP.[2]

In the longer term, with carbon pricing applied more widely across the European economies and the price of carbon rising, the revenues are likely to be higher still. Projections of global revenues from pervasive carbon pricing in models of stringent climate change mitigation[3] suggest that they could reach several percentage points of global income, well above total receipts from *all* environmental taxes today (Bowen et al., 2014). Although models disagree about the details, they generally show revenues from optimal global carbon pricing rising for several decades (e.g. Edenhofer et al., 2009). Policymakers could use the growing revenue stream from carbon pricing in many ways – and competing voices are already lobbying to direct the stream towards particular purposes.

One approach would be to allocate spending under three headings: (1) spending on complementary environmental policies; (2) cushioning any adverse impacts of carbon pricing; and (3) improving the tax-benefit system as a whole. But revenues could also be used to reduce outstanding public debt or spent on social objectives that have nothing to do with climate change. Reforming the tax-benefit system and public debt management are of course issues that arise irrespective of the need for carbon pricing and raise questions that are quite separate from the ones raised by the need to make growth green.

This categorisation is reflected in public debate. Environmentalists point out that carbon pricing is only one of several tools available to policymakers aiming to stop human-induced climate change in a cost-effective way and some of the other tools require government financial support. Thus the European Union insists that at least half of the revenues from EU ETS auctions should be spent on climate- and energy-related purposes.[4] Carbon pricing in developed countries could also be a source of funding for the climate finance promised to developing countries.

1 €150 billion figure estimated by Point Carbon, as reported by Reuters (7 May 2015) in "Greece, other EU strugglers emerge winners from carbon reforms-data." EU GDP is assumed to grow at an average real rate of 1.75% per annum from 2014.

2 This figure is in terms of the price level in 2014; with inflation between now and 2030, it would be higher in nominal terms.

3 By 'stringent' is meant 'sufficient to put the world on a trajectory towards stabilising the concentration of greenhouse gases in the atmosphere at 450ppm CO_2 equivalent,' the concentration giving around a 50 per cent probability of the planet warming by 2°C or less in the long run.

4 See http://ec.europa.eu/clima/policies/ets/cap/auctioning/index_en.htm

Yet some advocates of carbon pricing (e.g. the Citizens' Climate Lobby) have argued for a revenue-neutral citizen's dividend, conscious that carbon pricing can increase the cost of living and that citizens are suspicious that carbon pricing is just another device to increase taxation. Some others discuss targeting new payments to either those households particularly hurt by the introduction of carbon pricing (see, for example, Advani et al., 2013a) or the firms suffering from reduced demand for carbon-intensive products. Several economists have argued that other, more distortionary, taxes can be reduced, thus achieving a so-called 'double dividend' of climate change mitigation and a more efficient tax system (Goulder, 1994). Yet, at a time when many governments are trying to stabilise or reduce public debt-GDP ratios, finance ministries may prefer to use revenues to narrow their fiscal deficits more quickly.

This Policy Brief examines the arguments for the three main classes of spending proposals. It also discusses the merits of formal earmarking or 'hypothecation' of revenues. The pros and cons of different proposals are likely to have different weights in different countries, so this brief concludes with some thoughts about the questions policymakers need to answer before they decide which proposals to adopt.

2. Spending on environmental policies: the domestic aspect

Carbon pricing is only one of several policies that should be put in place to encourage a cost-effective transition to a low-carbon world. A coherent, inter-related set of measures is required. There are several market failures that warrant intervention, such as underinvestment in R&D because of the inability of innovators to capture all the economic returns to new ideas and under-investment in 'learning by doing' because firms cannot capture all the benefits of learning (Stern et al., 2007). The transition to low-carbon growth may also require the provision of finance and financial guarantees by governments to reduce the perceived risk of investing in new low-carbon production and other barriers to the financing of low-carbon investment. Low-carbon energy systems are likely to require new or re-engineered networks in electricity supply and distribution, where a public 'pump priming' initiative may be needed to reassure investors that the networks will be profitable at scale. Some elements of the energy supply system may be public goods that would be undersupplied by competitive private markets. Similarly, public intervention may be necessary in land planning, for example, to ensure that cities choose low-carbon transport and infrastructure options (Global Commission on the Economy and Climate, 2014).

All of these supplementary policies may require subsidies to the private sector or increased public spending, for which carbon pricing revenues may be able to provide the finance. India, for example, has decided to promote low-carbon innovation and is directing the revenues from its tax on coal into the National Clean Energy Fund, which is to be used for renewable energy-based projects and initiatives. Over the five years of its existence, the tax rate on coal has quadrupled and fund's size has grown to about US$ 6.7 billion. However, there is no reason why the scale and trajectory of the cost-effective policies needed alongside carbon pricing should be commensurate with the scale or trajectory of carbon pricing revenues.

Subsidies to low-carbon R&D are perhaps the most obvious candidate for spending the revenues from carbon pricing. Their importance in theory has been illustrated by Acemoglu et al (2012), who show that the socially optimal allocation of production to 'clean' and 'dirty' activities (e.g. production based on renewable energy and fossil-fuel energy respectively) over time can be implemented using a carbon tax, a subsidy to research into clean technologies, a subsidy on the use of machinery and other capital used in production and a resource tax. This combination of policy instruments speeds up the transition to clean production. It also means that the carbon tax can be lower than if it were the only instrument available. However, that means that there will be less revenue from carbon pricing and more spending on clean R&D.

A similar point has been made in less abstract contexts, for example by Fischer and Newell (2007), who compare a range of policies for decarbonising the US electricity industry. They find that, if only one instrument can be used, the ranking of instruments is roughly as follows: (1) emissions price; (2) emissions performance standard; (3) fossil power tax; (4) renewables share requirement; (5) renewables subsidy; and (6) R&D subsidy. However, they show that optimal policy involves a portfolio of different instruments targeted at emissions, learning and R&D. For example, without the subsidies for learning and R&D, the industry would not generate enough positive spillovers from learning and new ideas. With the subsidies, the carbon tax can be over one third lower (the authors do not report the net fiscal implications of the optimal policy mix).

Similar reasoning leads King et al. (2014) to emphasise the need for more R&D, noting that, "Even in the major international companies which manufacture solar and wind equipment, the ratio of R&D to sales is under 2 per cent, compared with over 5 per cent in consumer electronics and 15 per cent in pharmaceuticals." The authors argue strongly for a 'global Apollo Programme' of clean energy research to combat climate change, of a similar order of magnitude as the spending on the original Apollo space programme. It may make less sense for developing countries to spend as large a portion of GDP as advanced industrial economies on R&D, given that their innovation systems are generally less effective and that the proportion of their workforces qualified to undertake research is generally lower. However, developing countries do need to spend on facilitating knowledge transfer, building better innovation systems and tailoring innovation to their specific endowments and needs, which differ from those of advanced industrial countries. China's striking progress in patenting 'green' innovations (Dechezleprêtre and Martin, 2010) shows that such a strategy can be successful.

3. Spending on environmental policies: an international dimension

At the 2009 Copenhagen Conference of the Parties to the UN Framework Convention on Climate Change (UNFCCC), rich countries agreed to ramp up their assistance to developing countries for climate change mitigation and adaptation to US$ 100 billion by 2020. This element of the Copenhagen Accord expanded upon UNFCCC treaty provisions that obligated developed countries to cover the 'agreed full incremental costs' of implementing mitigation measures and to 'assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation.' While US$ 100 billion annually is unlikely to be enough to pay for the full incremental costs of measures in developing countries to keep the global temperature increase below 2°C (Bowen et al., 2014), it is nevertheless a substantial sum, not far below the current level of Official Development Aid as monitored by the OECD.

There is debate about the proportion of the promised figure that should come as grants from public funds and how much as private-sector finance, with developed countries tending to put more emphasis on the private sector's role. But despite that debate, carbon pricing revenues in developed countries could provide a useful source of climate finance, even though strict earmarking is unlikely to be helpful (see Bowen (2011) and Section 9 below on earmarking or 'hypothecation'). Carbon pricing in the developing world can also generate revenue for governments to finance the transformation of their energy systems in the event that political considerations prevent developed countries paying the bills. Projections derived from large-scale energy and growth models suggest that, region by region, carbon pricing is likely to be sufficient to pay for *all* the extra investment needed to expand energy supply, not just that part of the investment made necessary by choosing low-carbon options (in other words, the portion reflecting the incremental costs of climate change mitigation) (Bowen et al, 2014).

4. Cushioning adverse effects of carbon pricing: households

The case for carbon pricing rests on the way in which it alters relative prices and thus incentives to use carbon-intensive production methods and to buy currently carbon-intensive goods and services. However, it also hits people's real incomes, businesses' profits and the rents received by fossil-fuel owners. The impacts are unevenly distributed. This has consequences for the political economy of environmental policies (OECD, 2006).

The impact of carbon pricing on real incomes via higher consumer prices appears to be regressive – that is, lower-income groups lose a larger proportion of their real incomes than do higher-income groups, largely because energy tends to comprise a larger part of poorer families' expenditure. As EBRD (2011) reports, this conclusion emerges from studies based on input-output tables (e.g. Symons et al., 1994), econometric studies (e.g. Barker and Köhler, 1998) and general equilibrium models (e.g. Hassett et al., 2009) for developed countries. Gough et al. (2011) showed that in the UK direct and indirect emissions per capita across households rise less than proportionately with per capita income, so that carbon taxation is regressive. The regressivity is particularly acute for emissions associated with domestic energy usage, food and housing. A recent detailed study confirmed the broad conclusion for the UK (Advani et al., 2013b). However, there have been counter-findings (e.g. for the UK and Italy – but not Germany, France and Spain – in Symons et al., 2002) and the evidence suggests differences among countries. Flues and Thomas (2015) draw attention to these differences and the fact that taxes on transport fuels are not regressive everywhere, although taxes on heating fuels tend to be slightly regressive and taxes on electricity more so. The problem of the unequal incidence of carbon pricing may not be as pronounced for lifetime incomes, at least for fuel taxes (Sterner, 2012).

Lower-income groups in most nations tend to spend a larger proportion of their incomes on energy. But in low-income countries, the evidence for the regressivity of carbon pricing is less well established. Many of the very poor in the least developed countries do not use gasoline or diesel but traditional biofuels such as foraged wood (which would be difficult to subject to carbon pricing in the first place). However, kerosene is an important fuel for poor people in many countries. Dercon (2014) explores a range of potential conflicts in developing countries between green growth policies, including carbon pricing, and alleviation of poverty amongst the world's poorest people. There is a danger that carbon pricing would force up the price of and restrict access to energy. Raising the price of fuel for transport may discourage trade and the development of comparative advantages for poor countries in currently relatively carbon-intensive activities, such as metallurgical manufacturing processes and fishing.

However, existing subsidies to energy (except those to kerosene) in less developed countries tend to benefit the poor less and the well-off more in proportion to their income (Arze del Granado et al., 2012; OECD, 2014; Garcia Romero and Calderon Etter, 2013; Agostini and Jimenez, 2015). For fossil fuels, these subsidies can be thought of as 'negative' carbon prices. The World Bank, OECD and other agencies have carried out extensive research into the distributional effects of reducing energy subsidies (e.g. Vagliasindi, 2012a and 2012b). The research points towards various strategies that can help to offset any adverse impacts on the poor, for example, offering a targeted cash transfer to the poorest (not an equal dividend to everyone) at the same time as the energy price reform is implemented. Public outreach to explain the reasons for reform has been vital for success, too, as illustrated by the case of Iran (Guillaume et al., 2011), where cash transfers were deposited in around 19 million bank accounts but were frozen until the subsidy reform was agreed by the legislature.

The OECD has been carrying out detailed analysis of the impact of energy subsidies and the consequences of reducing them.[5] Following earlier studies (e.g. Mourougane, 2010), the OECD has been examining subsidy reform in a general equilibrium context, using the example of Indonesia, allowing for the second-round effects through changes in spending patterns and saving rates as subsidies are reduced, cushioned by different types of compensatory schemes. Provisional findings suggest that the form of compensatory scheme matters, with cash transfers to households better for growth and income distribution than either food subsidies or payments related to labour incomes. This suggests that a cash transfer system may be a valuable supplementary policy instrument when widespread carbon pricing is adopted.

This finding suggests some support for the idea of rebating some or all of the revenue from carbon pricing via a citizen's dividend, as advocated, for example, by the Citizens' Climate Lobby (CCL) in the US.[6] This organisation campaigns for a carbon fee with 100 per cent of the revenue being rebated each month on a per capita basis to every US person (or, more precisely, equal monthly per-person dividend payments to be made to all American households, with ½ payment per child under 18 years old and a limit of payments to two children per family). This would compensate for the regressive impact of carbon pricing because the dividend would be a larger share of a poor household's income, although it would be paid to rich and poor alike. CCL also points out that this would help people outside the labour force more than a reduction in payroll taxes, even though economic studies suggest that the latter would boost output a little more in the long run.

In developed countries with progressive tax-benefit systems, benefit recipients are protected to some extent from the impact of carbon pricing on their real incomes by indexation of their benefits. For example, Rausch et al (2011) point out that nearly all transfer payments in the US tax-benefit system are indexed to the general price level, so that they increase automatically when carbon pricing is introduced. Some two thirds of Canada's government transfers are directly tied to the Consumer Prices Index (Rivers, 2012), helping to cushion the effect of carbon pricing in British Columbia and Quebec. This type of indexation is more targeted than a citizen's dividend, which means that more revenue is left over for other purposes, but it does not help poor households not in receipt of benefits and does not generate the political pay-off from giving something back to all households. Nevertheless, some might argue that a robust, well-designed tax-benefit system reflecting society's preferences about income distribution and work incentives should be sufficient to cushion the impacts of all sorts of policy-induced price changes, including those resulting from carbon pricing.

5 See http://www.oecd.org/ctp/fossilfuelsubsidies.htm
6 See https://citizensclimatelobby.org.

Advani et al. (2013) review a number of studies of potential compensatory packages to accompany energy tax reform. They argue that, in the UK case, a more sophisticated approach than a per capita dividend or reliance on the existing tax-benefit system would beneficial. They propose an increase in the Value Added Tax charged on domestic consumption of energy and a new domestic gas tax, a combination designed to make carbon pricing more uniform across the economy and thereby more cost-effective. These changes would be complemented by a range of adjustments to several elements of the UK benefits system[7] designed to mitigate the distributional impact of the VAT increase and new gas tax. Some poor families would still be net losers because of factors such as their housing tenure and the age of their dwelling, but fewer than 15 per cent of the poorest 10 per cent of the population would be in this situation.

Some carbon pricing schemes, unlike the European Union Emissions Trading System, have explicitly incorporated elements designed to protect less well-off families. The recently introduced Californian scheme, for example, is subject to a law requiring that at least 25 per cent of the revenue be spent on programmes that benefit disadvantaged communities, which tend to suffer disproportionately from air pollution.

One important issue that has not yet been explored in detail is the distributional impact of the so-called 'co-benefits' of climate change mitigation policies, in particular reduced particulate and NO_2 pollution (but also possibly reduced traffic congestion and increased energy efficiency). These co-benefits are in addition to the benefits of climate change mitigation itself and are generated sooner. Many of them accrue disproportionately to the poor, elderly and infirm, as a recent report illustrates (World Bank/ClimateWorks Foundation, 2014). As the report notes:

> "Effective interventions to scale up the dissemination of clean-burning, fuel-efficient stoves for household cooking and heating can mitigate the health hazards of burning solid fuels. In China, household burning of solid fuels ranks fourth among all risk factors for poor health. It is estimated that household air pollution from solid fuel use results in more than one million premature deaths each year in China (Lim et al, 2012)."

Some of the valuable co-benefits require more than simply carbon pricing to bring them about. For example, revenues from carbon pricing may need to be used to subsidise solar-powered ovens and building insulation. But it seems likely that a proper reckoning of their incidence would suggest that there is less need in some circumstances for measures to compensate low-income families than previously thought.

7 These include changes to pension credit, job-seeker's allowance, income support, the benefit cap, the working tax credit, child tax benefit and long-term incapacity benefit.

5. Cushioning adverse effects of carbon pricing: firms

Although the emphasis in the green growth literature has been on whether carbon revenues can be used to create jobs, temporarily or permanently, in practice policymakers have show themselves to be concerned about the impact of carbon pricing on the profits of the corporate sector as well. For example, according to Article 10 of the first European Union Emissions Trading System (EU ETS) Directive, during the first and second trading periods (2005-2007 and 2008-2012), at least 95 per cent and 90 per cent of emission permits respectively were assigned free of charge – 'grandfathered' – to industry. As permits can be traded in a secondary market, this amounts to the transfer of valuable assets from the government to the private corporate sector.

Various rationales can be offered for this approach. First, temporary aid to carbon-intensive firms can give them a breathing space to develop lower-carbon technologies and/or change their product mixes, rather than relying on the potentially more disruptive early closure of such firms to achieve the necessary reallocation of productive capital to less carbon-intensive activities. The danger is that overly generous protection of incumbents' profits in carbon-intensive industries may allow them to price new low-carbon competitors out of the market.

Second, there is the more pragmatic political economy argument that the carbon-intensive industries are able to lobby more effectively than either the potential beneficiaries of new 'green' technologies or the beneficiaries of climate change mitigation (many of whom are not yet born). Hence they need to be offered compensation if carbon pricing is to win legitimacy in the first place. However, research indicates that a profit-neutral allocation of permits is likely to require less than 50 per cent of permits to be grandfathered, given reasonable assumptions about market structure and demand and supply elasticities, and less than that in less monopolistic sectors (Hepburn et al., 2013). It remains debatable whether the cost of maintaining profits from pre-existing monopolistic power is worth a corresponding reduction in political opposition to environmental taxation reforms.

A third concern is about the interaction of carbon pricing with pre-existing distortions arising from capital taxation, an issue discussed below in Section 7.

One particular concern of the corporate sector is that carbon pricing is not enforced worldwide and threatens to put firms in countries and sectors where it does apply at a competitive disadvantage. It may also lead firms to re-allocate carbon-intensive activities to jurisdictions where carbon pricing is lower or non-existent.

This worry has led to special treatment for some firms competing in international markets. As Clò describes (2010), during the third post-Kyoto trading period (2013–2020) of the EU ETS, the previous allocation rule – grandfathering – is being progressively replaced by three different allocation criteria: allowances are going to be fully auctioned to the energy sectors and progressively auctioned to the ETS-covered industrial sectors, while exemption from auctioning and free allocation according to a benchmark is going to be applied to the industrial sectors which are found to be exposed to the risk of carbon leakage. Clò argues that, unfortunately, because of the way the exemptions are calculated, they are unlikely to mitigate carbon leakage or improve the transparency of the allocation process. Rather, it is likely to increase the distortion of competition, worsening rather than improving harmonisation within the EU ETS.

Concerns about the impact of carbon pricing and other 'green growth' policies on competitiveness are often couched in terms of the adverse effects they will have on productivity and employment rather than the return on capital, although from the point of view of firms, the latter is likely to be the most important consideration. The evidence about competitiveness effects is mixed but tends to suggest that concerns have been overblown (Bassi and Zenghelis, 2014; Flues and Lutz, 2015; Arlinghaus, 2015;). There is some evidence of minor adverse productivity effects from environmental policies for some regulated entities, at least in the short run; costs have been small relative to the size of national economies but may be significant in some pollution-intensive or energy-intensive sectors (Dechezleprêtre and Sato, 2014).

Overall, it seems possible that carbon pricing may have some small adverse effects on the productivity, employment and profits of the most carbon-intensive firms, but not nearly large enough to merit full recycling of revenues to the corporate sector. Even where there are adverse effects, it is not clear that governments should protect shareholders from the signal given by the induced change in rates of return, given that the owners of firms are ultimately responsible for the choices made by firms about inputs, outputs and technologies. However, winning political support for carbon pricing may require that they be given some protection.

6. Reforming tax-benefit systems: a labour market focus

One major concern about carbon pricing is that, by pushing up the general price level, it reduces the real value of a given nominal wage. This is likely to lead to reduced labour supply and demands for higher wages, which if granted will in turn reduce labour demand. The fear is that ultimately an economy introducing carbon pricing will end up with lower real wages, higher unit labour costs, lower employment and lower output. Beck et al (2015), for example, find that the British Columbian scheme has reduced real wages below what they would otherwise have been. The GDP losses and adjustment costs are likely to be larger, real wages will likely be less flexible in response to macroeconomic shocks, and the retraining and re-allocation of workers from high-carbon to low-carbon sectors will become more difficult (Babiker and Eckaus, 2007; Chateau et al., 2011). Bowen and Kuralbayeva (2015) discuss the labour market challenges posed by 'green growth' policies, including carbon pricing, while recognising that low-carbon energy supply may be more labour intensive than high-carbon supply.

Some economists have challenged the presumption that carbon pricing will adversely affect real wages. It depends on the sectoral impact of carbon pricing and the mix of factors of production used in high- and low-carbon industries. For example, carbon pricing could be regressive if emission-abatement measures are capital-intensive, because those measures would benefit owners of capital at the expense of workers. But some switching from traditional to greener technologies and activities is likely to entail a switch towards more unskilled labour-intensive activities rather than capital-intensive ones. Indeed, advocates of renewable energy emphasise that most forms of renewable energy are more labour-intensive per kilowatt-hour than fossil fuel-based energy and argue that a switch to renewable energy would generate a net increase in jobs (Bowen and Kuralbayeva, 2015). Carbon pricing also encourages firms and households to switch away from goods and services produced in a capital-intensive way, because most carbon-intensive activities also happen to be highly capital-intensive.

The fear that carbon pricing will indeed reduce real wages and employment has led economists to explore the possibility of offsetting these adverse effects by reducing taxes on employment, achieving a so-called 'double dividend' (e.g. Goulder, 1994; Fullerton and Metcalf, 1997;

Sartzetakis and Tsigaris, 2007; Goulder, 2013). This focus is predicated on the assumption that an employment tax is distortionary, which begs two questions: why is the tax being imposed in the first place and is this the most distortionary existing tax at the margin? These two questions should take the analysis into the broader area of the principles of public finance (although that has not always been recognised in the environmental economics literature). Taxes are needed to raise revenues to finance public expenditure as well as to correct market distortions such as those caused by pollution. If, prior to the recognition of the threat of climate change, tax rates in a country had been set to raise a target amount in a way that minimised deadweight losses, the introduction of carbon pricing would warrant all tax rates being reduced, not just taxes on employment.

Another possible source of a double dividend, particularly in developing countries, relates to the presence of informal sectors and the associated low taxation of income from informal activities. One source of inefficiency is that labour in the formal sector is over-taxed relative to labour in the informal sector (Bento et al., 2014; Markandya et al., 2013). Revenue recycling to reduce taxes on formal-sector labour discourages the substitution of informal for formal sector production. As a result, the size of the informal sector shrinks, the tax base expands and labour moves into the formal sector, possibly with an increase in total employment.

The focus on labour taxation in analysis of the 'double dividend' may be warranted by the fact that labour income is the largest component of national income. But other market failures and taxes on other activities may be more distortionary in practice. Policymakers ideally should take a broader perspective on the corrective and distortionary effects of tax-benefit systems and how they might interact with new environmental taxes. An example of a broader perspective is given by Bento and Jacobsen (2007), who argue that resource rents are under-taxed and a broad environmental tax reform would shift taxation from labour to all sorts of natural resources in fixed supply (not just greenhouse gas emissions quotas).

Some tax experts have suggested that labour and income taxes are easier to evade than carbon taxes such as taxes on gasoline or electricity. Shifting the tax base from easily evaded taxes to difficult-to-evade carbon taxes can decrease the total amount of tax evasion in the system, increasing its efficiency and thus enhancing welfare (Liu, 2013). This works through two mechanisms: first, fewer resources are spent on evading taxes; second, the burden of taxation spreads more evenly in the system as industries that prior to the green tax reform experienced lower tax evasion and thus higher effective tax rates see the biggest falls in taxes. This effect can be sizeable in countries such as China or India with high levels of pre-existing tax evasion. For example, simulation of a simple general equilibrium model suggests that the welfare costs of environmental tax policies can be reduced by 89 per cent in China and by 97 per cent in India (Liu, 2013).

Thus economic factors such as how the social security benefit system works, the efficiency of the tax system in general and what equilibrates migration between regions and sectors turn out to be important for the precise distributional impacts of carbon pricing or other new environmental taxes in any particular setting. The varying predictions of theoretical models about the impact of environmental taxes on labour markets reflect varying characteristics of labour markets that have nothing to do with environmental policies as such. This is likely to be particularly relevant in developing economies, where there may be larger divergences between labour productivity levels at the margin in different sectors (especially between the formal urban sector and the informal own-account rural sector). This suggests that analysis should further differentiate types of economy according to their labour market institutions, tax arrangements, production structure and endowments. Some sort of 'double dividend' from the use of carbon revenues is possible if revenue recycling is carried out judiciously but cutting labour taxes may not be the only or even the best way to achieve that goal.

Another way in which carbon pricing interacts with an economy is by changing the pattern of firms' and households' demand for goods and services. This necessitates structural change across industries. Empirical studies therefore tend to draw attention to broader sectoral redistributions of labour, particularly from the energy sector as a whole (as well as fossil-fuel energy industries in particular) towards services (see, for example, Goettle and Fawcett, 2009; Chateau et al., 2011; and OECD, 2012). Some of the projections are perhaps surprising, such as the adverse impact of climate change mitigation on employment in the European rice and livestock industries (Chateau et al., p.21) and the beneficial impact on the US tobacco and textile industries (Goettle and Fawcett, p. S250).

The employment effects do not seem to be closely correlated with relative wage rates, so there is little suggestion from such studies that carbon pricing would reallocate labour systematically to high-wage or to low-wage sectors. However, they do reinforce the importance of using active labour market policies such as job-seeking allowances, relocation support and retraining in conjunction with carbon pricing. This is particularly important with respect to workers in high-carbon industries that are geographically isolated, as is the case with, for example, much coal mining. Active labour market policies are another legitimate use of carbon pricing revenues. But they are warranted to cushion the impact of structural change on working people regardless of the source of the structural change.

7. Reforming tax-benefit systems: firms

Many tax economists have argued that the most serious distortion in tax systems tends to be excessive taxation of corporate income – partly because it can discourage (or divert) saving and the accumulation of productive capital and partly because it can lead to capital income being taxed twice over, at the corporate level and then when shareholders and bondholders are taxed on their personal incomes (see, for example, the discussions in Auerbach et al, 2008, and Auerbach and Hassett, 2015). If this is the case, there is a 'double dividend' argument for reducing corporate taxation rather than taxes on labour. Distortions may be larger when there are low barriers to financial capital flows across borders. In practice, large-scale tax reform proposals often encourage both a switch from income taxation (including labour income taxation) towards consumption taxation and the introduction of tax relief for corporate equity (e.g. Mirrlees et al, 2012). The emphasis in the environmental 'double dividend' literature on payroll taxes may be misplaced. More generally, this discussion reinforces the point that carbon pricing ought to be considered in the context of the strengths and weaknesses of each tax-benefit system as a whole.

8. Paying down public debt or spending more on social objectives

Finally, carbon pricing revenues can be used to help reduce public debt relative to GDP or spending more on unrelated social objectives. The former goal is a high priority for some, particularly among advanced industrial countries after the 2008 financial crisis and subsequent sharp slowdown in economic growth. Public debt rose sharply as a result of reductions in tax revenues (particularly from financial sectors), increases in public spending (including through the so-called 'automatic stabilisers' provided by welfare spending and progressive income tax systems) and costs of rescuing key banks and some other financial sector firms.

This is not the place for a full discussion of the appropriate timing, merits and faults of reducing fiscal deficits. There continues to be much debate about the pace at which public debt should be reduced relative to GDP and about whether fiscal consolidation via public spending cuts will have an expansionary effect or will reduce growth, in certain circumstances leading to an increase in the debt/GDP ratio (see, inter alia, Alesina and Ardagna, 2009; DeLong and Summers, 2012; Taylor, 2011; and Ostry et al, 2015). Some have argued that a Keynesian fiscal stimulus can in some circumstances both stimulate economic growth and improve the environment through opportunistic increases in spending on low-carbon infrastructure investment, although a strategy to manage the ensuing increase in public debt is required (e.g. Bowen and Stern, 2010). Nevertheless, despite the debate, in the political realm (at least in the EU) and among international advisory bodies such as the OECD, the consensus seems to be in favour of reduced fiscal deficits and public debt reduction relative to GDP. Governments engaged in fiscal consolidation may welcome the contribution that increased environmental taxation, including carbon pricing, can make to that goal, unless the political cost of new or higher taxes is prohibitive. When the pressure to consolidate abates, carbon pricing revenues will still be available to spend on other social objectives, including those unrelated to environmental concerns, such as the provision of schools, hospitals and military hardware. Carbon pricing has the potential to relax the financial constraint on governments a little, giving them a wide range of options for extra spending at the margin.

9. Conclusions

Carbon pricing makes sense as a central element of policies to bring human-induced climate change to a halt. The key point of carbon pricing is to 'get prices right' – to make carbon-intensive goods and services more expensive to reflect the cost that their production imposes in the planet. But in the process carbon pricing generate revenues. That is a double-edged sword. On the one hand, it imposes costs on firms and households. On the other, it offers public authorities opportunities to make economies more efficient, cushion the impact of environmental policies on costs and buy off political opposition to climate-change mitigation.

The trade-off is likely to be calculated differently in different countries, as illustrated by Table 1 and Box 1 below. In practice, some governments that have imposed carbon prices have earmarked some fraction of revenues for particular purposes while others have channelled the revenues into the general government budget (Sumner et al., 2011; ICMM, 2013). One popular tactic has been to attribute specific income tax or payroll tax cuts to the revenues from carbon pricing without imposing any formal hypothecation.

Table 1. Use of carbon pricing revenues in practice

Country/jurisdiction	Start date	Use of carbon pricing revenues
Finland	1990	General central government budget; some reductions in personal income taxes and employers' social security contributions later (no formal hypothecation)
Netherlands	1990	Some reductions in personal income taxes and employers' social security contributions (no formal hypothecation); climate mitigation programmes
Norway	1991	General central government budget; some reductions in personal income taxes (no formal hypothecation)
Sweden	1991	General central government budget; some reductions in personal income taxes and (later) employers' social security contributions (no formal hypothecation)
Denmark	1992	Environmental subsidies and returned to industry; some reductions in personal income tax and employers' social security payments (no formal hypothecation)
UK	2001	Initial reductions in employers' social security payments (no formal hypothecation)
Boulder, CO	2007	Climate mitigation programmes
Quebec	2007	Climate mitigation programmes
British Columbia	2008	Reductions in business and personal taxation; "revenue neutrality" mandated
California	2013	Some free allocation of quotas to emitters; spending for environmental purposes, with an emphasis on improving air quality; at least 25 per cent to be spent on programmes that benefit disadvantaged communities

Sources: Sumner et al. (2011), ICMM (2013), C2ES (2014).

Governments have proceeded at different speeds in implementing the different tools in the portfolio of instruments available to fight human-induced climate change. In countries and regions that have been early adopters of carbon pricing, a strong case can be made for using some of the revenues to finance the public expenditure needed to support some of the other tools of decarbonisation. Spending on the public infrastructure needed for low-carbon development, on subsidies for renewable energy deployment and on subsidies for investment in improved energy efficiency where private markets have proved inadequate are good examples. However, in some countries and regions, carbon pricing will be a relatively late addition to the portfolio and earmarking revenues for extra low-carbon RD&D would make less sense. In all countries, however, the use of carbon revenues to demonstrate governments' long-run commitment to climate and other environmental goals may be helpful in setting private-sector expectations and winning public support. Also, in one vital area, the support of RD&D for low-carbon technologies, it is clear that much more public expenditure is warranted worldwide, together with efforts to disseminate such technologies more readily across countries at different levels of development.

Those advanced industrial nations that have pledged to contribute to climate finance for developing countries (the countries listed on Annex II to the UNFCCC) may wish to consider using carbon revenues to augment the public-sector contributions to the US$ 100 billion per year promised in the Copenhagen Accord. This can be seen as an extension to the international arena of the argument at the beginning of these conclusions for redistributive measures to protect the poor.

One use of revenues that is likely to be attractive everywhere is to use transfer payments and tax breaks to lessen the impact on the households whose cost of living is disproportionately affected by carbon pricing. This has appeal on the grounds of equity and, in many polities, political realism – the need to win popular support for carbon pricing. Hence governments need to assess which groups in society are going to be hit hardest. That depends on factors such as whether the poor predominantly use electricity, fossil fuels including kerosene or traditional biofuels, and what their transport, heating and cooling requirements are.

A straightforward 'citizen's dividend' is a simple but blunt way to redistribute resources in roughly the right direction. It is a more attractive option where there is strong political opposition to closing budget deficits through net increases in taxation rather than cuts in public spending. Its simplicity may appeal where tax-benefit systems are unsophisticated or are difficult to tweak for other reasons. But empirical studies suggest that governments can generally target compensatory transfers better, at the very least by focusing transfers on poorer families.

Compensating corporate losers is a more difficult question. It is a less pressing need on the basis of equity, where the owners of capital hold their wealth through diversified portfolios and where there are few monopoly profits in the industries hit hardest (the impact of carbon pricing is likely to be accompanied by an erosion of any monopoly power as new, low-carbon entrants appear in the marketplace).

Box 1: The case of British Columbia

British Columbia introduced a carbon tax in July 2008. The legislation emphasised revenue neutrality rather than spending on climate change mitigation and other environmental policies. Businesses now benefit more from direct revenue recycling than do households. According to Harrison (2013), "in establishing the carbon tax, the provincial government made a binding legislative commitment to return all carbon tax revenues to individuals and firms via corresponding tax cuts. Indeed, the enacting legislation threatens to reduce the Finance Minister's salary by 15 per cent should she or he fail to do so. Interestingly, revenue-neutrality is defined as having tax cuts of value equal to or greater than carbon tax revenues. In practice, the tax reform has in fact been revenue-negative: the province gave back more money in tax cuts than it collected in each of the first five years."

Revenue recycling to households amounts to around 40 per cent of revenues and combines personal income tax rate reductions and lump-sum transfers, both primarily targeted at protecting low-income households (Beck et al, 2015). In 2008/09, the government cut the income tax rates for the two bottom brackets by 5 per cent using carbon tax revenues. There is also a Low Income Climate Action Tax Credit programme and a Northern and Rural Area Homeowner Benefit programme, eligibility for which depends on property value and additional criteria related to age and income. Some 60 per cent of the revenue from carbon pricing is recycled to firms, not households, through business tax rate reductions and increased corporate tax credits (Beck et al., 2015).

Harrison (2013) draws attention to two interesting features of the tax regime:
"First, corporate tax cuts were phased in more gradually than tax cuts for individuals, and were proportionately deeper relative to a lower initial corporate tax rate. Thus, two thirds of tax cuts initially went to individuals and one third to firms, even though the opposite proportion applied to tax revenues. Over time, however, the ratio shifted, and more than half of tax cuts now flow to the business community. Second, as increases in the tax have necessitated further cuts to achieve revenue neutrality beyond those initially announced for the first three years, the list of new tax expenditures has included increasingly specific and, in some cases, seemingly unrelated tax credits… 2012 additions included business tax credits for video game production, film production, and scientific research, and individual tax credits for children's fitness and seniors' home renovations."

A study of the impact of the scheme finds that the carbon tax has in fact been highly progressive, even before any revenue recycling, because indexed transfer income is a larger share of total income for lower income groups (Beck et al, 2015). That brings into question the need for recycling revenues to low-income families on equity grounds. Yet the politics of introducing a new tax have obliged the government to signal strongly that carbon taxation is not a device to increase the size of the state.

Another good use for carbon pricing revenues is to take the opportunity to reduce distortions created elsewhere in fiscal systems. Concerns about the impact of carbon pricing on total employment – via falls in real wages – have led many economists to advocate reductions in payroll taxes.[8] This can be presented as increasing taxes on 'bads' – greenhouse gas emissions – and reducing them on 'goods' – labour supply.

However, governments need to assess two objections to this line of argument. First, does the existing tax system have obvious and remediable inefficiencies built into it? Governments need to raise revenue for the purposes of the state and in principle may already have adjusted the mix of taxes to impose the least deadweight costs or to minimise political opposition. Hence there may not be big gains to be made by this approach – the second part of the 'double dividend' may turn out to be small.

Second, are there particularly inefficient taxes elsewhere that can be reduced? The focus on payroll taxes may be misplaced, not least because the whole portfolio of climate change mitigation measures may increase the returns to labour relative to capital. In developed industrial economies, advocates of wholesale reform of tax systems often point to distortions in capital taxation rather than labour taxation as the most likely source of inefficiencies.

This highlights the need for governments to consider carefully the impact of the tax system as a whole on productive efficiency and incentives. They also need to assess the constraints on making the rest of the tax system more efficient. In many developing countries, the scope for extending taxation to informal and household-based activities is very limited. Tinkering around with taxation where the government's writ runs may have unintended consequences elsewhere in the economy. However, carbon pricing has the advantage of being relatively easy to impose administratively, as long as it is applied upstream in the production process.

Finally, some countries facing the need for fiscal retrenchment may wish to use a larger share of carbon revenues to reduce public budget deficits. Some advanced industrial countries have historically very high ratios of public debt to GDP since the global financial crisis that started in 2008. However, there is debate about the dangers of high ratios of public debt to GDP and disagreement about the pace at which such ratios should be reduced. Absorbing carbon pricing revenues into the general budget may also arouse scepticism amongst the public about the commitment of governments to their stated environmental objectives. Hence governments need to be clear about their overall fiscal strategies at both the micro level – what are they trying to do to change incentives facing firms and households and what for? – and the macro level – how do they intend to manage debt, deficits and the level of public spending in the long run?

The answers to these questions will probably vary in different places and at different times. They will differ according to economic factors, such as the level of development and the size of local endowments of fossil fuels, and political factors, such as attitudes towards (and definitions of) fairness and equity, the credibility of governments, the competence and reach of the fiscal authorities and the macroeconomic theories adopted by political leaders.

8 This argument is based on textbook economics analysis that suggests that labour supply will be lower for a given nominal wage paid by the employer because the carbon price reduces the real consumption wage. Total employment in the long run falls. The argument abstracts from any induced variation in unemployment in the short to medium run resulting, for example, from the fiscal contraction imposed by carbon pricing if the revenues are not fully recycled.

A simple rule for using carbon pricing revenues – one that does not vary by time or place – would not be optimal, even if such an approach sometimes appears to make pragmatic political sense. For example, it would not make sense to finance low-carbon R&D wholly by a fixed proportion of carbon revenues. There would be no guarantee that the ideal time profile of R&D spending would follow the trajectory of carbon revenues – the R&D might need to be front-loaded, for example, with greater reliance on 'learning by doing' later on when the fundamental scientific breakthroughs needed have been achieved. Also, projections of carbon revenues are surrounded by uncertainty, depending on economic growth, the way in which carbon pricing is implemented, the pace of technological change and developments in climate science. Hence earmarking – 'hypothecation' of revenues in the language of finance ministries – is unlikely to be a good idea in the long run (see Bowen, 2011, for a further discussion of the pros and cons of hypothecation).

It is clear that governments will have a continuing need to assess and re-assess what best to do with new revenues. They should consider: (1) spending on policies complementing the impact of carbon pricing on greenhouse gases; (2) measures to cushion any adverse side effects of carbon pricing; (3) opportunities to improve the functioning of tax-benefit systems, particularly to mitigate any adverse effects of carbon pricing; (4) reducing fiscal deficits; and (5) spending on non-environmental social objectives. There is a danger that if carbon pricing policies try to mandate the use of the revenues they create, the breadth of opportunities under category (3) will be not be fully appreciated and categories (4) and (5) will be neglected. However, the potential revenues of carbon pricing do give societies many attractive options for pursuing a range of goals – environmental and otherwise – in addition to the environmental benefits of carbon pricing.

References

Acemoglu, D., Aghion, P., Bursztyn, L., and Hemous, D., 2012. The environment and directed technical change. *American Economic Review,* Vol. 102 (1), pp. 131-166.

Advani, A., Bassi, S., Bowen, A., Fankhauser, S., Johnson, P., Leicester, A., and Stoye, G., 2013a. *Energy use policies and carbon pricing in the UK,* IFS Report R84. London: The Institute for Fiscal Studies and Centre for Climate Change Economics and Policy at the London School of Economics and Political Science.

Advani, A., Johnson, P., Leicester, A., and Stoye, G., 2013b. *Household energy use in Britain: A distributional analysis,* IFS Report R85. London: Institute for Fiscal Studies.

Agostini, C.A., and Jimenez, J., 2015. The distributional incidence of the gasoline tax in Chile, *Energy Policy,* 85, pp.243-252.

Albrizio, S., Botta, E., Koźluk, T., Zipperer, V., 2014. *Do environmental policies matter for productivity growth? Insights from new cross-country measures of environmental policies,* OECD Economics Department Working Paper No. 1176. Paris: OECD.

Albrizio, S., Botta, E., Koźluk, T., Zipperer, V., 2014. *'Empirical evidence on the effects of environmental policy stringency on productivity growth,* OECD Economics Department Working Paper No. 1179. Paris: OECD.

Alesina, A.F., and Ardagna, S., 2009. *Large changes in fiscal policy: Taxes versus spending,* NBER Working Paper No. 15438. Cambridge, Massachusetts: NBER.

Arlinghaus, J., 2015. Competitiveness impacts of carbon pricing: *A review of empirical findings,* OECD Environment Working Papers, No. 87. Paris: OECD.

Arze del Granado, J., Coady, D., and Gillingham, R., 2012. The unequal benefits of fuel subsidies: A review of evidence for developing countries. *World Development,* 40, pp.2234-2248.

Auerbach, A.J., Devereux, M.P., and Simpson, H., 2008. *Taxing corporate income,* NBER Working Paper No. 14494. Cambridge, Massachusetts: NBER.

Auerbach, A.J., and Hassett, K., 2015. *Capital taxation in the 21st century,* NBER Working Paper No. 20871. Cambridge, Massachusetts: NBER

Babiker, M.H., and. Eckaus, R.S., 2007. Unemployment effects of climate policy. *Environmental Science & Policy, 10,* pp.600-609.

Barker, T., and Köhler, J., 1998. Equity and ecotax reform in the EU: Achieving a 10 per cent reduction in CO_2 emissions using excise duties. *Fiscal Studies,* 19(4), pp.375-402.

Bassi, S., and Zenghelis, D., 2014. *Burden or opportunity? How UK policies affect the competitiveness of businesses,* Policy Paper, Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, London. [online] Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/07/Burden-or-opportunity.pdf

Beck, M., Rivers, N., Wigle, R., and Yonezawa, H., 2015. Carbon tax and revenue recycling: Impacts on households in British Columbia. *Resource and Energy Economics,* 41, pp.40-69

Bento, A., and Jacobsen, M., 2007. Ricardian rents, environmental policy and the "double dividend" hypothesis. *Journal of Environmental Economics and Management,* 53, pp.17-31.

Bento, A., Jacobsen, M., and Liu, A., 2014. *Environmental policy in the presence of an informal sector,* RFF working paper. Washington D.C.: Resources for the Future.

Bowen, A., 2011. Raising climate finance to support developing country action: some economic considerations. *Climate Policy,* 11, pp.1020-1036.

Bowen, A., Campiglio, E., and Tavoni, M., 2014. A macroeconomic perspective on climate change mitigation: meeting the financing challenge. *Climate Change Economics,* 5(1), [online] Available at: http://www.worldscientific.com/doi/pdfplus/10.1142/S2010007814400053

Bowen, A., and Kuralbayeva, K., 2015. *Looking for green jobs: The impact of green growth on employment,* Policy Brief, Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, London. [online] Available at: http://www.lse.ac.uk/GranthamInstitute/publication/looking-for-green-jobs-the-impact-of-green-growth-on-employment/

Bowen, A., and Stern, N., 2010. Environmental policy and the economic downturn. *Oxford Review of Economic Policy,* 26(2), pp.137-163.

Cambridge Econometrics, 2014. *The economics of climate change policy in the UK.* Cambridge: Cambridge Econometrics.

C2ES, 2014. California cap-and-trade program summary. Arlington, VA: Center for Climate and Energy Solutions.

Chan, H.S., Li S., and Zhang, F., 2013. Firm competitiveness and the European Union Emissions Trading Scheme. *Energy Policy,* 63, pp.1056-1064.

Chateau, J., Saint-Martin, A., and Manfredi, T., 2011. *Employment impacts of climate change mitigation policies in OECD: A general-equilibrium perspective,* OECD Environment Working Paper No. 32. Paris: OECD

Clò, S., 2010. Grandfathering, auctioning and carbon leakage: Assessing the inconsistencies of the new ETS Directive. *Energy Policy,* 38, pp.2420-2430.

Dechezleprêtre, A., and Martin, R., 2010. *Low carbon innovation in the UK: evidence from patent data,* Policy Paper, Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, London. [online] Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/03/PP-low-carbon-innovation-UK.pdf

Dechezleprêtre, A., and Sato, M., 2014. *The competitiveness impacts of green policies,* Policy Brief. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

DeLong, J.B., and Summers, L.H., 2012. Fiscal policy in a depressed economy. *Brookings Papers on Economic Activity,* Spring, pp. 233-274.

Dercon, S., 2014. *Is green growth good for the poor?,* World Bank Policy Research Working Paper No. 6936. Washington DC: World Bank.

EBRD, 2011. *Special report on climate change: The low carbon transition.* London: European Bank for Reconstruction and Development.

Edenhofer, O., C. Carraro, J.-C. Hourcade, K. Neuhoff, G. Luderer, C. Flachsland, M. Jakob, A. Popp, J. Steckel, J. Strohschein, N. Bauer, S. Brunner, M. Leimbach, H. Lotze-Campen, V. Bosetti, E. de Cian, M. Tavoni, O. Sassi, H. Waisman, R. Crassous-Doerfler, S. Monjon, S. Dröge, H. van Essen, P. del Río and Türk, A., 2009. *The Economics of Decarbonization,* Report of the RECIPE project. Potsdam: Potsdam-Institute for Climate Impact Research.

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

Flues, F. and Johannes Lutz, B., 2015. *Competitiveness impacts of the German electricity tax,* OECD Environment Working Paper No. 88. Paris: OECD.

Flues, F. and Thomas, A., 2015. *The distributional effects of energy taxes,* OECD Taxation Working Paper No. 23. Paris: OECD.

Fullerton, D., and Metcalf, G.E., 1997. *Environmental taxes and the double-dividend hypothesis: did you really expect something for nothing?* NBER Working Paper No. 6199. Cambridge, Massachusetts: NBER.

Garcia Romero, H. and Calderon Etter, L., 2013. *The political economy of fuel subsidies in Colombia,* OECD Environment Working Papers No. 61. Paris: OECD.

Global Commission on the Economy and Climate, 2014. *The new climate economy.* [online] Available at http://newclimateeconomy.report

Goettle, R.J., and Fawcett, A.A., 2009. The structural effects of cap and trade climate policy, *Energy Economics,* 31, pp.S244-S253.

Gough, I., Abdallah, S., Johnson, V., Ryan-Collins, J., and Smith, C., 2011. *The distribution of total greenhouse gas emissions by households in the UK, and some implications for social policy,* CASE paper No. 152, Centre for Analysis of Social Exclusion, Suntory and Toyota Centres for Economics and Related Disciplines. London: London School of Economics and Political Science

Goulder, L., 1994. *Environmental taxation and the 'double dividend:' A reader's guide,* NBER Working Paper No. 4896. Cambridge, Massachusetts: NBER.

Goulder, L., 2013. Climate change policy's interactions with the tax system, *Energy Economics,* 40, pp. S3-S11.

Greenstone, M., 2002. The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 Clean Air Act amendments and the Census of Manufactures. *Journal of Political Economy,* 110(6), pp.1175-1219.

Guillaume, D., Zytek, R., and Farzin, M.R., 2011. Iran – *The chronicles of the subsidy reform,* IMF Working Paper WP/11/167. Washington D.C: IMF.

Harrison, K., 2013. *The political economy of British Columbia's carbon tax,* OECD Environment Working Papers, No. 63. Paris: OECD.

Hassett, K.A., Mathur, A., and Metcalf, G.E., 2007. *The incidence of a US carbon tax: A lifetime and regional analysis,* NBER Working Paper No. 13544. Cambridge, Massachusetts: NBER.

Hepburn, C.J., Quah, J.K.-H., and Ritz, R.A., 2013. Emissions trading with profit-neutral permit allocations. *Journal of Public Economics,* 98, pp.85-99.

International Council on Mining & Metals (ICMM), 2013. *Options in recycling revenues generated through carbon pricing: How 16 governments invest their carbon revenues.* [online] Available at: https://www.icmm.com/document/5362

IEA, 2013. World energy outlook special report : Redrawing the energy-climate map, new policies scenario. Paris: IEA/OECD.

King, D., Browne, J., Layard, R., O'Donnell, G., Rees, M., Stern, N., and Turner, A., 2015. A global Apollo Programme to combat climate change. London: Centre for Economic Performance, London School of Economics and Political Science.

Kuralbayeva, K., 2013. *Effects of carbon taxes in an economy with large informal sector and rural-urban migration,* Grantham Research Institute Working Paper No. 139. London: London School of Economics and Political Science.

Lim, S. S., et al., 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the global burden of disease study 2010. *Lancet,* 380(9859), pp.2224-60.

Liu, A.A., 2013. Tax evasion and optimal environmental taxes. *Journal of Environmental Economics and Management,* 66, pp.656-670.

Markandya, A., Gonzalez-Eguino, M., and Escapa, M., 2013. From shadow to green: linking environmental fiscal reforms and the informal economy. *Energy Economics,* 40, pp.S108-S118.

Martin, R., de Preux, L.B., and Wagner, U.J., 2009. *The impacts of the Climate Change Levy on business: Evidence from microdata,* CEP Discussion Paper No. 917, Centre for Economic Performance. London: London School of Economics and Political Science.

Mirrlees, J., Adam, S., Besley, T., Blundell, R., Bond, S., Chote, R., Gammie, M., Johnson, P., Myles, G., and Poterba, J., 2012. The Mirrlees Review: A proposal for systematic tax reform. *National Tax Journal,* 65(3), pp.655-684.

Mourougane, A., 2010. *Phasing out energy subsidies in Indonesia,* OECD Economics Department Working Paper No. 808. Paris: OECD.

OECD, 2006. *The Political Economy of Environmentally Related Taxes.* Paris: OECD.

OECD, 2012. *Employment outlook 2012.* Paris: OECD.

OECD, 2014. *The political economy of the increase in Turkish taxes on motor vehicle fuels,* paper for the Joint Meetings of Tax and Environment Experts, COM/ENV/EPOC/CTPA/CFA(2013)8/FINAL. Paris: OECD.

Ostry, J.D., Ghosh, A.R., and Espinoza, R., 2015. *When should public debt be reduced?* IMF Staff Discussion Note SDN/15/10. Washington D.C.: IMF.

Rivers, N., 2012. The distribution of costs of a carbon tax among Canadian households. *Canadian Tax Journal,* 60(4), pp.899-915.

Sartzetakis, E.F., and Tsigaris, P.D., 2007. *Uncertainty and the double dividend hypothesis,* Nota di Lavoro 99.2007. Milan: Fondazione Eni Enrico Mattei.

Stern, N., et al., 2007. *The economics of climate change: The Stern review.* Cambridge, U.K: Cambridge University Press.

Sterner, T., 2012. Distributional effects of taxing transport fuel. *Energy Policy,* 41, pp.75-83.

Sumner, J., Bird, L., and Dobos, H., 2011. Carbon taxes: a review of experience and policy design considerations, *Climate Policy,* 11(2), pp.922-943.

Symons, E.J., Proops, J., and Gay, P., 1994. Carbon taxes, consumer demand and carbon dioxide emissions: a simulation analysis for the UK. *Fiscal Studies,* 15(2), pp.18-43.

Symons, E.J., Speck, S., and Proops, J.L.R., 2002. The distributional effects of carbon and energy taxes: The cases of France, Spain, Italy, Germany and UK. *European Environment,* 12, pp.203-212.

Taylor, J.B., 2011. An empirical analysis of the revival of fiscal activism in the 2000s, *Journal of Economic Literature,* 49(3), pp.686-702.

Vagliasindi, M., 2012a. *Implementing energy subsidy reforms: Evidence from developing countries.* Washington D.C: World Bank.

Vagliasindi, M., 2012b. *Implementing energy subsidy reforms: An overview of the key issues,* Policy Research Working Paper No. 6122, World Bank, Sustainable Energy Department, Energy Unit. Washington D.C: World Bank.

World Bank/ClimateWorks Foundation, 2014. *Climate-smart development.* Washington D.C. and San Francisco: The World Bank and ClimateWorks Foundation.

Printed on 100% recycled paper.

Typeset by The Digital Parent Company Ltd, www.digitalparentco.com

Grantham Research Institute on
Climate Change and
the Environment

Global
Green Growth
Institute