*Environment and Development Economics* 5 (2000): 457–481


# Reducing coal subsidies and trade barriers: their contribution to greenhouse gas abatement

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ABSTRACT. International negotiations for an agreement to reduce the emission of greenhouse gases have not produced cost-effective policies for reducing emissions, not least because they are unlikely to prevent 'leakage' through a re-location of carbon-intensive activities to poorer countries. An alternative or supplementary approach that is more likely to achieve at least some emission reductions, and at the same time generate national and global economic benefits rather than costs, involves lowering coal subsidies and trade barriers. Past coal policies have encouraged excessive production of coal in a number of industrial countries and excessive coal consumption in numerous developing and transition economies. This paper documents those distortions and outlines the circumstances under which their reform (currently under way in some countries) could both improve the economy and lower greenhouse gas emissions globally. It then quantifies the effects on economic activity as well as global carbon emissions, using the G-Cubed multi-country general equilibrium model of the world economy. Both the gains in economic efficiency and the reductions in carbon dioxide emissions that could result from such reforms are found to be substantial—a 'no regrets' outcome or win–win Pareto improvement for the economy and the environment.

**Keywords**: Coal subsidies, trade and environment, carbon emissions, global warming, greenhouse gases, IPCC

This paper draws on two earlier ones: an Invited Paper for the 41st Australian Agricultural and Resource Economics Society Conference, held at Broadbeach, January 20–25, 1997, and a paper prepared for the Global Environment and Trade Study based at the London Business School, Yale University, and the University of London's Foundation for International Environmental Law and Development. The authors are grateful for very helpful comments from conference participants plus Scott Barrett and two anonymous referees. Financial support from the Australian Research Council and the MacArthur Foundation is gratefully acknowledged. Since this paper used the G-Cubed model developed jointly with Peter Wilcoxen, it has also benefited from funding of a project at the Brookings Institution and has received financial support from the US Environmental Protection Agency through Cooperative Agreement CR818579–01–0 and from the National Science Foundation through grant SBR–9321010. The views expressed are those of the authors and should not be interpreted as reflecting the views of others including the trustees, officers or other staff of the University of Adelaide, the Australian National University, the Brookings Institution, the Environmental Protection Agency, or the National Science Foundation.

## 1. Introduction

With respect to the environment, governments are often blamed for not doing enough, such as taxing polluters. Their reticence is understandable from a political viewpoint: the interventions advocated by environmental groups are typically harmful to the economic interests of powerful industry groups. Yet there are many situations where it would be more appropriate for environmentalists to ask governments not so much to 'do something' as to 'undo something'. Among the innovative suggestions being made by economists for addressing environmental problems, following the Rio Earth Summit in 1992, is the removal of excessive government subsidies to pollutive activities (World Bank, 1997a). This action is attractive both because it benefits rather than retards the national economy involved and because it can be done unilaterally rather than requiring collective international action with attendant free-rider problems.

A classic example has to do with 'greenhouse' gases. The scientific community continues to debate the question as to whether the build-up of carbon dioxide, ethane, and other greenhouse gases is contributing to a significant warming of the earth's surface; what the economic consequences of global warming might be; and even whether the world as a whole will be better or worse off. Yet, despite these gaps in our knowledge, there seems to be a widespread presumption that governments must intervene to ensure greenhouse gas emissions are reduced. For example, 150 countries gathered in Geneva in July 1996 to reach a United Nations consensus on setting binding targets for reducing carbon emissions in stages over the next 25 years. Given the uncertainty surrounding the likelihood and possible consequences of global warming, it would seem prudent to first search for ways to reduce greenhouse gas emissions with policy changes that can be justified on standard economic and local environmental grounds. That is, to what extent are there unambiguous win–win possibilities for reducing those emissions that would benefit the global economy *and* the global environment? This paper explores one such set of reforms that have recently begun to be implemented, namely reductions in government distortions to the world's coal markets, bearing in mind that coal accounts for around 30 per cent of the world's primary energy supply and 40 per cent of carbon emissions from energy use (ignoring firewood).

Since both coal mining and coal burning are pollutive, it would be optimal to tax the pollutive contributions of both production and consumption of coal. Yet we observe several industrial countries subsidizing coal mining, and many developing and former socialist countries subsidizing coal burning, either explicitly and/or implicitly with the help of coal trade barriers. To what extent is it possible that replacing those effective production and consumption subsidies with optimal taxes—or even just removing the subsidies and trade barriers—could simultaneously improve the efficiency of resource use, reduce damage to local environments, and lower greenhouse gas emissions? Earlier studies suggest there may well be such possibilities (Burniaux, Martin and Oliveira-Martins, 1992; Hoeller and Coppel, 1992; Larson and Shah, 1995), but they focus on all fossil fuels rather than just on coal. It is of interest to examine the contribution of coal policies alone, since policies affecting the export supply of the other fossil fuels are controlled largely by OPEC and, unlike coal policies, are not under political pressure to change.

This paper addresses the issue in a series of steps. It first provides some details of the environmental externalities on the demand and supply sides of the coal market, from which it is then clear what the optimal policy interventions would be for national governments if they ignore international pollution spillovers. These are then compared with the actual policy interventions we observe in key national coal markets around the world. The evidence on the extent of divergences between domestic and international coal prices in various groups of countries shows that, as with agriculture, coal producer and consumer prices have tended to be well below border prices in developing and former socialist countries, and to be well above border prices in several large industrial countries that are net importers of coal. The possible consequences for economic activity and greenhouse gas emissions of removing those subsidies—as has begun to happen in the 1990s—are then explored. This is done first using a simple theoretical partial equilibrium approach. Then some empirical results are summarized from a recent study that uses a global computable general equilibrium model known as G-Cubed. That model is able not only to capture the effects exposed through partial equilibrium thinking but also to take into account the possibilities for substitution in production and consumption between products (including within the energy group) both within and across countries when domestic relative prices are changed in some or all regions. Notwithstanding the reforms of recent years, those results suggest that significantly lower greenhouse gas emissions could result from further reducing the remaining coal mining subsidies in the OECD. Even larger benefits would result if poorer countries also raised their artificially low domestic prices for coal. Some qualifications and the environmental, trade, and policy implications of the analysis are discussed in the final section of the paper.

## 2. Environmental externalities and optimal policy intervention in the coal market

Traditionally, the externality most commonly thought of with respect to coal was local air pollution in the form of smog generated from the burning of coal by households and industry. That pollution is substantially greater per unit of energy provided than that generated from other fuel sources (except perhaps from firewood).[1] More recently we have come to appreciate the contribution also of sulphur dioxide emissions from coal burning, especially in the form of acid rain. Those sulphur emissions—which can vary considerably among coal sources—have down-wind trans-border as well as intra-national effects that are undesirable. And even more recently the additional worry has been coal's contribution to global greenhouse gases, most notably through carbon dioxide emissions:

[1] Apart from emitting far less visual pollution than coal, oil emits into the atmosphere only about two-thirds as much carbon per unit of energy as does coal, and gas only about half as much (World Bank, 1997b, table 4.1).

40 per cent of the $CO_2$ emitted globally from energy use came from coal in the early 1990s (World Resources Institute, 1996). The distinguishing feature of those emissions is that their contribution to global warming occurs regardless of the location on the globe of the coal-burning activity.

Much less appreciated are the adverse environmental effects on the production side, from coal mining. They include not just the visual eyesore of holes in the ground in the case of open-cut mines or of mine overburden, but also run-off and leaching from tailings and coal washeries can pollute rivers and lakes. And of significance internationally are the contributions to global warming from methane ($CH_4$) from the mine, which increase with mine depth. Coal mining contributed 13 per cent of global methane emissions in the early 1990s (World Resources Institute, 1996). As it happens, many of the mines in Europe are now extremely deep, and are providing coal with relatively high sulphur content. Moreover, once pit mines are exhausted, problems continue. During normal working of a mine, water is pumped out virtually as soon as it enters, which prevents it being contaminated by soluble minerals; but if that pumping is not continued after the mine closes, unpumped water gradually builds up and eventually contaminates groundwater (Steenblik and Coroyannakis, 1995). Government subsidies and protection from imports for such mines thus add present and future production externalities to the more-commonly understood local, regional, and global externalities on the consumption side from coal burning.

These facts suggest the social marginal benefit curve in a national coal market is below the private demand curve, and the social marginal cost curve is above the private supply curve, and more so if the welfare of other countries is also taken into account. Even ignoring the latter, the optimal intervention in the presence of these externalities (assuming optimal interventions are in place in all other markets) involves taxing the undesired pollution both from coal mining and from coal burning.[2] Thus the removal of any subsidies to coal mining or coal consumption, including indirect subsidies via trade policies, are likely to be at least a partial step towards the optimal measures and levels of government intervention in coal markets.

## 3. Coal markets and current coal policies in various parts of the world[3]

The world's coal production is remarkably concentrated. As of 1993 there were just 13 countries whose production accounted for more than 1 per cent of the world's coal. They accounted for 91 per cent of global coal production. They also accounted for 83 per cent of global coal consumption, which suggests that countries which have coal use it but do not export it much. In fact international trade accounts for only about one tenth of global coal sales. (North America, Australia, and South Africa supply three-quarters of that trade, with another 15 per cent coming from the

[2] In the past a case might have been made for some restriction of coal imports on energy supply security grounds, but that is no longer valid now that coal is a much smaller contributor to energy in coal-importing countries.

[3] This and the next section draw on and extend analysis in Anderson (1992, 1995b).

former Soviet Union, China and Poland.) The trade propensity is low partly because of the bulkiness of the product (high transport costs per unit of energy), so that only the highest quality hard coal is worth trading. But also to blame for the small share of production traded are the distortionary subsidy and trade policies in both importing and exporting countries, which happen to have a strong anti-trade bias.

Coal producer subsidies in Western Europe and Japan have been enormous since the 1960s. On the other hand, the opposite policy bias has prevailed in Eastern Europe and the former Soviet Union where policies have kept coal prices below international levels, with perhaps even worse economic and environmental consequences. Coal prices have been kept artificially low in other developing countries too, most notably in the two big coal-burning countries of China and India. In examining these distortions, it is therefore helpful to separate the high-priced OECD countries from the low-priced non-OECD countries.

*OECD countries*

Within the OECD, North American and Australasian coal markets are reasonably free of coal market distortions. In Western Europe, by contrast, costs of coal production per ton are as much as two to three times import prices. These differences are maintained partly by restricting imports to raise the domestic coal price, partly by the treasury subsidizing producers directly, and partly by imposing minimum purchase obligations on electricity generating utilities, requiring them to buy certain volumes of coal from local mines at above international prices. In Germany, for example, the electricity utilities agreed to buy during 1992–1995 at least 87 per cent of their coal needs from local mines, with only a quarter of that coal priced at import parity and the rest at more than twice the import price—in return for which the utilities have been allowed to pass on the high input cost to electricity consumers, who also contribute an 8 per cent tax to help finance the coal producer subsidy (Newbery, 1995).

The producer subsidy equivalent (PSE) of assistance to production of hard coal, shown in table 1 as a percentage of the import price, reveals that assistance to European Union and Japanese coal production has been very large and grew rapidly during the 1980s. By the early 1990s it was equivalent to providing a domestic producer price that was more than three times the import price in Belgium and Germany, two times in Spain, and 40 per cent higher in France and the UK. There has in addition been considerable assistance to coal producers that is not price related. In fact, over the 1986–1992 period the assistance to production shown in table 1, as a fraction of total assistance, was just two thirds for the UK, about half for Germany and Spain, only a third for Belgium, and less than one tenth for France (IEA, 1993, and earlier editions, and, for France, EC, 1992).

These estimated rates of assistance exceed those for agriculture in Western Europe and Japan. As shown in the middle rows of table 1, in the 1990s the PSE is estimated to have averaged near 90 per cent of the border price for EU agriculture, compared with more than 150 per cent for EU coal. When expressed on a per worker basis, the difference in support has been even larger. During 1987–1993, for example, the support in the EU for

Table 1. *Production subsidies in Western Europe's and Japan's hard coal and farm sectors, 1979–1997 (per unit producer price subsidy equivalent as a percentage of the border price)*

*Hard coal*[a]

| | *1979–1981* | *1982–1984* | *1985–1987* | *1988–1990* | *1991–1992* | *1993–1996* |
|---|---|---|---|---|---|---|
| Belgium | na | 47 | 124 | 215 | 267 | na |
| France[c] | 67 | 54 | 68 | 40 | 39 | na |
| Germany, West | 56 | 45 | 113 | 205 | 228 | 223 |
| Spain[c] | na | na | 58[b] | 74 | 98 | 107 |
| United Kingdom | na | 65 | 55 | 107 | 40 | 17[f] |
| **EU-12**[d] | **na** | **52** | **91** | **165** | **163** | **na** |
| Japan | na | 62 | 205 | 267 | 226 | 263 |

*Agriculture*

| | *1979–1986* | *1985–1987* | *1988–1990* | *1991–1993* | *1994–1997* |
|---|---|---|---|---|---|
| **EU-12** | **57** | **85** | **78** | **90** | **84** |
| Japan | 147 | 250 | 184 | 187 | 267 |

*Hard coal support per miner employed (1990 US dollars)*

| | *1982* | *1986* | *1990* | *(1990)*[e] |
|---|---|---|---|---|
| Belgium | 14,800 | 23,800 | 33,600 | (84,400) |
| Germany | 14,200 | 26,900 | 45,100 | (90,200) |
| United Kingdom | 6,500 | 18,700 | 26,600 | (38,000) |

*Notes*: [a] The United States thermal coal export price fob plus $7 per tonne for freight was used as a proxy for the cif import price for Western Europe, while for Japan Australia's export price fob plus $7 was used. Only subsidies affecting current production are included.

[b] 1986–1987 only.

[c] The numbers for Spain and France are lower-bound estimates. In the case of France (and Germany in 1979–1981) they are based only on the extent to which domestic prices exceed import prices, from EC (1992).

[d] Weighted average with weights based on coal production in 1985–1989, and with Spain's PSE in 1982–1985 assumed to be 50 per cent. The 7 EU member countries not listed have weights under 0.5 per cent so their exclusion has almost no affect on the EU average.

[e] Values in parentheses include 1990 assistance that does not directly affect current production.

[f] Fiscal years ending 31 March.

*Sources*: Based on PSE estimates from Steenblik and Wigley (1990), IEA (1993, 1997), and EC (1992) for coal, and OECD (1994, 1998) for agriculture.

current production per full-time worker equivalent was $11,400 for farmers (OECD, 1994),[4] compared with two to four times that for coal miners. Indeed total assistance per coal miner employed was close to $90,000 for Belgium and Germany (nearly half of which was supporting current production) and $38,000 for the UK in 1990 (see final three rows of table 1). And, based on EC (1992) data, it was well over $100,000 for France. According to these estimates—which were three times as large in real terms as a decade earlier—it would have been far cheaper to close all coal production in these countries (and Spain) and pay miners their current wage to do nothing.

Estimates of the extent of consumer price distortion are more difficult to determine, but the IEA (1994b) does provide user prices and import prices for coal. Based on those data, it would appear that for Western Europe as a whole both coking and steaming coal prices for users as compared with the prices of imports from outside Western Europe have become steadily greater. On average during 1984–1991, coking coal was priced to industry about 15 per cent above the price of the most expensive imported US coal, and steaming coal was about 40 per cent above for electricity utilities and 55 per cent above for industry users. Again this rivals the extent to which food prices for consumers exceed border prices, which for the EU averaged 55 per cent during 1979–1993 (OECD, 1994). In addition, because coal mined in the EU is 'dirtier' than its imported coal (Steenblik and Coroyannakis, 1995, table 7), the utilities' minimum local purchase obligations require more to be spent on filters to burn the higher-priced domestic coal.

An indication of the extent to which user prices in the most protective European countries exceed those in the United States is given in table 2. Steaming coal in the early 1990s was four times higher than the US price in Germany, twice as high in the United Kingdom, and between 1.3 and 2.3 times as high in Belgium and France. Not surprisingly, electricity prices were roughly double those of the US as well. Some of those differ-

Table 2. *Steaming coal and electricity prices in Europe relative to the United States, 1990–1992 (US = 100)*

| | *Coal price for industry* | *Coal price for electricity* | *Electricity price for households* |
|---|---|---|---|
| Belgium | 133 | 143 | 212 |
| France | 234 | 130 | 191 |
| Germany | 459 | 377 | 205 |
| United Kingdom | 212 | 227 | 144 |
| Hungary | 250 | 197 | 55 |
| Poland | 81 | 55 | 33 |
| Slovakia | 72 | 58 | 32 |
| India[a] | 90 | 39 | na |

*Note*: [a] 1990 only.
*Source*: IEA (1994b).

[4] It had risen to $21,000 by 1995–1997 (OECD, 1998: 40).

ences may reflect costs of transporting coal (and other energy raw materials) to power plants, some is the result of different preferences for preserving the environment, and some may reflect the greater need to tax emissions in densely populated Europe; but much of it is the result of protective producer coal subsidies and associated barriers to coal import competition.

During the 1990s, these subsidies have come under domestic political pressure to be reduced. Belgium and the United Kingdom began the process with actual cuts, and now France and Germany have made commitments to gradually reduce government support to coal mining over the next decade. For the United Kingdom at least, that has shown up as a fall in the estimated coal PSE to 1996 (last column of table 1). The potential to reform these policies is thus very real, making an examination of the effects of such reform timely.

*Non-OECD countries*

Obtaining estimates of price distortions in Eastern Europe, the former Soviet Union, and other transition and developing countries is more problematic. What is clear, though, is that in the past coal has been grossly underpriced there, which helps explain the relatively high consumption levels in some of those countries. Except in Hungary, the price of steaming coal paid by electricity utilities in Eastern Europe has been only a fraction (half or less) of the border price. Industry users paid somewhat more, but they still received it at well below its opportunity cost on the world market. The extent of underpricing is currently being reduced though, with Hungary's coal prices now matching the user prices in Western Europe. Even so, it appears from the lower part of table 2 that electricity users in the early 1990s were still hugely subsidised in Eastern Europe, as in India, with prices between one third and one half those of the United States. Thus the OECD's GREEN model, calibrated to 1985, assumes that coal prices average close to half border prices for each of Eastern Europe, the former Soviet Union, China and India, which together account for all but a sixth of the non-OECD coal market (Lee, Oliveira-Martins, and Mensbrugghe, 1994). Table 3 shows that even up to the mid 1990s coal prices in China were less than three-quarters of border prices, although the higher 'market' as distinct from 'plan' prices there are applying to an

Table 3. *Domestic and border prices for coal, China, 1990–1995 (yuan per tonne)*

| | *Plan price* | *Market price* | *Border[a] price* | *Market-to-border price* |
|---|---|---|---|---|
| 1990 | 56[b] | 150 | 225 | 0.67 |
| 1991 | na | 160 | 237 | 0.68 |
| 1992 | na | 147 | 248 | 0.59 |
| 1993 | na | 173 | 307 | 0.56 |
| 1994 | na | 189 | 285 | 0.66 |
| 1995 | na | 214 | 284 | 0.75 |

*Notes*: [a] Converted to yuan at market exchange rates.
[b] Unweighted average of 'basic' and 'high' plan prices.
*Source*: Anderson and Peng (1998).

increasing proportion (now more than half) of sales as non-state owned mines develop (Wang, 1996).[5]

What would be the implications of completely dismantling these coal subsidies and trade barriers? We begin using a simple theoretical partial equilibrium approach and then turn to some empirical results that draw on a global computable general equilibrium model known as G-Cubed.

## 4. Effects of dismantling coal subsidies: partial equilibrium analysis

Consider the coal market of a small open economy under the following assumptions: coal is a homogeneous product; the domestic coal-mining industry competes with imports that are freely available at a landed price of $P_w$; there are negative production and consumption externalities associated with coal mining that are both intra- and inter-national/global such that the private marginal cost curve for mining, $S_p$, is below the national social marginal cost curve $S_s$, which in turn would be below the global social marginal cost curve (not shown) if international pollution spillovers were to be taken into account, and the private marginal benefit curve $D_p$ is above the national social marginal benefit curve $D_s$, which in turn would be above the global social benefit curve (not shown) if international pollution spillovers were to be taken into account; and the demand and supply curves incorporate changes in productivity and any international factor movements that would accompany domestic price changes. Under these conditions, and assuming also that in related markets in the economy there are no other distortions nor any externalities that are not offset with optimal intervention measures, then this coal market can be depicted as in figure 1.

### *Laissez faire versus optimal intervention*

Equilibrium in figure 1 in the absence of any government intervention in this coal market would involve a domestic price equal to $P_w$ that would induce O*Q* being produced and O*C* being consumed each year, with *QC* imports satisfying the excess domestic demand at that price. These levels differ from the optimal levels, however, given the presence of externalities in this market. To simplify the analysis, assume transactions costs of taxing environmental damage at the source (e.g., water contamination from mining or sulphur emissions from burning coal) are sufficiently expensive as to make coal production and consumption taxes the optimal intervention instruments, and that this small nation ignores its contribution to neighbouring countries' and global pollution. Then on the production side, O*Q** is the optimal output level since it is where the national social marginal cost curve $S_s$ intersects the import price line that represents the

[5] A rough preliminary set of estimates by the World Bank (1997b) suggests the rate of underpricing of coal has halved in EEFSU and fallen by one-sixth in China and India during the 1990s. Why coal, like food, should have been underpriced in poorer countries and overpriced in coal-importing richer countries, and why those policies are now beginning to be reformed, are important questions. Space limitations preclude discussing them here, but see Anderson (1995a, b).

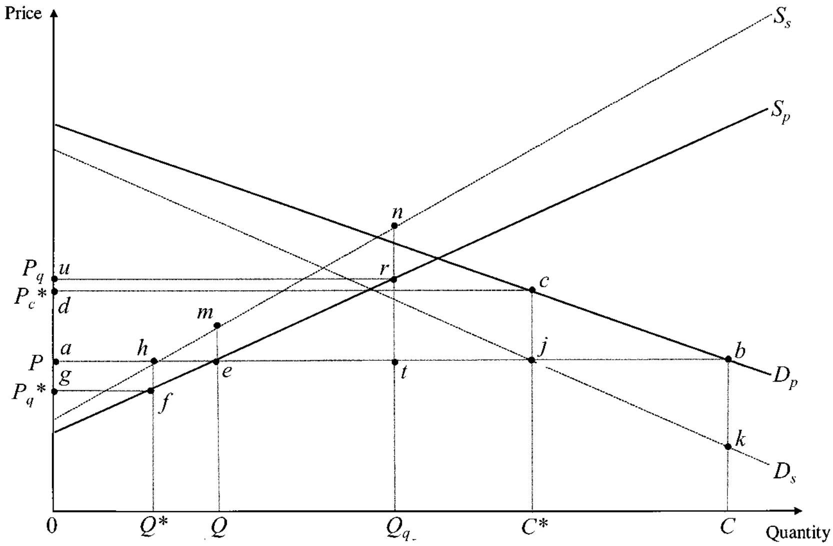


Figure 1. *The effects of removing a subsidy to coal mining in a small open economy*

opportunity cost of producing domestically. That output level would be attained if a tax on coal production were imposed which lowered the domestic price received by miners from $P_w$ to $P_q$*. And, on the demand side, OC* is the optimal consumption level. At that level the curve representing the national social marginal benefit from coal burning, $D_s$, intersects the import price line; it would be attained if a tax on coal consumption were imposed which raised the domestic price paid for coal from $P_w$ to $P_c$*.

The welfare effects of imposing the tax on production can be shown in areas in figure 1. That tax reduces coal producer welfare by *aefg*, raises government tax revenue by *ahfg*, boosts the welfare of those outside this market who are harmed by coal mining activities by *hmef*, and thus increases net economic welfare in this country by ($-aefg + ahfg + hmef =$) *hme*. Welfare also is increased by imposing the optimal tax on coal consumption. In that case coal consumer welfare is lowered by *abcd*, government tax revenue is raised by *ajcd*, the welfare of those outside this market but within the country who are harmed by local pollution from coal burning activities is raised by *bkjc*, and thus net economic welfare in this country is increased by ($-abcd + ajcd + bkjc =$) *bkj*.

*Effects of removing coal production subsidies*

Now suppose this economy has in fact put in place a tax on coal consumption that has raised the domestic price to $P_c$* and reduced coal use to the optimal level of OC*; but instead of also putting in place a tax on domestic production it has subsidised coal mining by offering a producer price of $P_q$ which has induced production to the level $OQ_q$ and thus lowered imports to $Q_qC^*$.[6] Removing that inappropriate production subsidy would lower production by $QQ_q$ and producer welfare by *aeru*, but it would also lower government outlays by *atru* and boost the welfare of those outside this market who are harmed by coal mining activities by *emnr*, hence net economic welfare would be greater by *emnt*.[7] (If the government not only abolished the producer subsidy but also imposed the optimal producer tax of $P_wP_q^*$, there would be the additional net social welfare gain of *hme*, or a total gain of *hnt*.) Thus both the economy and the environment in this reforming economy would improve by removing that coal production subsidy.

Should enough small open economies simultaneously remove their subsidies to coal mining (and replace any associated coal import tariff with an optimal consumption tax—see footnotes 2 and 3), import demand for and hence the price of coal in the international market would rise. That would reduce coal consumption globally and induce substitution towards using other fuels, virtually all of which are less environmentally damaging and in particular contribute less greenhouse gases than coal. Thus there would be an environmental improvement not only in the reforming economies (less local damage from coal mining and burning) but also in the world at large (less greenhouse gas emissions of methane and carbon). Should domestically mined coal in the reforming countries also be more sulphuric than imported coal, the substitution by consumers away from domestic to imported coal in these countries also would reduce acid rain at home and in neighbouring down-wind countries.

Other countries that are net exporters of coal would benefit from the rise in the international coal price, as would net exporters of substitute fuels to a lesser extent, and conversely for net importers of energy. (This would have second-round effects on aggregate demand including the demand for coal, not shown in the diagram). But the world economy as a whole would be better off, in addition there would be less local pollution in both the reforming countries and other economies[8] as well as less greenhouse gas emissions (and even more so if those coal producer subsidies were replaced by optimal producer taxes).

It is true that, if enough coal-importing economies removed their coal production subsidies simultaneously, their loss from the adverse change in their terms of trade may more than offset their gain from reducing their

[6] The equivalent result would be achieved with an import tariff of $P_c^*P_w$ and an additional production subsidy of $P_qP_c^*$. In that case government direct outlays to producers would have been smaller but there would have been no consumer tax revenue, so the net impact on government revenue is the same.

[7] If $P_q = P_c^*$, then only an import tariff would have been necessary and the equivalent reform would be a replacement of that tariff with an optimal consumption tax of $P_c^*P_w$.

[8] The only possible exception is in those non-reforming countries where the extra pollution from coal production expansion may more than offset the reduced pollution from cuts in coal use. Globally the increase in pollution from such production expansion is likely to be less than the reduction in pollution from coal mining in reforming countries, however, since the latter tend to be among the deepest in the world.

coal market distortion. Even so, that does not alter the fact that each small reforming nation is better off economically and environmentally from so reforming, for to abstain while others reformed would make them even worse off because they would not have the domestic efficiency and environmental gains to offset their deteriorating terms of trade.

*Effects of removing coal consumer subsidies*

Consider now another type of small open economy that is a net exporter of coal, as depicted in figure 2. The notation and assumptions are otherwise as for figure 1 and in particular both production and consumption externalities are still present. In this case, however, the country is pricing coal below rather than above the price at its border, $P_w$. Specifically, suppose the country has taxed production so as to set the producer price optimally at $P_q$* so that $0Q^*$ is being mined per year; but instead of also taxing coal use it has provided a consumption subsidy equal to $P_wP_c$ so that $0C_c$ rather than the optimal quantity of just $0C^*$ is being consumed each year. Thus instead of exports being $C^*Q^*$ as under optimal national policies, they are just $C_cQ^*$. Removing that inappropriate consumer subsidy would lower consumption by $CC_c$ and consumer welfare by *abvw*, but it would also lower government outlays by *ayvw* and boost the welfare of those domestic residents outside this market who are harmed by the local pollution from coal burning by *bvzk*, hence net economic welfare would be greater by *byzk*.[9] (If the govern-

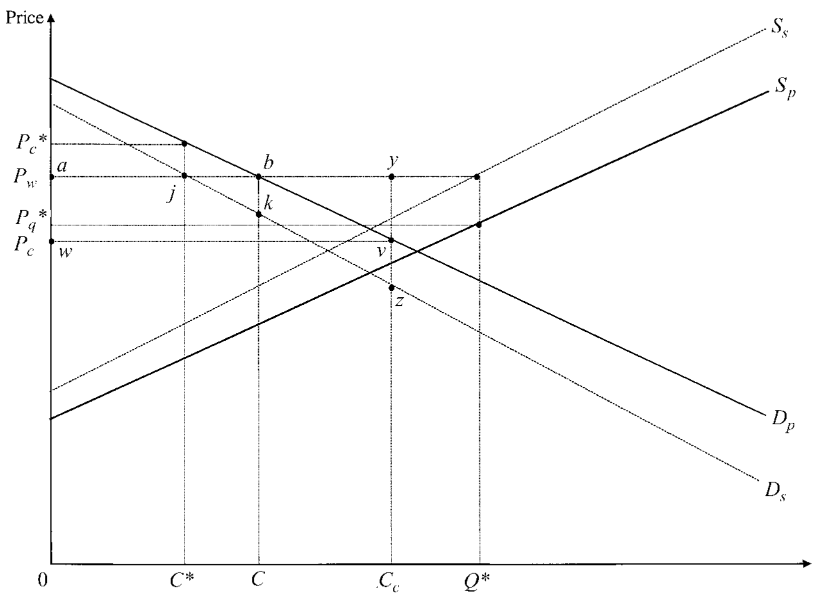


Figure 2. *The effects of removing a subsidy to coal use in a small open economy*

[9] As in the producer subsidy case, this consumer subsidy case could equally result from a export tax of $P_wP_q$* plus an additional consumer subsidy of just $P_q$*$P_c$. If $P_c = P_q$*, then only an export tax would have been necessary and the equivalent reform would be a replacement of that export tax with an optimal production tax of $P_q$*$P_w$.

ment not only abolished the consumer subsidy but also imposed the optimal consumer tax of $P_c*P_w$, there would be the additional net social welfare gain of *jbk*, or a total gain of *jyz*.) Thus both the economy and the environment in this reforming economy would improve. Should coal burning in these countries also contribute to acid rain at home and in neighbouring down-wind countries, the reduction in coal use would reduce that environmental damage too.

Should enough small open economies simultaneously reduce their subsidies to coal users (and replace any associated coal export tax with an optimal production tax—see footnote 5), two offsetting effects on the global environment would result. One is that coal consumption in these reforming economies would fall, lowering global carbon emissions. The other is that coal export supplies in the international market would rise, causing the price of coal in that market to fall. That would encourage coal consumption in the rest of the world. Thus it is an empirical question as to whether there would be a net improvement or worsening of the global environment from carbon emissions, even though there is an unequivocal improvement in the local environment of these reforming countries.

Given their current low incomes, it is possible that some of these countries may place little or no negative value on their pollution from coal mining. In that case their optimal producer price would be $P_w$ and so reform would also involve lifting the currently low prices received by miners in those countries. That would add to production and to the increase in net exports from these reforming economies, and hence to their downward pressure on the international price of coal.

Other countries that are net importers of coal would benefit from the fall in the international coal price, as would net importers of substitute fuels to a lesser extent, and conversely for net energy exporters. (Again this would have second-round effects on aggregate demand, including the demand for coal, that are not shown in the diagram.) But the world economy as a whole would be better off by the removal of coal consumer subsidies, so long as the welfare gains in the reforming economies are not more than offset by the welfare loss from any increase in greenhouse gas emissions, should the latter occur.

If enough coal-exporting economies simultaneously removed their coal consumer subsidies (and possible also their coal producer taxes), it is true that their loss from the adverse change in their terms of trade may more than offset their gain from removing their coal market distortions. Even so, as with the case of producer subsidy reform in the coal-importing countries, that does not alter the fact that each small reforming nation is better off economically and environmentally from so reforming, for if it abstained while others reformed it would be even worse off because it would not have the domestic efficiency and environmental gains to offset its deteriorating terms of trade.

*Reforming producer and consumer subsidies simultaneously*

If both sets of countries were to remove their coal subsidies simultaneously, the coal trade expansion would be greater but the change in the price of coal in the international market from producer subsidy cuts in rich countries would be more or less than offset by the change as a result of removing the coal price distortions in poorer countries. Hence the sign of the net price change, and of the changes in economic welfare in most countries, are empirical questions. The answers to those questions also depend on the degrees of substitution in production and consumption as between coal, other fuels, and other products, the net effects of which can only be captured using a global multi-commodity model. In the next section we describe an intertemporal multi-country global general equilibrium model useful for that purpose, known as G-Cubed, discuss the simulation design to be used, and then present some empirical results.

## 5. Effects of dismantling coal subsidies: empirical general equilibrium analysis

*The G-Cubed multi-country model of the world economy*

The G-Cubed multi-country model has been constructed specifically to contribute to the current policy debate on global warming, but it has many features that make it useful for answering a range of issues in environmental regulation and other economic policy questions. It is a global model with substantial regional disaggregation and sectoral detail. In the present version the world economy is divided into eight regions and the model distinguishes five energy sectors (electric utilities, natural gas utilities, petroleum processing, coal extraction, and crude oil and gas extraction) and seven non-energy sectors (mining, agriculture, forestry and wood products, durable manufacturing, non-durable manufacturing, transportation, and services). A key feature of the model is that substitution possibilities in production and consumption are based on econometrically estimated cost functions. Intertemporal budget constraints of households, governments, and nations (the latter through accumulations of foreign debt) are imposed. To accommodate these constraints, forward-looking behaviour is incorporated in consumption and investment decisions. Countries are linked not only by the flow of goods and factors of production but also flows of financial assets with rates of return based on returns in the real economy. The model has an internally consistent macroeconomic framework in which saving and investment decisions are determined endogenously. Overall, the model is designed to provide a bridge between computable general equilibrium models and macroeconomic models by integrating the more desirable features of both approaches. In addition, it includes an environmental module which provides information on changes in carbon emissions as economic activities change. Full details of the model are documented in McKibbin and Wilcoxen (1995).

*Simulation design*

Using this model we assume the divergences between domestic and international coal prices in 1990 were as shown in table 4. That table also shows the shares of each region in global coal production, consumption, and greenhouse gas emissions, as well as the importance of coal in primary energy use in each region at that time. The model is then used to project the world economy from 1990 to 2050 under the assumption of no change

Table 4. *Shares of global hard coal production and consumption, of coal's contribution to global $CO_2$ and methane emissions, and coal producer subsidy and consumer tax equivalents (PSEs and CTEs), various countries/regions, circa 1990 (per cent)*

| | *Share of world coal production* | *Share of world coal consumption* | *Share of primary energy consumption from coal* | *Coal mining's contribn. to global methane emissions* | *Coal burning's contribn. to global $CO_2$ emissions* | ***PSE***[a] *coal mining* | ***CTE***[a] *coal used by industry* | ***PSE***[a] *coal used for electricity* |
|---|---|---|---|---|---|---|---|---|
| United States and Canada | 26 | 24 | 23 | 3.8 | 8.7 | 0 | 0 | 0 |
| Australia and New Zealand | 6 | 2 | 43 | 0.5 | 0.7 | 0 | 0 | 0 |
| Japan | 0 | 3 | 17 | 0.0 | 1.5 | 250 | 100 | 180 |
| Western Europe | 7 | 11 | 21 | 0.7 | 6.6 | 140 | 130 | 170 |
| C. and E. Europe and former USSR | 19 | 18 | 30 | 1.8 | 6.3 | −50 | −50 | −50 |
| China | 26 | 25 | 76 | 5.6 | 9.3 | −40 | −40 | −40 |
| India | 6 | 6 | 66 | 0.8 | 2.3 | −40 | −40 | −40 |
| Other developing countries | 12 | 13 | 18 | 0.1 | 4.6 | −40 | −40 | −40 |
| **WORLD** | **100** | **100** | **30** | **13.3** | **40.0** | | | |

*Notes*: [a] 'Guesstimated' percentage by which the domestic price exceeds the border price.
*Source*: IEA (1994a, b, c, d), BP (1994), World Resources Institute (1996) and the references on distortions cited in the text and the above tables.

in coal or any other policies. Given this baseline scenario we then present two scenarios as alternatives to a continuation of the policies of the early 1990s, both phased in over the period to 2005. One scenario involves coal policy reforms just in OECD countries; the second scenario explores coal policy reforms in non-OECD regions as well. In so far as some reform has already taken place during the 1990s our results exaggerate the benefits that *remain* to be reaped from continuing the process, but do not exaggerate the benefits of the overall reform.

Specifically, we analyse in the first case the effects of completely removing the coal producer subsidies and import restrictions in Japan and Western Europe, on the assumption that current consumer taxes there are optimal from the viewpoint of society's concerns with pollution from coal in those densely populated countries.[10] Removing coal producer subsidies and import restrictions in the protective OECD economies would be expected to lower their coal production and raise their coal imports, causing coal prices in international markets to rise and stimulating substitution away from coal use in all economies with open coal markets. In the second scenario, we also raise domestic coal prices in non-OECD countries up to international levels. This should have the effect of reducing coal consumption in these countries, thereby lowering their carbon emissions in so far as they use less fossil fuels in aggregate and they substitute towards less carbon-intensive fuels than coal. But that reform also raises prices received by coal producers in those non-OECD countries. This encourages coal production and hence net exports of coal from these countries, which would depress international coal prices and so encourage coal use and hence greenhouse gas emissions elsewhere.[11] The interesting empirical question is whether the removal also of policies that depress domestic coal prices in non-OECD countries adds to or offsets the positive environmental effects of removing coal production subsidies and import restrictions in Western Europe and Japan.

*Empirical results: removing OECD production subsidies and import restrictions*

The assumed policy decision to phase out production subsidies for coal in Western Europe (denoted ROECD in the figures below) and Japan has the effects expected within those regions, but some non-intuitive results emerge for other regions. Figure 3 shows that global carbon dioxide emissions fall over time as those production subsidies are gradually eliminated.

[10] In fact, according to Hoeller and Coppel (1992, chart 2), the coal consumption tax per ton of carbon is far smaller in all OECD countries than the user taxes on oil and gas, whereas if coal is more pollutive its use should be taxed more rather than less than those other fuels. This suggests there is further scope for beneficial reform beyond that considered in this paper.

[11] We assume that by the beginning of the simulated reform the coal-mining enterprises in transition economies are operating as normal profit centres. In so far as some state-owned mining enterprises are in fact still being propped up by government subsidies to cover operating losses and these are removed over the simulated reform period to 2005, then we will have overstated the coal supply response in these economies and thereby understated the contribution of reform to reducing global carbon emission.

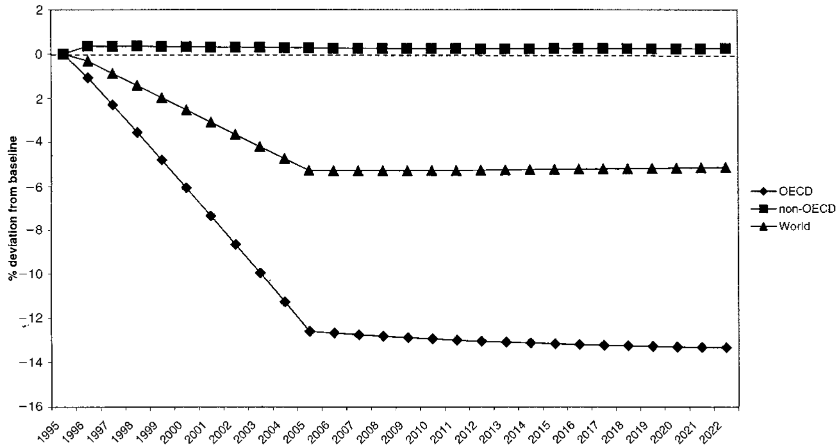


Figure 3. *$CO_2$ emissions*

(This and subsequent figures present results as percentage deviations from the baseline. Thus a value of zero indicates that the variable is equal to its baseline value.) By 2005, global emissions are permanently reduced by over 5 per cent per year forever. This fall in global emissions (relative to what otherwise would happen) is almost entirely the result of a fall, of one-eighth, in emissions from the OECD countries. Most of this decline occurs in Western Europe, but emissions also decline in Japan and the United States.

These changes can be understood by first recognizing that the removal of OECD coal production subsidies leads to a rise in the price of coal in international markets and hence in all regions where domestic prices respond to change in international prices. That stimulates coal output in and net exports from all other regions. The rise in the user price of coal also leads to a substitution away from coal as an energy source and away from producing carbon-intensive goods whose prices in international markets also rise. Thus emissions fall in most OECD countries. The exception is Australia where, as in the non-OECD regions, carbon emissions rise very slightly. This is because those regions, as net exporters of coal, enjoy a terms of trade gain and hence an income boost: although their coal prices rise and the share of carbon-intensive energy falls relative to other energy sources used (as occurs elsewhere in the world), the absolute amount of carbon-based energy use nonetheless increases as a result of the effects of higher incomes and foreign direct investment inflows in aggregate demand in these economies.

In addition to these effects, a number of other factors are at work. In particular, the phasing out of coal production subsidies has a direct impact on the fiscal positions of governments that have been paying the subsidies. The saving in fiscal outlays is assumed to be used to reduce fiscal deficits in those countries. In Western Europe especially this is a substantial saving which, through macroeconomic adjustments, helps to offset the effect on

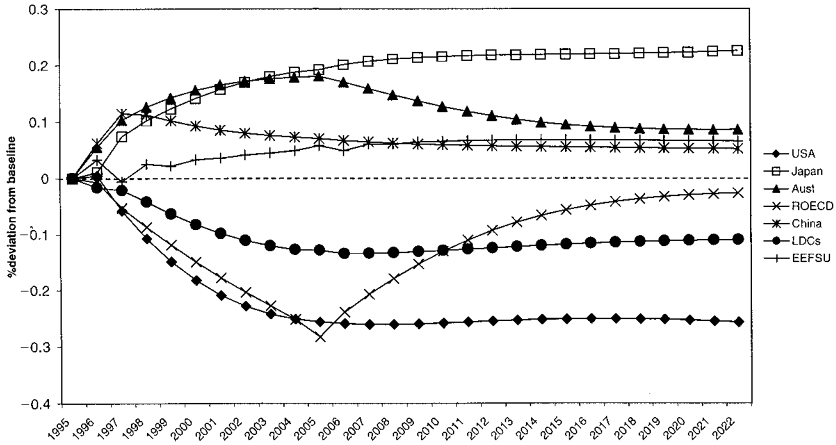


Figure 4. *Gross domestic product (GDP)*

the economy of the adverse terms of trade change resulting from the rise in the international price of coal. This beneficial fiscal effect is absent in North America, Australasia, and the non-OECD regions where there are assumed to be no policy changes; hence firms in these regions face higher input costs for energy without any compensatory offset from greater domestic saving lowering the cost of capital.

It should be stressed that the decline in carbon dioxide emissions from fossil fuel use that is depicted in figure 3 is a decline relative to a baseline in which global emissions are projected to rise from around 22 billion tonnes in 1990 to around 32 billion tonnes by 2010 (IEA, 1994c), and hence to almost 30 billion tonnes by 2005. Under this scenario they would still rise, but only to about 28 billion tonnes by 2005.

The effects on national outputs and incomes are more diverse. Figure 4 contains results for real GDP, again as a deviation from baseline. GDP is the value added by domestically located factors of production in each economy. This is a measure of aggregate domestic production change; but it does not take into account the international movements of capital allowed for in the G-Cubed model. GNP, on the other hand, is a measure of income to domestically owned factors of production no matter whether they are located at home or abroad. Thus it is a better measure of economic well-being of domestic residents than GDP since it measures their income from all their owned factors of production.[12] It does not include the negative valuation society places on greenhouse gas emissions though, and so will understate the gains in well-being from policy changes that reduce those emissions.

[12] Both GDP and GNP are measured in constant (1990) US dollars at the prices prevailing in each scenario. Thus the difference between scenarios in estimated GDP or GNP includes the effect of both quantity and price differences. Even GNP is not an ideal measure of utility, however, but it is the best indicator of welfare that is available in the model.

In Western Europe (ROECD in the figures), the rise in energy import prices and hence the prices to users leads to a fall in GDP during the adjustment period as industries respond to higher input cost and the economy adjusts to the deterioration in its terms of trade. By 2005, when the coal production subsidies are completely removed, the gains from reallocating resources within Western Europe begin to offset the negative shock of higher energy import prices.[13] By about 2020 those economies have adjusted to the change in relative prices and GDP returns to close to baseline. The recovery in its GDP is also the result of the permanently higher level of saving by Western European governments as a result of the fiscal savings from the reduction in subsidies. As in Japan, gains from an improvement in economic efficiency and the government budget in Europe outweigh the impact of slightly higher coal import prices and hence user prices of coal within the domestic economy. Countries with a relative abundance of coal experience a terms of trade improvement, by contrast, and hence enjoy a rise in GDP (most notably Australia, China, and the EEFSU region).

Bear in mind, though, that these GDP changes are not the same as changes in GNP in particular regions. This is because the G-Cubed model used here allows for foreign capital flows which adjust to changes in market conditions, as is evident by comparing figures 4 and 5. Western Europe, for example, exports financial capital to other regions under this scenario so as to take advantage of the now higher earnings abroad than at home. These higher earnings are reflected in GNP. Thus the reforms, although leading to a lower level of GDP relative to baseline for Western Europe, raise incomes there by 2014 because some of the capital released

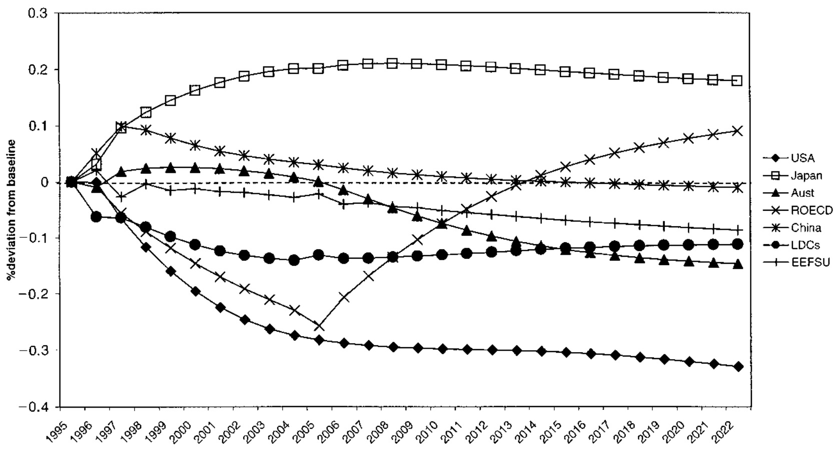


Figure 5. *Gross national product (GNP)*

[13] That negative shock is exaggerated in our modelling because we have not incorporated the fact that some electricity utilities in Western Europe are currently forced to use more high-cost local coal than they would prefer at prevailing prices (see section 3 above and Newbery, 1995).

from the coal- and fossil-fuel intensive industries (or what would otherwise have been invested in those industries) eventually earns a higher return overseas than it would have if it had stayed in those industries as in the baseline.

Overall, the effect of cutting coal production subsidies in the OECD is to reduce significantly the emission of carbon dioxide, particularly in the OECD. Even though this leads to some minor increase in carbon dioxide emissions in relatively carbon-intensive developing countries as a result of substitution away from the production of carbon-intensive goods in the OECD, this 'leakage' effect is a negligible offset to the OECD's carbon emission reduction—in contrast to the leakage that would occur under an international agreement in which only OECD countries voluntarily agreed to curtail their carbon dioxide emissions while imposing no discipline on non-OECD countries' emissions. The reason to expect substantial leakage in the latter case is because a voluntary cut-back in carbon emissions in the OECD would cause a major reduction in OECD coal use and hence in the international price of coal, thereby encouraging expanded use of coal in non-OECD regions.[14]

*Empirical results: effects of removing also coal consumer subsidies and export taxes in non-OECD regions*

Now consider the effect of adding to the phase-out of OECD production subsidies (which began earlier this decade) a phase-out of coal market distortions in non-OECD economies (which are just beginning, most notably in China and Central Europe). In this scenario we also completely remove the subsidy to consumption of coal and the tax on coal production (together with any associated export restriction) to bring coal prices to international market levels in the non-OECD economies. The results for the combined simulation are shown in figures 6 through 8.

As expected, the consequent rise in coal prices in the non-OECD economies leads to an expansion of coal production and a contraction of coal use within those economies. The expansion of production relative to consumption implies an increase in net exports from non-OECD to OECD economies, which on its own reduces the price of coal in international markets and hence in these economies, offsetting slightly the rise resulting from the OECD's production subsidy cuts. The effects on total carbon emissions, shown in figure 6, are the net effect of the removal of both OECD and non-OECD coal market distortions compared with no reform. In this case emissions from non-OECD countries also fall as their consumption subsides are removed. By 2005 carbon dioxide emissions from non-OECD economies are 4 per cent lower, when both OECD and non-OECD policies are reformed together, than otherwise would have been the case.

[14] How large that leakage would be depends on the nature of any international agreement of course. Numerous attempts have been made to simulate various possibilities. An early example is Piggott, Whalley, and Wigle (1992). See also ABARE and DFAT (1995), McKibbin and Wilcoxen (1996), and the surveys in Winters (1992) and IPCC (1996, ch. 11).

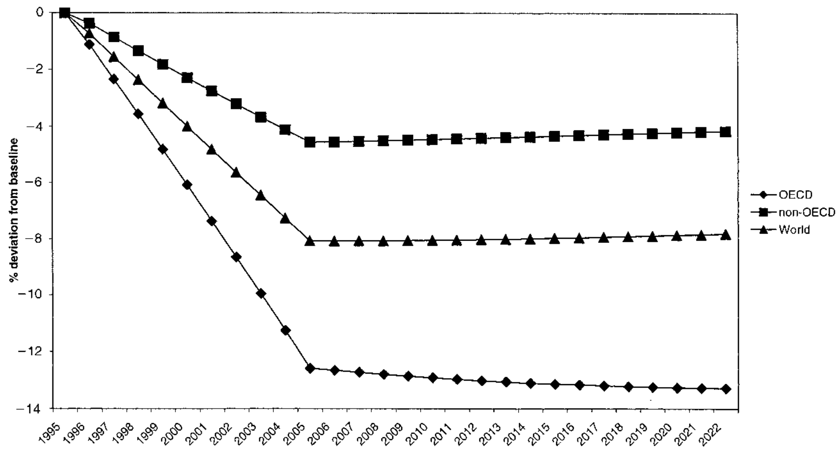


Figure 6. *$CO_2$ emissions*

To understand the effect of the non-OECD policy reform alone, the first set of simulation results should be subtracted from the combined results. We showed in the simulation results for the OECD policy reform that emissions from non-OECD economies rise slightly. Thus the effect of non-OECD policies on reducing non-OECD emissions are slightly larger than shown in figure 6. There is only a very slight rise in OECD emissions as a result of the lower price of coal in international markets in this as compared with the previous scenario, an effect that is dwarfed by the reduction resulting from the OECD's policy reform. Overall, global carbon dioxide emissions fall by 8 per cent relative to what otherwise would have been experienced by 2005, compared with just 5 per cent in the first scenario involving only OECD reform. That is, despite the fact that reforms in the non-OECD regions raise their net exports and hence lower the international price of coal, global carbon emissions are estimated to fall more, evidently because the effect of eliminating coal consumption subsidies turns out to dominate the effect of encouraging more coal mining in those regions.

Not only do the transition and developing economies gain in terms of emission reduction, but as well the changes in production contained in figure 7 show that GDP rises in each of these regions. This is the result of the efficiency gains from reducing their production and consumption distortions. Resources are freed up from the distorted sectors and reallocated through the global economy, yielding higher rates of return. EEFSU output expands substantially, while developing country output hardly alters in this combined scenario as compared with the reduction in output shown in figure 4, in which just the OECD countries reform.

Again the GNP effects are somewhat different from the GDP ones. While the GNPs of the transition and developing economies are raised by this combined reform, as compared with either no policy changes or just OECD reform, Australia's GNP is eventually lowered slightly when the

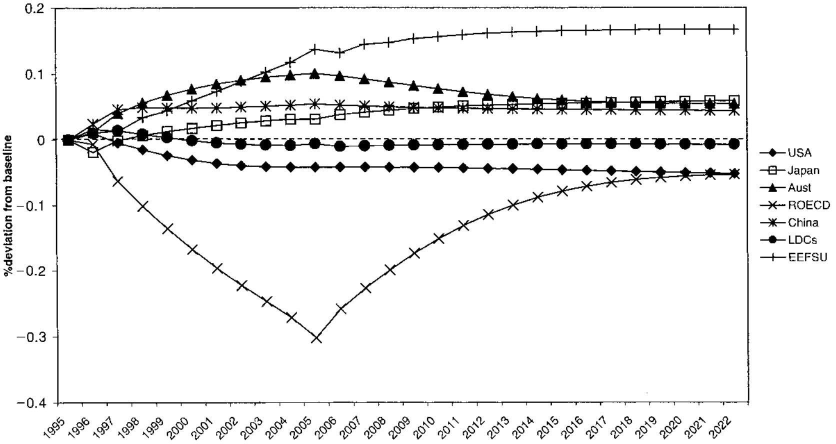


Figure 7. *Gross domestic product (GDP)*

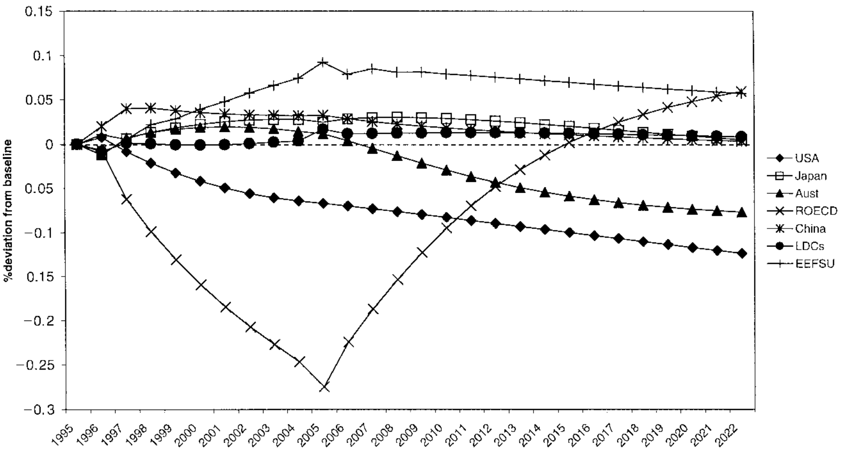


Figure 8. *Gross national product (GNP)*

non-OECD countries also reform. The latter is mainly because the terms of trade of coal-exporting and capital-importing Australia gradually deteriorate as the non-OECD countries' net exports of coal expand.

## 6. Conclusion

This paper has examined distortions in global coal markets that point to a significant subsidization of coal production in OECD economies and significant coal consumption subsidies in developing and transition economies—when the opposite policies are what are needed to overcome the environmental policies associated with coal mining and burning. Model-based empirical evidence summarized here suggests that the gradual removal of production subsidies in the OECD and the removal of distortions to coal markets in developing and transition economies can potentially reduce global emissions of carbon dioxide by up to 8 per cent relative to emissions that otherwise would have been experienced early next century. This environmental gain is achieved with gains in economic efficiency rather than economic costs—a win–win outcome for the environment and the economy. Both gains would be even greater if Western European countries also raised their low coal consumer tax rates as they phase out their coal producer subsidies, since those consumer taxes are currently relatively low (see footnotes 10 and 13 above), presumably to lower the cost to electricity utilities of requiring them to use lower-quality locally mined coal. And both gains would also be enhanced if countries taxed domestic coal production optimally so as to ensure coal mining enterprises compensate society for the pollution they cause.

Thankfully the process of lowering coal subsidies and trade barriers has already begun, with some EU economies (most notably Belgium and the UK) already advanced in dismantling their coal production subsidies and others (France and Germany) committing themselves to do so. And in some transition economies the low prices of coal (and also oil and gas) are gradually being raised. For example, in China many state-owned coal mines are being transferred out of the hands of the state and gradually subjected to domestic market forces. The results in this paper suggest these reforms should be applauded as a positive contribution to the reduction of greenhouse gas emissions, and countries should be encouraged to complete the process.[15]

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[15] Three caveats need to be kept in mind though. One is that the above results are for reforms from the 1990 level of price distortions, so the gains that *remain* to be reaped from completing the reform are less than those presented above. The second caveat is that in so far as electricity utilities in Western Europe were forced to use coal more than they would have preferred at prevailing prices, they may opt to use other fuel sources after the reform—in which case there would be less upward pressure on international coal prices (but more on the price of other energy raw materials). Also, under electricity de-regulation in the European Union the prospects for freer international trade in electricity may further alter the location of its production and hence the demand for the different fuels used to produce it (Hoster, 1997). These factors are not accounted for in our analysis. And, thirdly, no account is taken of the possible technological changes that might occur with or without these reforms.

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