OECD Environment Working Papers No. 32

Employment Impacts of Climate Change Mitigation Policies in OECD: A General-Equilibrium Perspective

Jean Château,

Anne Saint-Martin,

Thomas Manfredi

https://dx.doi.org/10.1787/5kg0ps847h8q-en

OECD

Unclassified **ENV/WKP(2011)2**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development **12-Dec-2011**

English - Or. English

ENVIRONMENT DIRECTORATE

ENV/WKP(2011)2
Unclassified

ENVIRONMENT WORKING PAPER NO. 32

EMPLOYMENT IMPACTS OF CLIMATE CHANGE MITIGATION POLICIES IN OECD: A GENERAL-EQUILIBRIUM PERSPECTIVE

By Jean Chateau, Anne Saint-Martin and Thomas Manfredi, OECD

JEL Classification: D58, Q54, E24, H23
Keywords: CGE Model - Climate Change mitigation policy, Unemployment, Carbon Pricing

All Environment Working Papers are available at www.oecd.org/env/workingpapers

JT03313285

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

English - Or. English

OECD ENVIRONMENT WORKING PAPERS

This series is designed to make available to a wider readership selected studies on environmental issues prepared for use within the OECD. Authorship is usually collective, but principal authors are named.

The papers are generally available only in their original language English or French with a summary in the other if available.

The opinions expressed in these papers are the sole responsibility of the author(s) and do not necessarily reflect those of the OECD or the governments of its member countries.

Comment on the series is welcome, and should be sent to either env.contact@oecd.org or the Environment Directorate, 2 rue André Pascal, 75775 PARIS CEDEX 16, France.

OECD Environment Working Papers are published on
www.oecd.org/env/workingpapers

ABSTRACT

Using a computable general equilibrium, this paper quantifies the GDP and employment effects of an illustrative greenhouse gas emissions reduction policy. The paper first analyses the direct negative economic effects of the emissions restrictions on GDP and examines labour sectoral reallocations in a framework where labour markets are perfectly flexible. The model is then modified to incorporate labour market imperfections in OECD countries that could generate unemployment, namely, short-run rigidities in real wage adjustment. It is shown that imperfect wage adjustment increases the cost of mitigation policy since unemployment increases in the short-run, but that the carbon tax revenue generated can be recycled so as offset some or all of this effect, notably when it is used to reduce wage-taxes. Thus, taking realistic labour market imperfections into account in a CGE model affects the GDP costs of mitigation policy in two ways: first by introducing extra costs due to the increased unemployment that such policy may entail; second by creating the possibility of a *double dividend effect* when carbon taxes are recycled so as to reduce distorting taxes on labour income..

JEL Classification: D58, Q54, E24, H23
Keywords: CGE Model - Climate Change mitigation policy, Unemployment, Carbon Pricing

RÉSUMÉ

A l'aide d'un modèle d'équilibre général calculable ce papier cherche à quantifier les effets sur l'emploi et le PIB d'une politique d'atténuation du changement climatique. Dans un premier temps, le papier analyse les effets négatifs directs sur le PIB d'une politique de réduction des émissions et examine les réallocations sectorielles de l'emploi, dans un cadre où les marchés du travail sont considérés comme parfaitement flexibles. Dans un second temps une hypothèse d'imperfection du marché du travail dans les pays de l'OCDE est adoptée, cette hypothèse peut créer du chômage en raison de rigidité dans l'ajustement des salaires réels. Dans un tel cas, il est montré que les recettes fiscales associées à une taxe carbone peuvent permettre de mettre en place des politiques d'emploi actives, telles des réductions des impôts sur les salaires, qui peuvent à court-terme contrecarrer l'effet négatif de la politique d'atténuation du changement climatique. Ainsi, la prise en compte dans un modèle EGC d'une imperfection du marché du travail altère la perception des effets sur le PIB des politiques de changement climatique de deux façons : premièrement en soulignant les coûts supplémentaires qu'une telle politique peut entraîner en termes d'emplois et secondement en créant des conditions favorables à l'apparition d'un *phénomène de double-dividende* associée à des politiques adéquates d'utilisation des recettes fiscales liées aux taxes carbones.

Classification JEL : D58, Q54, E24, H23
Mots-clés : Modèle EGC – Politiques d'atténuation du changement climatique, Chômage, valeur du carbone.

FOREWORD

This paper was written by Jean Chateau (Environment Directorate), Anne Saint-Martin and Thomas Manfredi (OECD Employment, Labour and Social Affairs Directorate). This paper provides analytical background material which underlies the discussion of labour market and training policy in the Synthesis Report on the OECD Green Growth Strategy (OECD, 2011).The authors would like to thank Rob Dellink, Nathalie Girouard and Paul Swaim of the OECD for valuable comments. This document has been produced with the financial assistance of the European Union.

This paper is released as part of the OECD Environment Working Papers series [ENV/WKP(2011)2]. It can be downloaded on the OECD website: www.oecd.org/env/workingpapers or www.oecd.org/env/cc/econ

Further enquiries on ongoing work on Mitigation of Climate Change should be directed to: Jean Chateau, OECD Environment Directorate (jean.chateau@oecd.org; Tel: +33 1 45 24 93 05).

TABLE OF CONTENT

EXECUTIVE SUMMARY

The overall employment impact of green growth policies is likely to be limited in the long run. Nonetheless, the sectoral composition of employment will be affected by these policies and this impact is likely to spread well beyond the sectors directly affected via indirect channels and can thus have pervasive effects across the entire labour market. Carbon pricing, for example, can create various structural adjustment pressures that interact with each other in complex ways, and a general equilibrium approach is required to capture all of the direct and indirect channels through which these policies will reshape labour markets.

By causing important changes in relative prices, carbon pricing will affect the composition of both final and intermediate demand and hence composition of labour demand. In particular, the relative price of energy and energy-intensive goods and services will increase. Barriers to industrial restructuring, such as those potentially created by labour market institutions, could hinder the reallocation process and reduce the pace of employment growth. On the other hand, carbon pricing raises public revenue which can be used to reduce other distorting taxes, including those on labour income. Revenue-neutral mitigation policies are sometimes advocated on the basis that they can generate a "double-dividend": the first dividend in terms of more effective environmental protection and the second reflecting the efficiency gains arising from the reduction in distortive taxes.

A growing number of economic modelling teams have developed and applied computable general equilibrium (CGE) models to analyse the economic impacts of climate change policies, including the impacts on labour markets. In order to clarify some of the implications of a transition towards green growth for labour markets, illustrative simulation exercises have been conducted looking at the implications of climate policies using the cross-country multi-sector general equilibrium OECD ENV-linkages model. Because labour market policies and institutions vary widely across countries and interact in complex ways with policies in other markets, it is not possible to introduce a thorough representation of labour market structure into environmental CGE models that are already complex and not easily-tractable tools. Consequently, the labour market imperfections that are introduced into the ENV-Linkage model in this paper are somewhat stylised, taking the form of *ad-hoc* wage rigidities.

The illustrative policy scenario applied in the modelling is an emission trading scheme (ETS) which, over the period 2013-2050, progressively reduces greenhouse gas (GHG) emissions in the OECD area as a whole by 50% in 2050 as compared to their 1990 levels. The target is less stringent for other countries: emissions are reduced by 25% in 2050 as compared to what would be observed in these countries in the absence of mitigation efforts, under the so-called business-as-usual (BAU) scenario.

Overall, the simulations indicate that this mitigation policy has a limited impact on economic growth and job creation. When permit revenues are redistributed in the form of uniform lump-sum transfers, carbon pricing tends to reduce slightly the pace of economic growth. Mitigation costs increase with the degree of labour market imperfection, as this structural distortion reinforces the deadweight losses associated with a given carbon price. Yet, even in the worst-case scenario incorporating very strong labour market imperfections, economic growth is only slightly affected by the introduction of carbon permits: on average in the OECD area, real GDP increases by almost 41% over the period 2013-2030, as compared to 44% in the absence of mitigation actions. Interestingly, it is shown that the mitigation policy could actually boosts employment growth when permit revenues are used to reduce taxation on labour.

1. Introduction: Climate Change Mitigation as part of a green-growth strategy

Achieving ambitious environmental goals raises important transitional issues, as OECD and emerging economies will have to adjust to new patterns of growth. In particular, the realisation of a green growth agenda may translate into deep changes in the labour market that extend far beyond the creation of what are often labelled as "green jobs". While there are a number of opportunities associated with green growth, there are also costs associated with the transition. These costs may be scattered across the economy, with a potentially heavy burden supported by "brown sectors" and local economies heavily dependent on these industries. Furthermore, reducing the environmental footprint of production will imply changes in technology, skill requirements and work organisation that occur along the whole value chain and thus affect the labour force very broadly. Both benefits and costs of a new growth model will be pervasive across the labour force.

But analysing and assessing the employment impact of climate change mitigation policies is not an easy task and a lot remains to be done is this area. A general equilibrium approach is required to capture the direct and indirect channels through which mitigation policies can reshape labour markets and create structural adjustment pressures. This requires developing sophisticated evaluation tools that incorporate detailed specifications of industries into multi-sectored general equilibrium models, but also a detailed modelling of labour market behaviour. Because labour market policies and institutions vary widely across countries and interact in complex ways with policies in other markets, it remains quite a challenge to introduce a thorough representation of labour market functioning in environmental models that are already complex and not easily-tractable tools.

This paper starts with a brief review, covering both theoretical aspects and available empirical evidence about transition towards a greener growth (Section 2). A green-growth strategy suggests a very broad and deep transformation of the economy. To limit the scope of the analysis on transitory labour impacts of green growth, the paper will then focus, in the section 3, on climate change mitigation policies as an illustration of a typical "green policy". In order to clarify some of the general equilibrium effects associated with the implementation of mitigation policies, such as emission trading schemes, illustrative simulation exercises have been conducted with the OECD ENV-linkages model under an assumption of perfectly flexible labour markets. In the section 4, the characterisation of the labour market is modified to model short-run real wages rigidities at the macroeconomic level. While the formulation adopted is quite rudimentary it is a sufficient way to shed light on the magnitude of labour market adjustment pressures at stake when mitigation policies are implemented and the role of recycling carbon taxes revenues.

2. Understanding the labour market implications of green growth: a work in progress

One of the difficulties encountered in analysing the labour market impacts of green growth is that there is so little historical experience with low-carbon and resource efficient growth from which lessons could be drawn. Similarly, economic theory does not provide much guidance in the absence of detailed knowledge about which mix of environmental policies will be implemented and which green technologies –including those not yet developed– will be of greatest importance in decoupling production and consumption from harmful environmental impacts. Even when specific policies and technologies are being studied, great uncertainty remains such as how the scaling up and diffusion of cleaner production technologies will affect the composition of labour demand, including the distribution of job skill requirements. In the context of so much uncertainty, historical analogies to other recent drivers of deep structural changes in labour markets may provide qualitative insights into the potential challenges that lie ahead.

2.1 How much can we learn from the ICT revolution and deepening globalisation?

The ICT revolution and the deepening international economic integration ("globalisation") were the most important drivers of structural changes in OECD economies and developing countries over recent decades. How does the emerging green revolution compare with these two more mature revolutions, and how much can we learn from this comparison? These historical analogies must be approached with caution because there is no way to know how closely the changes associated with the forthcoming green revolution will resemble the labour market restructuring triggered by the ICT revolution and globalisation. Despite this fundamental caveat, both apparent similarities between green growth and these two previous episodes of structural change and apparent differences are suggestive of the qualitative impacts that can be expected as labour markets adjust to greener growth and the resulting challenges for employment and skill policy.

Similarities in labour markets mutation between the ICT and/or globalization revolutions and a Green Growth transformation

Four labour market adjustment patterns associated with the ICT and/or globalization revolutions are also likely to characterize the transition to greener labour markets. First, *workers in particular sectors will be most strongly and directly affected*, both positively and negatively, but workers across the entire economy will be affected via a number of indirect channels. Green workers are in a similar position to direct beneficiaries of the ICT revolution (e.g. ICT workers such as software engineers) and globalization (e.g. workers in successful export industries), while the workers in the most polluting industries are in a similar position to workers specialized in the use of technologies replaced by ICT (e.g. typists) or employed in import competing industries (e.g. textile workers in many OECD countries). As illustrated by both the ICT and globalization cases, the sectoral concentration of benefits and costs also tends to translate into strong spatial disparities in the economic impacts, with some regions benefiting from new development impulses and others experiencing prolonged economic decline.

Second, globalisation illustrates *the central role that labour reallocation is almost certain to play* in the transition to green growth. While increases in international economic integration have not had a systematic effect on total employment, changing patterns of comparative advantage have had a strong impact on the sectoral mix of employment (OECD, 2005). Much recent analysis of international trade has emphasized that extensive labour reallocation also occurs within industries as the most efficient firms, including foreign-owned multinationals, gain market share at the expense of less efficient firms. It is less clear whether this will also tend to happen in the case of green growth, but it appears plausible that many new firms with greener technologies will displace obsolete firms. Even among existing firms, the challenge to adopt or develop green technologies is likely to give an added advantage to the best managed and most innovative firms who will thus gain market share.

Third, the ICT revolution illustrates *the deep and diffuse ways that green technology is likely to affect workers and jobs*. As was the case with ICT, the development and application of new green technologies will require a simultaneous development of a cadre of specialized and often highly skilled green researchers and production workers employed in firms specializing in eco-innovation and the production of advanced environmental goods and services. As has been the case with ICT, green technologies and working methods may also need to diffuse across the economy in order to realise much of the potential benefits. If so, this diffusion will affect working methods and job skill requirements across the labour force, albeit typically in an incremental rather than revolutionary manner. Just as it now makes sense to speak of most workers as being "knowledge workers," even though most are not highly skilled developers and users of ICT, it may soon make sense to speak of a general greening of jobs and the workforce. However, it is still difficult to gauge whether green technology will prove to be as general and transformative of work across the economy as ICT has been, as well as whether it will tend to systematically raise cognitive skill requirements.

Finally, globalisation illustrates *the important role of indirect effects operating through changes in product prices* in determining labour market impacts. For example, the Stolper-Samuelson theorem shows that relative wages will tend to rise for workers whose skills are especially suited to the industries whose relative product prices rise in the wake of trade liberalization, while changes in product prices are also a key channel explaining why the real wages of all workers tend to rise, even those working in sectors that produce non-traded goods and services. Similarly, a transition to green growth will almost inevitably imply increases in the relative price of energy and other goods and services that have large environmental footprints. These relative price changes will induce changes in the composition of final demand and hence of labour demand.

Differences in labour markets mutation between the ICT and/or globalization revolutions and a Green Growth transformation

The labour market adjustment patterns that will characterize the transition to greener labour markets are also likely to differ from those that have been associated with the ICT and globalization revolutions in several ways. First, whereas both the ICT and globalization revolutions have generally led to raising real wages, green growth policies are initially likely to involve falling real wages and hence a need for downward wage flexibility. Indeed, while the adoption of green technologies has the potential to raise productivity in sectors producing a combination of marketed goods and services and (typically) un-marketed environmental services (which will often take the form of diminished environmental damage), average labour productivity in terms of marketed output is likely to fall reducing employers' ability to pay wages and requiring wages to fall in order to maintain full employment. Achieving downward wage flexibility to minimise the disemployment effect may be quite a challenge since considerable research suggests that wages display considerable downward rigidity in many countries.

Second, a climate change policy also opens up the possibility of double-dividend strategies that can improve both environmental and employment outcomes, such as using revenue from a carbon tax to lower the tax wedge on labour income. By contrast, trade liberalization via reductions in tariffs typically imply lower government revenues and hence little scope for this type of policy package.

Third, whereas the ICT and globalization revolutions appear to have generally raised job skill requirements, it is not yet clear whether green growth will have a systematic impact on overall skill demand. That ICT should generally raise cognitive skill requirements is intuitive and has been confirmed by a large body of empirical research. Although the Stolper-Samuelson theorem suggests that deepening trade integration will only raise skill demand in countries that already have the most skilled workforces, a growing body of empirical research suggests that rising skill demands is much more general, perhaps due to the role of trade and foreign direct investment in diffusing new technologies and more efficient management practices. By contrast, much less is known about whether green growth will generally raise job skill requirements. Ramping up the pace of eco-innovation will tend to raise skill demands, at least for an extended period of time, provided that the expansion in green R&D does not imply an equal reduction in R&D for less environmentally friendly technologies. While it is clear that greening the labour market will imply some changes in job skill requirements, it appears to be too early to predict any overall tendency on skill demand.

All in all, historical comparisons with the ICT revolution and the progressive deepening of international trade and investment illustrate how important drivers of structural change may initially affect mainly specific sectors, but come to have pervasive effects across the economy. The impact of green growth policies is likely to spread well beyond the sectors directly affected *via* indirect channels and thus have rather pervasive effects across the entire labour market. This implies that the labour market and skill policy response to green growth cannot be limited to managing the impacts on the relatively small numbers of workers employed in the green and brown jobs, even if these groups of workers (and employers) require special attention.

2.2 Structural adjustment pressures brought about a carbon-pricing driven transition to a less carbon intensive growth

A great degree of uncertainty still remains with regard to the impact that a policy-driven transition to green growth could have on labour market outcomes. In part, this is due to the complexity of the general equilibrium effects that will reshape economies worldwide. As underlined in the previous section, green growth policies, such as a carbon pricing, will affect labour market outcomes through many channels.

Therefore these policies will create various structural adjustment pressures that will interact with each other in complex ways, by generating:

- *A new paradigm for energy production* – Carbon pricing will cause important changes in relative prices within the energy sector, which will result in the emergence of a new and more environmentally-friendly energy-mix. This constitutes the primary purpose of mitigation policies, but as a side effect, energy prices will increase at least in the short and medium run.

- *A new paradigm for consumption* – Changes in energy prices will, in turn, affect the composition of both final and intermediate demand, as the relative price of energy intensive goods and services will increase relative to less energy-intensive ones. The extent to which this will translate into deep changes in the composition of total demand will depend on the substitution possibilities between more and less energy intensive goods and services in both intermediate and final consumption. If these substitution possibilities are limited, aggregate demand could fall substantially, due to rising aggregate consumption prices.

- *A new paradigm for innovation* – These various changes in relative prices will create incentives for R&D investments in a number of economic areas, while the expected return of innovation will decrease in other economic areas. In particular, they should encourage technological innovations related to the production and use of clean energy, and boost R&D investments in energy-saving technologies. By modifying the substitution possibilities between clean and polluting energy sources and between energy and others inputs, these technological changes could attenuate the rise in energy prices and the variations in intermediate and final consumption prices.

- *New macroeconomic conditions* – Carbon pricing acts as a tax on production activities, and therefore, will tend to reduce economic efficiency and cause GDP loss at least in the short and medium run. Barriers to industrial re-structuring and primary factor reallocations across sectors, such as poorly designed product market regulations or labour market institutions, would exacerbate this potential negative impact on economic growth. On the other hand, the induced technological changes will help restore economic efficiency but they will take time to materialise. However, environmental taxes raise public revenue, which can be used to reduce other taxes. Revenue-neutral mitigation policies are sometimes advocated on the basis that they can generate a “double-dividend”: the first dividend in terms of more effective environmental protection and the second reflecting the efficiency gains arising from the reduction in distortive taxes, such as labour taxes (Box 1).

How will these multiple adjustment pressures reshape the labour market? Both industrial re-structuring and eco-innovation will affect job skill requirements, while their net impact on total employment will depend on whether expanding production activities are more intensive in labour than contracting production activities are. But first and foremost, the net employment impact of mitigation policies will be shaped by the new macroeconomic situation brought about by carbon pricing, and therefore, cannot be assessed without a general equilibrium approach.

2.3 Computable General Equilibrium approach to analyse the economic impacts of climate change policies

A growing number of economic modelling teams have developed and applied computable general equilibrium (CGE) models or hybrid models to analyse the economic impacts of climate change policies, including the impacts on labour markets. For the sake of simplicity, labour market imperfections are most often introduced through more or less ad-hoc forms of wage rigidities, as environmental CGE models are complex and not easily-tractable tools.

The estimated impact of mitigation policies on economic growth and employment varies somewhat across countries and studies (see Table 2). In large part, this reflects differences across studies with respect the mitigation policies considered, and for a given mitigation scenario, differences across countries with respect to the level of GHG emissions in a *business-as-usual* scenario , which determines mitigation efforts that need to be achieved. Overall, the impact tends to be relatively small, however. A evaluation conducted by the European Commission suggests that the pace of employment growth in Europe could slow down slightly, should participating countries meet the EU's objectives on climate change and renewable energy for 2020 (Commission of European Communities, 2008). For selected European countries, Boeters and van Leeuwen (2010) show that a 20% reduction in energy uses could slightly reduce unemployment, provided that energy taxes are used to reduce labour taxes. Montgomery et al. (2009) obtain the same qualitative results for the United States, while also showing how labour market imperfections could increase mitigation costs.

Box 1. The double dividend hypothesis

First and foremost, environmental taxes respond to the need to better internalise environmental externalities. Hence, like many other taxes not aimed at correcting economic market failure *per se*, green taxes involve potential economic costs. But these taxes also raise public revenue, which can be used to mitigate –if not to fully offset– their potential efficiency costs. In this context, the improvement of environmental quality could be achieved at relatively low costs, and may even go hand in hand with improved economic efficiency. This view corresponds to the so-called “double dividend” hypothesis:

- In its weak form, the double dividend hypothesis states that the efficiency costs of a revenue-neutral environmental tax reform are lower if the additional revenues from the environmental taxes are recycled in the form of lower distortive taxes compared to a situation where these revenues are recycled in a lump-sum fashion.
- The strong form of the double dividend hypothesis asserts that an environmental tax reform enhances not only environmental quality but also non-environmental outcomes, such as employment.

The rationale behind the double dividend hypothesis relies on the likely sub-optimality of the tax system in many countries, where substantial differences in the marginal excess burden of various taxes can be observed. The weak form compares two different policy changes –that is, two different recycling options for green tax revenues– and implies that green taxes are more efficient instruments (from an economic perspective) than environmental policies that do not yield any revenues, such as regulations. The strong form of the double dividend hypothesis compares the equilibrium after a single policy change with the *status quo*, where the existence of distortive taxes –other than environmental taxes– makes room for governments to implement a revenue-neutral green tax reform that improves economic efficiency by shifting the tax burden away from production factors with high marginal excess burdens to factors with low marginal excess burdens.

Conceptually, however, a green tax reform aimed at reaping a strong double dividend can be seen as consisting of two separate policies: one policy is aimed at improving the quality of the environment; the other policy is targeted at the non-environmental objective, and aimed at reducing inefficiencies arising from the tax system. This raises the question why governments have not reformed their tax systems to address these inefficiencies. There may be a political case for linking these two issues because such a linkage increases the number of instruments that can be used to compensate losers from separate reforms. To illustrate, an efficiency-enhancing tax reform that stimulates employment may not be politically acceptable because inactive households that rely on non-labour income lose from such a reform. If these latter households attach a high value to environmental quality, however, they may favour an environmental tax reform that shifts the tax burden away from labour.

In Europe, tax reforms that would allow a reduction in labour taxes by levying taxes on polluting consumptions have long been advocated as a potential policy option for improving both environmental quality and labour market functioning, thus reflecting a widespread concern among economists that the tax burden on labour income is relatively high and distorting in many countries. Denmark, Germany, Netherlands, Norway, Sweden and United Kingdom have, for instance, implemented such green tax reforms, but *ex post* evaluations of these measures are scarce and do not always isolate employment effects from more general macroeconomic effects (OECD, 2007). Yet, the likelihood of such a double dividend has given rise to a large body of theoretical literature and *ex ante* evaluations. Whether or not the strong form of the double dividend hypothesis may occur depends on two main effects: a tax-base effect and a tax-shifting effect.

- The so-called tax-base effect represents the consequences of a different tax mix for the efficiency of the tax system as an instrument to raise public revenue. In particular, an erosion of the tax base indicates that the tax system becomes a less efficient revenue-raising device, as higher marginal tax rates are required to collect the same amount of public revenue. This typically arises with environmental taxes: contrary to most taxes that are aimed at raising revenues and are all the more efficient that they do so without changing agents’ behavior very much, environmental taxes should be designed to change behavior so as to reduce environmental externalities, that is, their tax base. In other words, improvements in environmental quality reduce the scope for enhancing the efficiency of the tax system by using revenue from environmental taxes to cut other taxes. Hence, this tax-base effect works against the strong form of the double dividend hypothesis. Its magnitude depends on two main elements: the initial pollution levies and the substitution elasticity between clean and dirty commodities. Indeed, increasing environmental taxes is less efficient as a revenue-raising device for governments when starting from a relatively high tax rate, since the higher the initial level of environmental taxes, the smaller is their initial tax base. Likewise, for a given increase in environmental taxes, a large substitution elasticity between clean and polluting goods leads to great improvements in environmental quality, but also, to a large erosion of the tax base.

- In addition to this tax-base effect, economic agents on whom a particular tax is levied are not necessarily those that, *in fine*, fully pay the tax in question since various market adjustments may result in tax shifting. For the strong form of the double dividend hypothesis to occur, consumers of polluting goods should not be able to shift the green taxes they pay onto economic agents that are already overtaxed from an efficiency point of view. In large part, this so-called tax-shifting effect –its direction and its magnitude– is shaped by the various elements that govern the functioning of product and labour markets, and in particular, the policy framework. Therefore, even in countries where non-wage costs are relatively high and may restrain firms' labour demand, a green tax reform that would allow for lower labour taxes may not necessarily result in a lower level of unemployment. The outcome of such a reform depends on the extent to which workers will succeed in shifting the tax they pay on their consumption of polluting goods onto their employers, in the form of higher wages. Hence, the employment impact of a green tax reform may differ from one country to another, depending on national labour market policies and institutions that influence the wage determination process, such as the wage bargaining system, the existence of a legal minimum wage and the unemployment benefit system.

Overall, it comes out relatively clearly from this theoretical literature that pre-existing labour market distortions should be relatively strong for green tax reforms to raise employment. To take an example, Koskela and Schöb (1999) show that a green tax reform can increase employment if unemployment benefits are neither subject to the labour income tax nor indexed to the consumer price index. In this context, labour taxation is most distortive as it does not affect worker reservation wage, therefore implying that a rise in payroll taxes will translate, to a large extent, into higher labour costs and unemployment, rather than into lower take-home pay. But this constitutes a favourable context for an employment dividend to materialise. Higher pollution taxes on consumption depress the real value of worker reservation wage as unemployment benefits are not indexed the consumer price index. Furthermore, the unemployed do not get compensated by the cut in the labour tax because they do not pay that tax. Hence, the environmental tax reform shifts the tax burden towards the unemployed and away from workers.

Source: Goulder (1995); Bovenberg (1999); Bovenberg and Goulder (2002)

At the national level, CBO (2010) compares the estimated economic impacts produced by three leading CGEs for the United States when used to analyse a *standardised* climate change mitigation scenario: results differ sufficiently across the three models to make it clear that the precise modelling assumptions used require also careful scrutiny. Nonetheless, many of the qualitative conclusions were consistent across the models. This includes the findings that net employment effects are small whereas there is a considerable shift of workers away from declining sectors, such as coal mining (the biggest job loser) and other sectors that are producers or heavy users of fossil fuels, and towards industries producing clean energy and also goods and services whose products result in the least green house gas emissions when produced and consumed. The CBO analysis also provides robust evidence that real wages tend to fall due to the impact of higher energy prices in raising the cost of living. The findings that the transition towards low-carbon growth implies both the sectoral reallocation of labour and downward wage flexibility suggest that a substantial degree of labour market flexibility is a precondition for a smooth transition to green growth. Paroussos and Capros (2009) illustrate this point using the GEM-3 model for EU countries. Of particular interest, they analyse the same scenario for the expansion of renewable energy sectors under three alternative assumptions concerning the degree of labour market flexibility. Their results confirm that the impact on total employment and its sectoral composition is significantly affected by the degree of labour market flexibility.

In essence, green growth policies represent a timing issue: they require costs and economic adjustments in the short run to avoid larger costs and irreversible damage later. CGE models allow evaluating the transition costs, but over a longer time horizon, certain employment gains induced by mitigation policies (or job losses avoided) are not captured. Indeed, as innovation is intrinsically difficult to predict, the potential effects of environmental policies in stimulating the innovation of new green technologies is not fully captured.

Table1. Selected evaluations of the economic impact of mitigation policies

	Scenario / Country		**Estimated impact** (deviation from the business-as-usual scenario)						**Labour market modelling**
Boeters et al. (2010) WorldScan Model	**Target**: 20 % reduction in energy use **Policy**: uniform tax on energy use. Tax rate (as an ad-valorem tax to the energy price exclusive of other taxes): around 50%. **Implementation period**: 2001 (static model simulation)		**Unemployment** (% points)		**Participation** (%)		**Real wage** (%)		Collective wage bargaining, endogenous labour supply Empirical weakness of the model: no scope for calibrating the wage bargaining equation to empirical estimations of wage curve elasticities, because the only remaining free parameter, the relative bargaining power of trade unions, is needed to calibrate the model so that empirical unemployment rates are met.
			Worker skill:						
			High	Low	High	Low	High	Low	
			Recycling: lump-sum transfers						
		France	0.15	0.27	-0.58	-0.81	-3.5	-3.5	
		Germany	0.10	0.22	-0.33	-0.47	-3.5	-3.7	
		United Kingdom	0.04	0.15	-0.35	-0.40	-2.7	-2.8	
		Italy	0.09	0.27	-0.54	-0.49	-3.4	-3.5	
		Spain	0.05	0.17	-0.42	-0.47	-3.4	-3.9	
			Recycling: lower labour taxes						
		France	0.00	0.13	-0.31	-0.65	-3.7	-3.7	
		Germany	-0.12	-0.05	0.03	-0.23	-3.5	-3.9	
		United Kingdom	0.00	0.07	-0.19	-0.32	-2.7	-2.8	
		Italy	-0.14	-0.16	-0.02	-0.14	-3.8	-4.0	
		Spain	-0.26	-0.23	0.11	-0.12	-3.8	-4.2	
Montgomery et al. (2009) MNR-NEEM and MS-MRT models	**Target**: reduction of GHG emissions by 83% below 2005 levels by 2050 **Policy**: cap-and-trade program (H.R.2454). Recycling: lump-sum transfers to consumers. **Implementation period**: 2010-2050	**United States**	**GDP** (%)		**Employment** (Thousands of jobs)		**Real Wage** (USD)		Wages adjust by one-half the amount required for full employment
			-1.0 in 2030 -1.5 in 2050		-2,200 in 2030 -3,600 in 2050		-510 in 2030 -1,250 in 2050		
International Council for Capital Formation (2005a-d) DRI-WEFA model	**Target**: 60% below 2000 emissions by 2050 **Policy**: International carbon dioxide trading mechanism. Recycling: lump-sum transfers to consumers **Implementation period**: 2005-2025.		**GDP** (%)			**Employment** (%)			Real gross wages are sticky and adjust to expected inflation and unemployment rate. Labour supply is exogenous.
		United States	-2.0 in 2020			-0.1 in 2020			
		Italy	-1.6 in 2025			-1.25 in 2025			
		Spain	-4.1 in 2025			-2.9 in 2025			
		Germany	-1.4 in 2025			-1.6 in 2025			
		United Kingdom	-1.1 in 2025			-1.25 in 2025			
Commission of the European Communities (2008) GEM-E3 model	**Target**: at least a 20% reduction of GHG emissions by 2020 relative to 1990 levels, and target of 20% renewable energy by 2020. **Policy**: EU trading mechanism. Recycling: lump-sum transfers. **Implementation period**: 2005-2020	**Europe**	**GDP** (%)			**Employment** (%)			Labour supply not fully elastic. Wage bargaining with an intermediate value for trade-union bargaining power.
			-0.35 in 2020			-0.04 in 2020			

3. Employment Impacts of generic climate change mitigation policies: CGE analysis in a context of perfectly flexible labour markets

In order to clarify some of the implications of a transition toward green growth for labour markets, illustrative simulation exercises have been conducted with the OECD ENV-linkages model (see Box 2). In the core version of this model, aggregate employment is treated as an exogenous variable since the primary purpose of ENV-linkages model is to assess the impact of environmental policies on GHGs emissions and economic growth. When economic shocks arise or new policies are introduced, labour market clears and all the adjustment occurs on wages. While aggregate employment remains unchanged, the model allows for instantaneous job reallocations across economic sectors. This strong assumption about full flexibility in the labour market is at odds with extensive evidence about rigidities in OECD and non-OECD countries and frictions that affect the pace of labour reallocation. Nonetheless, this baseline version of the model provides a first indication of the magnitude of labour market adjustment pressures at stake when mitigation policies are implemented. Moreover, an augmented version of the model has also been used, which introduced some degrees of real wage rigidity so as to enable the impacts of green policies on both employment and wage levels to be analysed.

Box 2. Main characteristics of the OECD ENV-linkages model

The OECD ENV-Linkages model is a recursive dynamic neo-classical general equilibrium model, documented in details in Chateau *et al*. (2012). It has been used extensively for several OECD publications, notably the *Environmental Outlook to 2030* (OECD, 2008) and *The Economics of Climate Change* (OECD, 2009a). The version of the model used in this study represents the world economy in 15 countries/regions, each with 26 economic sectors. These include five electric generation sectors, five that are linked to agriculture (including fishing and forestry), five energy-intensive industries, three sectors linked to oil and gas extraction, refineries and distribution petroleum products, the remaining sectors being transport, services, construction and four other manufacturing sectors. Technological progress is exogenous, but alternative existing production technologies are modelled in great detail in the energy sector and the mix of technologies used evolves in response to changes in relative prices. A labour market clearing equation equalises the aggregate labour demand to an exogenous employment level, and therefore determines wages.

Exogenous employment levels are derived from labour force projections to 2050 and from estimates of national unemployment rates provided by the OECD Economics Department (see Duval and De la Maisonneuve, 2010). The model is built primarily on a database of national economies. The core of the static equilibrium is formed by the set of Social Account Matrices (SAMs) that described how economic sectors are linked; these are based on the GTAP database. Many key parameters are set on the basis of information drawn from various empirical studies and data sources. The "business as usual" projection used as a support for economic policy scenarios is described in detail in Chateau, Dellink and Rebolledo (2011).

3.1 Economic impacts of various mitigation scenarios and recycling options for carbon revenues

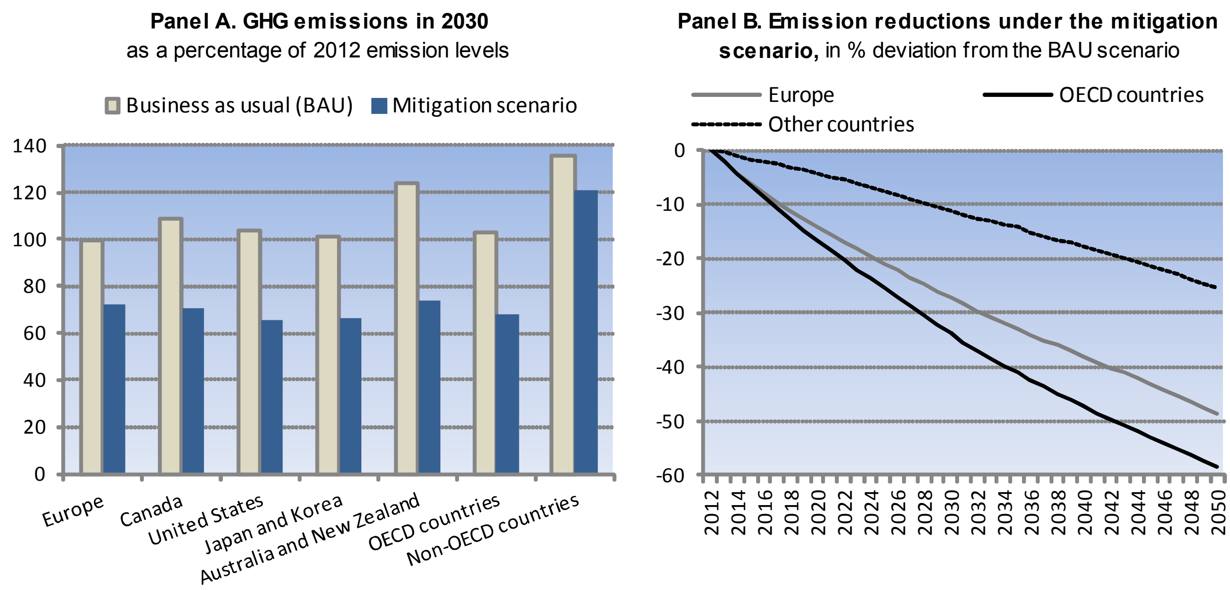
Faced with the consequences and costs of inaction, governments have reached a consensus internationally that global emissions need to be cut significantly. In this respect, both the long-term target for emissions reduction and the type of international agreement reached are key determinants of the potential implications of mitigation efforts for economic growth.

The illustrative policy scenario applied in the modelling is an emission trading scheme (ETS) which, over the period 2013-2050, progressively reduces greenhouse gas (GHG) emissions in the OECD area as a whole by 50% in 2050 as compared to their 1990 levels (Figure 1).[1] The target is less stringent for non-OECD countries: emissions are reduced by 25% in 2050 as compared to what would be observed in these

1. For Mexico, it is assumed that emissions are reduced by 50% in 2050 as compared to 2005 levels.

countries in the absence of mitigation efforts, under the so-called business-as-usual (BAU) scenario. Three different kinds of international agreements have been considered in this analysis: *i)* a "Fragmented ETSs" scenario, where all countries are reducing their own emissions through emissions trading schemes without linking to others countries' action: carbon markets are fragmented; *ii)* an "OECD-wide ETS" scenario: OECD countries are allocated emission rights (permits) corresponding to the same emission reduction targets as those in the fragmented scenario, but they can trade their permits. In this OECD cap-and-trade scheme, non-OECD countries still undertake their emissions reductions alone; and *iii)* a "Worldwide ETS" scenario, whereby all countries are participating in a global and linked carbon market, with initial emission permits still allocated according to the "Fragmented ETS" case. This allocation rule for emission rights is purely illustrative and not intended as policy recommendation.

Figure 1. Greenhouse gas (GHG) emissions



a) **European average** includes: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Iceland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom.

b) **OECD average** includes: Australia, Canada, Europe, Japan, Korea, New Zealand and the United States.

Source: OECD ENV-linkages model.

Simulation exercises have been conducted using the baseline version of the OECD ENV-linkages model, with full flexibility in the labour market. Therefore, structural adjustment pressures triggered by these various mitigation policies are apprehended through their impact on GDP levels, disposable income of working households (real net wage) and a welfare measure, the so-called "equivalent variation" in real income of all households. This variable is defined as the difference between the simulated level of real income when mitigation policies are introduced and the level of real income that would ensure the same utility level to consumers as would occur in the absence of such policies, *i.e.* in the baseline (or BAU) scenario. Therefore, the equivalent variation in real household income can be interpreted as the variation in aggregate welfare induced by the introduction of mitigation policies. As the damages from climate change, and hence the benefits from mitigation action, are not included in the analysis, these welfare losses represent only the cost of action and not the benefits.

All of these mitigation policy scenarios tend to slow down the pace of economic growth. In Europe, real GDP declines by less than 0.5% from baseline levels in 2030 and by 0.1% to 1.4% from baseline levels in 2050, depending on the policy scenario (Table 2). These GDP losses are slightly more pronounced for the OECD area as a whole, but larger than those projected for non-OECD countries (in part due the less stringent mitigation target that has been retained for these countries). Although these costs are certainly not negligible, *they should be viewed in the context*: these GDP losses are very small compared to the substantial growth in GDP in the baseline (Figure 2, Panel B).

Table2. Impact on GDP, wages and welfare of various mitigation policy scenarios

In % deviation from the business-as-usual scenario

		Central scenario: OECD-wide ETS			Fragmented ETSs			Worlwide ETS		
		Real GDP	Real net wage	Welfare measure	Real GDP	Real net wage	Welfare measure	Real GDP	Real net wage	Welfare measure
Europe	2015	-0.02	-0.13	-0.02	-0.01	-0.06	-0.01	0.00	-0.03	0.00
	2020	-0.12	-0.59	-0.08	-0.06	-0.38	-0.07	-0.01	-0.08	-0.02
	2030	-0.43	-1.27	-0.36	-0.36	-1.16	-0.36	-0.04	-0.30	-0.14
	2050	-1.36	-2.52	-1.38	-1.41	-2.61	-1.39	-0.14	-0.47	-0.53
OECD	2015	-0.02	-0.13	-0.02	-0.02	-0.12	-0.02	0.00	-0.03	0.00
	2020	-0.13	-0.61	-0.12	-0.13	-0.58	-0.12	-0.01	-0.09	-0.03
	2030	-0.55	-1.41	-0.51	-0.54	-1.42	-0.52	-0.09	-0.34	-0.22
	2050	-1.71	-2.56	-1.46	-1.74	-2.68	-1.49	-0.25	-0.51	-0.59
Other Countries	2015	-0.01	-0.09	-0.04	-0.01	-0.09	-0.04	-0.01	-0.16	-0.02
	2020	-0.06	-0.34	-0.25	-0.05	-0.36	-0.23	-0.07	-0.50	-0.08
	2030	-0.27	-1.13	-0.73	-0.26	-1.16	-0.71	-0.40	-1.67	-0.32
	2050	-0.65	-1.56	-1.40	-0.64	-1.60	-1.41	-1.08	-1.87	-0.87

For various definitions, see Figure 1, notes a), b) and c).

a) The welfare measure is defined as the difference between the simulated level of real income when mitigation policies are introduced and the level of real income that would ensure the same utility level to consumers as would occur in the absence of such policies, *i.e.* in the baseline (or BAU) scenario. *It takes no account of environmental benefits from mitigation policy*.

b) The real net wage is defined as the net-of-taxes wage perceived by households divided by the consumer price index. Therefore, it is directly affected by changes in carbon prices.

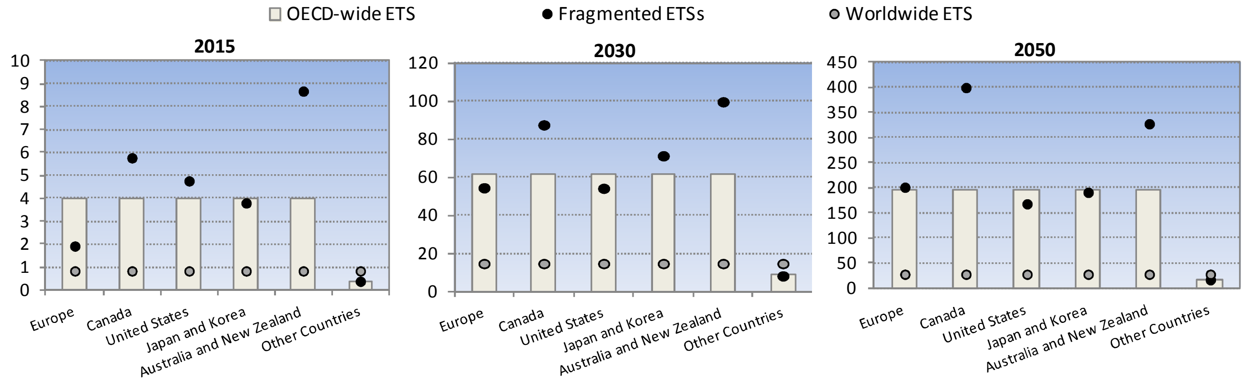
Source: OECD ENV-linkages model.

The cost of reaching a global target or a regional target could be significantly reduced by emissions trading. The trading of emission permits, among a group of participating countries, helps to equalise marginal abatement costs of GHG emission reductions across different countries and emission sources. These marginal abatement costs are reflected by carbon prices, which vary greatly between countries or regions and between the three mitigation scenarios considered for any given country or region (Figure 2, Panel A). The more the marginal mitigation costs differ among a group of countries in a unilateral action scenario –"Fragmented ETSs" –, the higher the cost-efficiency benefits of linking their mitigation effort through trading permits (OECD, 2009a).

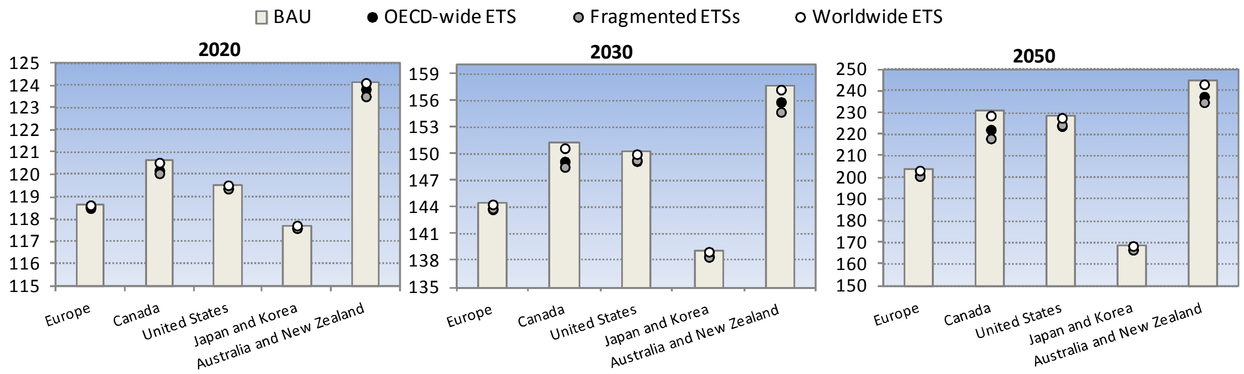
GDP effects in the "Fragmented ETSs" scenario vary across countries with the stringency of the target with respect to the baseline, reflecting *inter alia* the degree of carbon intensity of each economy and the different degree of flexibility of their economic structures. Compared with the Fragmented-ETS scenario, the integrated cap-and-trade scheme (OECD-wide ETS) has different implications for the cost of mitigation depending on whether countries are importers or exporters of permits. In the "OECD-wide ETS", Europe exports a growing amount of permits until 2030; then, this amount gradually declines and the European region becomes a net importer after 2040. By contrast, the United States benefits from the possibility of importing permits until 2020 and then becomes a net and growing exporter of carbon permits. Other OECD countries always benefit from the trading system as net importers. As a result, in terms of GDP, Europe starts to benefit from the OECD trading system linking after 2040 only while, for the United States, this scheme becomes costly, relative to the fragmented case, after 2020. All other OECD countries always benefit from the OECD trading system linking.

Figure 2. Mitigation costs for various mitigation policy scenarios

Panel A. Carbon prices, in 2007 USD per ton of CO2 equivalent



Panel B. Real GDP (100 = 2012)



Europe: see Figure 2, note a).

Source: OECD ENV-linkages model.

But GDP is not the most accurate indicator for examining the benefit of ETSs linking: potential gains are better reflected in the welfare measure of mitigation costs.[2] According to this measure, all participating countries would generally benefit from meeting their joint targets through a common ETS (Table 1). The "Worldwide ETS" scenario shows larger reduction in overall mitigation costs, in particular for OECD countries. This is because carbon price heterogeneity prior to ETSs linking is estimated to be relatively larger across all participating countries than it is within the OECD area (Figure 2, Panel A).

In fully flexible labour markets, all of these mitigation policy scenarios would lead to a reduction in real wages. This is because ETSs result in GDP losses through the increase in marginal costs of production that they imply. This puts a downward pressure on labour demand, and thus, on wages. This cost rises over

2. Real exchange rates are fully flexible in the model, which explains GDP changes in the ETS linking scenario relative to the fragmented scenario. Net importers of permits face a degradation of their current account and real exchange rates fully depreciate. Therefore, the trade balance in real terms increases as well as real GDP. For permit exporters, the opposite occurs. Moreover, the value of the exported permits equals zero in real terms (as the original price of permits in the BAU equals zero) and thus does not contribute to GDP in constant 2007 USD as it is discussed here. For these and other reasons, GDP is not the most accurate indicator for examining the benefit of ETSs linking.

time, reflecting the gradual introduction of larger emission reductions with respect to the baseline scenario. In the OECD-wide ETS and Fragmented ETSs scenarios, real wage in Europe would decline by around 1.5% from baseline levels in 2030 and by around 2.5% from baseline levels in 2050 (Table 1). By contrast, wage losses are almost negligible in the Worldwide ETS scenario. Similar projections are obtained for the OECD area as a whole. Besides, the depressive effect of mitigation policies is always more pronounced on real net wages than it is on GPD or aggregate welfare, whatever the scenario retained. These policies may generate distributional concerns and off-setting the resulting income losses for workers could thus be one of the considerations involved in deciding how to distribute the revenues from ETS.

In the simulation exercises described above, ETS revenues were redistributed to all households in the form of *uniform lump-sum transfers*. For illustrative purposes, four alternative recycling policies have been simulated within the "*OECD-wide ETS*" scenario, with ETS revenues being recycled respectively to: *i)* lower household wage income taxation; *ii)* lower household global income taxation; *iii)* reduce both capital and labour taxes paid by firms; and *iv)* subsidize gross-output or production. The two latter policy options are in part sector-specific in the sense that tax relief is assumed to be proportional to initial taxation.

Table 3 shows that the mitigation policy generates net additional public revenues that are large enough to offset its depressive effect on workers disposable income when the total amount of permit revenues is used to reduce taxes on wage income. Working households actually benefit from this mitigation policy as real net wages increase. In fully flexible labour markets, this alternative recycling option has only distributional consequences, shifting part of the adjustment burden away from working households.[3] Because capital incomes are earned by households, similar redistributive patterns are found when ETS revenues are used to reduce taxes on both labour and capital incomes. The recycling of ETS revenues in the form of lower income taxes is much less favourable to workers, because income taxes are more equally distributed across working and non-working households than taxes on labour and capital are.

Table3. OECD-wide ETS: Economic impact of mitigation policies for various recycling options

In % deviation from the business-as-usual scenario

			Taxes on labour			Household income tax			Capital and labour taxes			Production subsidies		
		Revenues from ETS	Real GDP	Real net wage	Welfare measure	Real GDP	Real net wage	Welfare measure	Real GDP	Real net wage	Welfare measure	Real GDP	Real net wage	Welfare measure
Europe	2015	0.12	-0.02	0.18	-0.02	-0.02	0.01	-0.02	-0.02	0.16	-0.02	-0.01	0.03	0.00
	2020	0.51	-0.12	0.68	-0.08	-0.12	-0.02	-0.08	-0.12	0.56	-0.08	-0.05	0.02	-0.02
	2030	0.92	-0.43	0.74	-0.36	-0.43	-0.34	-0.36	-0.43	0.54	-0.36	-0.26	-0.33	-0.25
OECD	2015	0.15	-0.02	0.16	-0.02	-0.02	0.03	-0.02	-0.02	0.12	-0.02	-0.01	0.02	-0.01
	2020	0.60	-0.13	0.54	-0.12	-0.13	0.02	-0.12	-0.13	0.38	-0.11	-0.10	-0.02	-0.09
	2030	1.04	-0.55	0.36	-0.51	-0.55	-0.41	-0.51	-0.55	0.11	-0.50	-0.48	-0.49	-0.46

OECD, Europe: see Figure 1, notes a) and b). Real net wage, welfare measure: see Table 1, note a) and b).

a) Revenues from ETS are expressed in % GDP and correspond to the policy scenario with lump-sum recycling.

Source: OECD ENV-linkages model.

These three alternative recycling options do not reduce GDP losses or aggregate welfare costs compared to the lump-sum redistribution presented in Table 1, since labour supply is exogenous and savings are not affected by recycling policies. For these policies to have some implications on GDP and aggregate welfare in this framework, they need to be directed towards producers in order to influence price-setting and offset, at least partially, the rise in marginal costs of production induced by the

3. The model assumes that household savings are not influenced by the rate of return on savings, and therefore, capital accumulation depends upon aggregate income only.

introduction of climate mitigation policies. And indeed, when ETS revenues are redistributed in the form of production subsidies, the recycling policy has only a small indirect redistributive pattern (through relative price changes) but limits costs to all households by attenuating GDP losses induced by the mitigation efforts. Consequently, this latter recycling option still reduces significantly the magnitude of wage losses compared to the lump-sum redistribution presented in Table 1.

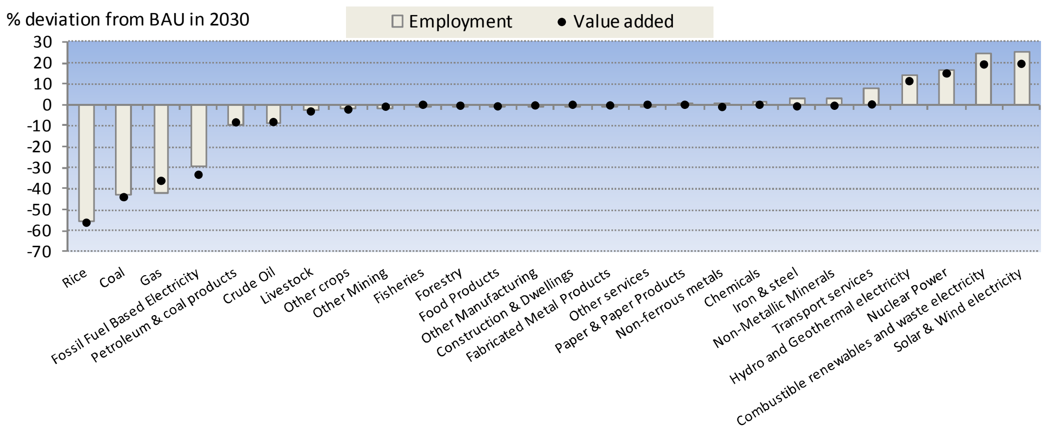
3.2 How do mitigation policies affect the sectoral mix of employment?

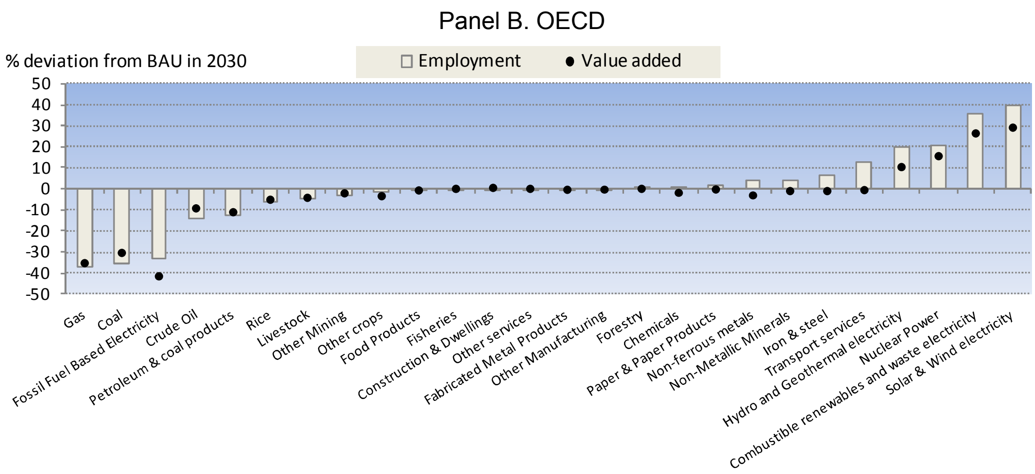
The transition to green growth will also affect labour reallocation across sectors, which is another source of distributional consequences from these policies. Labour reallocation is an intrinsic feature of all market economies, with large flows of jobs and workers across sectors but especially across firms within each individual sector. These sizeable job and worker flows imply both costs and benefits for firms, individual workers and the whole society (see OECD, 2010). As seen before, mitigation policies are likely to affect this process since the resulting rise in energy prices will translate into changes in relative prices between and within economic sectors.

Figure 3 shows how sectoral employment is affected by mitigation efforts in each economic sector considered in the ENV-linkages model. These results are based on the central mitigation scenario, the "OECD-wide ETS" case, and ETS revenues are redistributed towards households, either in the form of lump-sum transfers, or in the form of tax reliefs on labour income (with fully flexible labour markets and rigid labour supply, these two recycling options lead to the same results). The simulation suggests that by 2030 employment in solar and wind electricity sector in Europe and in the OECD area as a whole could be 25% and 40% higher than it would have been in the absence of the climate mitigation policy. By contrast, the fossil fuel and coal mining sectors in Europe and in the OECD area could lose more than 30% of their jobs in Europe, and 35% in the OECD area.

Figure 3. Change in sectoral composition of employment

Panel A. Europe



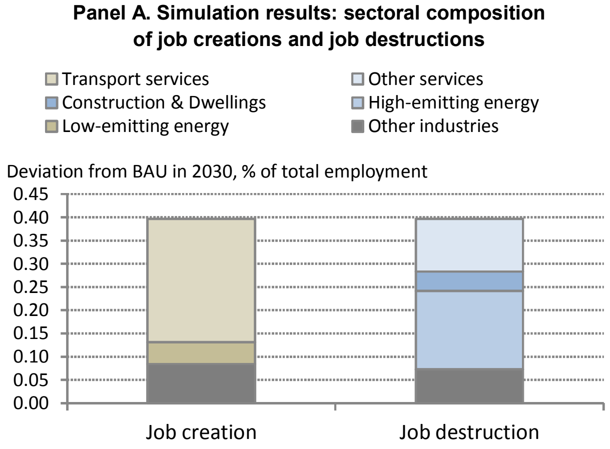


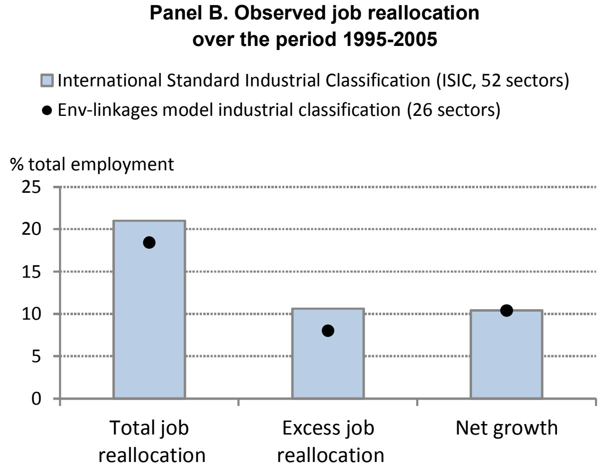
OECD, Europe: see Figure 1, notes a) and b).
Source: OECD ENV-linkages model.

Although these expansions and contractions are quite dramatic, they do not translate into a large overall reallocation of jobs, because the heavily impacted industries represent only a small share of total employment (Figure 4, Panel A). Indeed, summing up all sectoral job creations, it appears that jobs created by expanding sectors represent only 0.4% of total employment in the OECD area, and 0.3% in Europe. As national labour markets are assumed to be fully flexible, total employment is not affected by the mitigation policy, hence equalising job destructions and creations at the aggregate level. Therefore, by 2030, the change in the sectoral composition of employment induced by the mitigation policy would affect less than 1% of all jobs in the OECD and Europe. These are quite small numbers as compared to the magnitude of cross-sectoral employment shifts that were observed over the last decade (Figure 4, Panel B). Indeed, over the period 1995-2005, total job reallocation between economic sectors –*i.e.* the sum of sectoral job creation and destruction– accounted for 20% of total employment on average in the OECD area. Of this 20%, only 10% correspond to changes in the sectoral composition of employment for a constant level of total employment, the so-called "excess job reallocation". But even when the model projections for climate mitigation policies examined here are compared with this observed excess job reallocation, they are still small: less than a 1% change over a 18-year period as compared to a 10% change over a 10-year period.

Of course, the measurement of job reallocation between sectors is sensitive to the industry classification retained for the analysis. However, Figure 4 (Panel B) shows that the results obtained vary only slightly when the calculation is based on the industry classification in 26 economic sectors used in the ENV-linkages model, instead of being based on the International Standard Industrial Classification in 52 sectors (3-digit level). This is because most of job creations occurred within the same broad economic sector, namely the service sector (other than transportation), while most of job destructions took place within the manufacturing sector. However, OECD evidence suggests that gross job flows between firms in the same sector or sub-sector are an order of magnitude larger than gross job flows across sectors (OECD, 2010). But unfortunately, the OECD ENV-linkages model does not allow examining job reallocation within sectors, and therefore, some caveats are needed when considering the magnitude of job reallocations induced by mitigation policies presented in Figure 4.

Figure 4. Change in sectoral composition of employment, OECD





a) High-emitting energy sector: Coal, Crude oil, Gas, Petroleum and coal products, Fossil fuel based electricity.

b) Low-emitting energy sector: Hydro and geothermal electricity, Nuclear power, Solar and wind electricity, combustible renewables and waste electricity.

c) Definitions: *Total job reallocation* = sum of job creation and job destruction; *Absolute net growth* = absolute value of net employment growth (defined as the difference between job creation and job destruction); *Excess job reallocation* = difference between total job reallocation and absolute net growth.

Source: OECD ENV-linkages model (Panel A) and EU KELMS database (Panel B).

Although the magnitude of job reallocation between sectors is projected to be quite limited, the sectoral composition of job creation and job destruction reveals interesting patterns (Figure 4, Panel A). Indeed, general equilibrium effects appear to be larger than partial equilibrium effects in that most of job reallocations are projected to take place outside the green and brown sectors. The bulk of job creations take place in the transport services, even though this sector figures among the most polluting industries. First, the demand for transport services is complementary to many other economic activities and, thus, does not fall much although transportation prices increase due to rising energy prices. Second, transport services become more labour intensive due to changes in relative. By comparison, job creations in the so-called "clean energy sector", represent a small fraction of total job creations. And although a large proportion of sectoral job destructions corresponds to the contraction of the so-called "High-emitting energy sector", services other than transportation contribute to total job destruction by a large amount. This can be explained by the fact that the services sector is by far the largest employer, representing around two thirds of total employment.

All in all, in fully flexible labour markets, mitigation policies would not involve considerable changes in the industrial mix of employment, and mitigation costs are projected to be relatively limited, be they measured in terms of GDP, welfare or wage loss. To what extent would the introduction of labour market rigidities affect these results? In order to provide a tentative answer to this question, labour market imperfections have been introduced in the ENV-Linkages model through a wage equation implying that real wages do not immediately adjust to the new economic situation when mitigation policies are implemented.

4 How much do labour market imperfections reshape the economic impact of mitigation policies?

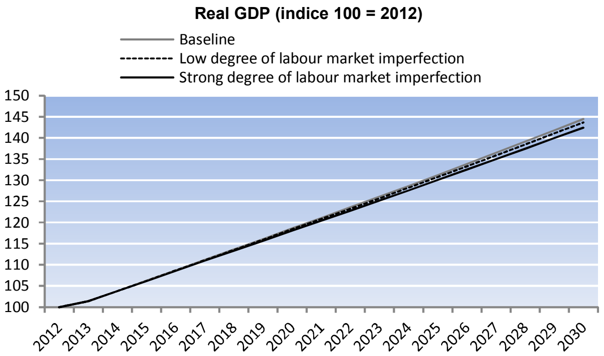
The modelling of labour market imperfections in the augmented version of the ENV-linkages model follows the approach adopted by Montgomery *et al.* (2009) for evaluating the economic and employment impact of the American Clean Energy and Security Act of 2009. As empirical evidence suggests that wages do not immediately adjust to economic changes, be they cyclical or structural, the real net wage is set, in each period, in-between: i) the real net wage that would be observed in absence of mitigation policies (*i.e.* the wage corresponding to baseline scenario), and; *ii)* the real wage that would be reached if wages fully adjust so that the employment level is not affected by mitigation policies (*i.e.* the market-clearing wage). In other words, workers in the short-run resist the reduction in real wages associated with mitigation policy and thus part of the adjustment is absorbed *via* job losses instead. In the model, temporary shocks have only a temporary effect on employment and wage levels since after the shock, the economy will return progressively to its BAU pathway. However, since the carbon permits are only gradually introduced and become increasingly stringent over time, mitigation efforts will have a long-lasting effect on employment. While this very simple representation of the labour market functioning summarises some of the main wage rigidities and at the same time keeps the model tractable, all numerical results need to be considered with caution.

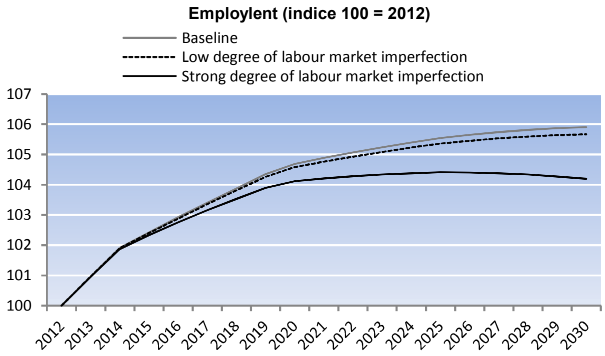
4.1 Lump-sum carbon revenues recycling

Figure 5 and Table 4 show how the introduction of labour market imperfections into the OECD ENV-linkages modifies the projected mitigation costs when permit revenues are redistributed in the form of uniform lump sum transfers. As there is no way to know precisely the degree of wage rigidity that would be relevant for calibrating the wage equation, lower- and upper bound projections are provided: a low degree of labour market imperfection refers to a situation where 80% of the decline in the market-clearing wage rate is absorbed by workers immediately, while this proportion is set at only 20% when strong labour market imperfection is assumed.

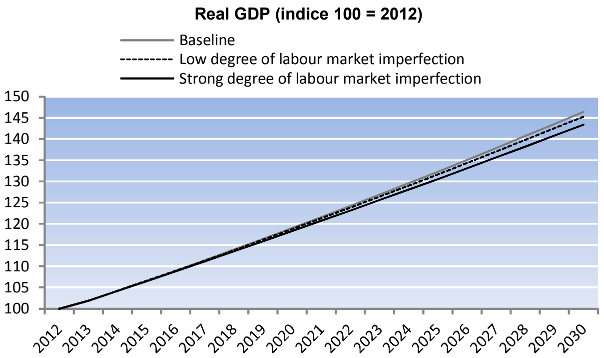
Figure 5. GDP and employment impacts for different degrees of labour market imperfections, when ETS revenues are recycled in the form of lump-sum transfers

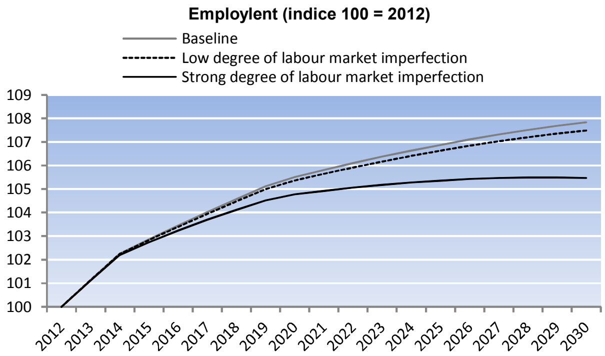
Panel A. Europe





Panel B. OECD





OECD, Europe: see Figure 1, notes a) and b).

Source: OECD ENV-linkages model.

Table 4. Economic impact of an OECD-wide ETS for different degrees of labour market imperfections, when ETS revenues are recycled in the form of lump-sum transfers

In % deviation from the business-as-usual scenario

		Real GDP		**Employment**		**Real wage**		**Welfare measure**	
		Low rigidity	Strong rigidity	Low rigidity	Strong rigidity	Low rigidity	Strong rigidity	Low rigidity	Strong rigidity
Europe	2015	-0.03	-0.08	-0.02	-0.09	-0.10	-0.03	-0.04	-0.10
	2020	-0.18	-0.45	-0.10	-0.54	-0.52	-0.17	-0.17	-0.58
	2030	-0.57	-1.41	-0.23	-1.62	-1.17	-0.52	-0.58	-1.88
OECD	2015	-0.04	-0.10	-0.03	-0.12	-0.11	-0.03	-0.04	-0.13
	2020	-0.23	-0.62	-0.13	-0.70	-0.53	-0.18	-0.25	-0.80
	2030	-0.78	-2.09	-0.32	-2.19	-1.30	-0.56	-0.83	-2.68

OECD, Europe: see Figure 1, notes a) and b).

Source: OECD ENV-linkages model.

Overall, the simulations indicate that the mitigation policy has a limited impact on economic growth. Even in the worst-case scenario, under very strong labour market imperfections, economic growth is only slightly affected by the introduction of carbon permits. In the OECD area as a whole, real GDP increases by around 43% over the period 2012-2030, as compared to 46% in the absence of mitigation actions. And in Europe, the pace of economic growth is reduced by two percentage points, as compared to a GDP increase of 44% over the 2012-2030 in the baseline scenario.

The resulting slowdown in job creation can be much more pronounced, however. Mitigation costs increase with the degree of labour market imperfection, as structural distortions, *ceteris paribus*, reinforce the deadweight losses associated with a given carbon price[4]. In Europe, employment declines by 0.2% from baseline levels in 2030 in the best-case scenario, and by 1.6% in presence of strong wage rigidities. Similar outcomes are projected for the OECD area as a whole. In both regions, the worst-case scenario represents a strong deficit in job creation. Indeed, the mitigation policy reduces substantially the pace of employment growth over the period 2012-2030, from 7.8% to 5.5% in the OECD, and from 5.9% to 4.2% in Europe. However, this scenario is most likely to be overly pessimistic as it assumes very strong wage rigidities than are unlikely to persist over a 18-year period.

Moreover, as most available CGE models developed for the economic analysis of mitigation costs, the ENV-linkages model has two characteristics which tend to overstate the long-run cost of mitigation policies: *i)* technological progress is assumed to be exogenous, so that the model does not fully capture the potential effects of environmental policies in stimulating the innovation of new green technologies; and *ii)* the ENV-linkages model does not account for the potential economic damages from climate change and, hence, omits the economic benefits from mitigation policies that operate through reduced environmental disruption. Both characteristics imply that in the long run, certain employment gains (or avoided job losses) induced by the mitigation policy that are not captured in the modelling framework. These characteristics are, however, less important in the coming decades, as innovation and climate changes are slow processes.

4.2 Some active carbon revenues recycling options: is a double dividend phenomenon possible?

The employment impact of mitigation policies crucially depends on how ETS revenues are redistributed. This is illustrated in Figure 6 and Table 5, which compare two recycling options when the degree of labour market imperfection is set to an intermediate level (40% of the decline in the market-clearing wage rate is absorbed by workers immediately) [5]. When permit revenues are used to reduce taxation on labour, the pace of employment growth would accelerate, and this, without any loss of purchasing power for workers. OECD employment would increase by 7.3% over the period 2012-2030, against 5.9% in absence of mitigation actions. In Europe, the migration policy boost job creation even more substantially: employment increase by 7.3% over the period 2012-2030, against 5.9% in the baseline scenario. In turn, this positive impact on employment could temporarily raise GDP levels above the baseline projection.

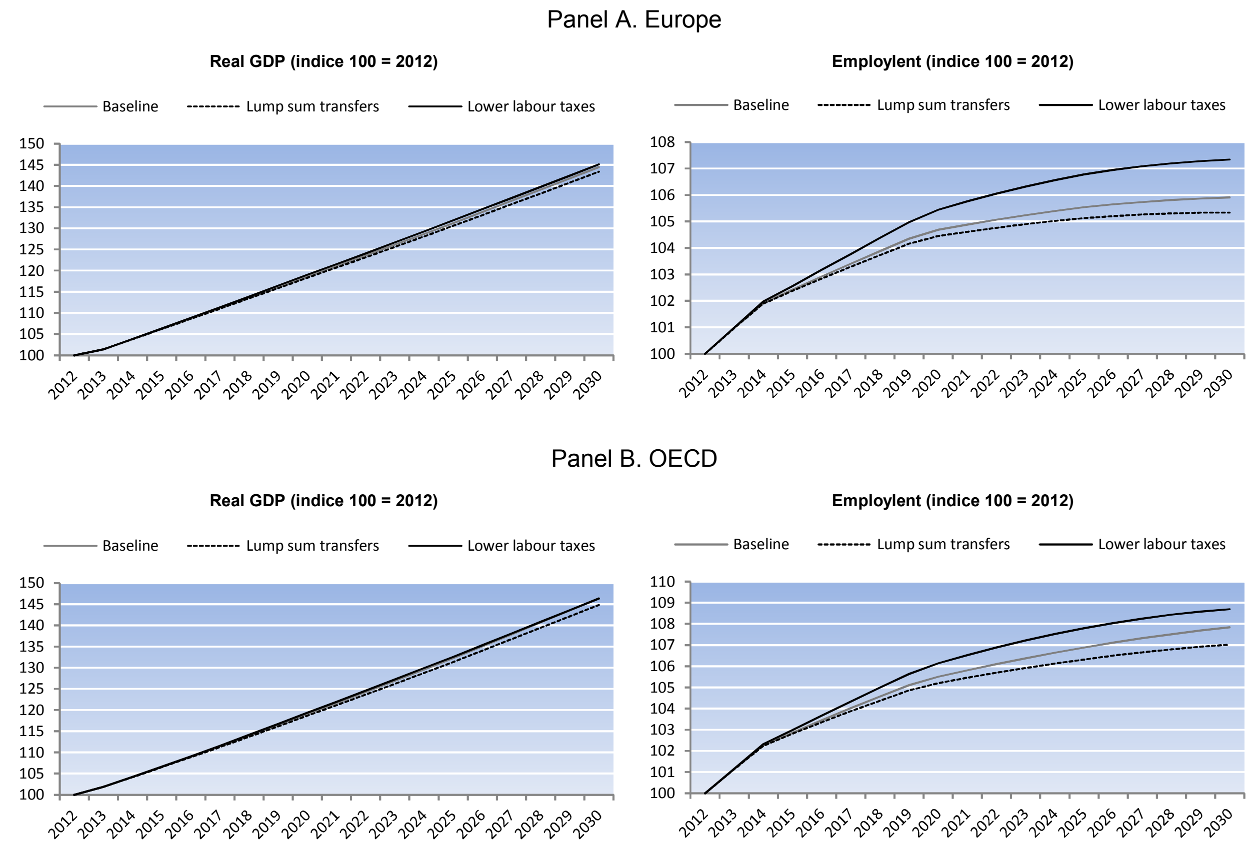
4 Welfare impacts of the policy for various degrees of market imperfections are reported in Figure A2 Panel A. of the appendix.

5 As noted in Table 2, the recycling policy through labour taxation is not the only option that could be considered. The four recycling options are presented in Annex A1, in a purely illustrative case, where the rigidity parameter is set in all OECD countries to its low value of alpha = 0.2. This shows that recycling through labour taxation is the most efficient option (within the present framework) and explains why it has been presented here as a polar case to the lump-sum recycling.

The positive employment impact reduces over time because the rising deadweight-loss associated to carbon pricing will offset the recycling effects on labour taxation in the long run[6]. In the modelling scenarios examined here, mitigation efforts –and thus corresponding carbon prices– are increasing over time and they progressively impact capital accumulation. Carbon pricing raises energy prices, and hence, the user cost of machinery and other physical capital since energy and capital are complementary inputs. This, together with the reduction in real GDP, lowers investment, but capital stock takes time to adjust. As seen before, this also puts a downward pressure on labour demand through the induced increase in marginal costs of production, and in the long run, when capital stock has fully adjusted downward, through the resulting decrease in labour productivity. On the other hand, as the relative price of labour inputs decreases, firms will tend to substitute employment from other more expensive production factors, which tend to raise labour demand. This positive substitution effect can dominate in the short and medium run as the capital stock adjusts slowly over time thus leaving labour productivity almost unchanged.

Additional simulations, not reported here, suggest that aggregate labour market imperfections, as well as, recycling policies do not change the picture about the change in the sectoral mix of employment consecutive to the climate mitigation scenario as presented in section 3.2

Figure 6. GDP and employment impacts for different recycling options of ETS revenues, and an intermediate degree of labour market imperfections



OECD, Europe: see Figure 1, notes a) and b).

Source: OECD ENV-linkages model.

6 The Figure A2 Panel B. reported in the appendix shows that the higher the degree of the initial rigidity of labour market is and the greater and the positive recycling effect is.

Table 5. Economic impact of an OECD-wide ETS for different recycling options of ETS revenues, and an intermediate degree of labour market imperfections

In % deviation from the business-as-usual scenario

		Real GDP		Employment		Real wage		Welfare measure	
		Lump sum transfers	Lower labour taxes	Lump sum transfers	Lower labour taxes	Lump sum transfers	Lower labour taxes	Lump sum transfers	Lower labour taxes
Europe	2015	-0.05	0.07	-0.04	0.14	-0.08	0.18	-0.06	0.15
	2020	-0.26	0.33	-0.22	0.72	-0.43	0.96	-0.28	0.73
	2030	-0.76	0.43	-0.54	1.35	-1.04	1.85	-0.87	1.09
OECD	2015	-0.06	0.06	-0.05	0.12	-0.08	0.11	-0.07	0.09
	2020	-0.34	0.26	-0.29	0.59	-0.44	0.54	-0.40	0.44
	2030	-1.08	-0.03	-0.75	0.80	-1.14	0.76	-1.26	0.24

OECD, Europe: see Figure 1, notes a) and b).

Source: OECD ENV-linkages model.

5. Conclusion

The simulation exercises performed in this paper using the OECD ENV-Linkage model illustrate how certain policy mixes can improve both environmental and labour market performance. They also show that both the quality of labour market institutions and the redistribution of permit revenues need to be addressed together by policy-makers in order to reap the full potential benefit of climate change policies in terms of job creation. These conclusions are in line with many other studies analysing the employment impact of mitigation actions within the framework of a CGE or hybrid model (cf. Section 2.2).

From a theoretical perspective the role of recycling option in presence of labour market rigidities (cf. Section 4.2) illustrates the result of the "second-best theory" that playing accurately on fiscal wedges (here a mix of carbon tax and labour taxation reduction) in a second best world (characterised here by labour market rigidities) could leads to welfare improvements.

The interaction between income and employment effects of a climate change mitigation policy illustrated here remains somewhat reductive and number of caveats should be noticed. Likewise, most CGE models we do not account for the potential economic damages from climate change and, hence, omits the economic benefits from mitigation policies that operate through reduced environmental disruption. And the economic and employment damages from climate change may be large. This includes substantial destruction of physical capital through more intense and frequent storms, droughts and floods, for example from a rise in sea level and storm surge in heavily populated coastal areas (Hanson et al., 2011).

Another way to extend our analysis is to take into account the absence of sector-specific rigidities in labour mobility. As indicated by Babiker and Eckaus (2007), in each economic activities a non negligible part of the employment is constituted by skilled-specific jobs. For such workers the migration towards another sector after structural change is not straightforward and worker would generally calls for extra human capital investment. This kind of sector specific rigidities or transition costs in labour mobility could be integrated in our analysis; in such context an alternative efficient use of carbon revenues as education and formation could be envisaged.

REFERENCES

American Council of Capital Formation (2002), *Kyoto Protocol and Beyond: The High Economic Cost to the United States.*

Babiker, M. and R. Eckaus (2007), "Unemployment effects of climate policy", *Environmental science & policy*, No. 10, pp. 600–609.

Boeters, S. and N. van Leeuwen (2010), "A Labour Market Extension for WordScan – Modelling Labour Supply, Wage Bargaining and Unemployment in a CGE framework", CPB Document No. 201.

Bovenberg, A.L. (1999), "Green Tax Reforms and the Double Dividend: an Updated Reader's Guide", *International Tax and Public Finance*, No. 6, pp. 421-443.

Bovenberg, A.L. and L.H. Goulder (2002), "Environmental Taxation and Regulation", in *Handbook of Publics Economy*, Volume 3 (Chapter 23), edited by A.J. Auerbach and M. Feldstein.

Chateau, J., Dellink, R., Lanzi, E., and Magne, B. (2012), "An overview of the ENV-Linkages Model, Version 3", *OECD Environment Working Paper,* No. 43, OECD Publishing.

Chateau, J, Rebolledo, C., Dellink, R. (2011), "The ENV-Linkages economic baseline projections to 2050" *OECD Environment Working Papers*, No. 41, OECD Publishing.

CBO (2010), *How Policies to Reduce Greenhouse Gas Emissions Could Affect Employment*, Economic and Budget Issue Brief, May 5, Washington.

Commission of the European Communities (2008), *Package of Implementation measures for the EU's objectives on climate change and renewable energy for 2020*

Duval, R. and C. De la Maisonneuve (2010), "A Long-Run Growth Framework and Scenarios for the World Economy", *Journal of Policy Modeling* 62, pp. 64-80.

Goulder, L.H. (1995), "Environmental Taxation and the Double Dividend: A Reader's Guide", International Tax and Public Finance, No. 2, pp. 157-183.

International Council of Capital Formation (2005a), *Kyoto Protocol and Beyond: The Economic Cost to Germany*.

International Council of Capital Formation (2005b), *Kyoto Protocol and Beyond: The Economic Cost to Italy*.

International Council of Capital Formation (2005c), *Kyoto Protocol and Beyond: The Economic Cost to Spain*.

International Council of Capital Formation (2005d), *Kyoto Protocol and Beyond: The Economic Cost to the United Kingdom*.

Koskela, E. and R. Schöb (1999), "Alleviating Unemployment: The Case for Green Tax Reforms", *European Economic Review*, No. 43.

Montgomery, D., Baron, R., Bernstein, P., Bloomberg, S., Ditzel, K., Lane, L., Smith, A., Tuladhar, S. and M. Yuan (2009), "Impact on the Economy of the American Clean Energy and Security Act of 2009 (H.R.2454)", CRA International report prepared for National Black Chamber of Commerce, Washington.

S. Hanson, R. Nicholls, N. Ranger, S. Hallegatte, J. Corfee-Morlot, C. Herweijer and J. Chateau (2011). A global ranking of port cities with high exposure to climate extremes, Climatic Change, No. 104, pp. 89–111.

OECD (2005), OECD Employment Outlook 2005, OECD Publishing. doi: 10.1787/empl_outlook-2005-en

OECD (2007), OECD Employment Outlook 2007, OECD Publishing. doi: 10.1787/empl_outlook-2007-en

OECD (2008), OECD Environmental Outlook to 2030, OECD Publishing. doi: 10.1787/9789264040519-en

OECD (2009), The Economics of Climate Change Mitigation: Policies and Options for Global Action beyond 2012, OECD Publishing. doi: 10.1787/9789264073616-en

OECD (2010), OECD Employment Outlook 2010: Moving beyond the Jobs Crisis, OECD Publishing. doi: 10.1787/empl_outlook-2010-en

OECD (2011), Towards Green Growth, OECD Green Growth Studies, OECD Publishing. doi: 10.1787/9789264111318-en

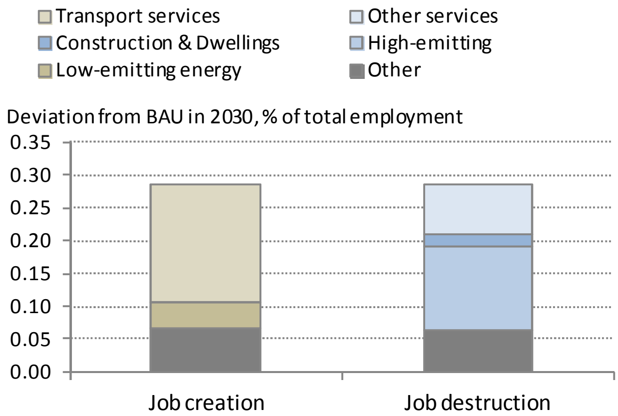
Paroussos, L. and P. Capros (2009), *Assessment of the employment effects from i) an increase in energy efficiency, and ii) a rise in renewable sectors*, Research Report for the European Commission.

Stern, N. (2006), *Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge.

UNEP (2011), Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication, UNEP, New York.

ANNEX

Figure A1. Change in sectoral composition of employment triggered by the OECD-wide ETS policy, Europe



a) High-emitting energy sector: Coal, Crude oil, Gas, Petroleum and coal products, Fossil fuel based electricity.

b) Low-emitting energy sector: Hydro and geothermal electricity, Nuclear power, Solar and wind electricity, combustible renewables and waste electricity.

Source: OECD ENV-linkages model.

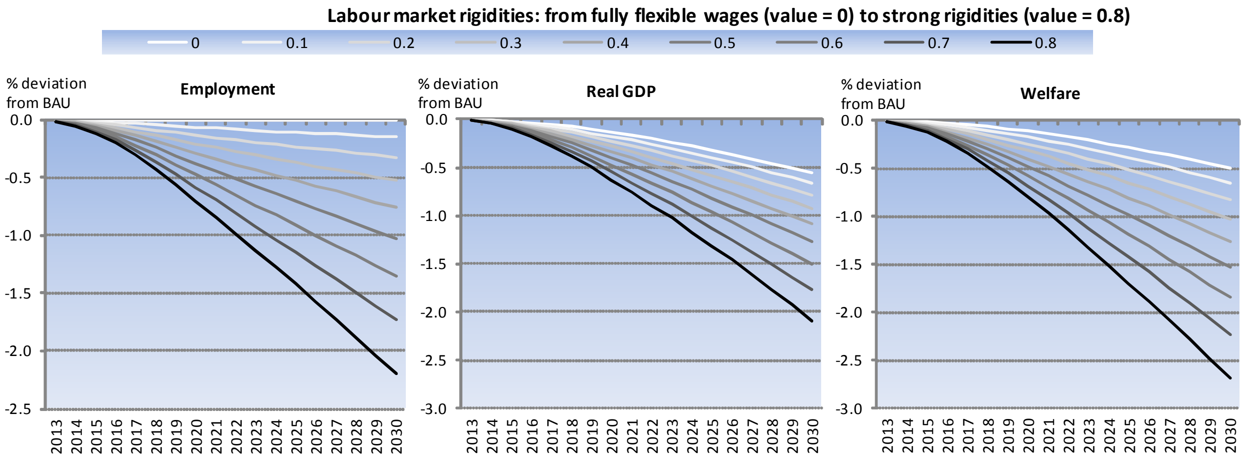
Table A1. Economic impact of an OECD-wide ETS for 5 different recycling options of ETS revenues, and a low degree of labour market imperfections

		Lump sum rebate			Labour income tax			Houshold income tax			Subsidies to gross-output			Tax on labour and capital		
		Employ.	GDP	Welfare	Employ.	GDP	Welfare	Employ.	GDP	Welfare	Employ.	GDP	Welfare	Employ.	GDP	Welfare
Europe	2015	-0.02	-0.03	-0.04	0.04	0.01	0.02	0.00	-0.02	-0.02	0.01	0.00	0.00	0.04	0.00	0.01
	2020	-0.10	-0.18	-0.17	0.19	0.00	0.10	0.00	-0.12	-0.08	0.01	-0.05	-0.01	0.15	-0.03	0.06
	2030	-0.23	-0.57	-0.58	0.25	-0.27	-0.12	-0.07	-0.47	-0.43	-0.07	-0.31	-0.32	0.17	-0.32	-0.20
OECD	2015	-0.03	-0.04	-0.04	0.06	0.02	0.04	0.01	-0.01	-0.01	0.00	-0.01	-0.01	0.04	0.01	0.02
	2020	-0.13	-0.23	-0.25	0.23	0.02	0.11	0.01	-0.13	-0.11	-0.01	-0.11	-0.11	0.14	-0.04	0.02
	2030	-0.32	-0.78	-0.83	0.18	-0.43	-0.33	-0.13	-0.65	-0.64	-0.15	-0.58	-0.60	0.05	-0.52	-0.46

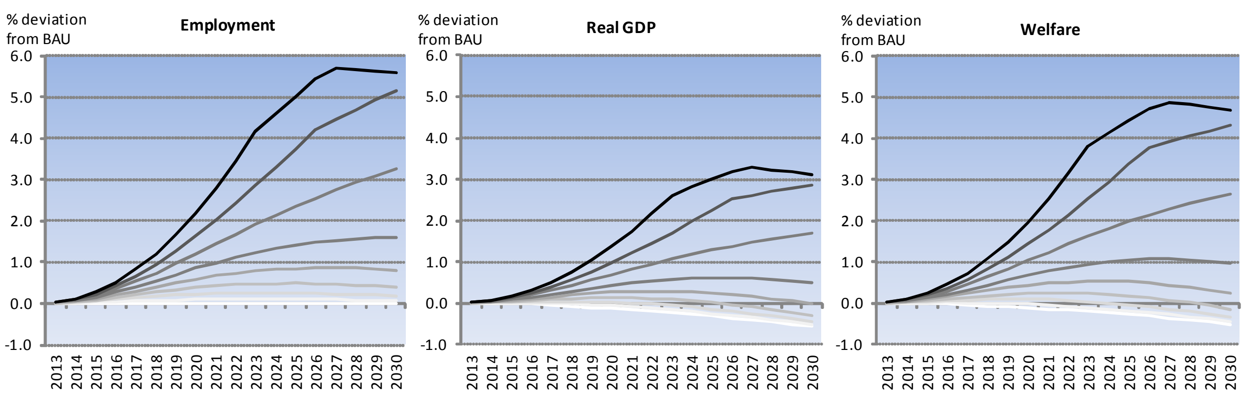
Source: OECD ENV-linkages model

Figure A2. GDP, Employment and Welfare impacts for various degrees of labour market imperfections

Panel A. Recycling policy: uniform lump sum transfers to households



Panel B. Recycling policy: reduction of taxes on wage income paid by households



Source: OECD ENV-linkages model