Modelling the macroeconomic effects of energy policies

Report prepared for
Department of Trade and Industry

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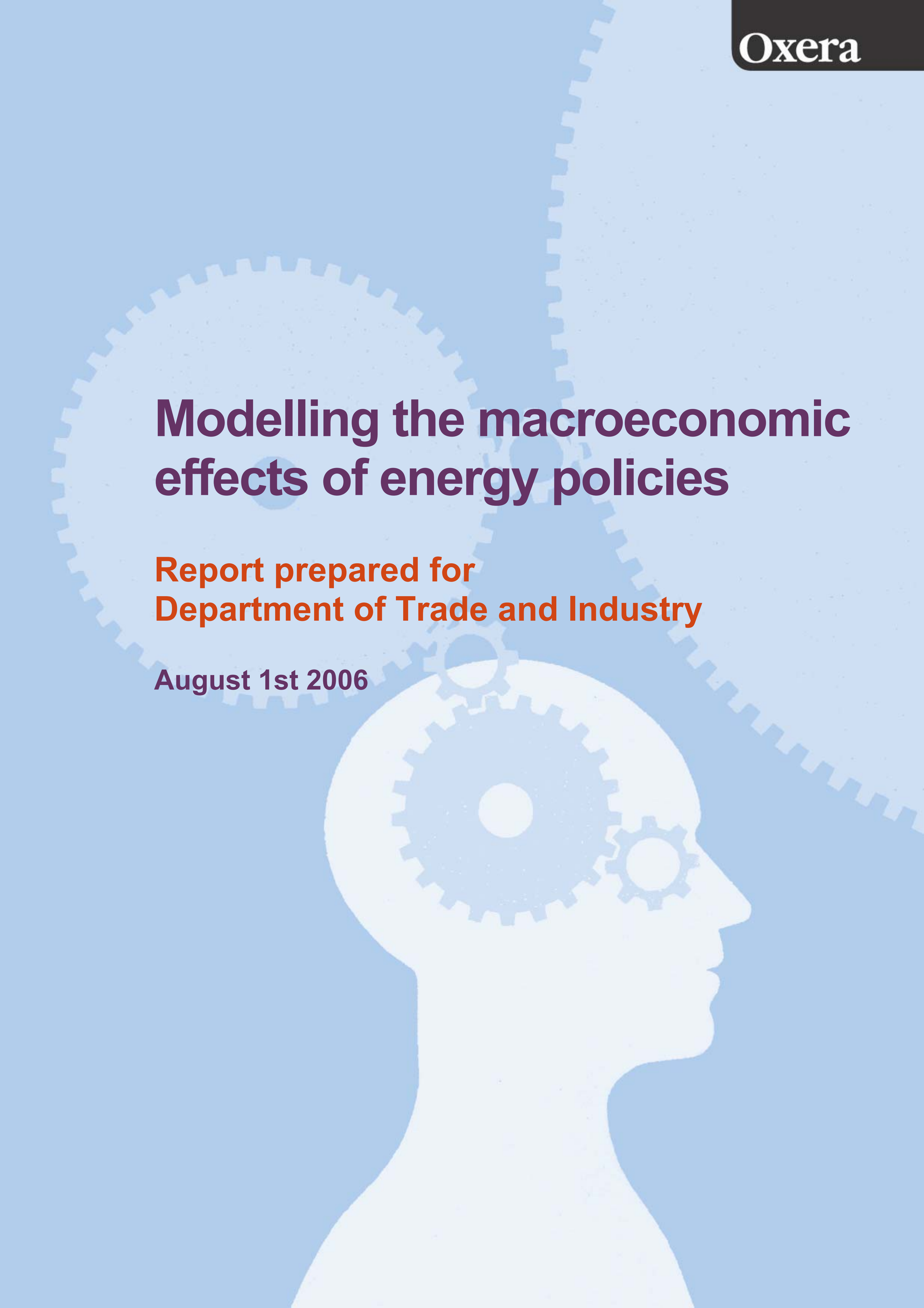

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Executive summary

The purpose of this report is to assist the Department of Trade and Industry (DTI) in making decisions on the use of macroeconomic models for assessing the costs associated with proposed energy policy measures. Particular emphasis has been placed on two aspects of the policy impact:

- the distinction between the long-run and short-run (or transitional) costs of a new policy;
- the impact on the competitiveness of the UK economy.

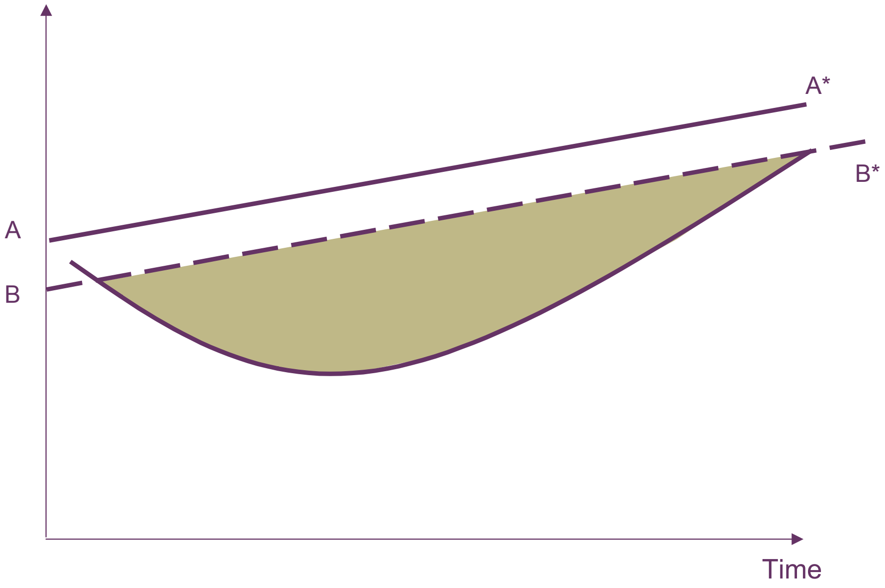
Given limitations in timing and budget, scenarios of energy price changes to assist in the completion of this report were undertaken using two macroeconomic models—those of Oxford Economic Forecasting (OEF) and Global Insight.

Transitional costs

Most studies on the cost of energy (or climate) policies focus on the long-run impact associated with a reduction in potential GDP as a consequence of increased resource costs. However, the transitional path to the new equilibrium position may be lengthy and may create additional costs as factor markets adjust to the new relative prices (or constraints on their behaviour). These additional costs arise due to imperfect short-run mobility in factor markets resulting in GDP falling below its new long-run potential. Since these costs are transitory, in the long run the new equilibrium will establish itself as production processes and households adjust to the changing relative prices.

This is illustrated in Figure 1. The line AA* shows the path of GDP over time prior to the change in policy, whereas BB* shows the implied long-run GDP path including the impact of the policy. The difference between these two lines represents the long-term effect of the new policy.

Figure 1 Illustration of transitional costs



Source: Oxera.

The extent of this gap, or long-term cost, depends on the technological options open to energy producers and consumers, and on how these options change over time in response to an increase in the price of energy relative to other factors of production. In the long run, it will depend on the ability to alter the underlying production or consumption function to use energy more efficiently. This is best analysed in models that allow explicitly for the introduction of new technologies or production processes and develop their scenarios using bottom-up, cost-minimisation techniques.

In the short run, however the production and consumption functions (technologies) are fixed and the GDP impact is bounded by the degree of factor substitutability assumed within them. As a consequence, the observed path of GDP may deviate from the long-run trend. For example, in Figure 1, the actual path falls below BB* initially, then recovers. The shaded area below BB* thus represents transitional costs.

The magnitude of these transitional costs depends on two underlying factors:

- how far below the new long-run equilibrium the economy must fall before markets begin to adjust;
- how long the economy takes to reach its long-run potential.

Since the focus of macroeconomic models is on the short-run dynamics, they are well suited to capturing the transitional costs and competitiveness effects associated with any policy change. However, lack of endogenous technological change means the true transitional costs may be hard to identify.

If the model fails to take account of technological change, this will affect the ability of the model to estimate transitional costs for two reasons.

- The model will be unable to achieve the potential output that would be possible with the new technologies, and, hence, relative to this long-run equilibrium, transitional costs will persist and the cost will be overestimated. This is illustrated in Figure 2 below where the actual GDP path is always below the long-run equilibrium.

- There will be no consistent means of determining the equivalent to BB* in the model. Essentially, the model will derive a new long-run equilibrium consistent with the fixed production function (CC* in Figure 2) and the path to this equilibrium may involve some adjustment but may not entail transitional costs (ie, the path of GDP is monotonically decreasing to CC*). Some external long-term benchmark would be required in these circumstances[1] and even then the point at which the upswing in GDP as production possibilities expand would need to be assumed.

The modelling exercise investigated the manner in which technological change was captured in the models. In both, there was no endogenous technological change, but exogenous technological change was incorporated through a total factor productivity (TFP) time trend. The increase in TFP over time would essentially produce a parallel shift outwards in the production function. While this would improve the production possibilities of the economy, it would not alter the underlying relationship between the factors of production (ie, the shares in total income in equilibrium would not change). It may be that factor-specific improvements would change the latter (ie, the coefficients on the factors in the Cobb–Douglas specification) and may therefore mitigate the relative price changes to a greater extent. However, it was unclear how significant this effect would be.

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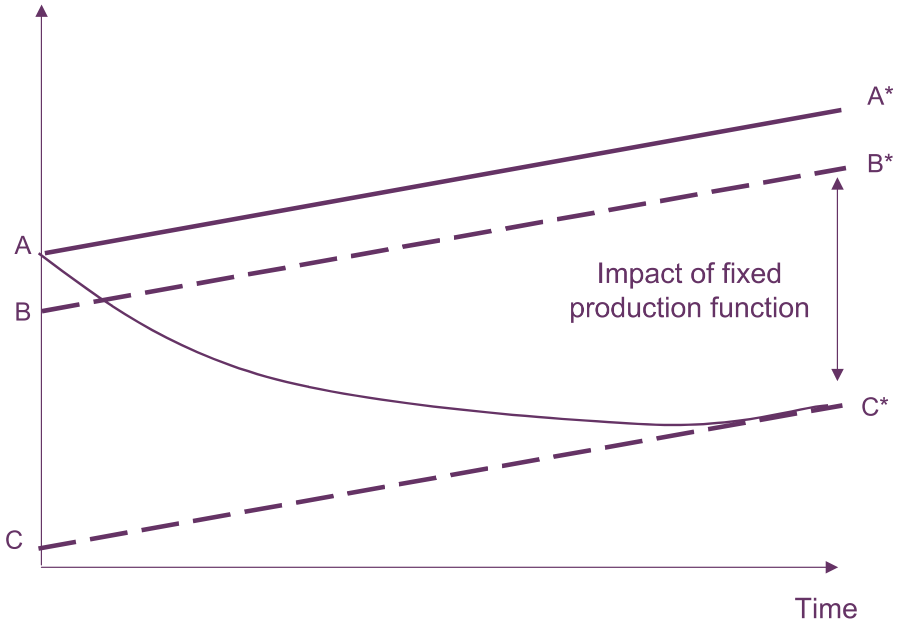
[1] This may, for example, be the application of a long-run policy cost estimate from a Markal scenario.

Figure 2 Impact of fixed production technology



Source: Oxera.

Modelling results

Attention has been focused on the **30% increase in UK end-user energy prices**. This case is equivalent to a policy change which increases the costs of energy production, and where this cost increase is fully passed through (the cost increase is 'lost' to the economy rather than being recycled, as would be the case with a carbon tax, for example).

Two measures of impact are analysed:

- **changes in GDP**, a widely used, though flawed, measure of economic welfare; and
- the **real exchange rate**, which is a measure of the impact of the shock to competitiveness.

Two cases are considered: one where the increase applies to the UK only, and one where the increase is worldwide.[2] This enabled a comparison of the relative competitiveness effect of unilateral action regarding certain energy policy objectives, such as climate change.

Over the period to 2020 as a whole the two models presented rather different stories. The adverse impact of the price shock is much more severe in the OEF runs than in the Global Insight runs. Taking the UK-only case: in the OEF runs, after ten years GDP is down by 2% and the real exchange rate has worsened by 2.5%; the equivalent Global Insight figures are 0.6% and 0.5%. In the Global Insight model there is some tendency for the economy to recover from the initial shock; in the OEF model the impact tends to lead to a lasting downward trend in economic activity. This difference is indicative of the more influential role played by supply-side forces in determining the long-run equilibrium in the OEF model.

Furthermore, the two separate exercises predict very different impacts on energy use (and therefore carbon emissions). An apparently similar price shock sets in chain two very different paths of adjustment. In the OEF model, substantial structural change—with demand switching from energy-intensive to less energy-intensive industries—has, after ten years,

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[2] There is also an intermediate case where the increase applies to the EU as a whole.

reduced energy intensity by 18%—a massive reduction in energy use. The Global Insight model exhibits no such change: energy intensity falls by 2% initially and remains at roughly this level, with some slight tendency for intensity to rise towards the baseline projection over time.

Modelling choices

The two models operate in different ways, as detailed below.

- In the OEF model, a separate CGE industry model determines the sectoral composition of both output and energy demand. The consequent impact on potential output is then imposed as a constraint on the macroeconometric model. Global Insight uses a macroeconometric model with a basic energy sector specification to run the scenarios. In this model, changes are primarily from the demand side, whereas the energy sector—and indeed the whole of the supply side—is more fully specified in the OEF model.

- As indicated, a particular difference is that the OEF model demonstrates much greater propensity for changes in competitiveness to induce sectoral shifts. Previous studies of the impact of world oil price rises have demonstrated that there are likely to be significant structural adjustments to changes in energy prices, but that such adjustments are likely to be identified only in models with a substantial degree of disaggregation. It is perhaps no surprise, therefore, that this difference arises between the model results. Nevertheless, the energy-intensity shift identified by OEF is remarkably large.

- Another indicator of the differences between the two approaches can be obtained by comparing the ‘UK-only’ and ‘world’ cases. In the Global Insight model, which is largely driven from the demand side, the fall in demand, and therefore GDP, is worse in the world case than in the UK case. In the OEF model, where the impact on competitiveness plays a greater role, the results are better in the world case than in the UK-only case since competitiveness is not affected to the same extent.

Given the DTI’s interest in the energy sector and in industrial carbon emissions, the model with the most detailed representation of the energy sector (ie, the OEF model) has an initial advantage. However, there are other models, not used in this exercise, that have a detailed representation of the energy sector, notably the Cambridge Econometrics model.

Conclusions

In summary, the following points can be made regarding the available modelling options.

- Markal may be appropriate to determine the long-run equilibrium, but does not capture the short-run dynamics in the economy.

- The OEF and Global Insight models can represent the dynamics of macroeconomic adjustment to shocks, but with limitations:

  - the Global Insight model has no long-run supply-side effect and all adjustment appears to be in nominal variables;
  - the OEF model acknowledges the supply-side constraint but may produce a long-run equilibrium below that potentially achievable if endogenous technological change is allowed for.

From a modelling perspective, the possible next steps would appear to be to:

- introduce endogenous technological change into the OEF model;

- find an alternative model that has endogenous technological change embedded in its structure;
- construct a hybrid transitional path using a combination of modelling results.

The feasible options may be limited by time and cost. It is proposed that:

- the DTI discusses with OEF the feasibility of introducing some technological change function within the model;
- consider in more detail the nature of the endogeneity that is present in the Cambridge Econometrics approach. However, this model will still have transitional costs and they may be substantive if the factor market behaviour is inflexible or adjusts with a relatively long lag. The model will still be sensitive to challenge on the assumptions regarding when technological changes occur and the speed of learning or technology adoption;
- a short-run solution is considered by linking the OEF and Markal models, with exogenous assumptions on where along the OEF GDP path technological change may begin and how quickly it manages the shift to the Markal solution.

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1 Introduction

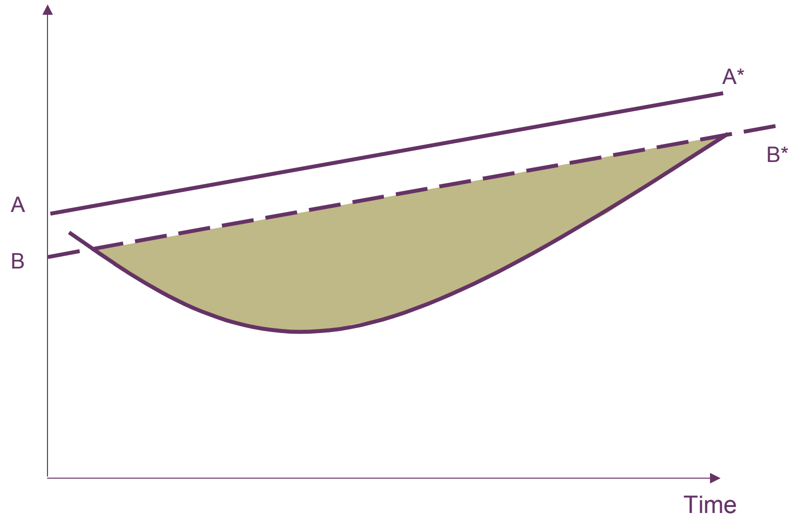
The purpose of this report is to assist the Department of Trade and Industry (DTI) in making decisions on the use of macroeconomic models for assessing the costs associated with proposed energy policy measures. Most studies on the cost of energy (or climate) policies focus on the long-run impact associated with a reduction in potential GDP as a consequence of increased resource costs. However, the transitional path to the new equilibrium position may be lengthy and may create additional costs as factor markets adjust to the new relative prices (or constraints on their behaviour). These additional costs arise due to imperfect short-run mobility in factor markets resulting in GDP falling below its new long-run potential. Since these costs are transitory, in the long run the new equilibrium will establish itself as production processes and households adjust to the changing relative prices.

This is illustrated in Figure 1.1. The line AA* shows the path of GDP over time prior to the change in policy, whereas BB* shows the implied long-run GDP path including the impact of the policy. The difference between these two lines represents the long-term effect of the new policy.

The extent of this gap, or long-term cost,[3] depends on the technological options open to energy producers and consumers and how these choice sets change over time in response to an increase in the price of energy relative to other factors of production. In the long run, it will depend on the ability to alter the underlying production or consumption function to use energy more efficiently.

However, in the short run, the production and consumption functions (technologies) are fixed and the GDP impact is bounded by the degree of factor substitutability assumed within them. As a consequence, the observed path of GDP may deviate from the long-run trend. For example, in Figure 1.1, the actual path falls below BB* initially, then recovers. The shaded area below BB* thus represents transitional costs.[4]

Figure 1.1 Illustration of transitional costs



Source: Oxera.

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[3] The policy may result in a long-term benefit if it serves to remove inefficiencies present in the current market.

[4] It is only the costs above those associated with the implied long-term potential that are relevant. A linear trend towards the new equilibrium would not include any transitional costs.

The magnitude of these transitional costs depends on two underlying factors:

- how far below the new long-run equilibrium the economy must fall before markets begin to adjust;
- how long the economy takes to reach its long-run potential.

For this reason, relatively simple energy price shocks have been used in the analysis to make the transmission of energy price changes through the economy more transparent and comparable. These shocks are not intended to reflect any actual policy responses, but, since the majority of policy instruments will work directly or indirectly through energy prices, there is an obvious link.

Several existing models have already been used, or are being considered for use, in simulating the broader macroeconomic impact of changes to energy policy. These include the models of:

- Oxford Economic Forecasting (OEF);
- Global Insight;
- Cambridge Econometrics (CE);
- the University of Strathclyde.

This report reviews studies of the wider economic burden of energy price shocks commissioned from two of these: OEF and Global Insight.[5] In addition, it draws on the academic literature that has developed to explain the differences in macroeconomic costs of energy and climate change policies predicted by various models. Whereas much of the early analysis in this area was in relation to the effect of oil price shocks, the last decade or more has switched attention to the cost of carbon abatement policies, mainly for the USA, but also for the UK.

Two well-known reviews have examined the reasons for the differences among models:

- the 1997 review by Repetto and Austin;[6] and
- the 1999 review by the US-based Energy Modelling Forum.[7]

More recently two articles—by Fischer & Morgenstern (2006)[8] and Barker, Koehler & Villena (2002)[9]—attempt further meta-analysis, again using statistical techniques to compare a range of results. A much earlier comparative exercise for the UK government was undertaken by Boero, Clarke and Winters.[10] Experience shows that there are many reasons why the results of such studies differ, and a brief review of these reasons is helpful as an introduction to the detailed modelling results.

This report is structured as follows:

- section 2 outlines the approaches to macroeconomic modelling and their relative merits, together with a brief review of the main reasons why results may differ;

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[5] This does not reflect any particular bias towards these models but was dictated by budget restrictions and availability of the model teams during the period. Both Strathclyde and CE were involved in other studies for Defra at this time and Oxera has had access to the reports and presentations associated with these. However, the majority of the analysis and discussion is based around the modelling results of the two commissioned studies.

[6] Repetto, R. and Austin, D. (1997), 'The Costs of Climate Protection: A Guide for the Perplexed', World Resources Institute.

[7] Weyant, J. P. (ed) (1999), 'The Costs of the Kyoto Protocol: A Multi-Model Evaluation', *The Energy Journal*.

[8] Fischer, C. and Morgenstern, R.D. (2006), 'Carbon Abatement Costs: Why the Wide Range of Estimates?', *The Energy Journal.*

[9] Barker, T., Koehler, J. and Villena, M. (2002), 'The Costs of Greenhouse Gas Abatement: A Meta-analysis of Post-SRES Mitigation Scenarios', *Environmental Economics and Policy Studies*.

[10] Boero, G., Clarke, R. and Winters, A.L. (1991), 'The Macroeconomic Consequences of Controlling Greenhouse Gases: A Survey', Department of the Environment, HMSO.

- section 3 provides a further qualitative assessment of the main drivers of differences in models results, highlighting the short- and long-run aspects of the policy question;
- section 4 presents an overview of the model runs and the key characteristics of the two models used in the study;
- section 5 sets out the main results from the OEF and Global Insight simulations;
- section 6 draws some initial conclusions.

2 Modelling options

The main objective of the modelling exercise is to assess the impact on macroeconomic variables of the introduction of new policy instruments for achieving the UK's energy policy goals. To make an informed choice about the ability of available models to deliver this service, it is important to be clear about:

- the measure of effectiveness or impact that is to be used;
- the relative strengths and weaknesses of different modelling approaches for replicating the types of policy (and transmission of the policy) in their framework;
- the importance of different model characteristics to the sensitivity of the results.

While no definitive discussion of all these issues is undertaken in this study, the main points are examined briefly below.

2.1 Measurement of the effectiveness or impact of policy

The study concentrates on transitional macroeconomic effects—the immediate impacts after the economy is 'shocked' by a change in energy policy. Over time, an economy will adjust to changes in relative prices, by changes in both demand and supply, but only some of these adjustments are included in the models studied. As Boero et al. state:

> There are two main types of transitional costs: the costs of re-equipping with different technologies (including human capital) and the cost of macroeconomic disruption.[11]

One issue is the time path of any process of transition. It is tempting to see the transitional impacts as short-term effects, but this is an issue for examination within the model simulations.

There are two stages in the adjustment process: first, there is factor substitution as the different sectors and consumers respond to the relative price shift. This response is defined by the existing production function in the economy. Second, there is innovation or technological progress driven by the relative price shift.

There may be a trade-off between the two aspects—a short, sharp shock may encourage a quicker response and hence a shorter period of time below equilibrium. Nevertheless, the speed of technology adoption will affect the transitional costs, as shown in Figure 2.1 below. If production and consumption patterns adjust more slowly than anticipated in a deterministic, perfect foresight model, the transitional costs will be higher (in Figure 2.1, this incremental cost is represented by the shaded area in red).

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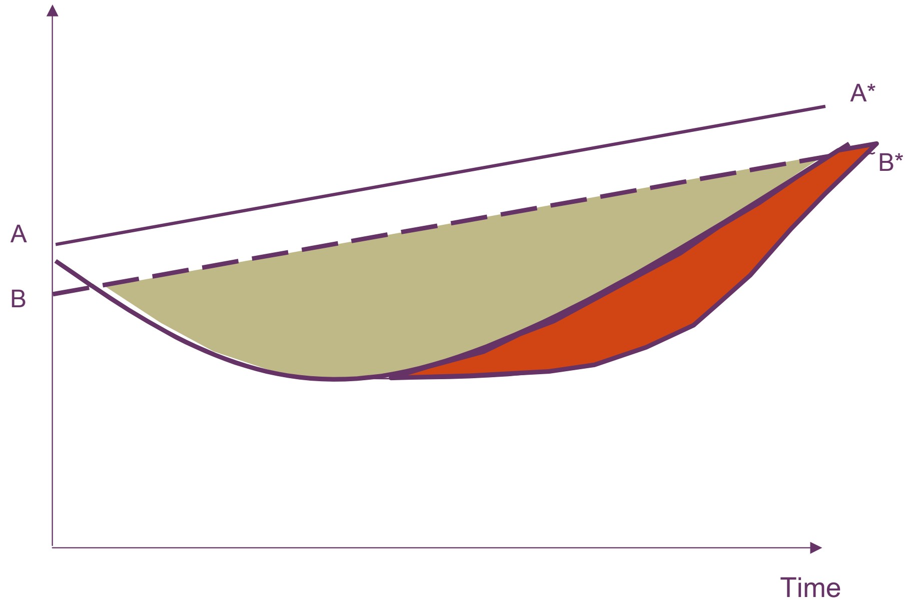
[11] Boero, Clarke and Winters (1991), op.cit.

Figure 2.1 Uncertainty over speed of technological change



Source: Oxera.

In the literature, the impact of energy policy is most often measured in terms of its impact on GDP. Although it is noted that GDP is not a direct welfare measure, and that other measures of welfare, such as compensating variation,[12] would be a more appropriate monetary metric, such welfare measures are not readily estimable in the models reviewed for this study (or, in fact, most macro models that investigate the impact of energy policy). As a consequence, the loss in GDP is used as a measure of welfare, noting that it is an imperfect measure of such changes.

The DTI is also interested in assessing the likely transitional impact of energy policies on competitiveness. It is likely that most of the energy policy packages that the DTI may be interested in modelling would be UK-specific. To the extent that the policies unilaterally increase the price of energy, the UK's international 'competitiveness' could be affected. Competitiveness can be studied at several levels:

– **intra-industry**, where some industries gain and others lose within a sector, although there is no overall adverse impact on performance (ie, it is solely a distributional issue);

– **sectoral**, where whole sectors (eg, traded goods, services, public sector, etc) gain or lose. For example, the public sector may have gained from the recycling methodology applied under the Climate Change Levy at the expense of some energy-intensive industries, or the traded goods sector may lose, but this is compensated for by a switch of resources to the non-traded goods sector. Crucially, it is not necessarily the case that overall competitiveness of the economy falls;

– **national**—ie, aggregate productivity in the economy falls, affecting all sectors.

Most macroeconomic models will adequately reflect the national competitiveness effects and, via their equations representing international trade links, will provide some insight into the sectoral effects. In discussion with the modelling groups and drawing on past academic and policy analysis, two measures of competitiveness have been investigated:

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[12] Compensating variation represents the amount of compensation to the economy/society in monetary terms that would be required in order to make the economy/society as well off after an exogenous shock as it was before the shock.

- the real effective exchange rate (an index of a currency's value relative to a basket of other currencies, weighted by the volume of trade between the country and its trading partners);
- labour productivity (GDP per worker).

There are, nevertheless, other competitiveness measures that are important but that may not be adequately captured in the current modelling approaches. Specifically, long-run mitigation of adverse costs depends on the ability of the economy to react to the new relative factor costs through technological change, research and development, process shifts and education and training. To the extent that these avenues for improving competitiveness are not modelled, additional work off-model may be required to determine the relationship between technological change, research and retraining.[13]

Finally, detailed industry impacts are not normally modelled in this setting, as the macroeconomic interactions are modelled at a level of abstraction from these intra-industry effects. Such effects will normally have to be analysed off-model (usually through the application of a more detailed, country-specific, industry-level model), with consistency checking between the two sets of results.

2.2 Types of model: bottom-up and top-down

It is well known that the different ‘philosophies’ towards modelling are likely to lead the results in specific directions. The broad options are:

- **‘bottom-up’ models**, based on detailed assumptions about the technological possibilities;
- **‘top-down’ models**, which take a much more aggregated approach to the problem.

As Barker et al. (2002) note:

> Top-down studies have tended to suggest that mitigation policies have economic costs because markets are assumed to operate efficiently and any policy that impairs this efficiency will be costly. Bottom-up studies tend to suggest that mitigation can yield financial and economic benefits, depending of the adoption of best-available technologies and the development of new technologies.

Within top-down models, Barker et al. (2002) distinguish between:

- **resource allocation models**—ie, computable general equilibrium (CGE) models;
- **time-series macroeconometric models**.

The former tend to assume that the economy is in equilibrium in the baseline scenario, while the latter do not. Similarly, in CGE models, the economy trends back to equilibrium, whereas in the past there has been no such automatic tendency in pure macroeconomic models, although hybrid variants are now used. Indeed, this basic distinction by no means exhausts the categories of models—for example, models may be partial rather than general equilibrium. A third approach is termed by Boero et al. as ‘growth modelling’.[14] Such models are rooted in economic theory and concentrate on the long-term properties of the economy as consumers and firms maximise the discounted value of consumption over several periods. Such models have a role to play in understanding the inter-temporal choices, but they do not play a part in this study.

Table 2.1 summaries the merits and limitations of the basic modelling techniques.

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[13] The treatment of technological change is discussed further in section 4.2.3.

[14] Boero, Clarke and Winters (1991), op.cit.

Table 2.1 Merits and limitations of the basic modelling techniques

Approach	Merits	Limitations
General equilibrium models	Full set of interconnections Role of prices in managing scarcity Efficient resource allocation Measure of consumer welfare	Adjustment paths and dislocation impacts may be poorly specified Non-optimising behaviour ignored Considerable data demands Simple specification
Macroeconometric models	Based on estimated relationships Provide standard economic indicators Allow gradual adjustments and estimate dislocation costs	GDP is a flawed measure of welfare Emphasis on short-run reactions means that models are not robust over medium and long term Large data requirements
Growth models	Dynamic analysis of long-run impacts Consistent intertemporal decisions	Uncertainties over predicting trends far into the future Limited capability to model determinants of technical progress Assumption of near-perfect foresight

Source: Adapted from Table S1 in Boero et al. (1991).

Recent meta studies—that is studies which rely not on original research, but on bringing together and comparing the results of a variety of independent studies—have shown that macroeconometric models tend to estimate higher abatement costs than CGE models (see, for example, Barker, Koehler and Villena [15]). The relative lack of emphasis in macroeconometric models on the long-run equilibrating role of relative prices and wages and their emphasis on short-term dynamics are likely to be seen as a failure in assessing a policy that is established over a very long time horizon, such as climate change policy. The fact that such models tend to be poor at identifying dynamic changes that are likely to be brought into play as a result of low-carbon intervention—most obviously, the new industries and technological advances that derive directly from the programme—is a further flaw.(One model that does attempt to incorporate such dynamic changes is the Cambridge Econometrics model.)

That said, as Boero et al. note, the difficulty of using macro models for long-term exercises:

> in no way detracts from their use over shorter time horizons to map the short and medium term effects of abatement polices … during which fundamental structural and relative price change was limited.

The analysis that follows concentrates on results for macro models, since the two firms of consultants whose work is examined use such models. Other modelling approaches, notably the Markal model, can be used to assess longer-term costs and benefits.[16]

2.3 Why do model results differ?

Reviews of several meta studies of modelling exercises to assess energy policy choices—in particular, those more recent ones looking at the macroeconomic impacts of carbon mitigation strategies—have highlighted factors that may contribute to the range of results observed. These can be summarised as follows.

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[15] Boero, Clarke and Winters (1991), op.cit.

[16] Information on the current Markal modelling has not been reviewed as part of this study.

1) **Structural characteristics of models**, including sectoral and technological detail, the representation of substitution possibilities, international links, and optimisation techniques.

2) Base-case assumptions on the **representation of policy instruments** within the model—for example, the manner in which government revenues are recycled.

3) The strength of **macroeconomic interactions**—the way in which the data set is used to calibrate the key macroeconomic relationships may result in similar model structures reporting different results for no reason other than the models are calibrated using different datasets.

In general, all three of these factors will be present to some extent. However, in this initial study, the focus is on the first and third factors, because no formal representation of actual energy policies is incorporated into the analysis.

The following are the principal considerations of differences in the structural characteristics of models.

- **International coverage**—domestic energy policy cannot be considered in isolation from the rest of the world, with important links being projections of world energy prices, trade structures and elasticities. This makes it imperative to distinguish results that cover independent action by one country from those that assume action throughout the world.

- **Technological assumptions**—since the analysis revolves around shocks to a major factor of production, modelled assumptions about possibilities for substitution between energy and other factors of production, together with assumptions about underlying technical change, will influence the extent to which an economy can mitigate adverse energy price shocks.

- **Level of disaggregation**—in general, models with greater disaggregation display lower costs, since there are more possibilities for factor and product market substitution.

- **Treatment of the energy sector**—where the energy sector is modelled in detail, there would be a presumption that 'the more different fuels that are distinguished in a model, the more potential for substitution and hence the lower the costs of mitigation' (Barker et al. 2002).[17]

- **International trade**—the assumption of perfectly mobile capital tends to be associated with higher marginal costs since, as a result, individual countries suffer a deterioration in their terms of trade, adverse investment flows, etc. However, an assumption that imports are imperfect substitutes for domestic production reduces costs, since there is less scope for balancing movements in international trade.

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[17] However, for reasons that are not clear, Fischer & Morgenstern (2006) found that greater disaggregation of the energy sector was associated with higher cost estimates.

3 Theoretical expectations

The initial analysis undertaken for this study has deliberately focused on very basic shocks to energy prices in order to expose any differences in the transmission mechanisms by which price shocks feed through into economic performance.

For the purposes of policy impact assessment, both the long-run impact and the transitional effects arising from short-run adjustment costs are important, and it is possible for differences to arise in both aspects. As such, this section aims to draw out some of the main drivers and constraints that may influence the macroeconomic effects observed in the economy and that may be subject to different representations across macroeconomic models.

3.1 Long-run effect

The long-run effect of an energy price shock is determined by the long-run elasticity of GDP with respect to energy prices. Since energy is one of the main factors of production (along with capital, labour and intermediate inputs), a rise in the cost of energy is likely to reduce potential GDP as the economy is able to produce a lower level of output using its existing endowment of resources.

For example, suppose that 5% of GDP is spent on fuel, and that there is a one-off, permanent, 30% increase in fuel costs. If this increase in fuel costs is uncompensated (ie, the cost increase causes an equivalent loss of UK income), this results in a one-off, permanent *reduction* in GDP of 1.5% (ie, 0.05 x 0.3 x 100). The reasoning is that, in order to maintain a given flow of energy services, resources previously used elsewhere have to be diverted to energy services.[18]

This long-run effect may be mitigated to the extent that there is scope for the following.

– **Inter-fuel substitution**—if the shock is not symmetric across all fuels, the ability for the economy to engage in fuel switching can reduce the effective impact of the real shock. For example, an oil price shock can be expected, in the current environment, to have a limited impact on the oil/gas price relativity, but will affect the oil (or gas)/coal relativity more substantially. Any ability to switch to cheaper fuel sources would alleviate some of the impacts of a shock.

– **Technological change**—both producers and consumers can be expected to respond to permanent price shocks[19] by adjusting behaviour. This does not just entail re-optimising among existing technologies, but should lead to dynamic incentives for innovation. Therefore, specifying technological change allows the production function to alter over time (for sectors and the economy as a whole), thereby changing the extent of available factor substitution (ie, reducing the share of energy in total income).

– **Specific policy reactions**—these may be broad monetary or fiscal responses that will reduce the negative demand impact of the original shock, or they may reflect recycling of revenues (ie, there is some compensation for the initial shock). The assumption about the net impact of the cost increase on UK demand is of central importance. If the price

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[18] This exposition is drawn from Saunders, H.D. (2000), 'A View from the Macro Side: Rebound, Backfire and Khazzoom-Brookes', *Energy Policy,* 2000. This article deals with the case where policy induces an improvement in energy productivity, but in principle the logic should also be applicable to the case where energy costs are increased.

[19] There may be little or no response if a shock is considered to be temporary.

shock is effected through, for example, a tax, the extra income can be recycled and the net impact on the economy is much reduced.[20]

However, the initial impact of the shock may be exacerbated if there are additional multiplier effects associated with the first-order demand reduction. Moreover, there may be additional second-round impacts on investment and on net exports.[21]

Furthermore, the new long-run position will imply a redistribution of resources between sectors, reflecting their relative energy intensities and factor substitution possibilities. This will tend to result in an increase in the output share from less energy-intensive industries that, typically, have lower average productivity

3.2 Short-run adjustment

Realisation of this new long-run position may entail additional macroeconomic costs to the economy as nominal adjustments occur to prices, wages, exchange rates and interest rates in order to effect the changes in the factor markets (through quantity adjustments, price adjustments, or a combination of the two). These nominal adjustments will have further impacts on aggregate demand and factor utilisation that may exacerbate the adverse effects on the economy.

The initial impact of an energy price shock is to raise the costs of production and primary energy consumption by households, thereby increasing both producer and consumer prices. The price increase itself feeds through several paths into the wider economy. On the demand side:

- real disposable income falls, thereby lowering consumption;
- investment falls due to lower economic activity;
- export prices rise and hence export demand declines.

These aggregate demand effects have knock-on impacts on both government policy and the factor markets.

In most macroeconomic models, there are certain government reaction functions applied to monetary and/or fiscal policy that act to ensure that the economy does not deviate too far from output and inflation targets. Monetary policy is often assumed to follow the Taylor rule.[22] In the current example, inflation rises and therefore nominal interest rates rise,[23] exacerbating the effect on aggregate demand and the costs of production (higher cost of capital goods) in the short run.

The factor market response to the shift in aggregate demand can be through both prices and quantities:

- in the labour market, lower output leads to higher unemployment, which, in turn, leads to a reduction in real wage pressure and subsequent recovery in employment. The extent to which employment recovers depends on the nature of the long-run labour supply

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[20] From a policy perspective, a domestic carbon tax or auctioned carbon rights would allow possibilities for recycling. Grandfathered carbon rights already assume recycling. Recycling will not be possible in cases where there is a worldwide increase in energy prices (except to the extent that the UK is itself an energy producer), or in cases where regulation has raised the resource costs of production (eg, by requiring the use of more expensive carbon-free technologies).

[21] Using a plausible set of coefficients, Saunders (2000) derives a slight increase in the longer-term effect, so that the above elasticity would be increased to –0.057.

[22] The Taylor rule describes the policy reaction function of the monetary policy-maker. The rule stipulates that the policy-maker changes the interest rate in response to real divergences of real GDP from the natural rate of GDP, and divergences of actual rates of inflation from the target rate of inflation.

[23] Two factors are noteworthy here: the fall in output may initially still be above the long-run equilibrium level and hence necessitate an increase in interest rates; and the relative weight on the inflation and output gap drivers, together with the extent of the output and inflation differentials over time, will determine the direction of movement in the interest rate.

curve. If this is assumed to be completely inelastic (ie, there is a fixed natural rate of unemployment) then labour will again be fully employed in the long run, albeit at a lower real wage, reflecting the lower productive potential of the economy. If the long-run labour supply curve is upward-sloping, an aggregate demand shock may have a more substantive long-run impact on employment levels;[24] and

- in the capital market, capital flows react to the relative differences in UK and global interest rates, moving to where capital can achieve the greatest return. In general, it is assumed that there is high capital mobility and the equilibrium price is likely to be set at a global level.

The scale of transitional costs depends on the speed with which nominal adjustments occur, their impact on aggregate demand, the flexibility of factors of production and their sensitivity to price changes. These factors influence the extent to which resources may be underutilised because of some stickiness or lack of factor mobility. One of the main mitigating factors of energy price shocks is the ability to switch from using that factor to others, or to switch to other fuel types (if the shock is fuel-specific).

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[24] Models without a long-run natural rate of unemployment also have the potential to exhibit positive employment effects from recycling of revenues through labour market routes.

4 Overview of OEF and Global Insight models

4.1 Energy price shock scenarios

The DTI has commissioned two macro modellers—OEF and Global Insight[25]—to implement a series of basic energy cost shocks and describe the rationale for observed patterns between scenarios in terms of key macroeconomic indicators.

Detailed descriptions of the two models can be found in the reports of the two companies. Very brief descriptions are as follows:

- The OEF model is an industry/energy model (MIEM), which is consistent with but distinct from OEF's suite of other macroeconomic models. The model provides a detailed framework for assessing the trade-off between energy changes and economic growth, sector by sector (30 industrial sectors are included, defined according to SIC classification). In the long run, all variables in the model converge on their long-run equilibrium levels, determined by theory. The OEF model is, therefore, in essence a GE model.
- The Global Insight Economic and Energy Modeling System combines two models—a macroeconomic model which defines the economic environment in which energy markets are operating and a separate Energy Model which determines the retail prices, demands, and supplies of the major energy sources. Outputs from the Energy Model can be fed back into the macroeconomic model. The Global Insight approach to modelling is, therefore, macroeconomic.

The modelling runs are not based on a specific energy policy package, but were designed to provide comparable data that would allow Oxera to draw out the key differences between the models and explain any potential observed differences in the patterns of response to shocks.

Table 4.1 indicates the runs undertaken by the modellers. The scenarios were designed to enable the effect of international links in each of the models to be analysed (through the comparison of UK-only shocks with EU and global shocks), with specific fuel price shocks included in case they shed any light on the treatment of inter-fuel substitutability within the models.

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[25] OEF (2006), 'DTI Energy Price Scenarios in the Oxford Models', May. Global Insight (2006), 'The impact of energy price shocks on the UK Economy, A report to the Department of Trade and Industry', May.

Table 4.1 Overview of modelling runs

	OEF			Global Insight		
Shock	**UK**	**EU**	**Global**	**UK**	**EU**	**Global**
End user energy price—30%	✓	✓	✓	✓	✓	✓
Oil price—10%			✓			
Oil price—30%			✓			✓
Gas price—10%			✓			
Gas price—30%			✓	✓		
Carbon price—increase in €15 per tonne of carbon		✓				
Reduction in UK carbon emissions by 60% relative to 1990 levels by 2050	✓					

Note: All shocks were specified as permanent shocks. Global Insight also provided a temporary 30% gas price shock.
Source: OEF and Global Insight.

OEF's model runs provide results for the period up to 2020 and Global Insight's model covers the period up to 2025. Upon the request of the DTI, all shocks were specified in 2010, providing ten years of overlapping data to compare the transitional impacts of the shocks in the models.

The shocks were specified as permanent in nature. The time horizon over which the results are provided means that the models have not yet settled fully into a new equilibrium. For example, in the OEF model, which runs up to 2020, the labour market converges to a fixed natural rate of employment. According to OEF (2006), a full equilibrium would be reached after around a further ten years. However, one of the main areas of interest for the DTI is to establish whether there are significant transitional adjustment costs from shocks. Therefore, a ten-year horizon would appear to be long enough to observe whether such transitional costs are likely to be significant in practice.

4.1.1 Scenarios analysed in detail

The full results of the OEF and Global Insight runs are provided in their companion reports to the DTI. Having reviewed the analysis and results therein, Oxera has chosen to focus on two of the comparable scenarios:

- a UK 30% end-user energy price shock;
- a global 30% end-user energy price shock.

The end-user price shock of 30% is used to investigate the general differences in patterns between the OEF and the Global Insight models. Most of the energy policy packages that the DTI is likely to want to model will be UK-specific. This shock is therefore most relevant to the DTI's assessment, as any potential costs are likely to have a unilateral impact on the UK economy. In addition, a comparison of the UK and global end-user price shocks is used to investigate any potential differences within and across models.

The exploration of these differences is limited to a graphical representation of the percentage difference between the shock scenario and the corresponding baseline of the modelling run at any given point in time (or, where more appropriate, the percentage *point* difference between the shock and the baseline scenario). This comparison appropriately reflects the sensitivity of each model's baseline projection to a shock.[26] The report does not analyse the

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[26] Other comparisons, such as those based on levels, are not appropriate since some of the series baseline scenarios differ significantly between models.

quantitative differences in outcomes between scenarios, such as a comparison of the loss in GDP over a specified time period.

As is discussed in section 5, the comparisons show substantial differences in the impact of the shock across a range of macroeconomic indicators.

4.2 Review of model characteristics

Oxera conducted interviews with the modellers in order to understand the dynamics of adjustment to the shocks and to ascertain some of the key characteristics of the models that previous studies have suggested may be important as explanatory factors in differential modelling results. The main results of this analysis are presented below. In summary, they suggest that:

- both models may overestimate the long-run impact of the policy due to the lack of any technological change induced by the relative price shifts;
- the OEF model would have a higher impact on GDP in the long run, largely due to the high long-run energy demand elasticity (0.6) against which the model is constrained to operate;
- oil and gas price shocks will lead to a high degree of fuel substitution in the OEF model, although how this is effected is not clear;
- competitiveness effects are stronger in the OEF model than in the Global Insight model, and thus the long-run effects of unilateral action will have correspondingly higher costs in the OEF model.

4.2.1 Model type

Both models are of the same broad type and both have separate industry sub-models. However, from discussions with the modellers, there is a fundamental difference in the interaction between the detailed industry and global macroeconomic models.

In the OEF model, UK energy use and potential output is determined in the Energy Industry Model (EIM), which is imposed on the macroeconometric model to derive short-run effects. In the Global Insight model, the role of the industry sub-models is more passive, energy use from the macroeconometric analysis being fed into the industry model where it is distributed among the sectors. This implies that this model does not capture some of the sector-specific effects of the energy price shocks. Thus, some of the short-run dislocation in markets may be less severe, although the dynamic long-run substitutability between sectors that is present in the OEF model may be expected to mitigate the initial transitional costs.

For this analysis, the differences in baseline data are not considered material. Table 4.2 summarises the main model characteristics.

Table 4.2 Main model characteristics

	OEF	Global Insight
Source for baseline data	GVA by sector from Treasury/DTI projections. Fuel use (by type) and carbon emissions projections imposed from DTI projections	Global Insight's country forecasts
Type of model/ modelling approach	Combination of models. A largely calibrated CGE model for industrial sub-sectors (EMI) is used to derive long-term potential output. This output is then imposed on a macroeconometric model for the whole economy (Global Macro Model, GMM) to derive the short- and medium-run dynamic effects	Global macroeconometric model.
Normal timeframe of study	2010–20, except for backwards-engineering scenario	2010–25
Number of countries/regions	More than 40 countries	15 countries and 7 regions
Number of industrial sectors	30 sectors	n/a
Treatment of energy sector	Energy production and energy demand by fuel type	Each country sub-model has a simple energy sector
Types of fuel	Oil, gas and coal	Oil, gas and coal

Source: OEF and Global Insight.

4.2.2 Factor substitution

As mentioned above, one of the main mitigating factors of energy price shocks is the ability to substitute between factors of production and between fuel types . Interestingly, the OEF model assumes relatively high inter-fuel elasticities for both oil and gas (a rise of 10% in the price of oil lowers its share of total fuel consumption by 0.8%). This would be likely to mitigate the effect of a shock to oil, as there would be a high degree of substitution away from oil to other fuels. The same holds for gas.

In addition, the estimated GDP/energy price elasticities show striking similarities in the short run, but vary substantially in the long run, with the GDP impact being substantially greater in the long run in the OEF model than in the Global Insight model. This may be indicative of two differences in the models.

- In the OEF macro model, the long-run macroeconomic position is constrained by the potential output position from the industry model, which is itself determined largely by the long-run energy price elasticity of 0.6. For a given production function, this energy demand elasticity thus defines the output loss. The macroeconomic model in the Global Insight simulations is not constrained in the same way, and therefore the long-run path of output is determined by the interaction of demand responses in the model.
- The relative competitiveness of the traded goods sector in the OEF model has a substantive impact in the long run, persisting as demand-side effects diminish. Conversely, the demand-side effects in the Global Insight model appear to dominate any supply-side competitiveness effects.

Table 4.3 sets out the factor substitutions and main elasticities in the models.

Table 4.3 Factor substitutions and elasticities

	OEF	Global Insight
Inter-fuel substitution elasticities	Some variation across sectors, but aggregate response is (change in fuel share in response to 10% increase in its price relative to other fuels), in percentage points, coal –0.1, oil –0.8, gas –0.9, electricity –0.3	n/a
Inter-factor substitution elasticities	Factor substitution elasticities vary by sector, according to the weights of each factor in the Cobb–Douglas constant returns to scale (CRS) production function for each sector	Inter-factor substitution elasticity of 1; the model uses Cobb–Douglas production function
Factor substitution elasticities between non-energy factors of production	Factor substitution elasticities vary by sector, according to the weights of each factor in the Cobb-Douglas CRS production function for each sector	Inter-factor substitution elasticity of 1; the model uses Cobb-Douglas production function
Primary energy demand elasticity GDP energy price elasticity	UK end-user price shock: short-run 0.03; after 10 years 0.07. Global end-user price shock: 0.04; after 10 years 0.04	UK end-user price shock: Short-run 0.03; after 10 years 0.02. Global end-user price shock: 0.03; after 10 years 0.02

Source: OEF and Global Insight.

4.2.3 Technological change

One of the main mitigating effects of long-run costs associated with policy interventions is the incentive to adopt different technologies provided by changes in relative factor costs. Neither model has an explicit treatment of technological change, both representing technological change through an exogenous total factor productivity term in the production function.

If the model fails to fully account for technological change, this may affect the ability of the model to estimate transitional costs as the model will be unable to achieve the potential output that would be possible with the new technologies and hence, relative to this long-run equilibrium, transitional costs will persist and the cost will be overestimated. This is illustrated in Figure 4.1 below where the actual GDP path trends to a different equilibrium (ie, CC* in Figure 3.1) and is always below the long-run equilibrium possible with technological change (ie, BB*).[27]

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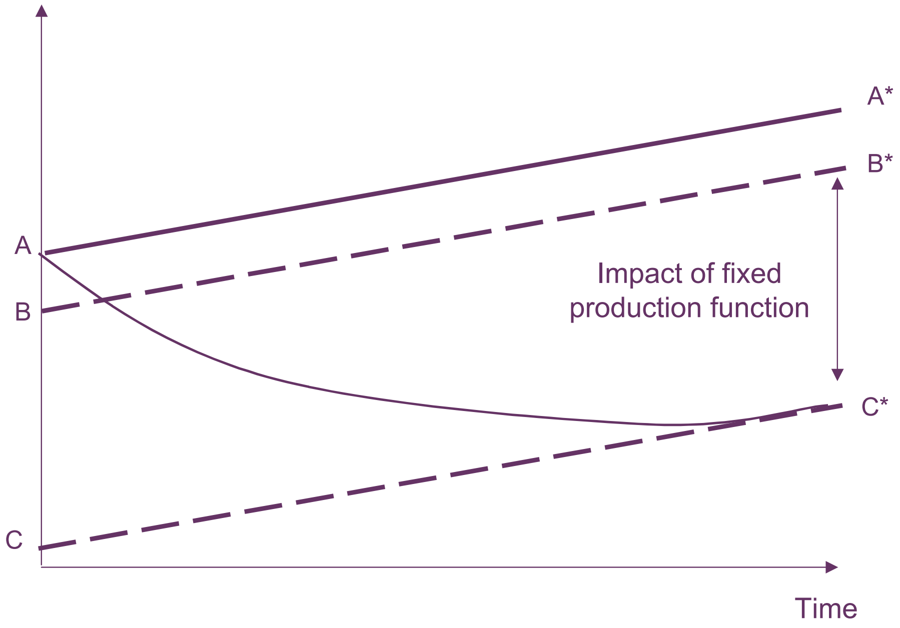
[27] Since the production functions are estimated using a relatively long time series of data, they may already capture some aspects of technological change. That is, the difference between BB* and CC* in Figure 3.1 may not be material. However, the path of the economy may be smoothed relative to the step changes in production process that tend to occur in practice.

Figure 4.1 Impact of fixed production technology



Source: Oxera.

This lack of endogenous technological change is a common limitation of this type of model. Some models, including the CE model, have attempted to include endogenous technological change linked to investment levels, but this has not been able to be reviewed during this study. It should be noted, however, that both models have the means of incorporating some additional technological change associated with specific policies (although the adjustment to model variables that is appropriate would need to be estimated off-model).

To the extent that there is no technological change, the models may represent an upper bound on the transitional effects of policies, since technological change would lower the long-run output loss (and may even improve total output). However, the speed of technical progress might mean that the impact of such technological change would be slow to feed through, and hence the speed with which the types of long-run technology mixes that arise within, say, the Markal modelling process, may still imply a degree of persistence in the transitional costs.

Table 4.4 provides details of the treatment of productivity and technological change in the models.

Table 4.4 Technological change

	OEF	Global Insight
Productivity growth	Exogenous time trend in total factor productivity (Solow residual)	Exogenous time trend in total factor productivity (Solow residual)
General endogenous technological change	No: endogenous technical progress will only occur if the real price of capital change —and this is exogenous in the long run in the model	No
How would a technological shock be modelled?	Impose a different path for total factor productivity, either sector by sector, or across the whole economy	Impose a change in total factor productivity
Treatment of new energy technologies	No	No
Energy intensity	Energy intensity falls in the baseline forecast, and changes relative to that baseline in response to movements in the real price of energy	Changes exogenously over time

Source: OEF and Global Insight.

4.2.4 Factor markets

The fundamental driver of transitional costs (in importance relative to the long-run position) is the flexibility of the factors of production. Essentially, as discussed in the previous section, transitional costs represent periods of under-utilisation of resources as factor markets react to the changing relative prices and redistribute themselves within the economy (between traded and non-traded goods, and between energy-intensive and non-energy-intensive industries).

In both models, labour and capital are homogeneous factors. That is, there is no skill differentiation in the labour market and no capital specificity assumptions in the capital market. In both cases, this long-run perfect mobility of the factors may be applicable, especially in the case of capital goods, but it does prevent non-price policies—eg, reskilling of the labour force—from having significant effects without some exogenous adjustment to model parameters.

Furthermore, the OEF model has a fixed natural rate of unemployment in the long run (ie, a vertical long-run Phillips Curve), which means that price (the real wage) must adjust to ensure a long-run equilibrium. As a consequence, policies that involve recycling of revenues through labour market avenues (such as the NICs recycling within the Climate Change Levy) will not affect potential output in the long run. However, where the long-run supply curve is upward-sloping, there may be persistent beneficial effects on employment levels.

Interestingly, the descriptions of capital stock adjustment in the models, while predicting the same direction of adjustment, have different explanations for the reason why, although the similar structures within the models should imply some form of consistency. Taking the OEF model as an example, a rise in the price of energy lowers potential output of the economy (as estimated in the EIM). Therefore, if labour and capital remain fully employed, the output per unit of each factor falls. In the labour market, this requires real wages to fall to reflect the lower labour productivity, whereas, in the capital market, capital must leave the UK so that capital productivity increases until it once again matches the exogenously set global cost of capital.

Table 4.5 provides details of the factor markets in the models.

Table 4.5 Factor markets

	OEF	Global Insight
Type of labour market	Natural rate	Labour supply depends on participation rate, which in turn is a function of real wage rate and unemployment gap. Labour demand is derived from the marginality condition but responds with a lag to represent labour market stickiness
Description of wage and employment adjustment mechanism in short and long run	Demand for labour shifts in response to aggregate demand in the short term, but then wages adjust to bring employment back to the natural rate	In the short run, employment will respond to transitory changes in real wage and output, with a long-run movement towards a steady state where the real wage converges to equilibrium labour productivity
Elasticity of employment with respect to real wage	Zero in the long run, since both the long-run real wage and the long-run rate of employment are tied down (the value of the marginal product of labour, and the natural rate of employment respectively)	In the short run a 1% increase in real wage will cause employment to fall by 0.05% In the long run a 1% increase in real wage will cause employment to fall by 0.13%
Labour tax treatment	A reduction in NICs could offset the impact on labour demand coming from, say, higher wage settlements, although this is a short-term effect only. In the long run, all taxes on labour are paid by workers, so the firm's real wage will not change in the long term in response to a change in taxes on labour	Social insurance tax is derived in the model as social insurance tax rate (exogenous) times labour income. Hence, by lowering the tax rate, labour income can be adjusted to offset the negative impact from a decrease in real wage rate
Mobility of capital	The stock of capital in each sector will eventually adjust to equalise the real value of the marginal product of capital with the real cost of capital, where the real cost of capital is exogenous with respect to the UK in the long run	Under full employment, with a Cobb–Douglas function defining the input–output process in the model, a change in the relative price of capital caused by higher energy prices should increase the demand for capital, providing the economy with a higher level of capital stock. However, the economy in the model operates in a less-than-full employment world. The resource-reallocating adjustment necessitated by a change in relative input prices tends to be very slow due to frictions and adjustment costs. Hence the income effect of higher energy prices comes to dominate the capital stock adjustment process, overshadowing the price effect. The UK economy thus ends up with less capital stock in the energy price scenarios

Source: OEF and Global Insight.

4.2.5 International links

The adjustment to the new long-run equilibrium will have a disproportionate impact on energy-intensive industries—particularly those that are part of the traded goods sector. Table 4.6 provides details of international links in the models.

Table 4.6 International links

	OEF	Global Insight
Terms of trade elasticities	Long-run price elasticity of demand for UK imports: –0.61; for exports: –0.48 imposed from DTI projections	Import –0.5 (long-run), –0.7(short-run); export –0.5
Share of trade with other countries/regions	Varies by sector, but on average nearly 60% of UK exports go to western Europe, 16% to the USA, 2% each to Japan and Canada, 2% to China/HK, and the remainder to other countries	Model uses 2002 nominal trade shares (source: UN)
Exchange-rate regime	Floating exchange rate for all scenarios	Floating exchange rate in UK and EU scenarios; fixed exchange rate in global scenarios

Source: OEF and Global Insight.

4.2.6 Policy instruments

In both models, the government is not considered to be passive in response to macroeconomic changes. As inflation or potential output deviate from government targets, broad monetary or fiscal policy responses can be expected and these are incorporated into the models. Consequently, the macroeconomic impact observed in each scenario is already mitigated by stabilising activities of the Central Bank or Treasury.

Both models have monetary policy reaction functions specified according to a Taylor Rule . No weights for the OEF model have been provided, but the Global Insight model has equal weights on inflation and output gaps, whereas it is often expected that the weight on the inflation gap will be larger. To the extent that current government policy is inappropriately represented in this framework, transitional costs may be over- or underestimated as a result.

Interestingly, the OEF model does not have an explicit constraint on the fiscal parameters of the model. There is therefore a possibility of structural budget deficits emerging and not being rectified. Once again, a judgement would need to be taken as to whether this is a realistic view of the government’s fiscal policy position.

Finally, in relation to potential specific energy policy options, both models have means of allowing for revenue recycling and off-model assessments of the benefits associated with this. In addition, OEF already has a functioning carbon price in its model, which is something that is not present in the Global Insight model.

Table 4.7 sets out the policy instruments specified in the models.

Table 4.7 Policy instruments

	OEF	Global Insight
Fiscal policy reaction function	Contraction in GDP leads to lower tax revenues and increased government spending (automatic stabiliser effects). Fiscal policy is assumed to accommodate these effects	Tax reaction function: government revenues down, deficit up, debt up, deviation from trend debt/GDP ratio up, tax rate up
Monetary policy reaction function	Monetary policy follows a Taylor rule—interest rates rise if inflation is higher than target and/or GDP is higher than its long-run potential level	Taylor rule, with equal weights on growth gap and inflation gap
Energy policies	Taxes on producer prices or consumer prices of energy. Incentives to encourage energy-saving investment. EU ETS carbon prices	n/a
Presence of/scope for carbon taxes/trading	Yes	No

	OEF	**Global Insight**
Currently available/scope for revenue recycling	Yes. Revenues raised by higher energy taxes can be recycled in ways that have an impact in the long run on the real price of one or more factors of production (eg, capital), thereby partly or completely offsetting the long-run impact on productive potential. Alternatively, they can be recycled in ways that have no impact on the real price of those factors in the long run (eg, via lump-sum redistribution to firms or consumers, or by reduction in NICs). Then the long-run impact on GDP is unchanged	Government transfer payments to households are inflation-indexed, so a revenue decision causing a change in inflation will have a direct impact on transfer payments to persons. Also, a policy decision affecting government balance will cause a tax response (tax reaction function), which will result in the transfer of a part of tax revenues to the private sector

Source: OEF and Global Insight.

5 Comparisons of OEF and Global Insight scenarios

5.1 Macroeconomic indicators examined

The modelling output provided by the macroeconomic modellers for the purpose of this exercise comprises a range of macroeconomic indicators, as shown in Table 5.1.

Table 5.1 Macroeconomic indicators

OEF[1]	Global Insight[2]
GDP	GDP
Consumer expenditure	Consumer expenditure
Investment	Investment
Net exports	Net exports
Government balance	Government balance
Average earnings	Average earnings
Consumer prices—RPIX	Consumer prices—CPI
Short-term interest rate	Short-term interest rate
Real/nominal effective exchange rate	Real effective exchange rate
Unemployment	Unemployment
Employment	–
Carbon emissions (Mt)	Carbon emissions (Mt)
Energy use (Mtoe)	Energy use (Mtoe)
Energy intensity[3] (energy use per unit of GDP)	Energy intensity (energy use per unit of GDP)

Note: [1] OEF also provided data on personal income, industrial output, capital exchange rate, capital stock and the nominal effective exchange rates. [2] Global Insight also provided data on capital stock. [3] Calculated by Oxera based on OEF data.
Source: OEF and Global Insight.

Where appropriate, Oxera undertook transformations to the data provided by the modellers to make it comparable across models.

5.1.1 Differences in the baseline

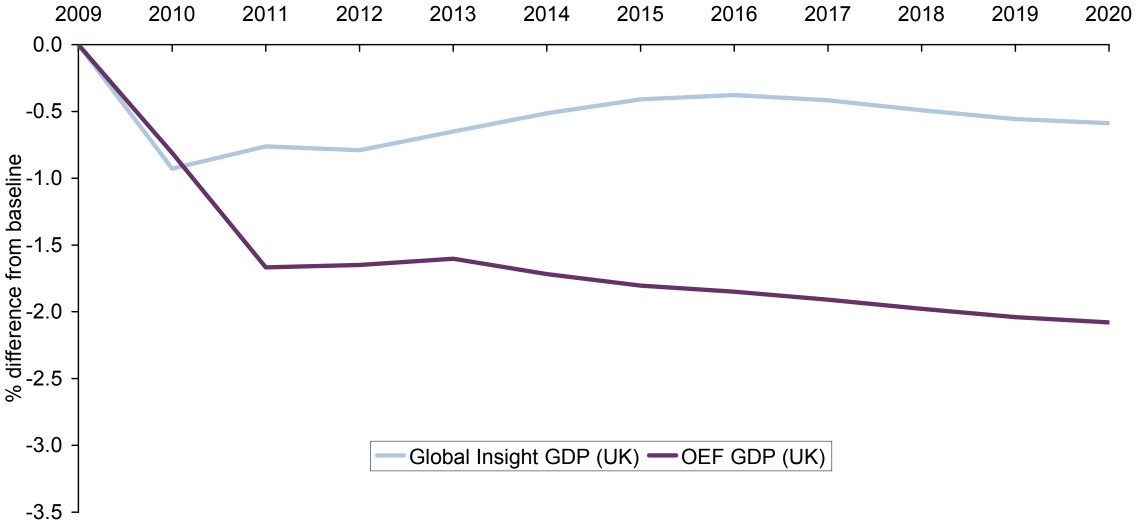
The baselines employed by OEF and Global Insight differ in several aspects. For example, in its model, OEF imposes fuel use and carbon emissions projections from DTI projections, with energy use and carbon emissions in 2020 lower than in 2010. In contrast, Global Insight uses data from its country forecasts, and energy use and carbon emissions are higher in 2020 than at the 2010 starting points. While both modellers expect that a change in baseline would lead to broadly similar results, the literature has highlighted that certain differences in baseline assumptions, such as population and productivity growth rates, may have an impact on results (see Barker et al., 2002).

5.2 Main results and differences

5.2.1 Overview of key results

In both models a 30% UK end-user energy price shock leads to a permanent loss in GDP relative to the baseline scenario, suggesting that there are important transitional costs in adjusting to a new equilibrium. Figure 5.1 compares the percentage reduction in GDP resulting in the OEF and Global insight models following the shock.

Figure 5.1 Impact of 30% end-user price shock on GDP



Sources: OEF and Global Insight; and Oxera analysis.

In the first year after the shock (ie, in 2010), both models exhibit a similar impact. After the initial impact, the response pattern and magnitude of the shock differ substantially. Global Insight's GDP impact is largest in the first year and then shows a tendency to move back towards the baseline. In contrast, in the OEF model GDP broadly declines (except for a brief recovery period) over the entire ten-year period, and the reduction in GDP at the end of the period is substantially greater compared with both the initial impact and the Global Insight reduction. However, this is as would be expected given the higher long-run elasticity of GDP with respect to energy price in the OEF model, and the relative importance of competitiveness effects in the traded goods sector.

Table 5.2 provides an overview of the some of main outputs from the models following a 30% shock to UK end-user prices. The general pattern is that the macroeconomic indicators in the OEF model respond more strongly to the shock than in the Global Insight model. This can also be illustrated with reference to elasticities (elasticity of energy demand to GDP, GDP energy price elasticity, price elasticity of energy demand), which are greater in the OEF model in the longer run.

Table 5.2 Summary of impacts: UK 30% end-user price shock (unless otherwise indicated, % deviation from baseline)

Indicator	Model	Year 1	Year 2	Year 3	Year 10
GDP	OEF	–0.8	–1.7	–1.6	–2.1
	Global Insight	–0.9	–0.8	–0.8	–0.6
Consumption	OEF	–1.5	–2.9	–2.9	–3.1
	Global Insight	–0.8	–1.1	–1.3	–1.1
Investment	OEF	–0.9	–2.7	–2.5	–1.5
	Global Insight	–0.2	–0.3	–0.6	–0.3
Net exports (% points difference)	OEF	0.3	0.6	0.6	0.0
	Global Insight	–0.3	0.2	0.3	0.2
Inflation (% difference in price level)	OEF	2.3	2.1	1.7	2.1
	Global Insight	1.1	0.7	0.5	1.0
Real effective exchange rate	OEF	2.5	1.7	2.2	2.8
	Global Insight	1.8	0.6	0.3	0.5
Energy use	OEF	–3.0	–8.0	–11.6	–18.7
	Global Insight	–2.7	–2.6	–2.6	–1.9
Elasticity of energy demand to GDP	OEF	3.7			9.0
	Global Insight	2.9			3.2
GDP energy price elasticity	OEF	–0.03			–0.07
	Global Insight	–0.03			–0.02
Price elasticity of energy demand	OEF	–0.3			–0.6
	Global Insight	–0.3			–0.2

Sources: OEF and Global Insight; and Oxera analysis.

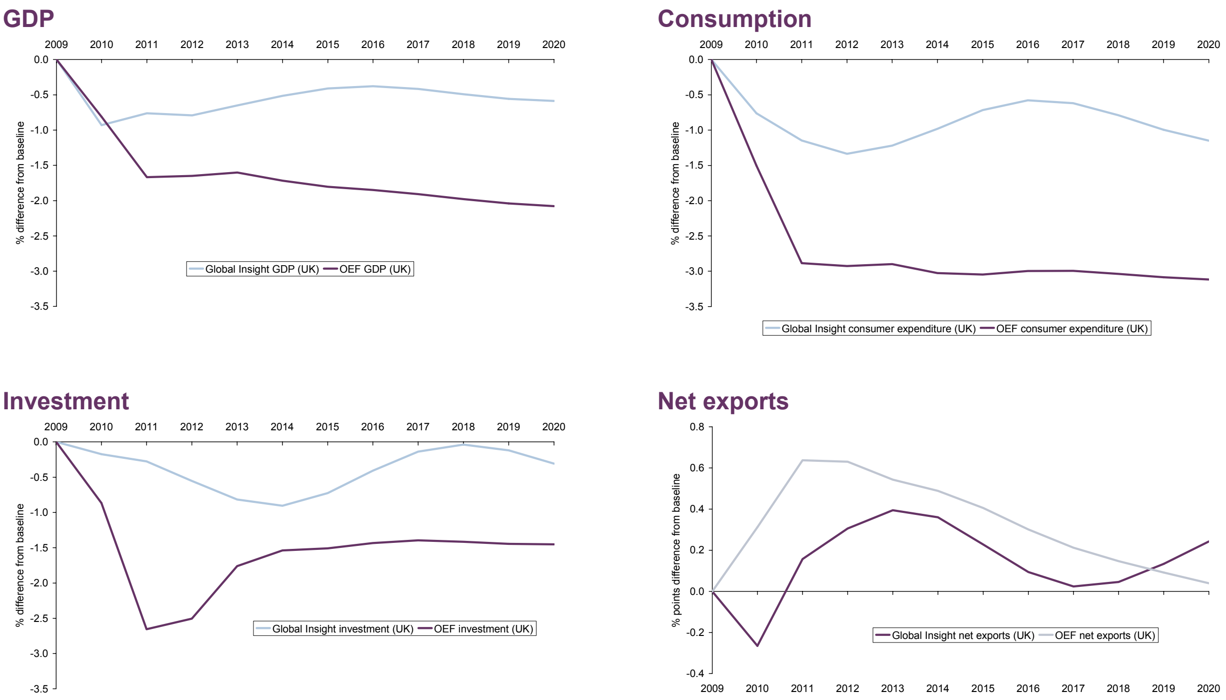
The remainder of this section examines in more detail the differences in the patterns, exploring the potential drivers of the observed differences, including:

- the impact on the demand side;
- the role of energy in the models;
- adjustments in price variables;
- the UK impact compared with the global impact;
- the impact on labour productivity.

5.2.2 Impact on the demand side

Figure 5.2 compares the patterns in the deviation from the baseline GDP and economy-wide demand as represented by consumption, investment and net exports following a 30% shock to UK end-user energy prices.

Figure 5.2 Comparison of overall patterns in GDP and domestic demand



Sources: OEF and Global Insight; and Oxera analysis.

In the Global Insight model, following the initial shock, GDP shows a tendency to converge back towards the baseline level. In contrast, in the OEF model, GDP declines steeply for another year, briefly stabilising and subsequently reverting to a downward trend.

The impact on the components of demand in the economy—represented by consumer expenditure, investment and net exports—is similarly greater in the OEF model. Investment declines after a reduction in domestic demand and export demand, following the loss in international competitiveness due to a rise in UK prices. Consumption expenditure decreases following an increase in the purchase price of goods and services and a reduction in real wage (required to re-establish equilibrium in the factor markets).

Net exports expressed as a share of GDP broadly improve (ie, the UK current-account deficit narrows) in both models (with an initial worsening in the Global Insight case). This suggests that the reduction in import demand resulting from the shock outweighs the reduction in the export demand caused by UK products becoming relatively more expensive in the world market.

The impact of the energy shock may also depend on the fiscal policy reaction in the models. If assumptions regarding fiscal policy differ between models, some of the observed differences may arise owing to differences in this assumed policy response.

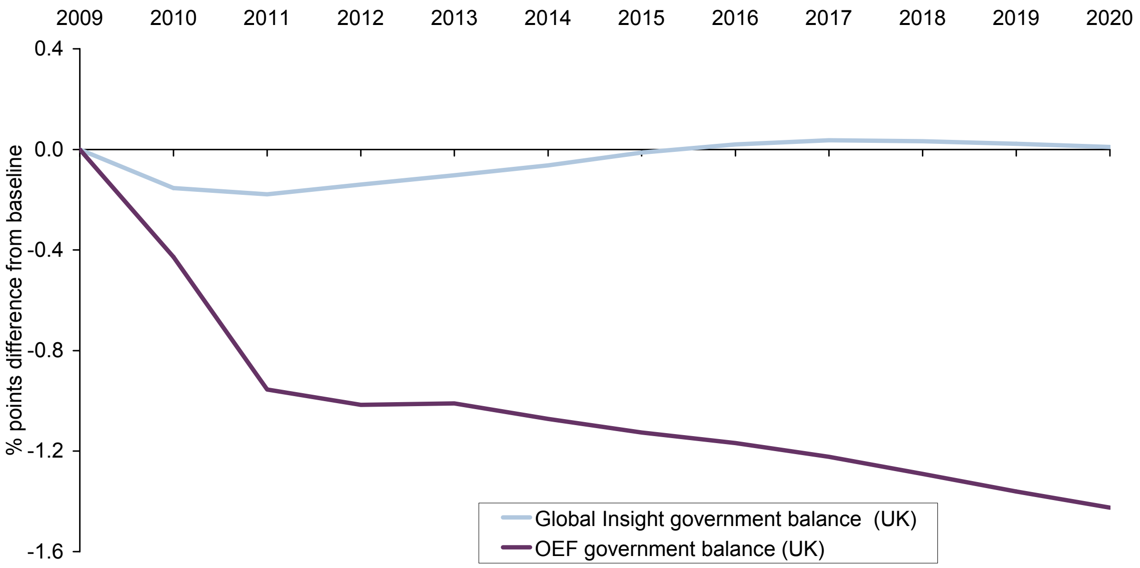
In the OEF model, a contraction in GDP, as brought about by the shock, leads to a reduction in tax revenues and increased government spending. The fiscal policy reaction function allows for these automatic stabiliser effects to reduce the impact on output. For the purpose of the modelling runs reviewed in this study, there are no mechanisms in place for higher tax rates or lower discretionary spending in the model. With a smaller economy, a smaller tax base and lower tax revenues supporting a constant public expenditure, the fiscal balance (ie, a larger budget deficit as a share of GDP, or a lower budget surplus as a share of GDP) worsens relative to the baseline. Hence, OEF's modelling runs are 'neutral' with respect to fiscal policy.

Global Insight's model contains a tax reaction function. The contraction in GDP leads to a reduction in the tax base and tax receipts. As government revenues fall, the budget deficit increases/the government surplus is reduced, so that government debt increases. The deviation from the trend debt/GDP ratio in turn leads to an increase in the tax rate.

Hence, while fiscal policy is assumed to be neutral in the OEF model, it tightens in the Global Insight model to bring the government balance back into line with its long-term trend position. This difference in fiscal policy assumption means that the two scenarios are *closer* together than they would otherwise have been. Since an increase in taxes (without an increase in expenditure) reduces aggregate demand in the economy, Global Insight's output is likely to have been worse than if a neutral fiscal response were imposed. Similarly, if OEF had assumed a response similar to Global Insight's, output and demand would have been likely to fall by more than in the present modelling runs with a neutral policy response.

Figure 5.3 shows the change in the government balance relative to the baseline. In the Global Insight model, government balance, expressed as a proportion of GDP, initially worsens and then gradually starts improving after 2015/16, as the government reacts to rising debt by raising tax rates and thereby boosting revenues. In the OEF scenario the government balance gradually deteriorates, as no measures are undertaken to increase revenues (or to reduce expenditure).

Figure 5.3 Government balance (percentage points difference in deficit:GDP ratio)



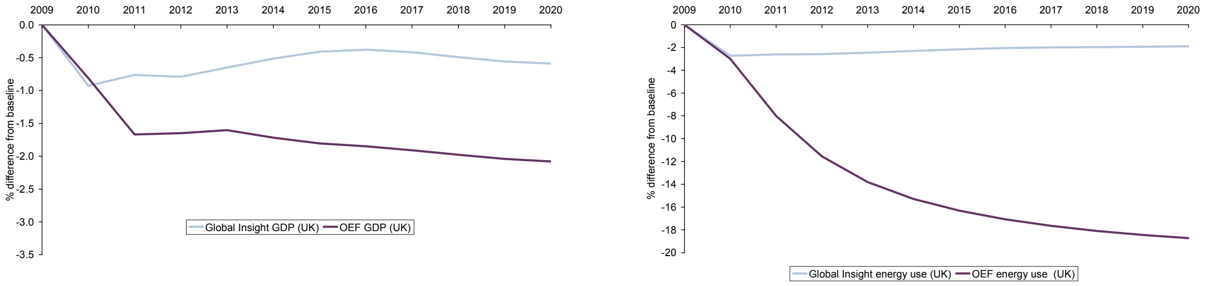
Sources: OEF and Global Insight; and Oxera analysis.

5.2.3 The role of energy in the models

The models exhibit a pronounced difference in the way in which energy variables are affected by the shock. As both models experience a comparable initial response, this suggests that energy plays a rather different role in the economies represented by the models.

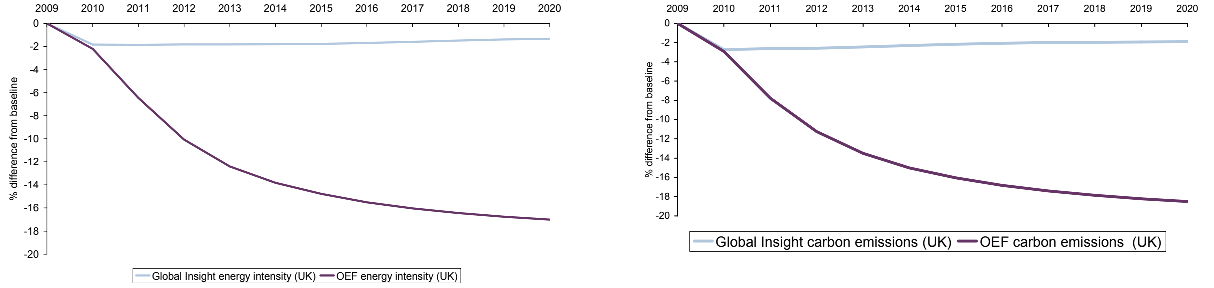
Figure 5.4 compares the patterns in the Global Insight and OEF models in output, energy use, energy intensity and carbon emissions of a 30% end-user energy price shock.

Figure 5.4 Output and the role of energy



GDP

Energy use



Energy intensity

Carbon emissions

Sources: OEF and Global Insight; and Oxera analysis.

In line with the impact on GDP, during the first year energy use (Mtoe) is reduced by a similar amount in both models. However, following this initial common reduction, in the Global Insight model, energy use, along with GDP, tends to be pulled back towards the baseline by the equilibrating forces of the model.[28] In contrast, in the OEF model, energy use decreases by substantially more (although at a decreasing rate), and, during the time period observed, there is no tendency to return to initial levels. An important part of the explanation for this observed difference is likely to be the structural change in the OEF model, in which economic activity in relatively energy-intensive sectors reduces, but increases in relatively less energy-intensive sectors.

In line with GDP and energy use, the patterns in energy intensity and carbon emissions diverge between the two models.

The relatively large reduction in energy consumption (and output) in the economy is likely to be a reflection, at least in part, of the view embodied in the OEF models regarding the response in the economy to an increase in the price of energy. The relative increase in the price of energy as an input to the production in the sectors of the OEF model changes the overall equilibrium quantity of energy employed in the economy. As described by OEF (2006):

> Some sectors make more intensive use of energy in their production process than others. A change in the real price of energy that is symmetric across all sectors will therefore have a disproportionately large impact on output in the more energy-intensive sectors. In the long-run, an increase in the real price of energy will lead to lower output in all sectors, but more so in the most energy intensive sectors. That disproportionate effect on the energy-intensive sectors will lead to a shift in the composition of employment across the sectors. In the long run, total employment will not change as a result of a shock to energy prices. But the composition of that employment will change:

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[28] In particular, the operation of the monetary policy response function (ie, the Taylor Rule) mitigates the adverse impact on GDP, with lower real interest rates (relative to the baseline) raising fixed investment and consumer spending after the initial shock. That is, the Global Insight scenarios allow energy use to recover in line with demand—there is no stock restriction on energy use in the long run.

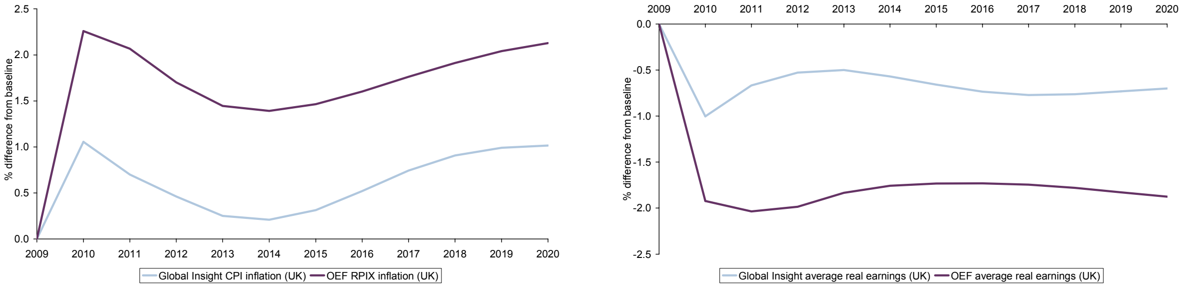
> higher energy prices will shift jobs out of energy-intensive sectors and into other sectors.

The switch in the composition of the economy towards less energy- (and capital-) intensive, but also less productive, sectors reduces output and energy use.

5.2.4 Adjustments in price variables

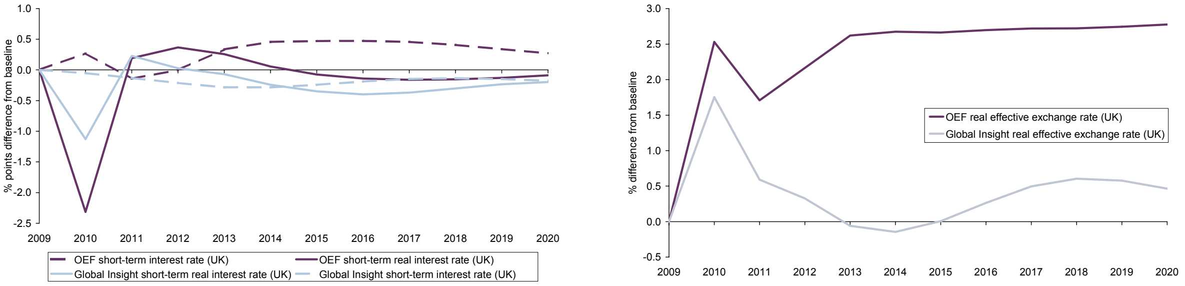
In parallel to the impact on the real variables of the economy, the price mechanism ensures that real variables move towards equilibrium in the long run. Figure 5.5 compares the impact of the shock on inflation, average earnings, interest rates and the real effective exchange rate.

Figure 5.5 Adjustments in price variables



Inflation (% difference in price level)

Average real earnings



Real and nominal interest rate

Real effective exchange rate

Note: The definition of the real effective exchange rate differs between models and therefore some of the observed differences may be due to differences in statistics rather than responses.
Source: OEF and Global Insight; Oxera analysis.

In addition to raising the input cost to producers, the energy shock increases consumer prices, raising the price of consumption of energy both directly and indirectly, as producers pass the cost increase through to customers. The overall patterns in inflation are similar in the OEF and the Global Insight models. However (ignoring the fact that slightly different measures of inflation are used in the models), the increase in consumer prices is considerably larger in the OEF model than in the Global Insight model in both the short and long run.

Theoretically, in the short run, the impact of the shock on overall consumer prices and producer costs depends on the share of energy in the average consumption basket of goods and services, and the share of energy in the production process. OEF (2006) states that:

> Since energy represents about 5% of the total costs of production in the UK (on average across all industries) this implies a 1.5% increase in total costs to industry. And, since energy represents about 10% of the cost of the average basket of consumer goods in the UK, it also implies a 3% increase in consumer prices, and therefore a 3% reduction in consumers’ real income.

Global Insight does not have comparable figures. However, the different impacts on the price level of goods (ignoring differences in the definition of consumer prices) in the year of the shock suggests that energy plays a different, perhaps less important, role in the Global Insight model compared with the OEF model, although it may be that producers adjust their price with a lag. This can also be examined with reference to the different amounts by which consumer expenditure is reduced by following the shock (see Figure 5.2) (although this also embodies the impact resulting from a range of other links). While, in the OEF model, consumer expenditure falls by around 3% after two years, Global Insight's consumption expenditure declines by less than 1.5% in any given year for ten years after the shock.

Real earnings and the labour market

The overall pattern in the reduction of real earnings—or, equivalently, for the purpose of this study, real wages—is broadly similar in both models, with somewhat greater cyclical effects in the Global Insight wage line. However, average earnings fall by less in the Global Insight model than in the OEF model. This may be due in part to the difference in the extent to which the labour market adjustment is effected through price changes in the Global Insight model (remembering that all long-run labour market adjustment is via the real wage in the OEF model).[29] However, it also reflects the lower long-run impact on actual GDP necessitating a less severe reduction in the real wage to maintain equilibrium.

Monetary policy

Assumptions regarding monetary policy responses may also lead to differences in observed outcomes. To the extent that policy is more accommodating with respect to a given rise in inflation, the adverse impact on short-run output may be lower. The change in real and nominal interest rates is shown in Figure 5.5. Both models use a form of the 'Taylor rule' as a basis for the monetary policy response in their models. To the extent that the model gives different weights to deviations of actual output from potential output, and deviations of actual inflation from desired inflation, different interest responses may be possible. However, since the impact on output and inflation (ignoring differences in definition) is greater in the OEF model output and interest rates may play different roles in the models, it is not possible to establish whether this might represent an important source of observed differences in the models.

Trade and the real effective exchange rate

The increase in the UK price level relative to the rest of the world leads to an appreciation of the real exchange rate.[30] With a greater (permanent) appreciation required in the OEF model to bring the economy back into balance, this suggests that, in the OEF model, UK exports experience a greater loss in competitiveness than in the Global Insight model. This is at least partly due to the structure of the OEF model.

OEF (2006) states that:

> If it is a global shock, then the competitiveness of the energy-intensive sectors in the UK relative to their counterparts will not be affected. But if it is a UK specific shock, it will drive up the real exchange rate of the energy intensive sectors and lead to weaker demand for the output of those sectors, amplifying and hastening the shift and employment to other sectors.

Global Insight also highlights the impact on international competitiveness, but the forces appear to be structurally embedded in the model, with less theoretical foundation than in the OEF model.

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[29] Ten years after the shock, the economy in the OEF model has not yet converged to a new equilibrium. This results in employment being lower compared with the baseline. OEF (2006) states that after approximately a further ten years employment effects would disappear, which would also reduce the negative impact on GDP in each scenario.

[30] Both models employ a floating exchange-rate specification in the UK scenario.

5.2.5 The UK impact compared with the global impact

In addition to the differences in the magnitude of the impact, there are differences across models in terms to their response to a unilateral UK and global shock. Figures 5.6 and 5.7 below illustrate the differences in the impact on GDP, demand (consumption, investment and net exports), energy use and inflation for OEF and Global Insight respectively.

In the OEF model, in the short-term aggregate demand effects dominate.

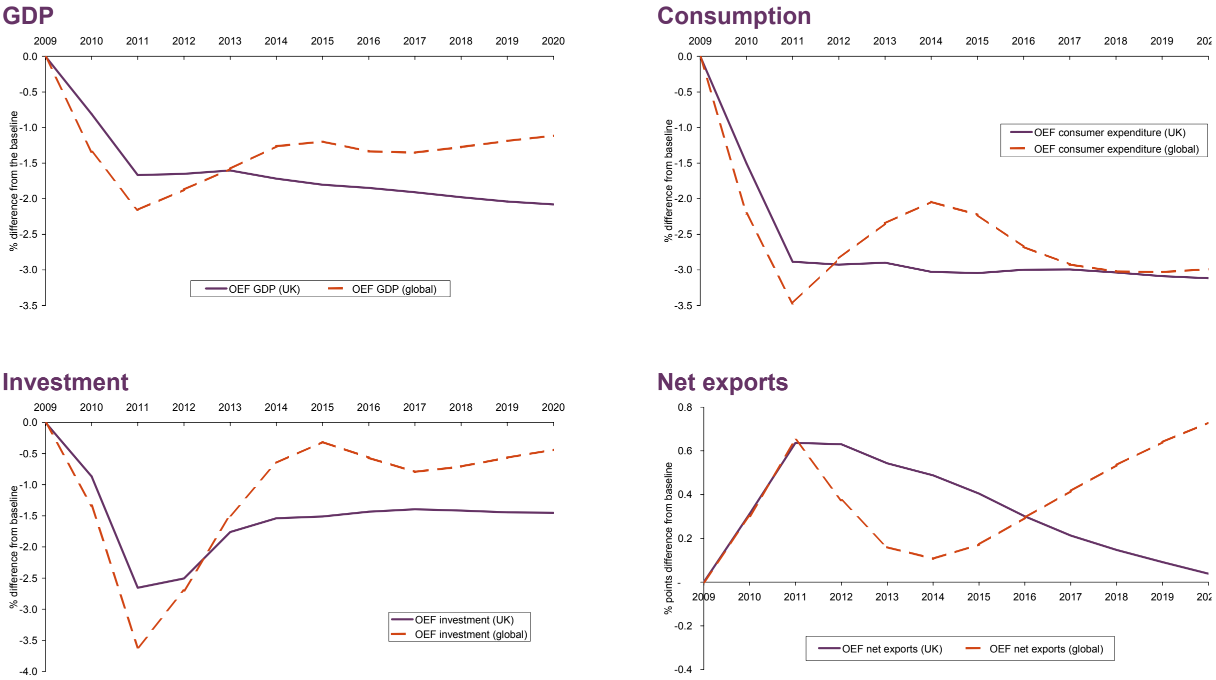
> The aggregate demand effects have two components: first, weaker domestic demand as a result of higher prices and lower real incomes and profits, multiplying up through the labour market as labour demand falls, and real wages fall as a result; and second, weaker external demand in the cases where it is a global shock. In those cases, demand for UK exports also falls, so UK net trade in the short term is worse affected than in the case where it is a UK-specific shock.[31]

In the longer term, competitiveness effects and changes in the sectoral composition of the economy dominate aggregate demand effects.

> By 2020, the short-term demand effects have washed out, leaving two other effects in place. First, higher energy costs mean lower energy use and lower productive potential, reducing the marginal product of capital. For an unchanged cost of capital, that implies a lower capital stock, driving productive potential down further. Second, real exchange rate effects, when they are present (in the case of a UK-only shock …) accelerate the shift out of energy intensive sectors of the economy into other sectors. Energy intensive sectors are, on average, more productive than other sectors (partly because they tend to be more capital-intensive sectors too). This change of sectoral composition therefore implies a further reduction in whole-economy productivity.[32]

Hence, in the OEF model the impact of the shock in the short term is smaller in the UK scenario than in the global scenario, but in the long run the impact is greater in the UK than in the global scenario.

Figure 5.6 OEF: comparison of UK and global 30% shock to end-user prices



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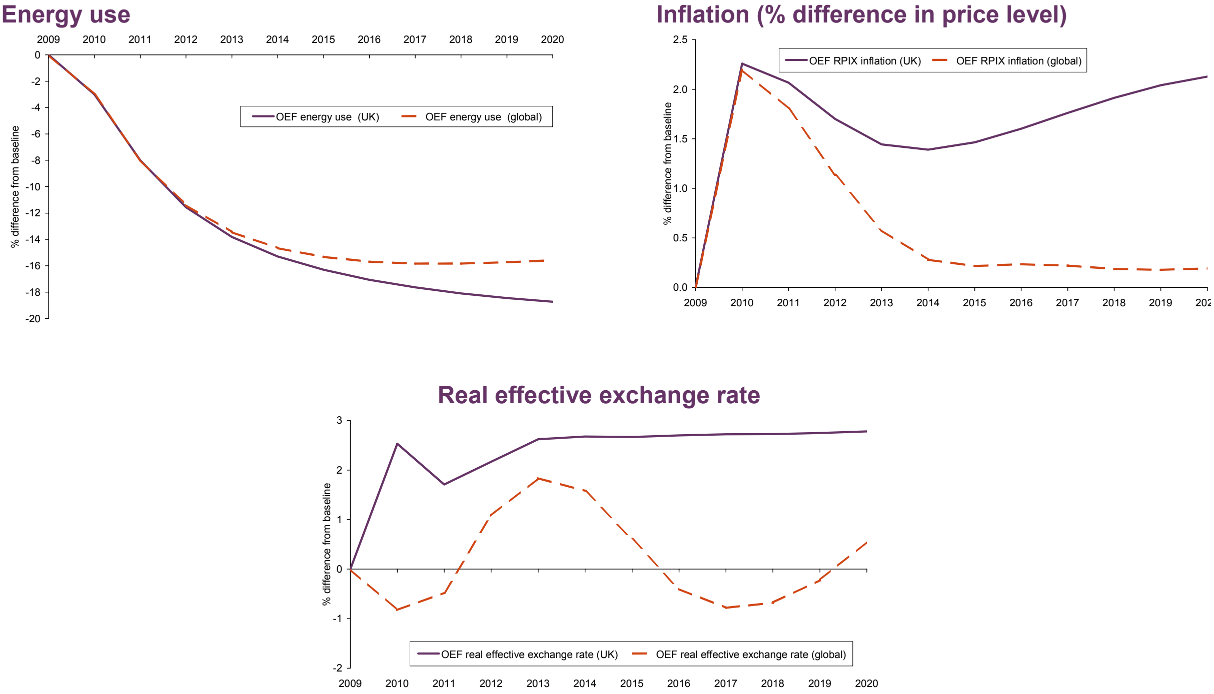
[31] OEF clarification of difference between impact in UK only and global case, provided to Oxera by email.

[32] Ibid.


Energy use

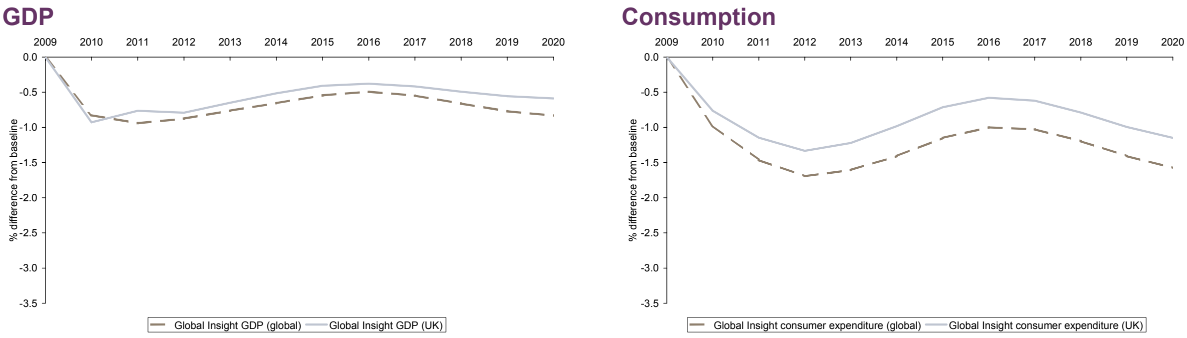
Inflation (% difference in price level)

Real effective exchange rate

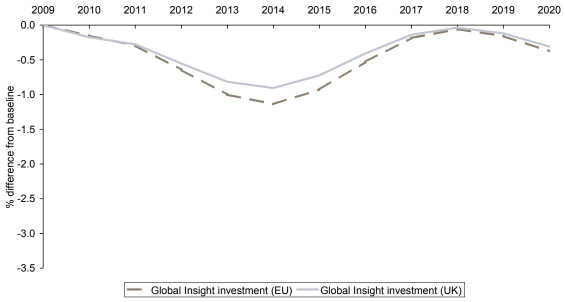
Source: OEF; Oxera analysis.

In the Global Insight model, apart from a slightly smaller loss in GDP in the year of the impact in the global scenario, the impact of a global shock is greater in the short and the long run. The overall pattern in the indicators in Table 5.2 is broadly similar in the global and UK shock, with a global shock exhibiting a greater shift relative to the baseline than a UK-specific shock. The relatively greater reduction in aggregate demand in the global case is the dominant driver of the greater impact on the economy. This result is in contrast with the OEF model, in which the supply side affects the decline in UK competitiveness, and the restructuring in the economy towards less productive activities dominates aggregate demand effects in the longer term.

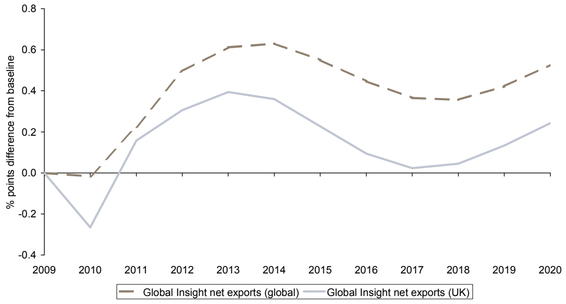
Figure 5.7 Global Insight: comparison of UK and global 30% shock to end-user energy prices


GDP

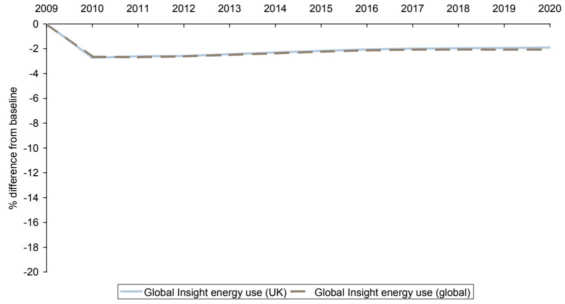
Consumption



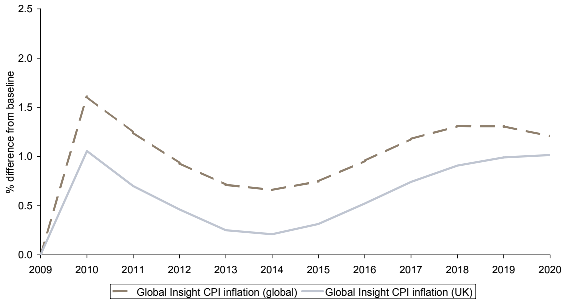
Investment



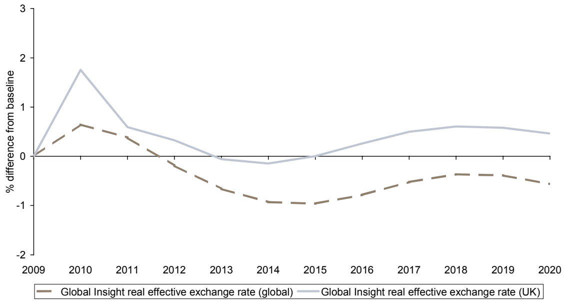
Net exports



Energy use



Inflation (% difference in price level)



Real effective exchange rate

Sources: OEF and Global Insight; and Oxera analysis.

Comparison of impact of oil shock[33]

Contrary to the impact observed in the end-user price, the long-run loss in output associated with an oil shock is greater in the Global Insight model than the OEF model (see Figure 5.8). Global Insight (2006) states that:

> The fact that GDP stabilizes at a level lower than the baseline appears at odds with a general expectation that even with a sustained oil price hike, the economy will trend toward the pre-shock state. The long-term nature of the impacts as indicated here reflects in part a limitation of the model, which lacks a built-in mechanism whereby the financial wealth, or 'petro-dollars', accrued to major oil exporters from higher oil prices is recycled back into the global economy. The windfall financial wealth recycled through trade and capital flows should mitigate substantially economic damages incurred from a sustained rise in oil prices, thereby contributing to the restoration of economic activity to the pre-shock state.

There is, however, some mitigating investment response, as higher oil prices lead to greater exploration and more oil output

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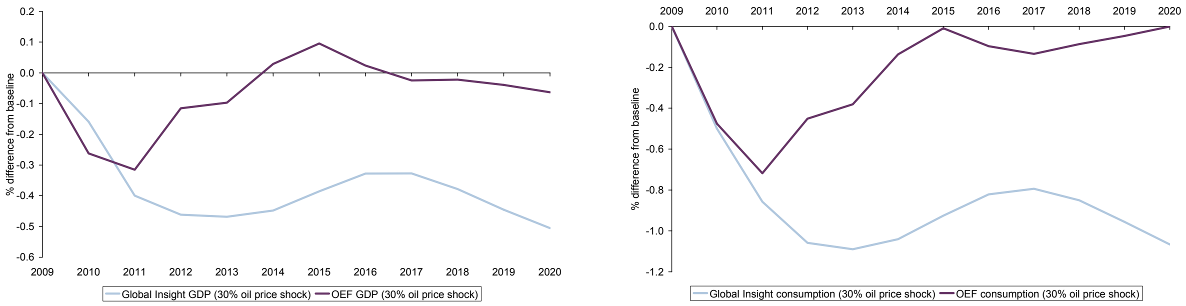
[33] The gas shocks provided by the modellers are not directly comparable since OEF modelled a 30% global shock, while Global Insight modelled a 30% UK-only gas shock.

> Despite rising capital costs brought by higher inflation and rising interest rates, higher oil prices cause fixed investment to rise by stimulating business investments in energy explorations. In the first three years of this period, real investment goes up by 1% on average from the baseline level. However, in the latter half of the period, fixed investment reverses its course falling by 0.7% on average as the positive effects on investment are more than offset by falling aggregate demand and output. Over the whole six-year period, fixed investment rises by 0.1% on average. (Global Insight, 2006)

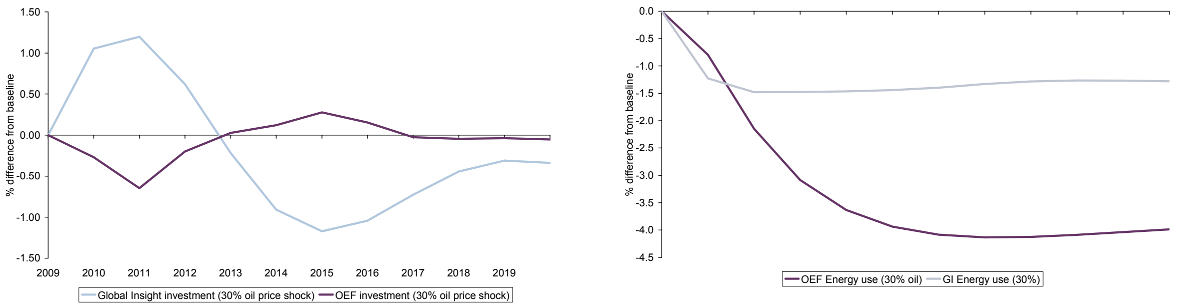
In the OEF model, the shock is broadly similar in the short run (although the impact on GDP is larger), but the impact by 2020 is different than in the case of a shock to all end-user energy prices. Since only the price of oil has increased, firms and consumers are free to substitute into other fuel types, and, over a ten-year period, they do so. As a result, the impact on the overall price of energy by 2020 is slight, as is the impact on overall energy consumption. Oil consumption falls, but the consumption of other energy types increases, so that overall energy consumption is largely unchanged. Therefore, the impact on productive potential by 2020 is also very small.

Figure 5.8 Comparison of the impact of a 30% oil shock



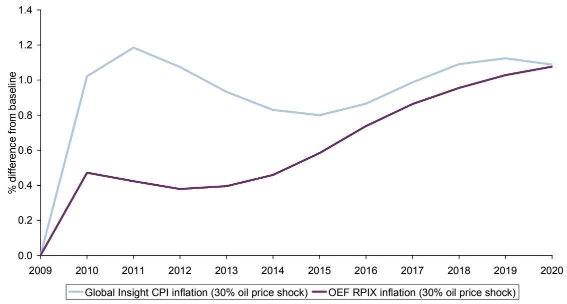
GDP

Consumption



Investment

Energy use



Inflation

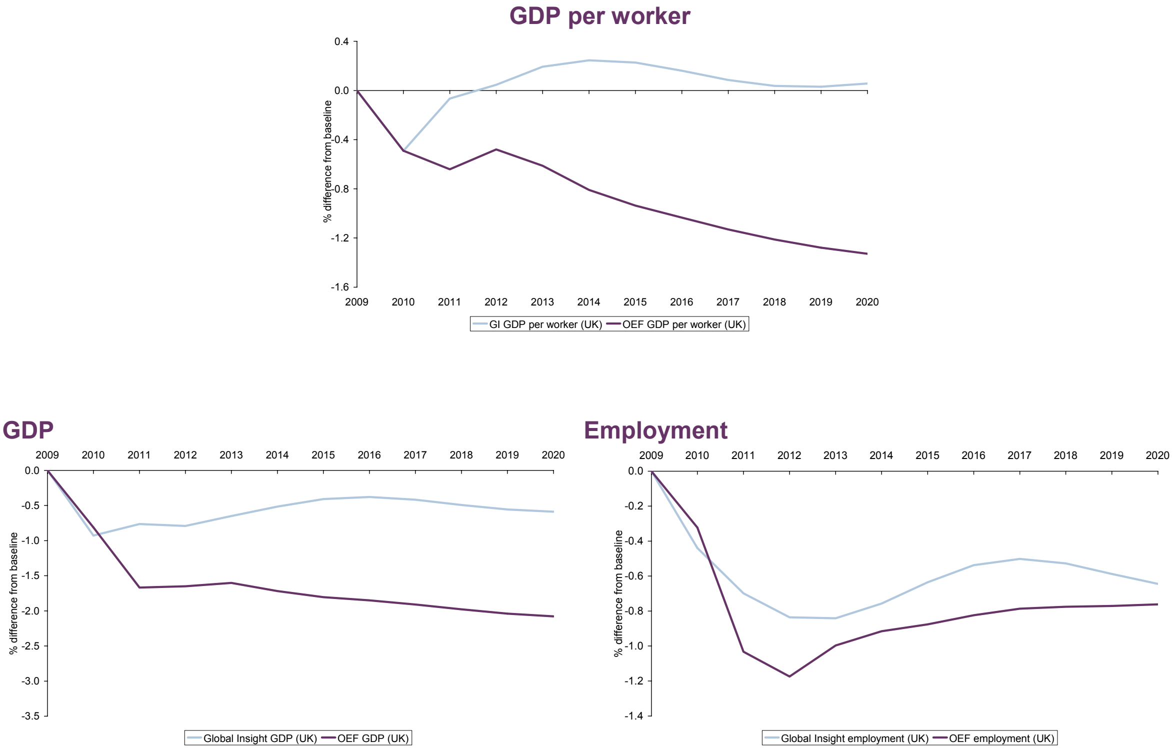
Sources: OEF and Global Insight; and Oxera analysis.

5.2.6 Impact on labour productivity

Comparisons of the relative changes in GDP per worker between the UK and other countries could be used to study the high-level impact of shocks on competitiveness. For the purpose of this report, the impact on absolute labour productivity rather than relative to other countries is examined.

Figure 5.9 compares the pattern of GDP per worker (and GDP and employment) in the OEF and Global Insight models.

Figure 5.9 GDP per worker



Sources: OEF and Global Insight; and Oxera analysis.

As highlighted above, the change in sectoral composition means that, in the OEF model, labour productivity in the economy is reduced. The broad downward trend in GDP per worker is consistent with the model's structural change towards less energy- (and capital-) intensive, but less productive, sectors. In comparison, the Global Insight model, while displaying a comparable reduction in labour productivity in the first year, reverts back to the initial baseline, temporarily overshooting. In discussion, Global Insight agreed that it would expect to see a tendency for labour productivity to fall, but noted that mechanisms in the model did not reflect this appropriately over the time period examined. In the absence of a theoretical mechanism in both models that ensures a tendency for labour productivity to fall following a shock, this indicator cannot therefore be used as a firm basis for comparing the impact on competitiveness.

6 Conclusions for policy

6.1 Macro models

This research has focused on the use of two macroeconometric models—the OEF model and the Global Insight model—to provide indicators of the impact of energy policy changes on the UK economy. In the absence of a precise policy package, generic price shocks have been used, as it is anticipated that most policy options will operate through price changes. Policies not operating through the price mechanism, such as those directly affecting innovation or technology adoption, are delivered more optimally within the long-term Markal-type framework [34].

Moreover, the emphasis on short-run dynamics limits their role in assessing any policy with a very long time horizon, such as climate change policy and some general aspects of energy policy.

The difficulty with using macro models for long-term exercises does not detract from their use over shorter time horizons, particularly given the importance of transitional costs as well as the longer-term equilibrium.

However, the lack of endogenous technological change means the true transitional costs may be hard to identify.

6.2 Results

While over the period to 2020 as a whole the two models present rather different stories, the immediate short-term impact is similar in both models, suggesting that similar demand-side forces dominate initially.

The detailed simulations (available in separate reports from OEF and Global Insight) show the impact of a 30% increase in the end-user energy price, two oil prices (one for Global Insight) and two gas price shocks, and, in the case of OEF, a carbon price increase and a backward-engineered carbon emission scenario.

Attention has been focused on the **30% increase in UK end-user energy prices**. This case is equivalent to a policy change which increases the costs of energy production, and where this cost increase is fully passed through (the cost increase is 'lost' to the economy rather than being recycled, as would be the case with a carbon tax, for example).

The main focus is on two measures of impact: **changes in GDP**, which is a widely used, though flawed, measure of economic welfare; and the **real exchange rate**, which is a measure of the impact of the shock to competitiveness.

Two cases are considered: one where the increase applies to the UK only, and one where the increase is worldwide. (There is also an intermediate case where the increase applies to the EU as a whole.)

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[34] 'As a bottom-up model, MARKAL consists of a menu of energy technologies characterising the production, transmission and use of energy, with associated information about the costs of those technologies. Different tranches of the same basic technology can be made available in the model at different assumed costs … or at costs which vary over time. … Having specified assumed levels of energy demand to be met, the model can be used to determine the combination of technologies which will meet those needs at least overall cost.' See pages 154 and 155 in the Annex 'Use of the Markel Energy Model' to DTI (2003), 'Options for a Low Carbon Future', Economics Paper No. 4, June.

As the comparative charts in section 5 showed, the adverse impact of this shock is much more severe in the OEF runs than in the Global Insight runs. Taking the UK-only case: in the OEF runs, after ten years GDP is down by 2% and the real exchange rate has worsened by 2.5%; the equivalent Global Insight figures are 0.6% and 0.5%. In the Global Insight model there is some tendency for the economy to recover from the initial shock; in the OEF model the impact tends to lead to a lasting downward trend in economic activity.

However, given that the main focus of this exercise is on transitional costs and on the impact on competitiveness, the path of energy use is also an important output as an indicator for energy policy, and as an illustration of the different modelling approaches and effects. What is remarkable about the two separate exercises are the very different impacts on energy use (and therefore carbon emissions). An apparently similar price shock sets in chain two very different paths of adjustment. In the OEF model (or, more correctly, models), substantial structural change—with demand switching from energy-intensive to less energy-intensive industries—has, after ten years, reduced energy intensity by 18%—a massive reduction in energy use. The Global Insight model exhibits no such change: energy intensity falls by 2% initially and remains at roughly this level, with some slight tendency for intensity to rise towards the baseline projection over time.

6.3 Modelling choices

The two models operate in different ways, as detailed below.

- In the OEF model, a separate CGE industry model determines the sectoral composition of both output and energy demand. The consequent impact on potential output is then imposed as a constraint on the macroeconometric model. Global Insight uses a macroeconometric model with a basic energy sector specification to run the scenarios. In this model, changes are primarily from the demand side, whereas the energy sector—and indeed the whole of the supply side—is more fully specified in the OEF model.

- As indicated, a particular difference is that the OEF model demonstrates much greater propensity for changes in competitiveness to induce sectoral shifts. Previous studies of the impact of world oil price rises have demonstrated that there are likely to be significant structural adjustments to changes in energy prices, but that such adjustments are likely to be identified only in models with a substantial degree of disaggregation. It is perhaps no surprise, therefore, that this difference arises between the model results. Nevertheless, the energy-intensity shift identified by OEF is remarkably large.

- Another indicator of the differences between the two approaches can be obtained by comparing the ‘UK-only’ and ‘world’ cases. In the Global Insight model, which is largely driven from the demand side, the fall in demand, and therefore GDP, is worse in the world case than in the UK case. In the OEF model, where the impact on competitiveness plays a greater role, the results are better in the world case than in the UK-only case since competitiveness is not affected to the same extent.

The two models have somewhat different assumptions about the workings of the labour market. In the OEF model there is, in the long run, a fixed labour supply, while the Global Insight model seems to exhibit more flexibility. In practice, however, the distinction is not material to the present exercise since any long-run properties hardly show over the ten-year simulation period.[35] In both cases, employment levels are lower.

Real earnings and productivity are significantly lower in the OEF runs, a reflection of the structural shifts. This also has implications for competitiveness, with the OEF model implying that the UK is moved onto a less skilled, less productive, path. Given that ‘the long-run

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[35] Discussion with OEF indicated that the model would tend towards the long-run equilibrium employment level over an additional 10–15-year period.

impact of mitigation measures on competitiveness … depends on its impact on capital accumulation, education and technological progress',[36] neither model has much to say about such dynamic adjustments.

Therefore, to some extent, the decision on which model to choose is determined by prior assumptions about the way the world works; for example, assumptions about the labour market and about the propensity for the economy to make significant shifts between energy- and non-energy-intensive sectors in response to relative factor prices and changes in competitiveness.

Given the DTI's interest in the energy sector and in industrial carbon emissions, the model with the most detailed representation of the energy sector (ie, the OEF model) has an initial advantage. However, there are other models, not used in this exercise, that have a detailed representation of the energy sector, notably the Cambridge Econometrics model.

In summary, the following points can be made regarding the available modelling options.

– Markal may be appropriate to determine the long-run equilibrium, but does not capture the short-run dynamics in the economy.

– The OEF and Global Insight models can represent the dynamics of macroeconomic adjustment to shocks, but with limitations:

  – the Global Insight model has no long-run supply-side effect and all adjustment appears to be in nominal variables;
  – the OEF model acknowledges the supply-side constraint but may produce a long-run equilibrium below that potentially achievable if endogenous technological change is allowed for.

From a modelling perspective, the possible next steps would appear to be:

– introduce endogenous technological change into the OEF model;
– find an alternative model that has endogenous technological change embedded in its structure;
– construct a hybrid transitional path utilising a combination of modelling results.

The feasible options may be limited by time and cost. It is proposed that:

– the DTI discusses with OEF the feasibility of introducing some technological change function within the model;
– consider in more detail the nature of the endogeneity that is present in the Cambridge Econometrics approach. However, this model will still have transitional costs and they may be substantive if the factor market behaviour is inflexible or adjusts with a relatively long lag. The model will still be sensitive to challenge on the assumptions regarding when technological changes occur and the speed of learning or technology adoption (as per Figure 2.1);
– a short-run solution is considered by linking the OEF and Markal models, with exogenous assumptions on where along the OEF GDP path technological change may begin and how quickly it manages the shift to the Markal solution.

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[36] HM Treasury (2006), 'What is 'Competitiveness'? How might Action to Mitigate Climate Change Affect it?', Stern Review discussion document.

6.4 Policy conclusions

For policy purposes, two questions arise:

- **could the transitional impact on economic welfare and competitiveness be as severe as indicated in the OEF model, or as (relatively) benign as in the Global Insight model?**
- **are these transitional costs that would be expected to fade away after a decade, or as innovation responds to the change in relative prices?**

The answer to the first is, based on the findings in this study, that the range of results shown in the two sets of simulations is perfectly plausible. Thus, the results represent something of the uncertainty surrounding these impacts. However, from the modelling runs and characteristics examined, it is not possible to conclude that one end of the range is more probable than the other.

It seems probable that risk-averse policy-makers would focus on the worst results—ie, those from OEF. An earlier international exercise comparing energy economy models showed that the then 'Oxford model' tended to give outlying results, but the preliminary conclusion based on the results of this study is that the energy price/GDP 'elasticity' implied by the OEF results does not seem to be exceptionally large in comparison with related results from the Cambridge Econometrics and Strathclyde models.

In relation to the second question, Oxera's assessment, based on our reading of the wider literature, is that a realistic assumption is that these costs are indeed transitional, and that beneficial changes in the economy would start to flow through in the medium To some extent, these may be the kind of macroeconomic adjustments incorporated in the Global Insight model, but, more importantly, they will be induced changes in the pattern of technological progress in response to the changes in factor prices.

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