Box 4.1 Carbon taxes and cap-and-trade schemes

In principle, the environment is a public good with free access. As such, its use is not properly reflected in market prices and it tends to be depleted (the so-called "tragedy of the commons"). To correct this externality, the carbon tax is one possible way of pricing carbon emissions in order to give appropriate market signals that reflect the costs that GHG emissions impose on society. Setting a price for using fossil fuels will change incentives in the economy. Alternatively, tradable emissions permit fix the maximum level of emissions (the "cap") and issue allowances into the economy that can be freely traded among private polluters. Here, the maximum level of pollution is decided by the government, and then the permits are distributed among firms, redefining their rights to pollute.

Both schemes may counteract the externality generated by GHG emissions by putting a price on carbon, thereby generating incentives to switch to alternative energy sources and adopt green technologies. However, their implementation requires information on emissions, and adequate mechanisms for monitoring and enforcement (Pew Center on Global Climate Change, 2009).

Some economists argue that a carbon tax is preferable to a cap-and-trade scheme (see Nordhaus, 2008; Nell et al., 2009; Uzawa, 2003; Mankiw, 2007; IPCC, 2007). In their view, cap-and-trade schemes come with several shortcomings. Tradable permits require that the actual polluter can be identified, and enforcement of the cap-and-trade scheme is difficult as trading systems have to be set up. In addition, trading of emission certificates is exposed to speculative investments, which can cause high volatility in the carbon price, as the European example shows. According to an estimate by Nell et al. (2009), the volatility of the carbon price, in the case of emission trading, is ten times higher than for stock prices, which are already about seven times more volatile than GDP. Instead, a carbon tax allows for a broader application, including energy supply, major polluting industries, the service sector, the transport system and households. Furthermore, the generated tax revenue can be used to reduce other taxes or to establish tax funds to compensate developing economies, or it can be spent on climate-friendly investments.

From a longer-term perspective, it is crucial to invest in R&D to develop new technologies. As emphasized by the Intergovernmental Panel on Climate Change, policies should gradually shift towards encouraging investment in R&D spending and technology transfer, in particular regarding the development and diffusion of alternative sources of energy, such as solar, tidal and wind power and biomass energy.

So far, green policies in developed countries have concentrated on introducing carbon taxes or implementing cap-and-trade schemes, while some efforts have also been made to prop up R&D spending, subsidize solar panels and other renewable sources of energy, and set new international standards. In developing countries, governments are less advanced in shifting towards green policies, partly due to a lack of investments, resources and technology. But even here, many countries are starting to switch to a greener economy, for instance through recourse to the Clean Development Mechanism (CDM) – an arrangement where developing countries (not included in the main targets associated with the Kyoto Protocol) will benefit from funding from developed countries for green projects. Thus, Argentina, Brazil, China and India use CDMs. In Indonesia, the government proposes a gradual reduction of fossil fuel subsidies, the possible introduction of a carbon tax, better use of the CDM programme and raising consumer awareness.

Earlier evidence suggests that green policies could be either neutral or favourable to employment…

It is sometimes argued that green policies could raise costs of goods, thereby threatening labour demand and living standards. However, green policies can also help to create new markets and unlock the development potential of entire regions and countries. As with any other structural change, the transition to a greener economy will be more or less successful depending on the particular country's characteristics, such as the labour intensity of adversely affected sectors, the matching between workers' skills and the new job requirements, the speed of technology diffusion and the availability of well-designed labour market policies to support workers and businesses in their move to a greener economy.

Advocates of green policies assert that environmental regulation could stimulate eco-innovation and investment in more efficient production techniques and so positively impact on employment. At the moment, enterprises are starting to see the potential of new climate-friendly markets (see, for instance, European Commission, 2005). Empirical studies also seem to confirm that the adverse effects on the economy are probably very limited. Several studies suggest that there is no loss of jobs or decline in output following the introduction of carbon taxes. Some of the studies take into account the scenario in which the revenues from the tax are redistributed, for example through a reduction in labour costs. The development of environmental technology, in and of itself, may have a positive impact on job creation.[7]

Overall, a majority of studies find that the net impact of environmental policies on employment is likely to be neutral or slightly positive. However, the distributional effects of these policies are less clear cut (see Appendix B for an overview of existing studies in this area).

…and this is confirmed in this study: green policies, even without technological change, could raise employment by between 0.5 per cent and 1.1 per cent in a period of five years...

The extent to which green policies affect the labour market also depends on how the additional resources that arise from taxing or pricing carbon emissions are used. In several countries, the additional public revenues generated by these policies have been used to target particular groups, with the aim of generating additional employment and offsetting the initial job destruction associated with adjustment. Properly designed green policies could help to achieve the double dividend of both lower GHG emissions and higher employment. In particular, policy-makers have two broad options for how best to make use of the additional resources. They could support (i) (low-wage) employment or (ii) specific low-carbon industries. An attempt has been made to quantify the employment effects associated with these two options based on a model for nine countries, specifically developed for the purposes of this chapter. In this model, the effect of putting a price on carbon emissions is modelled. The price can take the form of either a carbon tax or a cap-and-trade scheme. Though there are differences between these two instruments,

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7. Subsidies also have an important role, but they need to be applied cautiously. For instance, supporting biofuels contributes to energy security and rural employment (De la Torre et al., 2009), but careful cost-benefit assessment is needed given the potential effects of biofuel production on food prices and competition for land and water.

the model does not examine them in any detail. The results are as follows (see Appendix C for more details).

In order to illustrate the employment impacts of the two different policy options, a baseline scenario – where the revenues arising from carbon taxes or tradable permits are not used for other purposes – is developed. In this baseline scenario, carbon taxes or tradable permits raise the costs for producing high carbon intensive goods and services. Their introduction will affect production in high carbon intensive sectors, thereby creating incentives for a shift of resources to low carbon intensive sectors or the adoption of low carbon intensive technologies[8] The baseline scenario considers that: (i) high carbon intensive sectors have to pay the equivalent of 30 euros per ton of carbon emitted for a period of five years (for instance, in the form of a green tax). This payment comes close to the carbon tax level that is typically proposed in current debates and represents the equivalent of 2.5 per cent of the output of high carbon intensive sectors; and (ii) the revenues arising from this measure are kept by government in full (that is, these revenues are not spent in the form of tax reductions for low carbon intensive sectors, cuts in social contributions or other measures). Therefore, the government's primary surplus increases. But, in this baseline scenario, there is no consideration of any macroeconomic implications that this surplus may have. The main result is a decline in both total and sectoral employment in the baseline scenario, reflecting the fact that the policy merely taxes some sectors without any compensatory measures. Note that employment declines even faster in the low carbon intensive sector than in the high carbon intensive sector, which is due to a lag in the adjustment process.

A different employment outcome occurs when the increase in public revenues from taxing the high carbon intensive sector (or from selling pollution rights) is used to promote employment by cutting social contributions, as has been done in Germany and Sweden. In this case, high carbon intensive sectors still face higher production costs. However, in this scenario, the adverse consequences for employment are outweighed by support for labour demand. This is why in this scenario, employment rises in all sectors (table 4.2, second row). More than 1,700,000 jobs are created in the OECD-9 region over a period of five years. Employment gains are three time larger in the low carbon intensive sectors than in the high carbon intensive sectors when revenues are redistributed in the form of employment subsidies. This is probably because the employment content is higher in the low carbon intensive sectors than in the high carbon intensive sectors.

As an alternative, and with the aim of strengthening the incentive to reduce GHG emissions, policy-makers might also think of subsidizing particular low carbon intensive industries. Such industries could be targeted according to their job creation potential. Compared with the previous case, subsidizing green sectors adds a direct incentive to the production of low carbon intensive goods and services. The outcomes of this simulation are shown in table 4.2 (third row). Subsidizing green sectors appears to yield the best results from the point of view of employment. Employment in the low carbon intensive sectors grows by more than 1.8 per cent. Employment in the high carbon-intensive sectors also increases,

8. The simulation assumes that the high carbon intensive sector pays to pollute – either because CO_2 emissions are taxed or because polluters have to obtain pollution rights. Such a simulation differs slightly from standard experiments, where other sectors also have to pay to pollute. In other words, for the purposes of the simulations in this chapter, a "subsistence level" of carbon may be emitted without being subject to payments. This subsistence level applies to all the sectors other than high carbon intensive sectors.

Table 4.2 Estimated impacts of green policies on employment in nine countries (percentage change in employment five years after application of the green policy)

	Employment in high carbon intensive sectors	Total employment
No compensation (baseline scenario)	–0.5	-0.5
Green policy with employment subsidy	0.3	0.5
Green policy with industry subsidy	0.5	1.1

Note: The table presents (i) simulations (based on a vector autoregressive model) of the possible employment effects of different policy options, based on a model for nine countries (Australia, France, Germany, Hungary, Japan, Korea, Sweden, the United Kingdom and the US); and (ii) projections for developed countries and the world as a whole based on the simulations. See Appendix C.

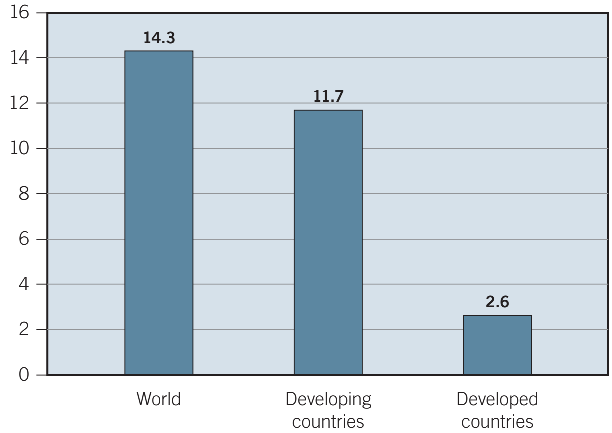
Source: IILS estimates.

by 0.5 per cent, despite the negative impact of the green policy on this sector. A possible explanation is that both sectors are complementary to some extent and that the growth of the low carbon intensive sector has a positive spill over effect on the high carbon intensive sector. Overall, 3.9 million jobs may be created for the nine countries altogether.

…this means that green policies, if combined with job support, could help raise employment by 2.6 million in developed countries and 14.3 million for the world as a whole.

A projection of these results for all OECD countries and for the world economy implies up to 2.6 million and 14.3 millions new jobs, respectively (figure 4.2). These results come close to those of three other major empirical studies, both in terms of CO_2 emission reductions and employment increases (table 4.3). The employment gains arise mainly because the funds raised by environmental policies are used to cut non-wage labour costs, thereby supporting labour demand. More fundamentally, as a result of green policies, relative prices change in a direction that supports employment. Consumers substitute, to a certain degree, low carbon intensive goods for high carbon intensive goods in the face of higher prices for the latter. Similarly, enterprises substitute capital for labour. It is often

Figure 4.2 Well-designed green policies will boost employment (change in net employment, in millions, within five years)



Note: The figure shows the projected impact on employment of green policies combined with lower labour taxes (see text for more explanation). The growth rate of employment estimated for developed countries was extrapolated to total employment worldwide.

Source: IILS estimates.

Table 4.3 Employment effects of green policies with employment subsidies: Outcomes from different studies

	Period of change, years	Increase in employment %
IILS (nine developed countries)	5	0.5
HERMES (EU-6)	8	0.6
QUEST (EU)	20	1.3
PANTA RHEI (Germany)	11	0.6

Note: The QUEST model discusses three different cases depending on which economic instrument bears the higher tax burden. This table presents the outcomes of the third case, in which households pay the carbon tax and accept wage moderation.

Source: IILS estimates for the IILS model; Bossier et al. (1993); Hayden (1999); Bach et al. (2002).

assumed that energy and capital are two complementary factors of production. The rises in energy price mechanically increase the cost of capital relative to the cost of labour.

In the empirical study carried out for this chapter, the simulation corresponds to a decrease in CO_2 emissions by 4.6 per cent for the nine-country sample (table 4.3, entry IILS). The employment effect in the scenario with employment subsidies is an increase of 1.1 per cent when aggregating countries and sectors. This result falls within the range of the estimates produced by other studies (see box 4.2). Assuming a linear effect, our results can be extrapolated to be compared with the results of the other three studies. The results from our study show that a decrease in CO_2 emissions of 2 per cent would produce a 0.5 per cent increase in employment, which is lower than the 0.6 per cent found by the PANTA RHEI model. The employment effect measured in our study is, however, larger than for the HERMES and QUEST models. A 4.4 per cent decrease in CO_2 emissions would produce a 1 per cent increase in employment, whereas the HERMES model predicts a 0.6 per cent increase in employment; and an 8 per cent reduction in CO_2 emissions would produce a 1.9 per cent increase in employment, but the QUEST model predicts a 1.3 per cent increase in employment. Such a comparison must, however, be viewed with caution as the methodologies implemented and the country coverage differ between studies.

And larger gains would arise due to technological change induced by green policies

A final option consists of using the additional public funds, raised by green taxes, to foster technological research, especially in the area of promoting green energy production. Such policies bear the potential to increase growth, for instance by lowering the future price of energy production in comparison with the current mix of energy technologies. Indeed, considering that the price for energy production based on non-renewable energy sources is likely to increase exponentially (the oil price hike observed in 2008 is probably a first indication of potential future price increases), the relative price for green energies can be expected to fall in the future. As mentioned by Tylecote (1997), the scarcity price for non-renewable energies could be reflected by the use of carbon taxes or cap and trade. Similarly, removing subsidies for fossil fuel energy will increase the expected returns from R&D in green technologies (OECD, 2009).

Box 4.2 Employment effects of green policies combined with lower labour taxes: Results from three studies

Three major studies, based on econometric models, have examined the employment effects of green policies and their findings come close to those presented in this chapter.[1] All three models are demand driven and allow for the possibility of unemployment as a result of adjustment processes, and each includes a wide range of sectors. They are therefore particularly useful for examining the inter-sectoral adjustments generated by climate change policies.

The HERMES model includes eight sectors and covers the EU (Bossier et al., 1993). A key finding is that a reduction of CO_2 emissions by 4 per cent via tax instruments increases employment by 0.6 per cent over a period of eight years. The result is driven by factor substitution between labour and capital. Labour demand is supported by both higher energy prices (which increase the cost of capital relative to labour) and lower labour taxes.

The QUEST model assesses the employment effect of reducing CO_2 emissions by 8 per cent between 1990 and 2010 in the EU (Hayden, 1999). QUEST shares similarities with the HERMES model, but there are fewer industries and no energy in the production function. Three scenarios are assessed, based on different sectors bearing the costs of higher energy prices. In the first case, the cost falls on industries. The employment effect is positive but small (+0.1 per cent) and GDP is reduced by 1 per cent. The contraction of output is due to the lower productivity of capital, which brings a contraction of investment. In the second case, the tax burden falls on consumers. The impact on employment is positive, with an increase by 0.9 per cent, and is mainly due to the substitution of capital for labour. The third case assumes a certain degree of wage moderation. The employment effect is the largest, with an increase by 1.3 per cent. Employment is not limited by the rise in wages that takes place in the second case.

The PANTA RHEI model (see Bach et al., 2002) includes 58 industries in Germany. Here as well the revenue from an energy tax is used to reduce labour costs, this time in the form of lower social pension contributions. CO2 emissions drop by 2 per cent, while employment increases by 0.55 per cent over the period 1999–2010. The substitution effect between capital and labour outweighs the negative employment effect of a contraction in GDP.

[1] See OECD (2004a) for a detailed discussion of the three models.

Existing empirical studies point to the potentially large impact of such an effect. A study by GHK (GHK in association with CE and IEEP, 2007) found that in a scenario of a 10 per cent substitution in electricity generation by renewable energy technologies, the result was an increase of EU-27 output and jobs. The positive impacts are due to the source (sectors) of inputs these new technologies require. However, a global agreement is important due to the uncertainty regarding the profitability of (private) R&D investments. Uncertainty on global commitments will depress R&D investments.

C. Conclusion

This chapter has argued that the employment challenge arising from green policies might eventually be smaller than critics of such policies argue. Indeed, with the right policy mix and by returning the additional government resources to the economy – ideally in the form of subsidies to low carbon intensive sectors – green policies have the potential to create a double dividend by lowering GHG emissions and creating employment. This chapter provides a novel attempt to estimate these employment effects. The findings are close to those of other studies – although this chapter is based on a broader range of countries.

The estimated employment gains associated with moving to a greener economy are likely to be a lower bound of the potential benefits of such a policy. Indeed, the estimates presented in this chapter do not take into account the possible technological advancements that might arise from green policies. Technological advancements could bring prices for green energy below those for energy based on fossil fuel combustion, further reinforcing the positive employment spin-offs. More fundamentally, new technology could pave the way for new business and employment opportunities. Further research is needed to assess the potential for green policies to stimulate innovation, new technology and job creation.

More work is needed to improve understanding of the social impacts of different types of green policies. In particular, the international dimensions need to be better understood. The empirical exercise presented in this chapter assumes that green policies are implemented simultaneously across the countries considered. This implies that all the countries implemented green policies at the same time. Therefore, the effects of green policies (with or without offsetting cuts in labour taxes) implemented by one country in isolation have not been assessed. This is a crucial issue. Indeed, there is concern that green policies might be translated into higher prices and a loss of competitiveness, which could result in jobs being reallocated in those countries that do not enforce stringent environmental standards. The issue of whether these concerns are valid, or whether countries can still make employment gains when acting in isolation, requires further analysis.

Also, the distributional consequences of green policies require further analysis. Carbon taxes and energy taxes that raise the cost of high carbon intensive goods are often found to be regressive. Generally speaking, all types of consumption taxes with a flat rate, such as a general sales tax, are regressive since the tax rate applied is not dependent on the income characteristics of the purchaser of the goods. Thus, high-income consumers and low-income consumers both pay the same absolute tax amount for a particular good, which results in lower relative taxation of high-income consumers.

Moreover, it is important to examine in more detail the pros and cons associated with carbon tax and cap-and-trade schemes. In this chapter, the mechanism through which green policies put a price on carbon emissions has not been examined in detail. Further work is important, as carbon tax and cap-and-trade schemes are also likely to have different impacts on growth and employment.

Finally, available research and evidence provide only a very rough picture of the costs of climate change. Estimates of the costs of adaptation to rising world temperature and the consequences this may have for the habitat of people around the world are wildly diverging. Based on current policies and without drastic action, however, one can reasonably expect some climate change to take place over the next few decades. Policy-makers need, therefore, to be able to evaluate these costs in order to make informed choices. This too is an issue requiring further investigation.

Appendix A

Estimating the size of the high carbon intensive sector

Data from German input–output tables for 1995 are used to estimate carbon intensity and employment in 71 sectors. Direct CO_2 intensities (CO_2 in kiloton over output in Euro) are used as a measure for the CO_2 intensities of sectors. Total CO_2 intensities could be used as an alternative criterion for classification. Total CO_2 intensities take into account the CO_2 intensities of inputs used in the production process.[9] To calculate total intensities, it is necessary to estimate CO_2 intensities of inputs used in the production process through the Leontief inverse, which is complex. This is why part of the analysis is done with the help of direct CO_2 intensities only. A table with the direct and total CO_2 intensities of different sectors is given below (table 4.4).

The 1995 classification has been compared with a classification based on the 2005 data. Even though the average CO_2 intensity fell for the economy (for example, the median of direct intensities fell from 0.051 to 0.043 kilotonnes CO_2 per million Euro), the ranking remains by and large the same. The year 1995 is therefore used as the base year for the classification of sectors into high and low carbon intensive groups.

For the empirical analysis in this chapter, the "high carbon intensive sectors" comprises those industries that emit more CO_2 in comparison with the other sectors. This includes all the sectors in table 4.4 for which the values are greater than one.

The results of this analysis are as follows. The energy sector (electricity, heat and gas) has the highest carbon intensity, followed by energy-intensive manufacturing sectors such as metals, coke, mechanical wood and paper. At the bottom of the table are service-oriented sectors, such as telecommunications, education, real estate, finance and public sector services, and also manufacturing sectors like medical, precision and optical instruments and electrical machinery and apparatus. Among the services, a high carbon intensive sector is air transport. It should be noted that direct intensities differ considerably from the total intensities. For example, the textiles sector is relatively low carbon intensive if we only look at the direct intensities but it is relatively high carbon intensive when looking at total CO_2 intensities.

Finally, it should be noted that the actual intensity numbers for particular sectors probably differ substantially across countries. This is due partly to the different fuel mixes used and partly to the different technologies employed. However, the ranking of the industries in different countries can be expected to be roughly the same, especially since we only make a binary classification into low and high carbon intensive sectors. A recent study by the OECD finds that the ranking of industries according to CO_2 intensity remains the same among different countries (see OECD, 2003). This seems to justify the choice of using the sectoral decomposition for Germany for other countries as well.

9. Total CO_2 intensities are based on the Leontief inverse of the input-output tables.

Table 4.4 Classification of Industries by CO_2-output intensity

Industries	CO_2-Output Intensity (as a ratio to median intensity)	
	Direct	Total
Agriculture	3.1	1.1
Forestry	4.5	1.0
Fishing	2.0	1.1
Mining and quarrying	3.5	2.0
Mining of coal and lignite; extraction of peat	3.7	2.5
Extraction of crude petroleum and natural gas and services	1.2	1.1
Other mining and quarrying	6.7	2.2
Food and beverages	1.8	1.3
Tobacco	0.7	0.9
Textiles	0.7	1.6
Wearing Apparel, Dressing And Dying Of Fur	0.2	1.0
Leather, leather and footwear	0.3	1.0
Wood and of wood and cork	1.0	1.2
Pulp, paper and paper	3.5	4.2
Printing, publishing and reproduction	0.7	0.9
Publishing	0.7	0.6
Printing and reproduction	0.7	1.2
Coke, refined petroleum and nuclear fuel	16.5	4.5
Chemicals and chemical	3.0	2.2
Pharmaceuticals	3.0	2.2
Chemicals excluding pharmaceuticals	3.0	2.2
Rubber and plastics	0.7	1.2
Other non-metallic mineral	9.2	2.6
Basic metals	10.9	5.3
Fabricated metal	1.0	1.6
Machinery, nec	0.5	1.0
Office, accounting and computing machinery	0.2	0.6
Electrical machinery and apparatus, nec	0.5	0.9
Radio, television and communication equipment	0.5	0.8
Medical, precision and optical instruments	0.5	0.7
Motor vehicles, trailers and semi-trailers	0.6	1.1
Other transport equipment	0.7	1.3
Manufacturing nec; recycling	1.0	1.2
Manufacturing nec	0.9	0.9
Recycling	4.5	1.5
Electricity and gas	110.8	14.7
Electricity supply	110.8	14.9
Gas supply	110.8	15.0
Water supply	0.6	1.6
Construction	0.9	0.9
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	1.1	0.5
Wholesale trade and commission trade, except of motor vehicles and motorcycles	1.6	0.5
Retail trade, except of motor vehicles and motorcycles; repair of household goods	1.8	0.6
Hotels and restaurants	1.1	0.8
Other Inland transport	5.9	2.3
Other Water transport	2.6	1.0
Other Air transport	17.0	3.1
Other Supporting and auxiliary transport activities; activities of travel agencies	2.4	1.0
Post and telecommunications	0.4	0.3
Financial intermediation, except insurance and pension funding	0.3	0.2
Insurance and pension funding, except compulsory social security	0.3	0.3
Activities related to financial intermediation	0.2	0.2
Real estate activities	0.0	0.1
Renting of machinery and equipment	0.2	0.1
Computer and related activities	0.4	0.2
Research and development	0.8	0.6
Other business activities	0.4	0.2
Public admin and defence; compulsory social security	1.4	0.4
Education	0.8	0.4
Health and social work	1.0	0.5
Sewage and refuse disposal, sanitation and similar activities	1.1	0.4
Activities of membership organizations nec	1.0	0.3
Recreational, cultural and sporting activities	0.5	0.3
Other service activities	0.4	0.3
Private households with employed persons	0.0	0.0

Note: A ratio greater than one means that the corresponding industry is relatively carbon intensive.

Source: IILS estimates based on input-output tables.

Appendix B

Selected empirical results of the distributional effects of green policies

Germany

(Bork, 2006)

Regressive effects for a tax on electricity, gas or heating oil (micro-simulation model). The negative effect is amplified by the reduction in social security contributions, as these reductions mostly favour the middle and upper income classes.

Indonesia

(Yusuf, 2008)

Distributional impacts of a carbon tax are progressive in rural areas and neutral or slightly progressive in urban ones (Computable General Equilibrium model). The reduction of subsidies on fuels for transportation has progressive effects.

Ireland

(Scott and Eakins, 2001)

Regressive impact of a carbon tax based on fuel (analysis based on households' purchases of fuel by income level).

United States studies

(Sutherland, 2006)

Regressive effects for both energy efficiency standards and subsidies for energy-efficient investments.

(Grainger and Kolstad, 2009)

Regressive effect for a carbon price due to differences in consumption baskets between income groups (input–output methodology). Polluting goods represent a relatively large percentage of the consumption basket of low-income households.

(Burtraw et al., 2009)

The allocation of revenue from cap-and-trade scheme leads to progressive distribution outcomes, depending on the compensation policies introduced (model of the electricity sector).

Various countries

(OECD, 2004b)

Carbon taxes are regressive in studies for two countries, while other studies lead to more ambiguous results (literature review).

Appendix B

Assessing the employment effects of green policies in nine countries: A vector autoregression approach

The empirical experiment is conducted by making use of the vector autoregression (VAR) technique. A VAR is a statistical method with which multivariate time series data can be analysed. The VAR describes the dynamic evolution of a number of variables from their common history. All variables in the VAR are treated as endogenous and the VAR allows for an analysis of the data without any theoretical priors: the effects of policies are studied solely on the basis of the characteristics contained in the data.

The VAR model comprises: high carbon intensity output (*Out*hi,t); low carbon intensity output (*Out*lo,t); and employment in the two sectors (*Emp*hi,t and *Emp*low,t). All variables in the VAR are specified in terms of annual growth rates (i.e. in log-differences) and collected in a vector *y*t, defined by:

$$y_t = \begin{pmatrix} out_{hi,t} \\ out_{lo,t} \\ emp_{hi,t} \\ emp_{lo,t} \end{pmatrix} = \begin{pmatrix} \ln(Out_{hi,t}) - \ln(Out_{hi,t-1}) \\ \ln(Out_{lo,t}) - \ln(Out_{lo,t-1}) \\ \ln(Emp_{hi,t}) - \ln(Emp_{hi,t-1}) \\ \ln(Emp_{lo,t}) - \ln(Emp_{lo,t-1}) \end{pmatrix}$$

The first-order VAR looks as follows:

$$y_t = c + Ay_{t-1} + \varepsilon_t$$

y_{t-1} is the vector of the respective growth rates of the four variables in the previous period, c is a constant and the matrix A contains the coefficients which may be estimated from the collected data. ε_t represents a vector of exogenous random shocks that also have an effect on y_t. This formulation provides a tool to study the statistical influences of the previous periods' growth rates of each of the variables on this period's growth rates of each of the variables. In view of the data limitations, higher than first-order VARs cannot be estimated. However, given that data are annual, a first-order VAR should be sufficient for a broad approximation of the employment–output dynamics.

To investigate dynamic dependencies among the variables and to assess the consequences of policy measures, a impulse response analysis is conducted using the estimated model. Impulse response functions generally indicate how the endogenous variables respond to external influences. In a VAR model, where all variables are endogenous, the only external inputs are the disturbances, which amount to one-step-ahead prediction errors. The specificities of the VAR (all variables are endogenous) implies that errors only arise through shocks. Disturbances are "innovations" or "surprises", such as "policy shocks", which cannot be explained by the model and past data.

The details of the VAR and key properties of response functions can be found in the Institute's website at www.ilo.org/inst (see "Background material to the Report").

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