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Will OPEC lose from the Kyoto Protocol?

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Abstract

A range of energy-economy models forecast losses to members of the Organisation of Petroleum Exporting Countries (OPEC) should the Kyoto Protocol come into force. These forecasts are a powerful influence in the United Nations Framework Convention on Climate Change negotiations. They are used by OPEC to advance the agenda on the impacts of response measures, covertly arguing for compensation for lost oil revenues arising from implementation of the Protocol. This paper discusses this issue, and explores the key assumptions of these models and their uncertainties. Assumptions about carbon leakage, future availability of oil reserves, substitution, innovation, and capital turnover are considered. The paper suggests that losses will not affect OPEC countries equally, and that these losses are not likely to be as substantial as the models forecast. A range of policy measures are proposed to lessen any impact the Protocol may have on OPEC.

Keywords: Kyoto Protocol; OPEC; Energy-economy models

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) estimates that by 2100 global mean temperature may have increased by 1.4–5.8°C and sea-level may have risen by between 9 and 88 cm, and that this increase is due to ongoing human activities (IPCC, 2001). Yet, international action on the problem is clouded by many unresolved issues among the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). One of these unresolved issues is the extent to which developed countries' efforts to reduce emissions will impact on the economies of oil exporting countries, and how these impacts can be minimised (Barnett and Dessai, 2002). Negotiations on this issue revolve around Article 4.8 of the UNFCCC and Article 2.3 and 3.14 of its Kyoto Protocol. A key player in these negotiations is the Organisation of Petroleum Exporting Countries (OPEC), a grouping of 11 oil exporting economies including: Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

Based on global energy-economy models of the impact of the Kyoto Protocol on energy exporters, the members of OPEC believe that the Protocol's implementation will slow growth in their revenues from oil exports. The models suggest that policies and measures (PAMs) to implement the Kyoto Protocol (such as a carbon tax) will increase oil prices to consumers and reduce demand in developed countries which account for 60% of world oil consumption, thereby driving down global oil demand and prices received by producers. In the climate negotiations, OPEC members argue that developed countries must minimise these impacts on OPEC, thereby implicitly arguing for compensation for their losses. They are opposed by developed countries. This will prove a significant challenge to the implementation of the Kyoto Protocol and the wellbeing of the Convention.

This paper discusses this issue, and explores the key assumptions and uncertainties in the energy-economy models that inform OPEC's policy position. Energy-economy models have been very influential in the political economy of climate change (Henman, 2002). As well as informing OPEC, energy-economy models

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have been used by the United States and Australia to justify their recalcitrant stance in the climate regime, leading ultimately to their withdrawal of support for the Kyoto Protocol in 2001 (Christoff, 1998; Hamilton, 2001; Harris, 1999; Harrison, 2001). Despite their powerful influence, the assumptions and uncertainties in these models are poorly understood by policymakers, and there are very few widely available reviews of them. This paper reviews those models that address the impact of the Kyoto Protocol on OPEC.

2. The UNFCCC, the Kyoto Protocol and the Marrakech Accords

International action to tackle to problem of climate change was formalised with the adoption of the UNFCCC in May 1992. The UNFCCC entered into force on 21 March 1994, and has now been ratified by 184 countries. The UNFCCC does not set binding emission targets on Parties. Its ultimate objective is the 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' in a time frame 'sufficient to allow ecosystems to adapt naturally... and to enable economic development to proceed in a sustainable manner' (Article 2).

Since the UNFCCC entered into force there have been eight meetings of its supreme body—the Conference of Parties (COP). At the third Conference of Parties (COP-3) in 1997, the Kyoto Protocol was adopted. The Kyoto Protocol is a supplement to the UNFCCC. It sets legally binding targets for greenhouse gas emissions on 38 developed and 'economies-in-transition' countries listed in its Annex B. In aggregate these emissions reductions equal a 5% reduction of the main greenhouse gases below 1990 levels, to be achieved in the first commitment period 2008–2012. The Kyoto Protocol will enter into force 90 days after 55 Parties to the Convention, including Parties accounting for 55% of Annex B reductions, have ratified it. At the time of writing (November 2002) ratification by Russia would make the Protocol international law, even though the US and Australia have rejected it.

Article 4.8 of the UNFCCC commits Parties to give:

> full consideration to what actions are necessary … including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures, especially on: ….. countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels….

The inclusion of Article 4.8 in the UNFCCC was required by OPEC countries in exchange for their support for the Convention, which reveals the 'true' global nature of this multilateral agreement. The issues of adverse effects and impacts of response measures are intrinsically linked in the Convention though they relate to quite different concerns (Barnett and Dessai, 2002).

Article 3.14 of the Kyoto Protocol contains a number of articles pertaining to this issue of the impacts of response measures (Yamin, 1998). In the long-term perhaps the most problematic of these is Article 2.3, which refers to the obligation of Parties to minimise the impacts of any PAMs on 'international trade... on other Parties, especially developing country Parties and in particular those identified in Article 4.8 and 4.9, of the Convention'. This linking of the impacts of implementing the Protocol to international trade 'has the potential to become the most heavily litigated of the Protocol's provisions' under the World Trade Organization's dispute settlement procedures (Yamin, 1998, p. 117). In fact, such efforts are already under way, with Saudi Arabia having recently challenged OECD climate policies at the WTO's Committees on Trade and Environment and the Non-Agricultural Market Access Negotiating Group (WTO, 2002).

The principal difference between Article 4.8 and 3.14 is that the latter refers to the obligation only of *developed* countries to 'strive to implement' their commitments 'in such a way so as to minimize adverse social, environmental and economic impacts on developing country Parties', particularly those identified in Article 4.8 of the Convention. The particular identification of developed countries as the source of minimising activities in Article 3.14 makes it more important to members of OPEC because it is these countries that are required by the Protocol to reduce emissions, and these countries are the largest consumers of OPEC oil.

Progress on a number of these bottlenecks was reached with the adoption of the Bonn Agreement and the subsequent Marrakech Accords to the UNFCCC at COP-7 (Barnett and Dessai, 2002; Dessai, 2001). A Special Climate Change fund was established under the Convention to finance climate change activities relating to adaptation, technology transfer and activities to assist OPEC countries in diversifying their economies (Dessai, 2003). With respect to Article 3.14, the Marrakech Accords require developed countries to provide annual information on how they are striving to minimise adverse social, environmental and economic impacts on developing countries as they implement their Kyoto commitments. This was a major achievement for OPEC, which also insisted that this information should be considered by the enforcement branch of the compliance committee, but which ended up in the facilitative branch due to developed country insistence. Some have argued that a decision on the legally binding nature of the compliance system was postponed until the Protocol enters into force exactly because of issues like Article 3.14, which make developed countries very uneasy. This shows that politically this issue is far from being resolved and will remain a problem in negotiations for years to come. We next briefly review OPEC's concern about climate mitigation policies.

3. A reason for concern?

Because oil consumption is responsible for some 25% of greenhouse gas emissions, efforts to reduce emissions would seem likely to affect the market for oil (Rowlands, 2000, p. 341). It is thought that implementing the Kyoto Protocol will require a carbon tax (or equivalent) in Annex B countries, and this will raise the price of oil to consumers and therefore reduce demand there. Because these Annex B countries account for more than 60% of world oil consumption any significant reduction in demand there may well cause a decline in the producers' price of oil on the global market. Further, if the principal mechanism by which Annex B countries reduce emissions is through a carbon tax, then this tax wedge may increase the 'rent' that governments in energy importing countries have in the oil market, transferring wealth from oil producers to consumers (Mabey et al., 1997, p. 274). To put this in perspective, the G7 countries (US, Canada, Japan, Germany, Italy, Britain and France) already earn some 70% more income from oil taxes than OPEC members earn from petroleum exports (OPEC, 2001). So, through reduced demand, reduced price and reduced market rent it is thought that implementation of the Kyoto Protocol will reduce oil export revenues. Other concerns expressed by OPEC countries include the potential increase in renewable subsides, which they perceive to be given at the expense of other energy forms (e.g. oil) and discriminatory in nature (WTO, 2002).

Thus, the models predict that a carbon tax or its equivalent will impose costs on both consuming countries and producing countries. The distribution of the effects (costs) of a tax is a well known aspect of the economic theory of taxation (OECD, 1993). In general, this distribution depends on the elasticities of supply and of demand with respect to price: relatively inelastic supply means that producers lose most; relatively inelastic demand means that consumers lose most. As we shall see later, these elasticities are also likely to be different in the long and in the short term: it is easier, for example, to improve the fuel efficiency of cars over a decade than over a 5-year period. However, in this paper we are less concerned with the distribution of costs between OPEC and the consuming countries than with the absolute size of the cost that OPEC members are likely to bear (in any event, the introduction of carbon taxes in consuming countries is likely to be offset by reduced taxes on other commodities, to ensure popular acceptance of the new taxes).

Oil export revenues account for between 9% and 40% of GDP in OPEC economies, so reduced oil revenues means reduced economic growth. For Saudi Arabia at least, a decline in economic growth has implications for unemployment given its high population growth rate; indeed Goldstone (2001) suggests that this may ultimately be a source of political instability in that country. It is these losses in revenues for which OPEC covertly seeks compensation through the UNFCCC's impacts of response measures agenda. Thus OPEC's statement to COP-3 said that 'the principle of compensation *must* be built into the protocol' that was to emerge from Kyoto (OPEC, 1997, p. 4). At COP-4 the Secretary General of OPEC expressed its compensation/equal progress position in the following terms: 'without a favourable disposition towards the compensation issue among the Parties to the Convention, how can fossil fuel producers be expected to give their wholehearted blessing to measures that could wreak havoc with their economies?' (OPEC, 1998, p. 2).

4. Modelling losses to OPEC

The findings of energy/economic models which seek to estimate the economic impact on various countries and sectors if the Kyoto Protocol is implemented are integral to OPEC's position in the climate negotiations. A number of models suggest that implementation of the Protocol will affect energy markets and oil revenues. These models are 'simplified representations of reality' developed to capture important relationships in energy markets embedded in the broader economy (Mabey et al., 1997, p. 47). Models are 'no more than a coherent set of assumptions about the structure and functioning of the economy', and their results depend entirely on their assumptions (Repetto and Austin, 1997, p. 5). A model's value lies not so much in the specific numbers it delivers, as these are highly uncertain, but in what it reveals about important relationships in the systems being modelled. Thus models seek to show relevant variables much more than they seek to predict outcomes (Mabey et al., 1997). Even though the documentation that accompanies models makes clear that predicted outcomes depend strongly on Ceteris paribus assumptions, this uncertainty and the ambiguous relationship between reality and model results are not sufficiently if at all recognised in many discussions of their results.

Macroeconomic models are most often used to show the impacts of climate PAMs on sectors of the global economy (such the energy sector) and on certain regions (such as oil exporting Middle Eastern countries). Most models are of the resource allocation type, and are often referred to as 'top-down' models. The aggregations necessary for these models to assess regional and global futures create very high degrees of uncertainty (Barker and Köhler, 2001). The alternative is 'bottom-up' models, which are based on available and likely future technologies to reduce emissions. Much is made of the difference between these two approaches because their estimates for the impact of climate PAMs on the energy sector differ widely, with macro models suggesting higher costs than engineering models. However, there is increasing hybridisation of the two approaches with 'bottom-up' estimates of technological developments being incorporated in 'top-down' multi-regional and multi-sectoral macro models. This is the case with most of the models listed in Table 1.

It is difficult to directly compare the different modelled estimates of the impact of the Kyoto Protocol on OPEC members because of: the different dates for which the results are solved (e.g. costs at 2010 as opposed to 2020); different cost measures of impact (e.g. reductions in GDP as opposed to reductions in oil revenue from business as usual scenarios); different regional groupings in which OPEC members are included (e.g. 'Middle East' which excludes 4 OPEC economies as opposed to 'OPEC'); and different assumptions about the Protocol's architecture (e.g. the extent to which emissions trading will be permitted among Annex B parties) (on the importance of cost measures see Bernstein et al., 1999). Table 1 shows the range of estimates of impact from recent models. There has been little comparison of such models in the past (Barker and Köhler, 2001). Because most cost estimates are almost certainly overestimates (see below), the losses forecast for a full Annex B trading scenario are seen here to be the most 'accurate', not least because this was what was agreed in the Marrakech Accords, although this assessment of course depends on the extent of uncertainty and the influence of caveats in results.

Table 1 shows that the largest estimate of the impact of the Kyoto Protocol on OPEC is a 13% reduction in oil revenues below the reference or business as usual (BAU) scenario for 2010 (McKibbin et al., 1999). Perhaps the only consistent outcome of all the models is that emissions trading reduces the costs of implementing the Kyoto Protocol for all Annex B and oil-exporting countries (Weyant and Hill, 1999). This finding has been used by the United States and others to argue for a full competitive emissions trading regime that includes carbon sink activities, which was indeed embraced by the Marrakech Accords.

All models show substantial future increases in OPEC oil revenues above present levels. It is not the case that oil revenues will decline, but rather that growth will be slightly slower as a result of the Kyoto Protocol. For example, in the CLIMOX model, OPEC oil revenues are expected to grow by some 65% between 1995 and 2010 in the BAU scenario, when in the Kyoto scenario they increase by some 49%. Further, the expected reduction in the price of oil from the BAU as a result of the Kyoto Protocol is in the order of US$2 per barrel (CLIMOX). Pershing (2000) puts this into perspective by pointing out that the price of oil has varied by more than US$50 per barrel in real 1990 dollars since 1970. Thus the Kyoto Protocol is likely to be a less significant factor in OPEC oil revenues than baseline fluctuations in the market: the price of oil tripled between January 1999 and September 2000, delivering an expected 60% increase in oil revenues to OPEC (OPEC, 2000) members for the year 2000 (EIA, 2001).

5. Assumptions and uncertainties in models

Models make assumptions about the future. These assumptions are influential in their results yet are largely untested with no a priori validation (Mabey et al., 1997, p. 47). Some assumptions are difficult to justify (Barker and Köhler, 2001). Models assume that energy-economies are linear in nature and so the impact of the Kyoto Protocol can be predicted to some degree. This assumption is in important respects false, for the economic world is 'organic' and complicated, it is a 'world of evolution rather than equilibrium; a world of probability and chance events' (Arthur, 1994, p. xx).

Table 1
Summary of estimates of the impact of the Kyoto Protocol on Oil Exporting countries (after Pershing, 2000, p. 98)

Model	Impact of Protocol on oil exporting countries	Reference
G-Cubed	13% decline in oil export revenue in 2010 from BAU with trading among Annex B Parties.	McKibbin et al. (1999)
GREEN	3% loss in real income in a situation of no permit trading	Pershing (2000)
GTEM	0.2% decline in real GNP at 2010 with trading among Annex B Parties.	Polidano et al. (2000)
MS-MRT	1.15% decline in welfare in 2010 in Mexico and OPEC countries (0.45% decline in GDP) with trading among Annex B Parties.	Bernstein et al. (1999)
OWEM	9.8% reduction in BAU annual oil revenue with trading among Annex B Parties and assuming that oil prices remain at BAU levels.	Ghanem et al. (1999)
CLIMOX	10% decline in oil revenue in 2010 from BAU with 'some' trading among Annex B Parties.	Bartsch and Müller (2000a)

Box 1
Assumptions in energy economy models

The reference or Business as Usual (BAU—no Kyoto; does not include policies driven by climate change concerns) scenario of future developments from which the cost of deviations due to the Kyoto Protocol are estimated. The higher the baseline, the greater the estimated cost of reducing emissions;
Assumptions about substitution among fossil fuels, between fossil fuels and non-fossil fuels, between energy and other factors of production, and substitution among products of differing energy intensities;
Assumptions about the availability of backstop technologies;
Assumptions about technological innovations that both facilitate substitution and reduce energy use per unit of output, and the responsiveness of technological innovation to changes in energy prices;
Assumptions about the rate at which energy using capital stock can be adjusted;
Whether the model accounts for the benefits of slowing the rate of climate change by implementing Kyoto as compared to BAU (for example less impacts on agricultural productivity);
Assumptions about the international policy regime to be pursued, including the amount of emissions trading, the use of flexibility mechanisms, and the use of sinks of CO_2 (this was unknown prior to November 2001 when the Marrakech Accords were adopted);
Assumptions about the policy mix in domestic economies. Most models use a carbon tax as a proxy for the policies and measures that might actually be pursued. Further, they assume that the tax is applied equally to final carbon emissions, whereas a tax that was applied to fuels, and differentiated according to their carbon contents would have different effects on oil demand. The way models account for the use of carbon tax revenues is also important;
Assumptions about the extent to which energy intensive industries may relocate. Some of this relocation may favour OPEC economies;
Whether the models account for OPEC's ability to act as a cartel to control the price of oil (few do, as equilibrium models assume perfectly competitive markets). Cartel action by OPEC may counteract possible impacts of response measures on oil revenue;
Whether the model accounts for reductions of other greenhouses gases besides CO_2;
What assumptions are made about future availability of conventional (cheap to access) oil reserves;
Data gaps, model structure inadequacies, verification and incomplete analytical frameworks.
(After: Barker and Köhler, 2001; FCCC, 2002; Mabey et al., 1997; Pershing, 2000; Repetto and Austin, 1997; Weyant and Hill, 1999; Weyant, 2000).

This alternative understanding of economies renders any claims to predicting the future problematic and demands that the multiple bases of uncertainty in models be explicitly acknowledged. Furthermore, even the energy markets embedded in the global economy are themselves 'dynamic, complex, interdependent systems, built on massive capital investments and relying on fuel supply systems that are in part commodity markets and in part transportation and conversion systems' (Ferriter, 1997, p. 145). Indeed, according to Austwick (1992), the complexities and uncertainties of the oil market render it too complex and contingent to model.

The most important assumptions which explain the uncertainties within and differences between all model results are shown in Box 1. The ways some of these assumptions influence OPEC's own OPEC World Energy Model are discussed later in the paper. It has been shown that, of these, assumptions about revenue recycling, backstop technologies, and flexibility instruments in the Kyoto Protocol are the most important factors in determining different results from models (Repetto and Austin, 1997; Barker and Köhler, 2001). Some of the most important of these assumptions (baselines, policy regimes, cartel behaviour, possible benefits to oil exporters from slowing climate change) are discussed later with reference to the OPEC World Energy Model. Critically, assumptions about supply elasticities do not significantly differentiate the predictions of the models, though some of the implications of supply policies will be reviewed later. Other important assumptions about carbon leakage, future availability of oil reserves, and substitution, innovation and capital turnover are now briefly discussed.

5.1. Carbon leakage

Because implementation of the Kyoto Protocol will probably involve some increase in energy prices to consumers in Annex B countries with downward pressure on the global market price of oil, energy costs in developed countries may increase at the same time as they may decrease in developing countries. Depending on the extent of this price effect, it is postulated that industrial activities for which oil costs are a significant factor of production (say, plastics manufactures) may increase in many developing countries either as Annex B producers lose advantage to developing country competitors, or because industries may choose to relocate. In so far as these and other trade-related impacts of the Kyoto Protocol may offset the amount of the intended CO_2 reduction through increased emissions in non-Annex B countries this issue is often referred as 'carbon leakage'.

The most direct form of carbon leakage will be through increased oil consumption in developing countries if the global price of oil declines. Further, if the Kyoto Protocol affects the terms of trade then incomes in developing countries may increase and so consumption of energy products may increase above a non-Kyoto situation. Predictions of carbon leakage have varied between 3.5% and 70% of OECD targets (Repetto and Austin, 1997), but some gradual confluence in recent models puts leakage in the order of 8% to 16% of Kyoto targets in 2010 with Annex B emissions trading allowed (Polidano et al., 2000; Bernstein et al., 1999, respectively). This variation reflects the substantial uncertainties associated with this issue. It is thought that emissions trading would reduce the factors that generate carbon leakage (Barrett, 1998).

The issue of carbon leakage is important in estimates of the impact of the Kyoto Protocol on oil exporting economies for two reasons. First, *no* carbon leakage implies that Annex B oil-dependent industries will remain in situ and depending on substitutability and innovation (see below), will continue to consume oil. So, despite price rises there may be a less than anticipated reduction in oil demand and therefore less impact on OPEC oil exports. Second, *if* oil price proves to be significant to certain industries then they may choose to relocate to places where oil is cheapest—presumably to OPEC economies. This may offset the GDP impact of the Protocol on OPEC members both through increasing domestic consumption of domestically produced oil and a through a growing share of GDP coming from new or expanding industrial activity.

The extent of any industrial relocation depends on both the magnitude of change in oil prices and the degree to which the cost of oil is important to manufacturing costs and therefore competitive advantage. The problem, then, is essentially one of the location of economic activity in terms of the cost of oil, a factor which Mabey et al. (1997) find to be insignificant. Repetto et al. (1997) also find that rising energy prices are highly unlikely to lead to industrial relocation because energy accounts for only 10–20% of total input costs in energy-intensive industries in the US (for example), and because international investment is not driven by differences in energy prices among countries. Other factors such as labour costs, skills needs, tax regimes, distance to markets, infrastructure costs, investment environments and technological needs all seem to be far more important in location decisions. Although highly uncertain, the Kyoto Protocol may well effect substantial changes in exchange rates, industrial activity and investment, yet there appears to be little, if any investigation of these other non-fuel price factors in discussions of carbon leakage. Finally, in practice governments will most probably act to protect sectors which will lose competitive advantage due to implementation of the Kyoto Protocol, perhaps through concessions on other company taxes, although such actions may be in breach of the rules of free trade regimes (Brack et al., 2000). Overall then, it seems unlikely that there will be much carbon leakage through industrial relocation as a consequence of the Kyoto Protocol.

5.2. Future availability of oil reserves

The price of oil is influenced by the amount of proven oil reserves as these determine the scarcity rent component of oil prices; less reserves means more future scarcity and therefore higher prices today. Models make assumptions about future changes in oil reserves. These assumptions must take account of potential new discoveries, changes in demand and oil price, and changes in extraction technologies as all these determine which reserves can be profitably exploited. If long-term reserves of conventional oil are limited then this would substantially reduce if not negate the long-term impact of the Kyoto Protocol on oil exporting countries through higher scarcity rents and in the long-term complete consumption of oil reserves. Indeed this appears to be the case as production from proven reserves is expected to peak around 2020, suggesting that given the level of future demand for oil in even the most restrictive Kyoto scenarios existing proven reserves will ultimately all be consumed, albeit at a slightly lower rate (Brack et al., 2000).

The issue, then, is the time scale over which lost revenues will occur. Over a short time horizon, revenues may be lower than BAU scenarios, but over longer periods all oil reserves are likely to be sold (Grubb, 2001). Furthermore, extraction of competitor fuels from non-conventional sources such as shales and tar sands is itself a carbon-intensive process, meaning that under a carbon-tax regime the price of these fuels will be greater again. Therefore, in a world where the price of oil declines, extraction from non-conventional sources will become considerably less profitable, ultimately increasing demand for cheaper-to-access conventional oil, the bulk of which is located in the Middle East (Pershing, 2000). These issues associated with oil reserves are highly uncertain, and are dealt with in varying ways in models (see Blank and Strobele, 1997).

OPEC controls 77% of global oil reserves and over the next few decades, regardless of Kyoto factors, other countries' share of reserves and production seems likely to decline (Ghanem et al., 1999). This means that OPEC's power to influence the price of oil will increase in the longer term. Furthermore, some 40% of the world's proven gas reserves are also held by OPEC (Blank and Strobele, 1997), with Iran, for example, having over 180 years of supply (Siddiqi, 2002). Most models show that the Kyoto Protocol will effect a substantial rise in demand for gas particularly through switching from coal to gas use in electricity generation (but CLIMOX is a notable exception, see Bartsch and Müller (2000a)). For example the US Energy Information Agency expects US gas consumption to grow by 2–12% by 2010 (although this is unlikely to be met by OPEC sources) (EIA, 1998). This means that OPEC's potential losses from oil exports can be offset through increased supply of gas at higher prices (some 19% higher according to EIA (1998)). The potential exists, then, for what Blank and Strobele call 'a sophisticated strategy to find the balance between oil and gas supply to maintain oil and gas prices high enough to prevent rent extracting taxes' (1997, p. 162).

OPEC needs reliable estimates of future oil demand to make optimal investments to ensure that production capacity expands to match future demand. The final form of the Kyoto Protocol, which is described in the Marrakech Accords, and its impact (or no) on oil demand is a very large area of uncertainty which makes present OPEC investment decisions more risky. Indeed, if OPEC misreads the final outcome of Protocol negotiations then their losses from wrong *investment* decisions may be substantially greater than those estimated to occur as a consequence of the Protocol's impact on oil prices. Yet OPEC's current negotiation tactics in the UNFCCC prolongs exactly the sort of uncertainty they need to avoid to make secure investment decisions.

5.3. Substitution, innovation and capital turnover

The PAMs Annex B countries adopt to meet their Kyoto targets will affect the prices of energy sources differently. This might occur, for example, through a carbon tax applied differentially to the three main fossil fuels of oil, gas and coal according to their respective carbon contents. The EU proposed to implement such a scheme in the 1990s, but it never went ahead (Lacasta et al., 2002). This would see coal taxed most heavily (1.04 tonnes of carbon emitted per tonne of oil equivalent (p/toe)), then oil (0.87 tonnes of carbon emitted p/toe), then natural gas (0.65 tonnes of carbon emitted p/toe). Such a tax would make gas the cheapest energy source, then oil, and would effect a substantial shift away from coal consumption. Such an approach to reducing emissions would substantially alter fuel prices and consumption where substitution among fuel sources is possible, leading to:

- substitution among fossil fuels (for example switching from coal to gas for electricity generation);
- substitution between fossil and non-fossil fuels (for example switching to solar instead of coal-fired electricity for residential power needs);
- substitution between energy and other factors of production (for example increased use of labour instead of machines);
- substitution of energy intensive products by non-energy intensive products in consumption (for example using public transport instead of privately owned vehicles) (Mabey et al., 1997, p. 58).

It is thought that any policy and measure taken to meet Kyoto targets will effect some change in energy prices and therefore some substitution among energy sources.

The way that models account for substitution matters because the extent of substitution away from or towards oil affects oil demand and therefore the extent of losses in revenues from oil exports. For example, some 56% of the final use of oil is accounted for by the transport sector, so unless there are major changes in car propulsion, the Kyoto Protocol will have minimal impact on oil consumption in this sector, and therefore, by Bartsch and Müller's (2000b) reasoning at least, little impact on overall oil trade. Further, it is conceivable that oil consumption may actually increase in the electricity sector in those economies where gas is unavailable for use in electricity generation (as oil will be the only available cheaper substitute for now more expensive coal) (Bartsch and Müller, 2000b). So, a model which assumes that little substitution will transpire will show that patterns of oil consumption will not change much, and so losses to oil exporters will be minimal. Assumptions about substitution affect both reference case scenarios and Kyoto scenarios.

The degree to which substitution can take place is contingent upon the technologies that are present and will be available. Assumptions about technological innovation are highly influential in both reference case scenarios and Kyoto scenarios. This innovation factor determines the extent to which substitution may not occur as price changes may stimulate technologies that deliver increased efficiency in existing consumption (making it cheaper to use the same fuel more efficiently than to substitute for it). So, models which assume large gains in efficiency will show reduced consumption of oil per unit of economic output, and therefore less oil demand, but this may imply less need to find substitutes for oil.

Innovation also determines the possibilities for substitution (for example future technologies may see a switch to hydrogen-powered vehicles). Thus models which assume low rates of innovation may show few extra possibilities for substitution in the future, implying that existing patterns of oil use may not change much, and so neither will oil demand and oil export revenues. In the past, changes in energy prices have stimulated innovation in energy technology, but innovation is for the most part driven by factors other than changes in energy prices (Weyant, 2000). Overall, the 'reality' of technological innovation and substitution is complicated, poorly understood, and highly uncertain (Barker and Köhler, 2001; Bernow et al., 1998).

Assumptions about substitution are also contingent upon the way that models account for capital stock dynamics. Over longer periods of time, old plant and equipment will be replaced with new (more efficient or substituting) technologies when they reach the end of their useful lives. However, in the short-term existing plant and equipment constrain the ability of producers and consumers to substitute energy in response to price changes (Grubler et al., 1999; Weyant, 2000). 'Short-term' refers to the 10-year time scale of modelled impacts on OPEC discussed in this paper (model results have only been shown for the year 2010 although most of the models shown in Table 1 forecast for longer time horizons). Accurately estimating these capital stock dynamics is a substantial challenge to models and there are significant limitations in data which render assumptions problematic (Grubler et al., 1999; Weyant, 2000). Most models assume little accelerated change in capital stock over the short-term, thereby limiting substitution and minimising losses to oil exporters. However, models vary in the degree to which existing capital stock can be changed to allow for greater efficiencies.

6. The OPEC world energy model

At the sixth Conference of Parties to the UNFCCC, OPEC issued a press release stating that potential losses to OPEC from the Kyoto Protocol may be as high as US$63 billion per annum. This was based on the results of the model that OPEC most uses to support its claim of potential losses in oil revenue—the OPEC World Energy Model (OWEM)—and so we now briefly discuss this model in some detail.

OWEM is a top-down econometric model (Ghanem et al., 1999). Its BAU scenario sees world energy demand growing from 73.4 million barrels/day (mb/d) in 1997 to 87.9 mb/d in 2010, of this: OECD demand grows from 43.6 to 48.5 mb/d, and OPEC oil production grows from 29 to 39.6 mb/d, with a corresponding growth in OPEC's share of world oil production from 39.5% in 1997 to 45.1% in 2010. In this scenario the real price of oil (in 1998 dollars) is the range of US$17–19/barrel in 2010. The model assumes a level of improvement in energy efficiency consistent with other models (1.5% per annum globally), no major changes in energy taxes or policies, and no major changes in the share of oil used in the transport sector. Under this reference case scenario OPEC's revenue from oil exports is expected to grow to US$114.2 billion by 2010 (in real 1998 dollars), up from $104 billion in 1998 (Ghanem et al., 1999; EIA, 2000).

OWEM's BAU scenario sees Annex B emissions grow to 5 billion tonnes of CO_2 by 2010, which is higher than most models, but within the overall band of possible future emissions discussed in Weyant and Hill (1999). In this respect OWEM's relatively high reference case means relatively high reductions in oil demand will be necessary to meet Kyoto targets, and therefore relatively greater reductions in future oil revenues are forecast.

OWEM calculates changes from the BAU scenario as a consequence of a number of possible Kyoto Protocol scenarios. Importantly, in all scenarios it assumes that the emissions reduction targets of all Annex B countries are met solely through reductions in CO_2. This is important because Kyoto targets can actually be achieved through reductions in five other greenhouse gases as well (methane, nitrous oxide, hydroflourocarbons, petroflourocarbons and sulfur hexaflouride). Any policy that seeks to reduce emissions across a 'basket' of these gases will substantially reduce the emphasis on CO_2 reductions (Reilly et al., 1999), and therefore oil consumption is likely to bear a lesser burden. So, the assumption that Kyoto targets will only be met through CO_2 reductions overstates the cost to oil producers.

OWEM makes no allowance for the use of carbon sinks as a measure to meet Kyoto targets. The inclusion of carbon sinks within the Marrakech Accords has reduced the costs of implementing the Protocol considerably and therefore reduced the emphasis on reducing energy consumption. OWEM also shows that a cap on the use of Kyoto mechanisms to meet emissions reduction targets in OECD countries affects OPEC revenues; the less emissions are able to be traded the higher the cost to OPEC. Though opposed by the EU, no cap on the Kyoto mechanisms was allowed in the Marrakech Accords.

The policies that national governments might pursue to implement the Kyoto Protocol are also important. In all OWEM scenarios it is assumed that the only domestic measure that Annex B governments will use to reduce emissions will be a carbon tax—used as a proxy for the actual policies each country might pursue. In some OWEM scenarios surplus emissions can be traded—among OECD countries, among all Annex B countries, and among all Parties to the UNFCCC. Each of these, respectively, expanding trading regimes subsequently reduces the level of carbon tax imposed in OECD countries required to meet their Kyoto targets, and in turn reduces OPEC losses from the BAU scenario (less US$23 billion in trading among OECD, less US$14.2 billion in trading among all Annex B countries, and less US$11.7 billion in trading among all Parties). However, a carbon tax is highly unlikely to be the only domestic policy OECD countries use to meet their Kyoto targets, with intra-country permits and trading, as well as other forms of regulation also quite likely to be in the final policy mix (DETR, 2000). So, OWEM's assumption that a uniform carbon tax will be the only policy Annex B countries pursue also overstates the impact of the Kyoto Protocol on oil demand in the OECD (and therefore overstates losses to OPEC) (Weyant, 2000).

OPEC's ability to influence the price of oil through restrictions in supply is a critical factor in whether they will experience less revenue as a consequence of the Kyoto Protocol. Cartel action by OPEC may be sufficient to fully counteract possible impacts of the Kyoto Protocol on oil revenue. One of the more interesting outcomes from OWEM is its estimate that OPEC's market share will decrease by some 2.1–4.5% of the market from the BAU case following implementation of the Kyoto Protocol. However, in all scenarios OPEC's share of the market increases from its present level. This implies that regardless of how the Protocol is implemented, OPEC's ability to influence the price of oil will not be diminished by the Protocol. OWEM shows that OPEC can maintain the projected BAU revenues by restricting production by some 26% below forecasted BAU levels. This produces an oil price of US$22.7/barrel in 2010 as opposed to the BAU price of US$19.4/barrel. Therefore, by exerting its cartel power OPEC need only influence the future price of oil by some US$3.3/barrel to prevent Kyoto-induced revenue losses. This compares with OPEC's recent restrictions in production which influenced a rise in the price of OPEC oil from (the exceptional low) US$10/barrel in January 1999 to over US$30/barrel in September 2000. Furthermore, as of March 2000 OPEC has adopted an informal mechanism which will adjust supply to keep the price of oil in a pricing band of US$22–$28/barrel, a level higher than even the price OWEM predicts will be necessary to protect OPEC revenue losses from the Kyoto Protocol (EIA, 2001).

Nevertheless, there is some uncertainty about the extent of the existing and future power of OPEC to influence the oil price to protect revenue losses (Berg et al., 1997; Braten and Golombek, 1998; Gulen, 1996). Recognising this, OWEM runs its Kyoto scenarios under an assumption that OPEC production increases at BAU levels, thereby substantially 'softening' the price of oil in a market where there will be reduced demand (so assuming OPEC will not only *not* act to influence oil price, but indeed *over-supply* despite reduced demand). It is from this 'soft' price assumption under the now incorrect no-trading scenario that the US$63 billion per annum in lost revenue that OPEC promoted at COP-6 is derived. Finally, OWEM also estimates that if all major developing country oil producers and the Former Soviet Union acted in a common oil-price maintenance strategy then OPEC losses would be substantially reduced, again pointing to the power of cartel behaviour to minimise losses due to the Kyoto Protocol (Ghanem et al., 1999).

7. Intra-OPEC differences

Not all OPEC countries will be equally affected by implementation of the Kyoto Protocol, indeed the differences may be vast. Kassler and Paterson (1997) suggest that Iran and Iraq would be the worst affected of the OPEC countries. Table 2 takes OWEM's Kyoto Annex B trading scenario, which predicts a decline in annual OPEC revenue in 2010 of US$14.2 billion below the BAU scenario for all OPEC countries, and divides this among OPEC countries on the basis of their shares of OPEC revenue in 1999 (after EIA, 2000).

Table 2 suggests that declines in oil revenue will be less important to some OPEC countries than the adverse effects of climate change proper on other important economic sectors such as agriculture (which accounted for over 20% of 1999 GDP in Indonesia, Iran and Nigeria). So, losses in revenue from damages in these sectors due to climate change may far outweigh losses in oil revenue due to implementation of the Kyoto Protocol. Therefore it is arguably in Indonesia, Iran, Nigeria and Venezuela's (at least) interests to support substantial emissions reduction measures and measures to transfer technologies and funding to help them adapt to climate change (on Venezuela see Cline, 1992, p. 342). Further, some OPEC countries such as Kuwait and the UAE have substantial non-oil overseas investments in stocks, foreign bonds, currencies, real estate and economic development projects (Pershing, 2000), and these investments will become increasingly risky in a world where the climate is changing. At the very least, for all of the OPEC countries a far more detailed assessment of the balance of potential losses due to the adverse effects of climate change against potential losses due to the implementation of emissions reduction responses is necessary. The IPCC concluded that arid

Table 2
Distribution of losses among OPEC countries on the basis of OWEM's Annex-B trading scenario

	% of OPEC revenue 1999	Losses in 2010 (billion $)	Losses in 2010 as a % of 1999 GDP	Ranking in terms of losses as % of GDP
Saudi Arabia	28	4	2	5
Iran	11	1.5	0.4	9
Venezuela	10	1.4	0.7	7
Nigeria	9	1.3	1.2	6
Iraq	9	1.3	2.2	4
UAE	9	1.3	3.1	2
Kuwait	7	1	2.2	4
Libya	6	0.9	2.3	3
Algeria	5	0.7	0.5	8
Indonesia	3	0.4	0.07	10
Qatar	3	0.4	3.3	1

and semi-arid Asia, where a number of Middle East OPEC countries are located, are highly vulnerable to the impacts of climate change in the water resources and food and fiber sectors (Lal et al., 2001).

There are two other reasons which suggest that the Kyoto Protocol will not uniformly affect all OPEC countries. First, those countries such as Saudi Arabia and Kuwait which are able to produce oil at low-cost (~US$2/barrel) will be better able to survive in a market where the price of oil has declined than those such as Nigeria (US$9/barrel) and Indonesia (US$13/barrel) (Pershing, 2000). However, given that the world oil price is not expected to drop below production costs anywhere this factor is probably of little importance except to indicate relative profitability. Second, those countries such as Saudi Arabia which are most dependent on energy export revenue, with relatively less economic diversification, will be relatively worse affected than those which have low dependence (such as Indonesia). Offsetting this, countries with substantial low-cost gas resources such as those in the Middle East may gain through increased supply of gas to meet growing demand.

8. Conclusions: minimising potential losses to OPEC

Payment of compensation for lost oil revenues is implicit in the strategies OPEC promotes to minimise the impacts of the Kyoto Protocol. This is politically unrealistic (see Barnett and Dessai, 2002), and practically problematic. The extent of lost revenues to be compensated is impossible to define with certainty because to ascertain how much was lost requires knowledge of how the world oil market would have operated without implementation of the Protocol (Kassler and Paterson, 1997; FCCC, 2002). Assessing such an impact requires, among other things, a distinction between the impact of *other* unrelated PAMs from those taken pursuant to the Protocol; and disaggregating the effect of climate change PAMs on developments in technology, macroeconomic variability, structural economic changes and other exogenous changes which would have otherwise affected oil export revenues. As modellers make clear, an accurate assessment of how much oil revenue was lost due the Kyoto Protocol requires accurate understanding of these counterfactual but inescapably *hypothetical* and *unknowable* scenarios.

Of course, as orthodox economic theory makes clear, subsidies and taxes always affect the distribution of incomes (Dasgupta and Heal, 1979). In general, they also have—in the short term at least—a negative effect on aggregate welfare. While there may be in principle a global gain in the long term—as forgone costs of climate impacts—from policies to implement the Kyoto Protocol there can be less understanding of the longer term distributional consequences of such policies. That is why there is argument over the implementation of the Protocol. We do not argue that policies to implement the Protocol will not affect the distribution of incomes between countries; rather that the level of this distributional impact is at present not known.

In addition to compensation, there are at least six other policy measures that might minimise any possible losses to OPEC countries (Kassler and Paterson, 1997; WTO, 2002). First, OPEC argue that the removal of subsidies on coal production, and removal of taxes on oil consumption in developed countries would lessen the impact of the Kyoto Protocol on their export revenues. This has been a long-standing concern of OPEC prior to the UNFCCC. These measures would raise the price of coal and reduce the price of oil in developed countries, effecting a significant shift in fuel consumption from coal to oil. This would result in less carbon emissions per unit of economic activity as coal is more carbon-intensive than oil. Second, tax restructuring in developed countries to reflect the carbon content of fuels would also lessen the impact of the Kyoto Protocol on oil exporters as it would raise the price of coal, effecting fuel switching from coal to oil, and from oil to gas (discussed earlier in this paper). Gas is the least carbon-intensive conventional fossil fuel and the bulk of long-term gas reserves are located in OPEC countries. Third, measures to discourage the production of fossil fuels within developed countries would increase OPEC's share of the oil market and their cartel power. Fourth, measures to abandon nuclear power generation would also favour oil exporters as more primary energy needs would presumably be met by oil. Fifth, developed countries could assist oil exporting economies to diversify sources of income, as models results show that economies with a diverse pattern of production and exports will be least affected by the Kyoto Protocol (Polidano et al., 2000). Finally, increased use of carbon sinks would lessen the emphasis on reductions in emissions from energy consumption as a means to implement the Kyoto Protocol. Though an accepted matter within the Marrakech Accords (under the form of forest management, cropland management, grazing land management and revegetation), this remains a contentious subject in climate science.

At the heart of OPEC's concerns about the impact of the Kyoto Protocol on their development lie questions of belief in the methods, assumptions and results of simplified models of world energy trade. Certain assumptions in these models leads to overstated estimates of the impact of the Kyoto Protocol on oil exporters, including assumptions about: future oil reserves, international and domestic policy measures to reduce greenhouse gas emissions, and the power of cartel behaviour to influence the price of oil in the future. Model results contain compounded uncertainties of such a magnitude as to question whether OPEC will experience any negative impacts from the Kyoto Protocol. Should there be any impact at all, it will not affect OPEC countries equally. Many will experience larger economic losses due to the adverse effects of climate change per se rather than from the impact of response measures. A range of policy measures are available to lessen whatever impact—if any—the Kyoto protocol may have on OPEC, and these are more palatable to developed countries than the sometimes mentioned argument of compensation for lost oil revenues.

Because the Marrakech Accords have provided more detail about the way the Kyoto Protocol will be implemented, there is a need to re-run all models to take this into account. An intensive comparative study of the results is necessary to establish the range of uncertainty, in the same way as is done for Global Climate Models. We expect that estimated losses to OPEC will be considerably lower if models are re-run to take account of the Marrakesh Accords. This, coupled with more detailed investigation of the adverse effects of climate change on OPEC countries, may substantially reduce the costs, and enhance the benefits of the Kyoto Protocol to OPEC.

So, to answer the question in the title of this paper, we agree with Pershing who argues that 'almost all (models) are likely to substantially overstate overall costs, and more specifically, overstate OPEC or oil exporting country costs' (2000, p. 99); and with Grubb who writes that after 'a sober appraisal ... neither oil exporting countries nor the companies that trade in oil have much to fear from long-run goals to stabilise the atmosphere' (2001, p. 843). Nevertheless, a precautionary approach is required lest there be some residual impacts on OPEC economies, and the recent establishment of the special climate change fund for technology transfer and activities to assist economic diversification will assist in mitigating the impact of the Kyoto Protocol on OPEC economies.

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