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■ policy analysis

# Climate change, innovation and jobs

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The employment effect of climate policy has emerged as an important concern of policy makers, not least in the USA. Yet the impact of climate policy on jobs is complex. In the short term, jobs will shift from high-carbon activities to low-carbon activities. The net effect could be job creation, as low-carbon technologies tend to be more labour-intensive, at least in the short term until efficiency gains bring down costs. In the medium term, the effect will be felt economy-wide as value chains and production patterns adjust. This effect is more difficult to gauge, particularly if climate policy is unilateral and trade effects have to be taken into account. However, the biggest effect is expected to be long term, when climate policy will trigger widespread structural adjustment. Such episodes of ‘creative destruction’ are often associated with innovation, job creation and growth.

*Keywords:* climate policy; employment; innovation; mitigation; renewable energy

*Les conséquences de la politique climatique sur l'emploi émergent en tant que question importante pour les décideurs, non pour le moindre aux Etats-Unis. Cependant l'impact des politiques climatiques sur les métiers est complexe. A court terme les métiers passeront d'activités à haute intensité carbone à des activités sobres en carbone. L'effet net pourrait se sentir dans la création d'emplois, vu que les technologies sobres en carbone ont tendance à être plus intensive en main d'œuvre, si ce n'est dans le court terme. A moyen terme, l'effet se répercutera dans toute l'économie par l'ajustement des chaînes de valeur et coûts de production. Cet effet est plus difficile à évaluer particulièrement pour une politique climatique unilatérale, et les effets sur le commerce doivent être pris en compte. Cependant l'effet le plus considérable sera à long terme, lorsque la politique climatique produira des ajustements structurels étendus. De tels épisodes de « destruction créatrice » sont souvent associés à l'innovation, la création d'emploi et la croissance.*

*Mots clés:* employ; énergie renouvelable; innovation; mitigation; politique climatique

## 1. Introduction

A consensus is emerging that addressing climate change will require a cut in global greenhouse gas emissions of at least 50% by the middle of the century – considerably more in developed countries – which will have to bear the brunt of the abatement effort (see Stern, 2007).

Making these adjustments will require wholesale changes in the way economies are structured; changes that will spread into every aspect of economic life – from what we consume, to the way we produce energy, the technologies we use, where we locate firms, and how we produce and distribute goods.

Change of this magnitude creates risks but also opportunities. There will be both winners and losers as the world moves towards a low-carbon economy. An important concern for many people in this respect is the impact of climate change policy on employment.

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The employment discussion has been particularly fierce in the USA. Several politicians have made it an explicit condition of their support of any climate policy that it would not cost jobs. Advocates of climate change action also use employment as an argument. Former President Bill Clinton emphasized the job opportunities that climate change might create (Financial Times, 2007). Others have highlighted the innovation (and hence job creation) potential of climate change policy. They assert that the USA's reluctance to act on climate change has given Europe a competitive edge in new, low-carbon technologies such as wind and solar power – a field that US companies used to lead.

To analyse this question it is useful to think of the employment impact of climate policy in three stages. Climate policy will have:

- *A short-term effect*, when jobs are lost in directly affected sectors and new ones are created in replacement industries. We can think of this as the direct employment effect.
- *A medium-term effect*, when the impact of climate change policy ripples through the economy. Jobs are created and lost along the value chains of affected industries. These are the higher-order, economy-wide effects of climate policy.
- *A long-term effect*, when innovation and the development of new technologies create opportunities for investment and growth. We can call this the dynamic effect of climate policy.

This note discusses each of these effects in turn. The focus is on job numbers, although we recognize that this is only half the story. The nature of the jobs created may differ from the nature of jobs lost, and this will have repercussions on labour productivity and pay. For a full assessment, this would have to be taken into account. However, productivity information is scant and little will therefore be said about the relative quality of jobs.

## 2. Short term: direct employment effect

In the short term there will be job creation and loss in directly affected industries. Jobs will be lost in carbon-intensive sectors, which will grow less fast or may even contract (for example, when coal-fired power plants are decommissioned). New jobs will be created in low-carbon sectors (for example, to run a wind farm). This is the direct employment effect of climate policy. Its sign will depend on the labour intensity of these industries.

There are only a few studies of the employment aspects of concrete climate change policies. Much richer is the literature on the employment effect of renewable energy, compared with fossil-fuel-based energy. To put this effect into perspective, we should note that the energy sector is a relatively small direct employer and source of value added to the economy. In 2006, the sector provided 1.1 million jobs across the 25 Member States of the European Union, which is 1% of total (non-financial) employment (EMCC, 2008). The sector generated a turnover of about €535 billion in 2007, or 2.9% of the value added by non-financial businesses. In the USA, utility jobs were at 557,000 in 2007, which is less than 0.4% of the employed labour force (US Department of Labor, 2008). At a turnover of \$431.2 billion in 2006, the sector accounted for 2.1% of US GDP excluding financial businesses (US Department of Commerce, 2008). If oil and gas extraction are added, these shares increase to 0.5% of US employment and 3.4% of US GDP. Since the mid-1990s, the energy sector has experienced a dramatic decline in employment levels, both in the USA and in Europe. Driven by market liberalization programmes, privatization, and general technical progress (i.e. growing labour productivity), 19% and 25% of utility jobs in the USA and the EU,

respectively, disappeared between 1995 and 2007. Similar trends dominate the extractive industries (WWI, 2007; EMCC, 2008).

An excellent summary of the employment effect of renewable energy technologies is that of Kammen et al. (2006). Comparisons are difficult to make, since each study uses slightly different assumptions, approaches and methodologies. One of the virtues of the Kammen et al. study is the systematic way in which it corrects for such differences. Table 1 shows the main results.

Table 1 suggests that renewables are more labour-intensive than conventional energy, both in terms of manufacture and, to a lesser extent, the operation of facilities. A switch to low-carbon technologies should thus lead to net job creation. The table essentially shows ‘comparative static’ results, comparing the jobs available in a renewable energy installation with those in a fossil fuel plant, once all adjustments have taken place. Note that these adjustments involve capital, energy and materials as well as labour. So if the demand for labour relative to other factors is to rise, the new technologies have to raise the labour–capital ratio, and not just the labour–output ratio. Only in the very short term can we assume the fixed capital stock to be fixed.

We should also note that the higher job creation rate reflects, in large part, the fact that renewables are not yet cost-effective. Not being ‘least cost’ means, by definition, that these options use up more inputs – both in terms of capital and labour – for a given amount of output. Two of the most obvious factors in this respect are that renewable energy installations are more short lived (25 years vs. 40 years for coal and gas) and have a lower capacity factor (they operate about 20% of the time, compared with about 80% for fossil fuel plants). This means that installations have to be replaced almost twice as often and that four times as much capacity has to be installed for the same output. Some of these differences are generic, but others are likely to diminish as low-carbon technologies become more competitive and technologies mature. Studies of renewable energy policy in Germany (Pfaffenberger et al., 2003, 2006; Schulz et al., 2004) project that, over a 10–15 year time horizon, employment gains cannot be sustained. Under most scenarios the net job creation effect turns negative towards the end of the analysis period.

Another caveat is that labour is a less mobile factor in the short run. Adjustments to the energy infrastructure cause structural unemployment. Laid-off workers may not immediately find a new

**TABLE 1** Average employment over the life of a facility (jobs/MW)

	Construction, manufacturing, installation	O&M and fuel processing	Total employment
Solar PV	5.76–6.21	1.20–4.80	7.41–10.56
Wind	0.43–2.51	0.27	0.71–2.79
Biomass	0.40	0.38–2.44	0.78–2.84
Coal	0.27	0.74	1.01
Gas	0.25	0.70	0.95

*Note:* Ranges refer to the results of different studies. Employment is shown relative to the average installed capacity, correcting for differences in capacity factor. (Because renewable installations operate only 20% of the time, compared with 80% for fossil fuel plants, 4 MW of renewable capacity is needed to produce the same output as 1 MW of fossil fuel capacity).

*Source:* Kammen et al. (2006).

job in the growing renewables industry as they have different abilities and the jobs have different requirements. Matching old workers to new jobs takes time. Limited short-run flexibility of real wages can further contribute to fluctuations in output, employment and unemployment.

Babiker and Eckhaus (2006) and Küster et al. (2007) include sectoral rigidities in labour mobility and in wage adjustments as a factor in a computable general equilibrium model to evaluate the impact of climate policy measures on overall economic performance. According to Babiker and Eckhaus, Kyoto-like limitations on greenhouse gas emissions could lead to a 4% reduction of US GNP within the first 10 years after the start of the policy as a result of increased unemployment in negatively affected sectors. They suggest labour market policies to counteract this effect. Furthermore, Küster et al. (2007) show that unemployment rises as a result of negative growth effects when subsidies for renewable energy technologies are applied, while unskilled workers are more seriously affected than skilled ones. However, they assume a comparatively lower labour intensity for renewable energy technologies.

### 3. Medium term: economy-wide effects

Over the medium term, climate change policy will percolate through the economy as behaviour changes and value chains adjust. For instance, a reduction in coal-fired power generation will lead to upstream job losses in the mining industry and rail freight. Demand for rotor blades (for wind turbines), silicone (for solar panels), and low-carbon appliances will grow at the expense of more polluting equipment. Stricter building standards will accelerate the refurbishment of the housing stock, creating jobs in the construction sector. There will be new jobs for carbon traders, wind power engineers and climate change consultants. These people will read trade magazines, commission market research and discuss their career with specialized recruitment firms. Some will have been trained in specialized university courses. However, because greenhouse gas mitigation is costly, firms that are subject to a carbon constraint may have to reduce expenditures elsewhere. The reduction in corporate demand will have economy-wide repercussions on output and employment. The magnitude of this budget effect depends on the price differential between low-carbon technologies and conventional solutions. The lower the differential (for example because gas prices are high), the lower will be the budget effect. For win-win measures such as energy efficiency improvements, the budget effect could even be positive. Often the cost differential is kept artificially low through technology support policies, such as feed-in tariffs that guarantee a minimum price per kWh to renewable power producers – although this will have fiscal implications that could in turn have economy-wide effects. Recent increases in energy prices and international efforts to price carbon are likely to improve the competitiveness of renewable energy technologies and thus increase employment impacts.

The economy-wide effects of climate policy have to be studied in an input-output framework that traces the effects of a policy through the supply chain. There is evidence from such models that the indirect effects of climate change or renewable energy policy are generally positive (Jochem and Madlener, 2003) and could be at least as high as the direct effects. A study for Germany (BMU, 2006) found that of 157,000 renewable energy-related jobs in 2004 only 71,500 were directly concerned with the manufacturing and operation of installations; 81,500 jobs were in related industries. Numerous similar studies for the USA (e.g. Bailie et al., 2001; Krause et al., 2003) – applying input-output analysis – showed how a comprehensive package of climate change policies could create positive economic outcomes. Bailie et al. (2001) projected that a policy mix comprising carbon, SO<sub>x</sub> and NO<sub>x</sub> trading, building, transport and renewable energy standards and various other measures would create more than 1.3 million net jobs across the US economy by 2020. The

study also found that average household wages would increase by US\$400 by 2020, compared with a no-policy scenario. However, the study is fairly bullish about the presence of win-win abatement options and the results are correspondingly optimistic.

The results of Krause et al. are lower, though still fairly robust. They showed net employment impacts of 200,000–300,000 by 2010 in the case of an integrated least-cost strategy involving fiscal, market and institutional reforms as well as domestic and international carbon trading. Their study demonstrated that job reductions in the conventional energy industries can be more than compensated by new jobs in the economy at large. The latter would emerge as firms in non-energy industries benefit from improved energy productivity and rising disposable incomes – a development that would be carried by annual output gains of about 0.4% and 0.9% of GDP in 2010 and 2020, respectively.

These conclusions are bolstered if one assumes that carbon capture and storage (CCS) holds some potential to maintain jobs in the oil and gas industry. CCS has received much attention in recent years as a pragmatic option to limit emissions from existing and upcoming power plants (or any high-emitting activity) and could become capable of large-scale deployment in a few decades (IPCC, 2005). On the positive side, the technology would allow its users to continue their business in a carbon-constrained world and would thus keep workers employed. A limited number of new jobs might also be created through companies manufacturing, installing and running capture and storage units as well as in firms constructing pipelines to transport the captured gas (ETUC et al., 2007). However, CCS could be a costly option. Therefore, the additional employment benefit relative to the capital invested is likely to be low, and budget effects could even trigger negative employment impacts – in particular if subsidies to stimulate CCS employment are provided. Furthermore, Irrek (2006) suspects that, by the time CCS is commercially viable, renewable energy technologies might have become the substantially cheaper option to reduce emissions. In a global context, the employment impact of climate policies will depend on their effect on international competitiveness.

Countries that can position themselves as leaders in low-carbon technology may boost their export potential. This appears to be the case for Germany, where generous support for renewable energy has created a competitive export industry. Over the next decade or so, the share of exports in total sales for renewable energy firms has been estimated at 69% (BMU, 2006). That is, two out of three jobs in the industry could be export-related. However, over time, Germany's competitive edge is likely to decrease as other countries catch up and manufacturing becomes localized.

There is a widespread concern that in the case of unilateral (rather than global) action, climate policy may lead to job losses if production in carbon-intensive sectors moves to jurisdictions where emissions are not yet regulated. This may happen as a result of conscious relocation decisions or because carbon-constrained firms lose market share in the international market place. The relocation of economic activity is a concern both from an economic point of view (loss of competitiveness) and from an environmental point of view (leakage of emission reductions). Studies of the economic effects of differential environmental regulation have found little evidence of either 'pollution havens' (where locations with low environmental standards attract investment) or 'pollution halos' (where foreign investment leads to an increase in environmental standards) – see OECD (1999), Fredriksson (1999) and Smarzynska and Wei (2001). Environmental regulation is not a key consideration for firms making location decisions. Energy prices – and by implication climate policy – are important, however, particularly in industries where energy is a large cost component (such as aluminium, cement and chemicals). Estimates of carbon leakage rates tend to be in the order of 4–20% (Gerlagh and Kuik, 2007). That is, emissions in third countries increase by 40–200 kilograms for every tonne abated in regulated countries. In the case of the EU Emissions Trading Scheme (EU ETS) leakage rates have been less than 5%, according to Grubb



(2007). Most leakage occurred in the cement sector, where coastal firms lost market share. (The impact on profitability, in contrast, was minimal, due to the free allocation of permits.)

Estimates of leakage rates are not necessarily a good proxy of the likely employment loss. However, they can tell us something about the factors that determine the level of job migration. In general, leakage rates increase with the stringency of the environmental constraint (the higher the emission cuts, the higher the leakage rate) and decrease with the size of the regulated industry, relative to the global market (the larger the market share of the carbon-constrained sector, the smaller the leakage rate).

Another key factor is the degree of substitutability between goods. Models that assume goods from different countries to be perfect substitutes (the Heckscher–Ohlin assumption, in modelling jargon) display substantially higher leakage rates than models in which goods are imperfect substitutes (the Armington specification). In plain English, the degree of leakage depends on the level of international competition, which in turn depends on such factors as transport costs, trade barriers and the level of (horizontal or vertical) product differentiation.

There are a number of other factors that determine leakage rates (for example, linkages in the energy market, technology spillovers). However, the three highlighted here – level of unilateral reductions, size of the regulated market, and level of international competition – are probably the most relevant in determining the degree of job losses internationally.

#### 4. Long term: dynamic innovation effect

In the longer term, climate change policy will unleash a wave of innovation as firms reposition themselves and seek to exploit carbon opportunities. Jobs will be created in research and the development of low-carbon technologies. Over time, the results of this research will generate new investment and further job opportunities. What these will be and how this would differ from what would have happened without these policies is hard to predict. What is not in doubt, however, is the powerful effect that innovation and technical change can have on productivity and economic growth. Growth theory has long identified technical change and innovation as a major source of economic growth. Skill-biased technical change is a major factor in explaining labour market developments over the last few decades in both Europe and the USA – including changes in wage income (through productivity growth), job creation (through expansion) but also wage inequality (since some low-productivity jobs remain).

The core of the argument is that the arrival of new technologies with wide-ranging applications (such as information technology or, earlier, the steam engine) will trigger a process of technology diffusion, adaptation and experimentation. The need to adopt the new technology will create a wave of secondary innovations as industries adjust their processes and adapt the technology to their specific requirements. This process, which may take place over a long period of time, will increase the demand for (skilled) labour (Aghion, 2001). In time, this process of creative destruction will increase productivity across the economy. From a policy point of view, evidence that (skill-biased) innovation triggers job growth and productivity gains is only the first step in the chain of argument. There is a second part to the argument that is equally important: evidence that good policy can trigger innovation.

There is a fair amount of theoretical and model-based literature that asserts this (see, for instance, Nordhaus, 2002; Sue Wing, 2006; and the 2006 Special Issue of *Energy Journal*), but actual empirical evidence is rare. One of the few empirical studies is that of Popp (2002), who used 1970–1994 US patent data to show that higher energy prices have had a significant impact on energy-saving

innovations. It is likely that putting a price on carbon would give a similar boost to innovation. This assumption is supported by modelling studies that incorporate endogenous technological change. They broadly indicate that, over time, climate policy induces additional technological change (Edenhofer et al., 2006). This again leads to a reduction of abatement costs and may thus moderate the overall economic impact of climate policy.

However, it still remains a subject for debate, how substantial the welfare gain from induced innovation is likely to be. Goulder and Schneider (1999) and Nordhaus (2002) point out that investments in low-carbon R&D may occur at the expense of innovation in non-energy sectors with potentially higher productivity and profitability. The key issue in this context is whether expenditures for the development and employment of new energy technologies are complementary to or substitutes for other investment options. Other authors (e.g. IEA, 2000) appear more optimistic, by highlighting the fact that additional knowledge gains through learning-by-doing could boost cost reductions. Notwithstanding the uncertainty in cost estimates, Weyant (2004) concludes from a survey of the underlying literature that overall welfare will be higher if policies to induce innovation start earlier rather than later.

## 5. Conclusions

Creating a global economy that emits a half or a quarter of the greenhouse gases of today's economy will require wholesale changes in the way economic activities take place. Economic systems have experienced such periods of change before. The invention of the steam engine, modern transport, computers and the internet have triggered structural changes that arguably went much deeper than the move to a low-carbon economy. However, the adjustments required now could be of a similar order of magnitude. These earlier episodes teach us that structural change entails both risks and opportunities. It creates winners as well as losers.

Change generally meets resistance, and climate change policy is no exception. However, 'constituencies for change' are slowly emerging – groups that see a business opportunity (as well as an environmental necessity) in the move to a low-carbon economy. This note has tried to analyse whether they have a case.

The picture that emerges is complex. In the short term, low-carbon technologies are more labour-intensive than conventional solutions. That differential will diminish as technologies become more efficient but, everything else being equal, the short-term employment effect of climate policy should be positive.

Economy-wide effects will reinforce this trend over the medium term, even if the cost burden associated with carbon abatement will dampen aggregate demand. Early movers may develop a comparative advantage that could create export-related jobs, while unilateral action could result in a loss of competitiveness and the migration of jobs elsewhere. However, neither effect may last. Over time, technology transfer will erode the comparative advantage of early movers, and 'job leakage' will diminish as more and more countries adopt climate policies.

The biggest effects will be felt over the long term, when technical change and innovation could trigger a fundamental overhaul of the economic system. Earlier episodes of innovation-led structural change teach us that it can be a powerful engine for job creation, productivity improvements and growth. Skill-biased technical change has been behind much of the wealth created in Western economies over the last few decades. There is also evidence that adept policy can trigger such innovation. If this evidence is right, climate change has the potential to create many more jobs than it destroys in the long run.



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