The impact of exempting electro-intensive industries from Contracts for Difference support costs

Report prepared for DECC and BIS

Final report
February 2014

Acknowledgements

Vivid Economics has relied upon the expertise, data, time and timely input from the staff of several industry associations and industrial firms in this work and would like to express its very warm thanks for all their contributions.

Vivid Economics is grateful to the encouragement and support of staff at DECC and BIS throughout this project and for the efficiency with which the project has been managed and the speed at which decisions have been taken.

The work has been a joint project between Vivid Economics and Cambridge Econometrics. As always, it has been a pleasure working with the Cambridge Econometrics team and Vivid Economics thanks them for their expert, professional and collaborative approach to the project.

An appropriate citation for this report is:

Vivid Economics with Cambridge Econometrics, *The impact of exempting electro-intensive industries from Contracts for Difference support costs*, report prepared for DECC and BIS, December 2013

Executive Summary

Evidence supports selective exemption on value for money grounds

Overview

Contracts for Differences (CfDs), and the associated Feed-in Tariff support costs, will fund an increasing proportion of the UK's low carbon power generation, and will underpin a key part of the UK's low carbon investment programme. Critical to the overall efficiency of the policy is the impact of the cost of funding on the UK economy. The Feed-in Tariff support costs can be expected to flow through to retail purchasers of electricity. The impact of that increase will be felt disproportionately by sectors with relatively electro-intense methods of production, or by sectors which, among other possible factors, are strongly exposed to competition from foreign imports, or whose consumers have a low tolerance for price increases.

It has thus been proposed that some sectors might be selected to receive an exemption from the costs associated with CfDs. This report investigates the costs and benefits of such exemptions. It reports value for money estimates for a range of policy options and sector scenarios in 2016, 2020 and 2030, discussing the various costs and benefits that are likely to result.

Sector and economy-wide modelling

The analysis is based around two streams of modelling, one microeconomic and one macroeconomic.

On the microeconomic side, twenty electricity-intensive sectors were selected for investigation. They were chosen for their diversity of characteristics, and, in some cases, national or regional economic importance, with the expectation that this would provide a range of potential value for money (VfM) estimates across sectors.

Vivid Economics' Industrial Market Models (IMMs) were used to analyse these sectors, generating a large amount of information concerning impacts on sector competitiveness, cost pass-through rates, price changes, and production choices. Five sectors were investigated in 'full detail', using the Full Industrial Market Model (FIMM), which can perform analysis down to the installation level, while fourteen were investigated with the Reduced Industrial Market Model (RIMM), which takes a more aggregated approach. Data limitations prevented the application of the FIMM to the pulp and paper sector, so it was analysed with several RIMMs, and was otherwise treated and referred to as a sector investigated in full detail.

Thus, of the six considered in full detail, four, paper, fertilisers, flat glass, and steel manufacture, are highly electro-intensive and extensively traded internationally. The other two, cement and heavy clay ceramics (that is, brick, tile, and clay pipe production, as opposed to, for example, more technical ceramics), are less widely traded. The fourteen sectors considered in less detail are generally both less electro-intensive and less trade exposed, though are fairly diverse overall.

The sector modelling made use of a large and rich set of data, some of which has kindly been provided by firms and sector associations specifically for this study. Government data sources, such as the ONS, were used preferentially, except where a compelling case was made that data direct from industry was of superior quality or relevance. Sensitivity analysis was used to test the robustness of the results against variations in variable values.

To complement the sector-level analysis, Cambridge Econometrics' MDM-E3 model was used to perform a broader assessment of the net macroeconomic impact of the exemption on the UK economy, including impacts on GDP and employment.

Scenario analysis allows the exploration of uncertainty, especially of the economic or policy situation. Upside and downside scenarios were created for the sector-level analysis by varying, for example, growth assumptions, and a range of exemption rates were tested in both the IMMs and MDM-E3. The macroeconomic modelling also allowed the testing of different coverage of sectors receiving the exemption.

Sector modelling: cost pass-through and effect on output

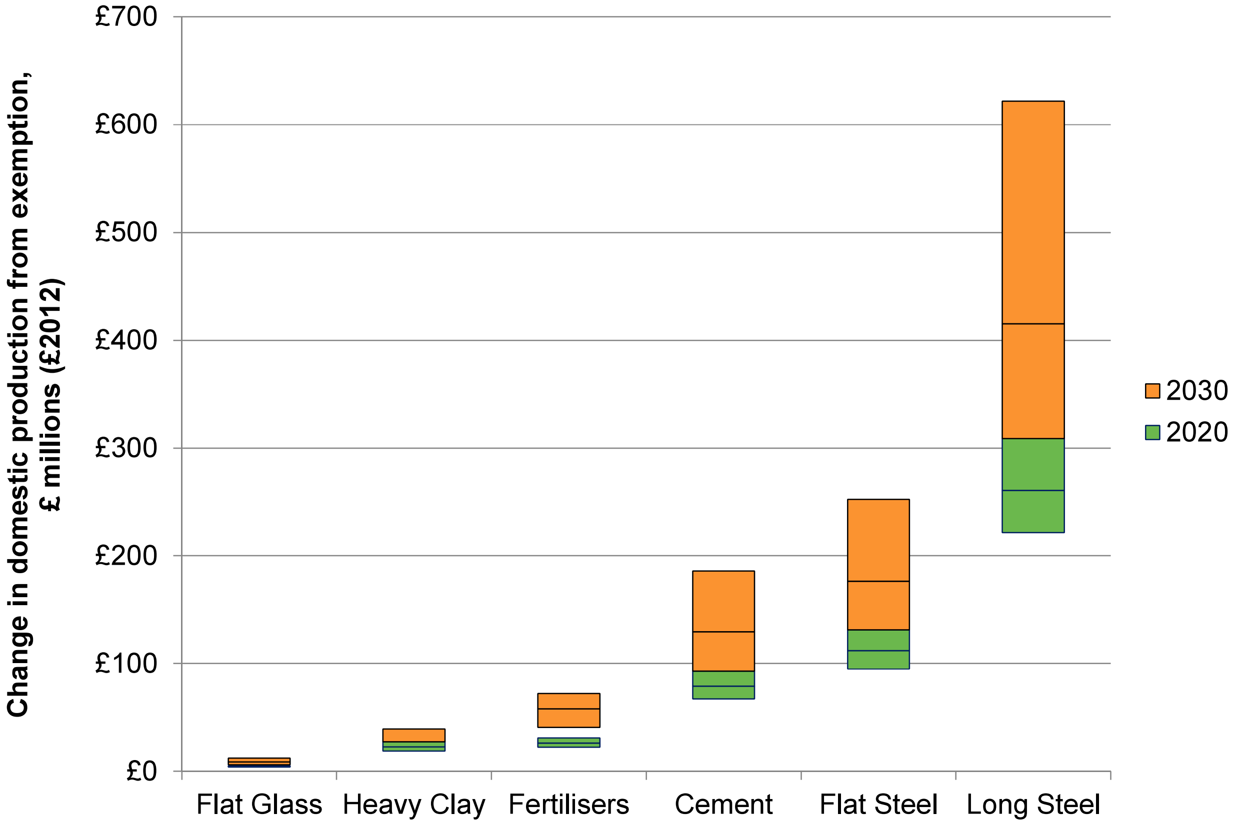
An exemption from CfD support costs will lower the price of electricity faced by exempt firms. It can be expected that part of this decrease in production costs will feed through to consumers in the form of lower prices, and part will be retained by the exempt sectors as higher profits. The extent to which such a change in costs is passed through to final prices is referred to as the 'rate of cost pass-through'.

Within the IMMs, the rate of cost pass-through is not an input or assumption but an output of the models, determined as a function of the various parameters describing sector competitiveness: the size and number of competing firms, the exposure to international trade, the magnitude of profit margins, and the responsiveness of demand to price changes. Cost pass-through is a key variable of interest, as it is closely tied to how the exemption affects firm profitability, output, and consumers: a low-rate of cost pass-through results in greater profit margins for firms, increasing their ability to capture market share at the expense of competitors; however, a high rate of cost pass-through will result in a greater reduction in the market price, increasing the demand response. While both these outcomes result in increases in output, the models suggest that the former effect is stronger.

For sectors investigated in full detail, rates of cost pass-through range from 2 per cent for flat steel to 78 per cent for heavy clay ceramics. That is to say, the heavy clay ceramics market equilibrium following the exemption features prices that have decreased by approximately 78 per cent of the per-unit value of the exemption. Within the RIMM model, rates of cost pass-through vary from around 1 per cent to 93 per cent. Even within a single sector, the figures can vary dramatically between markets. For example, printing and writing paper exhibits a cost pass-through rate of 1 per cent, while in sanitary paper (which is substantially less trade-exposed) it is 62 per cent. The competitiveness of the market drives variations in cost pass-through, and in the model is a product of the degree of trade exposure, profitability, and the elasticity of demand. For instance, the printing and writing paper sector is substantially more trade-exposed than sanitary paper. Consequently, the price is influenced by the behaviour of international producers and there is limited scope for EU producers to pass on energy policy costs.

The way in which firms respond to exemptions through their choice of output is also of importance for VfM analysis. Across the sectors investigated in detail, the changes in output in the 2020 core scenario vary from 3 per cent for flat glass to around 20 per cent for long steel. The sectors investigated in less detail span a similar range; these results are for the core scenario in 2020, and are expressed in terms of monetary value in Figure 1 and Figure 2. Variations across sector that are not explained by differences in the competitive situation of the market can generally be attributed to differences in the size of the cost shock relative to the price of the product. For example, take two sectors which are otherwise identical in competitive factors and electro-intensity of production: if one has a lower price, the relative size of the shock experienced by producers will be larger, with consequently greater consequences for market prices and quantities.

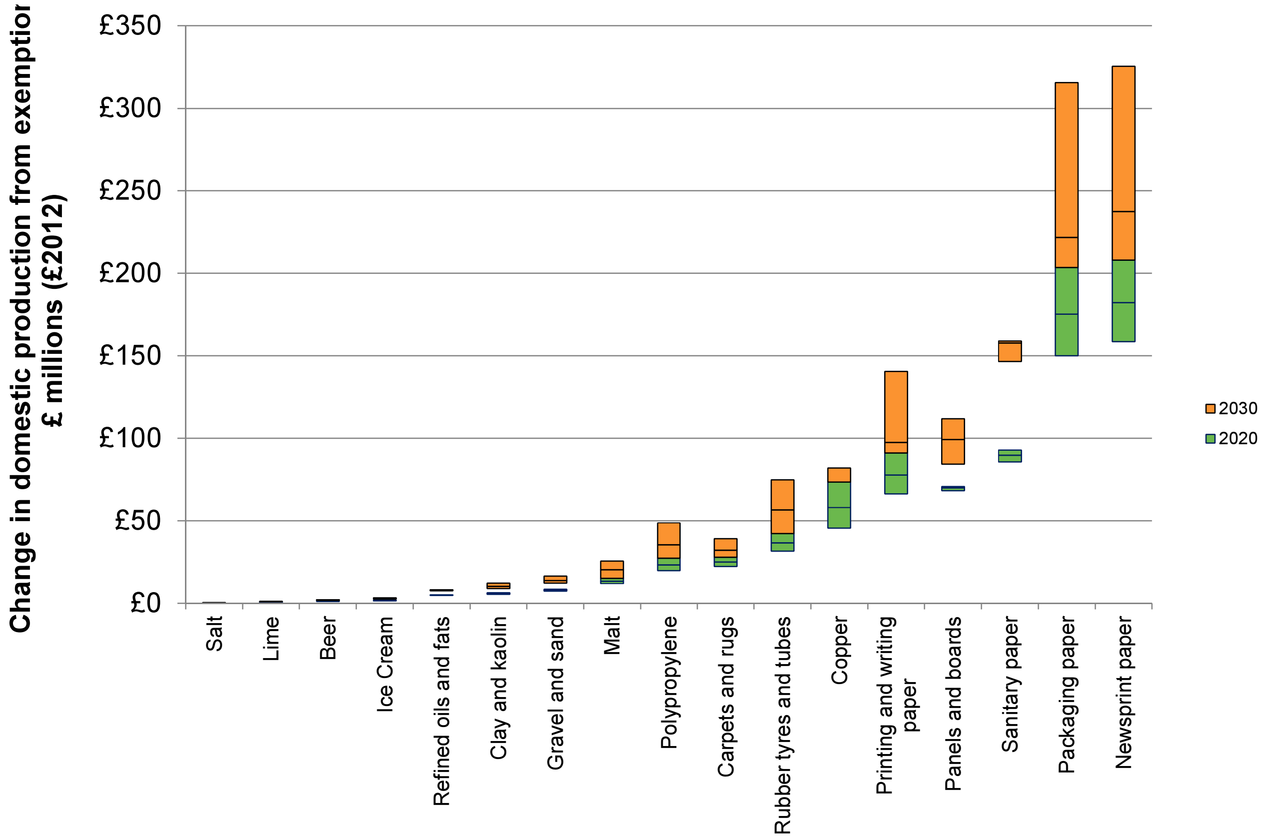
Figure 1. **The sectors investigated in detail show a wide range of changes in domestic production, both across sectors and scenarios (£2012)**



Notes: *Each bar shows the highest, lowest and central estimate of the value of the exemption. Note that for all sectors and years other than heavy clay in 2030, the highest value changes occur in the upside scenario, and the lowest occur in the downside scenario. An exception is heavy clay ceramics in 2030, where the largest value change occurs in the core scenario, and the lowest occurs in the upside scenario.*

Source: *Vivid Economics*

Figure 2. **Absolute change in domestic production in 2020 and 2030 under different scenarios for sectors analysed with RIMM (£2012)**



Note: *The petrochemicals sector is not shown on the chart for scaling reasons; in 2030, the change in the value of petroleum production ranges from around £550m to over £1,050m. This is due to the substantially larger size of the petrochemicals sector compared to other sectors examined.*

Source: *Vivid Economics*

Impacts on GDP

Cambridge Econometrics' MDM-E3 model performs a broader assessment of the net macroeconomic impact of the exemption on the UK economy. For example, the IMM results reported above do not consider the impact of the exemption on non-exempt consumers, who face higher electricity costs as a result of the exemption. This modelling provides an assessment of the impact of the exemption on both exempt and non-exempt consumers within a single modelling framework.

In contrast to the IMM sector modelling, the MDM-E3 model suggests that, in terms of their output responses, exempt sectors are much less sensitive to the exemption. This is the case even after making approximate corrections for differences in the scope of the more aggregated MDM-E3 sectors.

There are several possible explanations why the macro model might underestimate the effects on individual sectors and why the individual sector models might overstate them. In large part, the differential is driven by varying perspectives on the likely responsiveness of importers to changes in domestic market prices: the microeconomic model uses equations derived from theory and calibrated with real-world data, while the macro-econometric model estimates the import reaction from historic data series. It is practically and conceptually difficult to force an alignment of these estimates.

When considering both the benefits to exempt sectors and costs to non-exempt sectors, the MDM-E3 modelling suggests the impact of the exemptions on GDP and employment is small to the extent of being negligible. The effect on consumer spending and total GDP is negative, but only of the order of a few thousandths of a per cent, which in the context of such a modelling exercise can be considered negligible. The moderate size of the aggregate impact is unsurprising, given the manufacturing sectors that are subject to exemptions constitute a small fraction of total UK GDP, and positive effects for them are broadly offset by the negative effects of higher CfD costs for non-exempt sectors and consumers (including households).

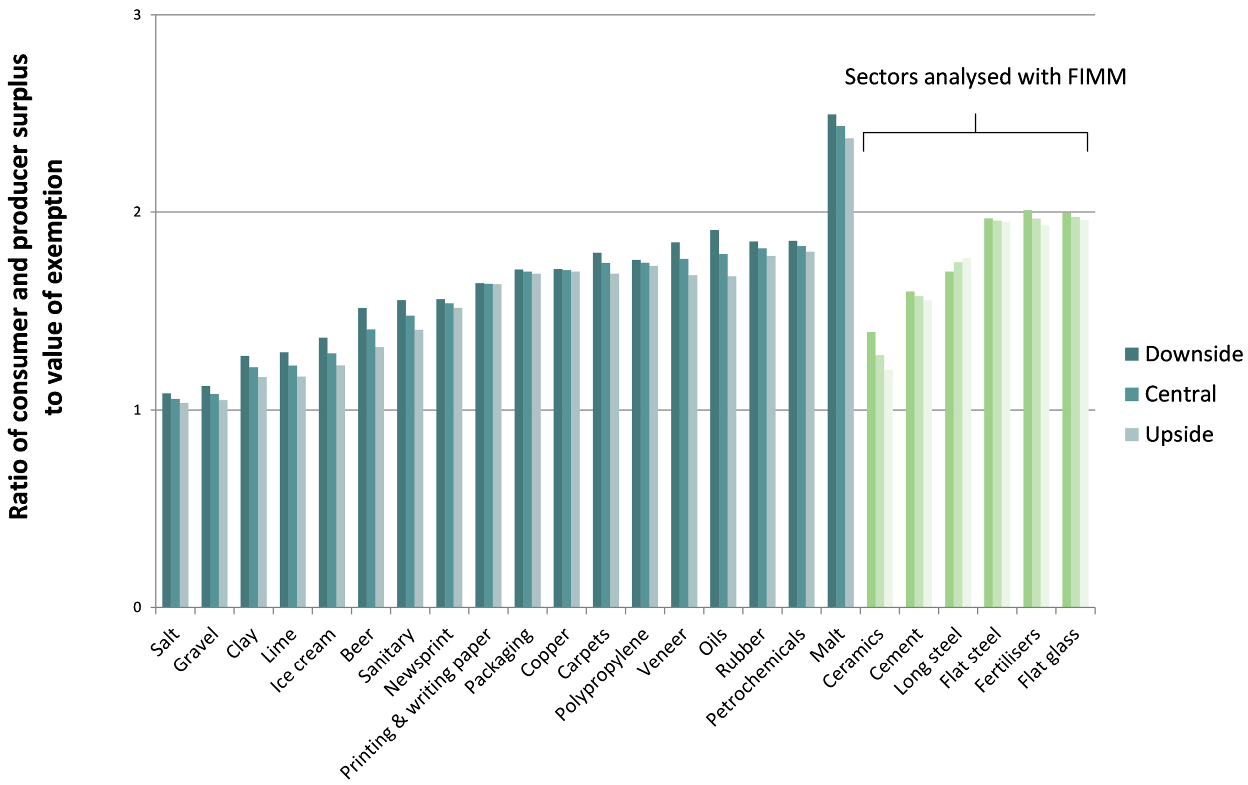
Benefits of exemption

To assess the net impact, or value for money, of the exemption, the costs and benefits are compared on social welfare grounds.

Producer and consumer surplus

Using the IMM model the welfare benefit of the exemption to exempt sectors is estimated by calculating the producer and consumer surplus: that is, broadly speaking, the benefit to consumers from lower prices, and the benefit to producers from higher profits. The IMMs indicate that most of the benefits accrue to producers, while a relatively small fraction is received by consumers. In many cases the sum of the benefits to producers and consumers generated by the exemption is close to £2, and higher in some instances, for every £1 of exemption granted, see Figure 3. Value for money is found where sectors cannot pass on costs to customers without losing market share to overseas rivals. These sectors have high electro-intensity, low margin and high overseas market share in the economic market (whether that is UK, EU or global). However, these value for money estimates reflect a partial analysis of the benefits of the exemption to exempt sectors, since they do not consider the associated welfare costs on non-exempt consumers.

Figure 3. **A large number of sectors show a value for money ratio from exemptions exceeding 1.5 (core scenario, 2020)**



Source: *Vivid Economics*

Sensitivity analysis for IMM

As noted, data was gathered from a range of sources, ranging from government agencies to industry associations. Some of the inputs to the modelling are potentially sensitive, such as gross profit margins, or innately difficult to estimate, such as demand elasticity. Given the associated uncertainties, sensitivity analysis at the sector level is used to provide an indication of the likely effect of varying such parameters. For the most part movements within likely possible ranges do not have a significant impact on the overall narrative of the results or likely value for money estimates. The sensitivity analysis is also useful for illustrating some of the mechanisms within the model: for instance, that sectors become much more sensitive to competition from foreign rivals when their profit margins are low.

Costs of exemption

As explained earlier, an exemption results in higher electricity costs for non-exempt consumers. The MDM-E3 macroeconomic modelling considers the costs and benefits of the exemption within a single modelling framework, and suggests grounds for caution. It shows a negative effect on household incomes which is marginally larger than the positive competitiveness effect, although the overall net impact of the exemption on GDP is small, to the extent of being negligible. This is partly because a part of the benefit of the exemptions is passed on to foreign purchasers of UK export products. Depending on the mix of sectors subject to exemptions, and their relative dependence on exports, the strength of this effect may be stronger or weaker.

Other impacts

Income distribution
The prices of typical consumption bundles across income groups change as a result of the exemption. There is a somewhat larger percentage increase in the prices facing lower income households than higher income deciles. The relative effects on low and high income households appear stable across the policy options.

Carbon emissions
Using a macro-econometric model, the impacts on carbon emissions were estimated to be small, at around 0.5 $mtCO_2$ per year in 2030, and less in earlier years. This is for two reasons. First, the macro-econometric model generates smaller estimates of impact than the industrial market model, as discussed elsewhere. Second, increases in electricity consumption by exempt industries are offset by decreases in electricity consumption in non-exempt sectors. The ongoing decarbonisation of the UK power sector out to 2030 will also lower the impact of changes in electricity demand on carbon emissions.

The impact on carbon emissions at the UK level is distinct from the global impact. Where UK sectoral carbon-intensities are lower than those of non-UK rival firms, increases in UK producers' market shares may result in a decline in net global emissions.

Other impacts
Other impacts of the policy that may be of interest to policymakers, such as employment effects, and particularly regionally-concentrated employment effects, are also recognised and discussed.

Conclusions

Detailed investigations of the impacts on individual sectors, based on theoretical models calibrated to actual market conditions, suggests that there is value for money in exempting sectors most exposed to international competition. The sector-level changes estimated using an alternative model, macro-econometric in structure, are substantially smaller. The two models each bring advantages and limitations, and in drawing conclusions it is best to consider the results together, bearing their relative merits in mind.

If a cautious approach is desired, more weight would be given to the microeconomic model results, so as to avoid the possibly irreversible adverse effects of production declines. Considering all the evidence together, there is a value for money case for exempting some, but not all, electro-intensive sectors from CfD support costs. The costs to the economy will be negligible and the benefits from preserving competitiveness could be significant.

Contents

List of tables

List of figures

List of boxes

1 Introduction and approach

Evidence to assist in the design of efficient funding of the UK low carbon power programme

Section contents:

Impacts of policy options on individual sectors and the wider economy
Contracts for Differences (CfDs) will fund an increasing proportion of the UK's low carbon power generation and underpin a key part of the UK's low carbon investment programme. Critical to the efficiency of the policy is the cost of funding. Here, the choice of how widely to spread the support costs and, in particular, whether to offer exemptions to electricity-intensive sectors will affect the value for money of the whole policy.

The work considers the benefits of exemptions for sectors and the costs to sectors which shoulder additional funding responsibilities as a result of the exemptions. It reports value for money estimates for a range of policy options and sector scenarios in 2016, 2020 and 2030.

1.1 Introduction

The efficiency of funding of the UK low carbon energy programme

1.1.1 Aims

This report investigates the costs and benefits of exemptions for energy-intensive industries from CfD FiTs (Contracts for Difference Feed-in Tariffs) support costs. This introduction provides some background on the policy context of this research, as well as a brief overview of the intended approach.

1.1.2 CfDs are considered an efficient way to support a large-scale low carbon energy programme

Under the Electricity Market Reform (EMR) package, the UK Government intends to use contracts for difference to provide price certainty for low carbon energy generators. When the price of electricity is below the ‘strike price’ specified in the contract, the generator will be compensated for the shortfall. Conversely, when the price of electricity is above the strike price, the generator will pay back the surplus.

This is intended to decrease uncertainty in investment returns for investors in low carbon energy, reducing the cost of finance and increasing the amount of investment. This contributes to the long-term aim of decarbonising power production and to medium-term targets for renewable energy production.

CfDs will be signed and managed by the CfD Counterparty, a publicly owned company. The difference between strike prices and reference price determines the support costs of CfDs. Electricity suppliers will be called upon to fund these costs, and it is assumed in turn that the costs will be fully passed on to electricity consumers, including industry.

The impact of CfD support costs will vary by industry. The immediate impact on the costs of production will depend on the electro-intensity of production in that sector. The consequent impact on production and prices will also depend on factors such as the threat of competition from foreign producers and the nature of consumer demand.

Since, from the perspective of the whole economy, the negative impact of CfD support costs may be substantially greater in some industries than others, it is possible that by allowing exemptions for selected sectors the same total quantity of revenue and support for low carbon energy can obtained with lower associated costs. This proposed system of allowing exemptions from CfD support costs is the subject of this document. Note the scope of this work does not include an assessment of the CfD policy more broadly nor any other aspect of electricity market reform.

1.2 Evidence for an impact assessment

Models to elicit impacts at sector and whole economy level

1.2.1 Choice of models and sectors

While the exemption of electro-intensive industries (EIIs) from CfD support costs might be justified on the grounds that such industries would otherwise be disadvantaged relative to their international competitors, any exemption narrows the base of consumption from which the support is funded and increases costs for non-exempt industries.

To evaluate the overall impact, the policy can be subject to cost-benefit analysis. This analysis identifies relevant costs and benefits should the policy be enacted, and compares them with a counterfactual case where the policy is not enacted. It looks over the whole life of the policy. It provides the raw evidence for the cost-benefit analysis.

1.2.2 Exemption scenarios are compared with a counterfactual

The choice of counterfactual is an important element of cost benefit analysis. The comparison isolates the policy change of interest.

This study answers the question: what is the value of exempting electro-intensive industry from the cost of funding CfDs? To answer this question, the models compare a scenario in which the CfDs are put in place without exemptions for electro-intensive industries to one where exemptions are offered.

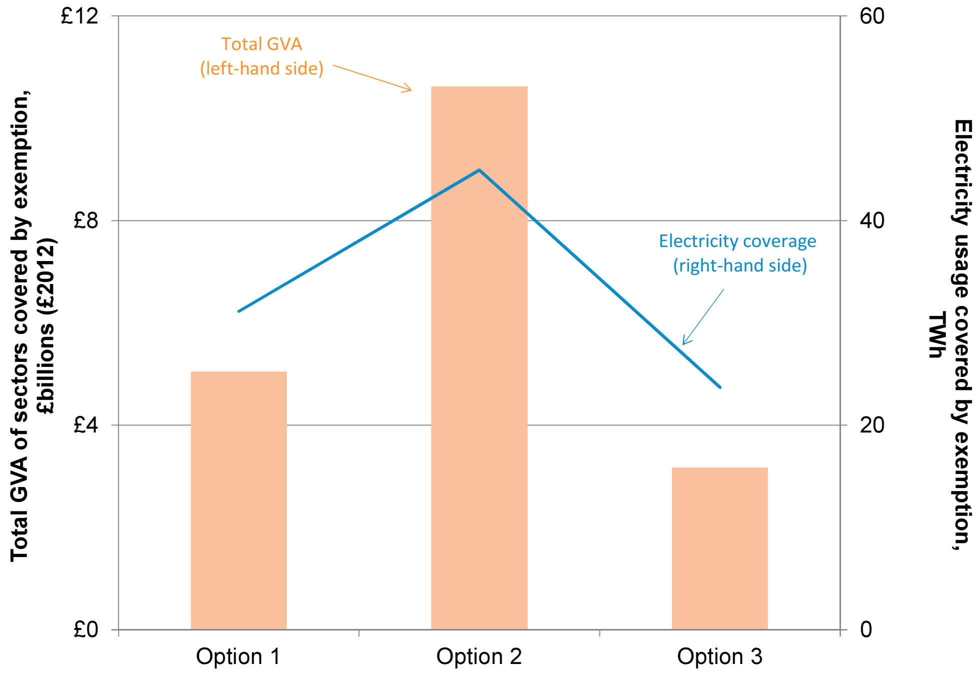
Six exemption policy scenarios are considered, see Table 1, applying exemption rates of between 50 and 80 per cent to a range of sectors. A seventh special case scenario, where 100 per cent exemption is applied to all industrial sectors, is also tested. The exempt sectors are identified as eligible using the same rules or criteria as for compensation under Carbon Price Support (CPS) and the EU Emissions Trading Scheme (ETS). Detailed information on exemption rates for individual sectors under each scenario is included in Appendix G. An indication of the scope of the policy scenarios is shown in Figure 4. These scenarios, and their labelling, are consistent with those published in the consultation for an exemption from the costs of Contracts for Difference, see DECC & BIS, 2013. Note that Option 3a and 3b in Table 1are equivalent to the lower bound of the Option 1a and 1b range, as presented in DECC & BIS consultation document. To provide a sense of the extent of coverage, Figure 4 provides an overview of total sectoral GVA and electricity usage under the different options.

Table 1. **Policy scenarios targeted in this report**

Policy name	Description
Option 1a – 'Compensation mirror'	80% exemption for proposed sectors eligible under CPS and ETS
Option 1b – 'Compensation mirror'	67% exemption for proposed sectors eligible under CPS and ETS
Option 2a – 'Compensation +'	80% exemption for an expanded set of sectors
Option 2b – 'Compensation + Taper'	80% exemption for proposed sectors eligible under CPS and ETS, 50% exemption for remaining sectors included in Option 2a.
Option 3a –' Narrow compensation'	80% exemption for a narrower set of sectors
Option 3b – 'Narrow compensation'	67% exemption for a narrower set of sectors
Option 4 – 'Limit test'	100% exemption for all industrial sectors

Source: *DECC, BIS*

Figure 4. **Policy scenarios vary widely in their GVA and electricity usage coverage**



Notes: *GVA is based on sector estimates for 2009, while electricity data is 2007 vintage. Later data with wide coverage across energy intensive industry is unavailable, with GVA estimates for many sectors of interest suppressed to avoid disclosure.*

Source: *ONS, 2013; DECC, 2013*

:vivideconomics cambridge econometrics

1.2.3 The analytical approach makes use of multiple modelling techniques

The costs and benefits of the exemption encompass both macro- and microeconomic effects. For example, macroeconomic redistributive effects on household incomes and output (GDP); impacts on individual industries and regional employment are microeconomic.

Vivid Economics and Cambridge Econometrics have come together to combine their expertise and modelling assets to give insights into both the industry-level and whole economy effects of the policy. Specifically:

- Vivid Economics' Full and Reduced Industrial Market Models (FIMM and RIMM) are used to evaluate impacts on specific sectors (FIMM involves detailed analysis down to, at least potentially, the level of individual productive facilities, while RIMM has a much more aggregated split between broad geographic regions); and
- Cambridge Econometrics' MDM-E3 is used to evaluate macroeconomic impacts on the overall UK economy.

The costs and benefits are assessed over the period 2016 to 2030.

1.2.4 Uncertainty is considered through non-policy scenarios

The value for money (VfM) of an exemption will reflect the future characteristics of electro-intensive industries. Since the size and competitive structure of these markets is somewhat uncertain, market scenarios are used to test the robustness of the exemption policy to future situations.

The scenarios were chosen to explore variation in a small number of parameters, to ease presentation of the final results. They span a wide variety of economic outcomes, for instance, that might result in UK production growing at a significantly faster or slower rate than its competitors. For sectors analysed with FIMMs and RIMMs, upside and downside scenarios were constructed in addition to the central estimates that were taken from projections in MDM-E3. These scenarios are included in various places when reporting results. They are as follows:

- for RIMM sectors, while growth in the non-UK market, which was comprised of either imports into the UK or EU production plus imports into the EU, remained calibrated to projections in MDM-E3, growth in domestic production was varied by either 2 per cent less per annum (for the downside scenario) or 2 per cent more (for the upside scenario);
- for FIMM sectors, in addition to the growth variation applied for the RIMM sectors, a gas price shock was also applied, based around gas price projections supplied by DECC. The shock was applied to all EU producers, with the gas-intensity of production based on DECC numbers for sector gas usage combined with production estimates. The size of the shock had the EU facing gas prices either approximately 10 per cent higher (downside) or 10 per cent lower (upside) than its competitors.

These variations are summarised in Table 2. The growth rate variation of plus or minus 2 per cent was judged to be within the realm of economic and historical feasibility while being large enough to produce an exhaustive range of results over a long time period. For comparison, a similar scenario exercise from

PricewaterhouseCoopers had variations in total UK GDP of plus or minus 1 per cent (PwC, 2009). The larger figure of 2 per cent would be unsurprising at the sector level. The gas price variation of plus or minus 10 per cent was also considered feasible based on historical gas prices, though further consolidation of global gas markets will likely decrease divergence over time.

Table 2. **Construction of upside, central, and downside scenarios for the Industrial Market Models**

Variable	Reduced Industrial Market Model	Full Industrial Market Model
Growth rate of EU production	In upside and downside scenarios: growth rates are 2 per cent higher or lower than the relevant sectoral projections from MDM-E3	In upside and downside scenarios: growth rates are 2 per cent higher or lower than the relevant sectoral projections from MDM-E3
Growth rate of non-EU production	In line with MDM-E3 projections for import growth into the UK across all scenarios	In line with MDM-E3 projections for import growth into the UK across all scenarios
Natural gas prices faced by EU producers	Unchanged across scenarios	In upside and downside scenarios: natural gas prices are 10 per cent lower or higher
Natural gas prices faced by non-EU producers	Unchanged across scenarios	Unchanged across scenarios

Source: Vivid Economics

In the downside scenarios, UK and EU firms generally find themselves with a lower market share. This combines a lower growth rate relative to their competitors and higher gas prices. Within the IMMs, a lower market share is interpreted as a fall in competitiveness. This results in exemptions generally providing a greater proportional benefit for that sector, though, as the sector is smaller in size, it is not necessarily the case that the value of the change in production is greater. The converse holds in the upside scenarios. Note that there is a large number of factors that might drive such variations in market size.

2 Sectors and models

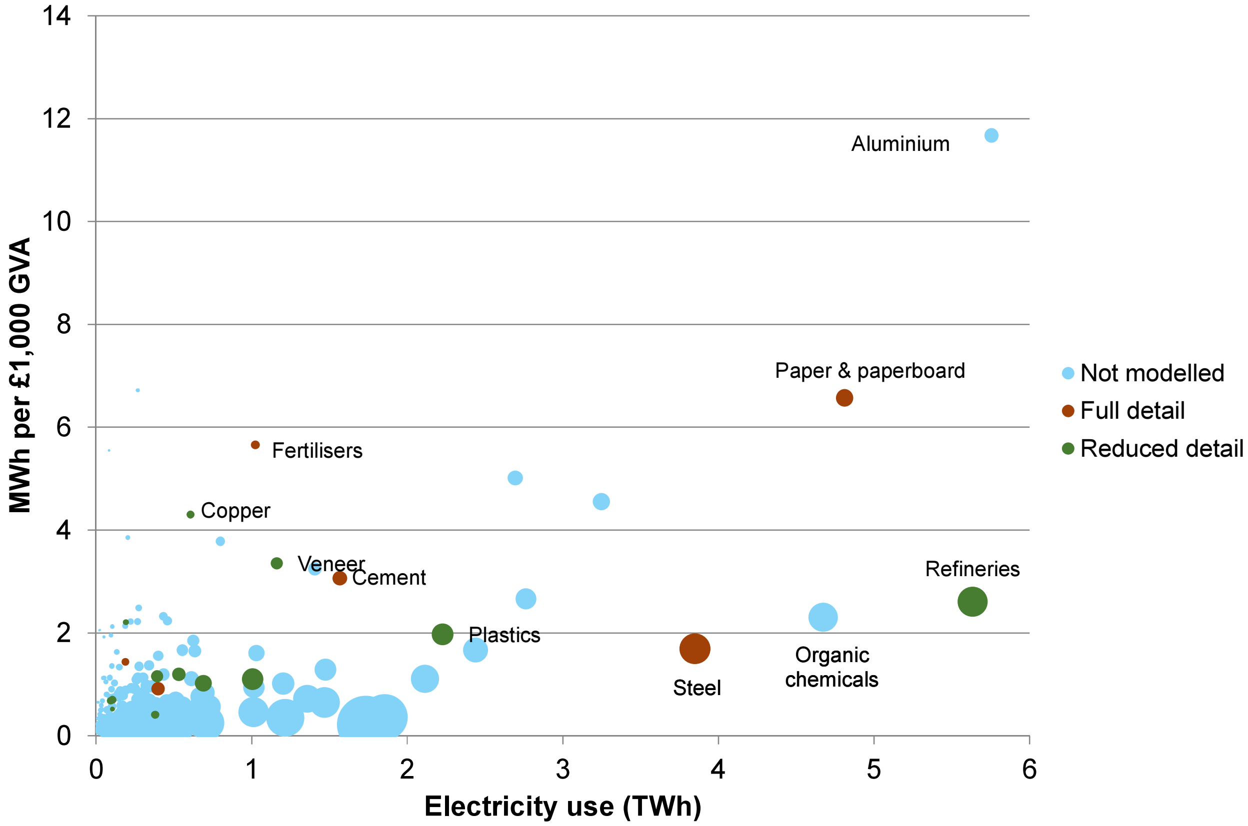
Twenty sectors and economy wide effects

Section contents:

Twenty sectors selected for individual modelling

Twenty electricity-intensive sectors were investigated, six in full detail and 14 in less detail. They have diverse characteristics and, in some cases, national or regional economic importance.

Figure 5. **Sectors investigated vary in both size and electricity usage**



Note: *Size of circle corresponds to GVA.*

Source: *DECC, ONS, Vivid Economics*

2.1 Selection of sectors

A diverse range of sectors

2.1.1 Introducing the sectors

Six sectors were investigated in full detail. Five of these were modelled with the FIMM approach; one, paper manufacturing, was investigated using RIMMs to explore several subsectors, to make the best use of available data.

The sample of sectors meets several criteria:

- to be representative of the UK manufacturing sector;
- to examine the situation faced by sectors particularly exposed to higher electricity prices, who might be most likely to be the recipients of an exemption;
- to investigate the impact of additional factors of influence, such as degree of trade exposure;
- to reflect particular issues likely to be associated with costs and benefits, such as carbon emissions or employment.

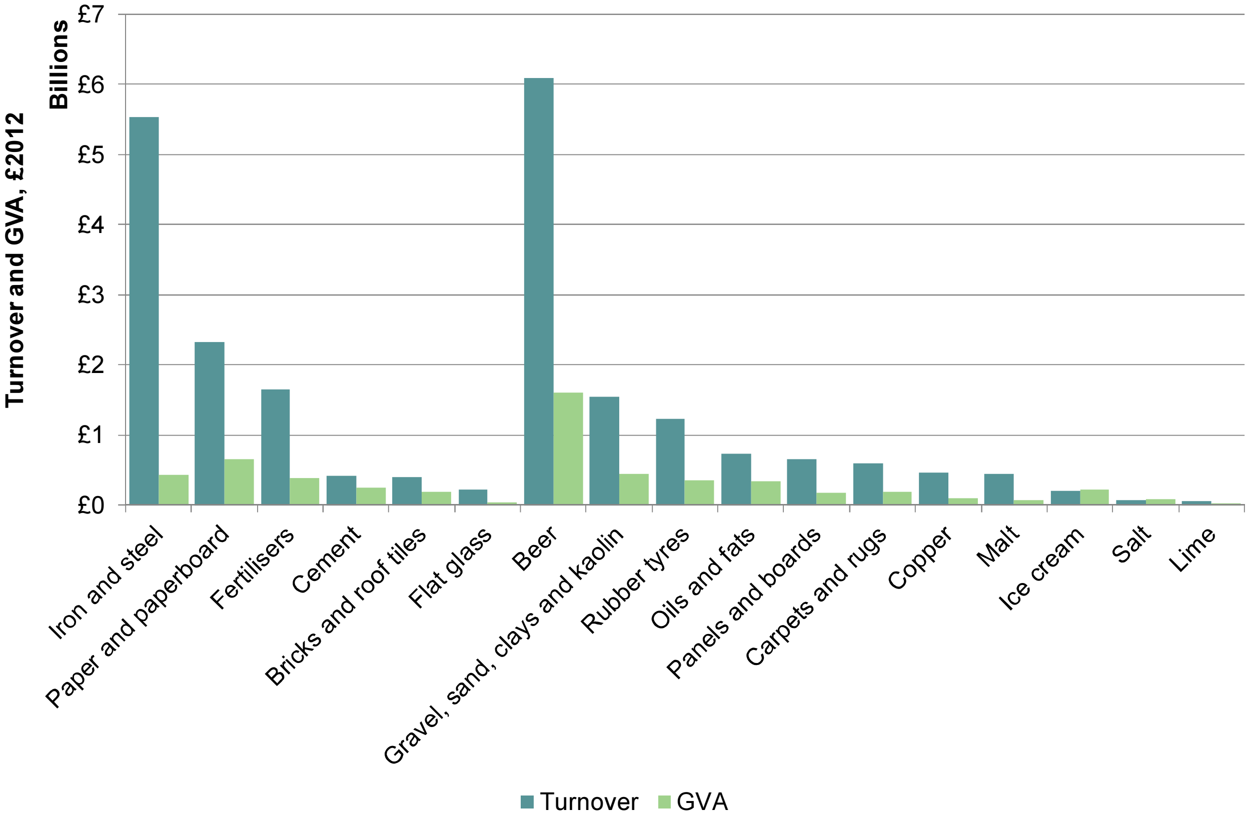
In choosing sectors, Vivid Economics took into account their suitability for analysis using the IMMs. This includes the extent to which the output of the sector is a homogenous commodity, the degree to which there is a clearly defined market and market price for the good, and the availability of data.

The six sectors investigated in detail were:

- paper, fertiliser, flat glass, and steel manufacture, which are highly electro-intensive and extensively traded internationally, and thus seemed likely to be relatively strongly impacted by electricity price rises. Furthermore, steel production is particularly of employment interest because it tends to be concentrated in regionally deprived areas, and fertiliser has the feature of exposure to changes in international production costs due to movements in gas prices;
- cement and ceramics manufacture are all also electro-intensive, but were thought before commencing the work to potentially be closer to the margins of exemption eligibility. Cement is not widely internationally traded today, but it may be that international rivals could contest the UK market.

A further 14 sectors were selected for analysis at a somewhat less detailed level and were modelled using RIMM. These sectors were, on average, both less electro-intensive and less trade exposed, though this is not true in each individual case. Along with the range of turnover and GVA shown in Figure 6, the electro-intensity and electricity use of the sectors investigated is shown in Figure 7, illustrating the diversity of the sectors studied. The intention partly was that this selection of sectors would provide a sample along a hypothetical 'value for money curve', where sectors can be ranked in terms of the extent to which an exemption would be in the public interest.

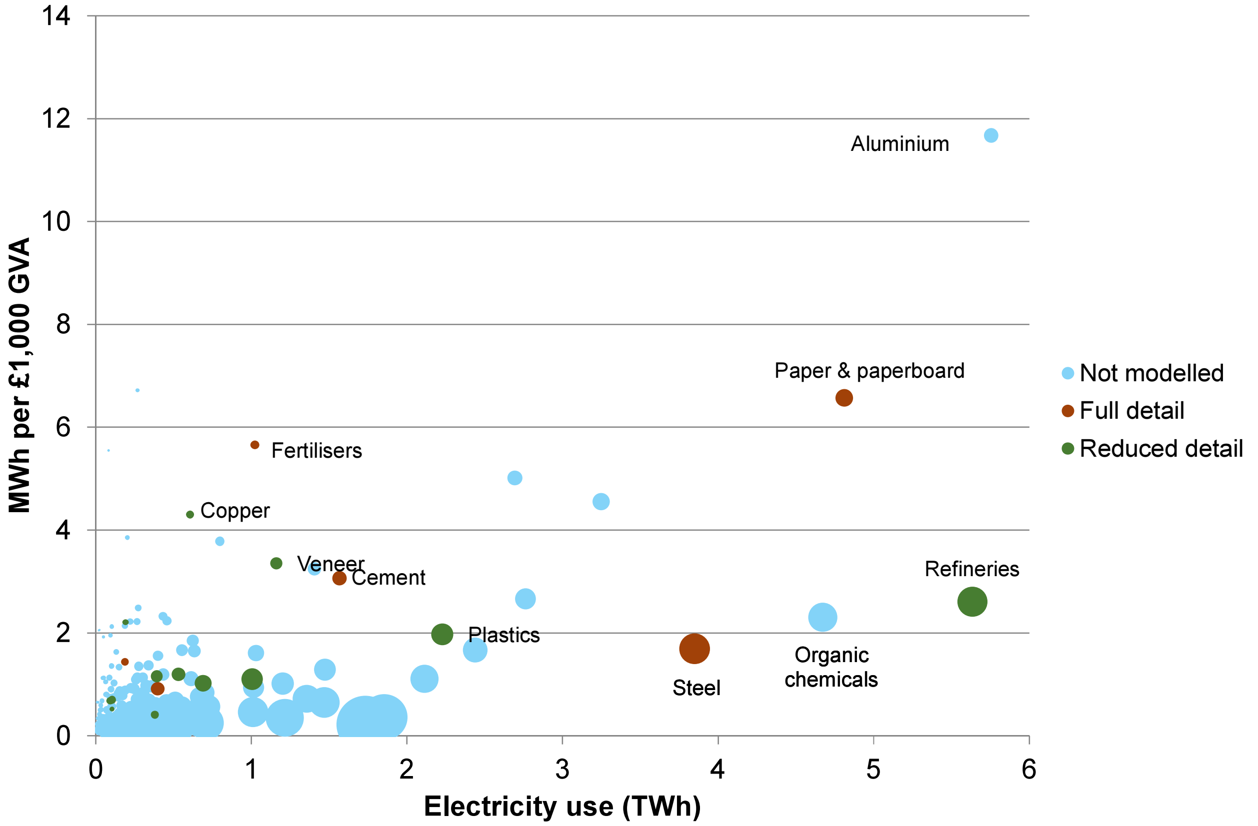
Figure 6. **Sectors investigated with the Industrial Market Models span a range of sizes and GVA levels**



Notes: GVA and turnover are based on 2009 data, with the exception of the 'fertilisers and nitrogen compounds' sector, which is based on 2008 data. For scaling reasons, the petrochemicals sector (the manufacture of refined petroleum products) is excluded; petrochemicals GVA was around £1.4b in 2008, with turnover of around £39b .

Source: Vivid Economics

Figure 7. **The sectors investigated span a range of electricity intensities and total electricity consumption**



Notes: *Size of circle corresponds to sector GVA. Includes all manufacturing and mining sectors with data available on electricity usage. Latest data on electricity usage is from 2007. Sector GVA from 2007 is also used to ensure consistency. The outlier to the upper right is the aluminium sector. Although the aluminium sector exhibits a high level of electro intensity in the chart above, current aluminium sector capacity is significantly lower than when the relevant data was collected in 2007, as a result of the closure of Anglesey Aluminium (2009) and Rio Tinto Alcan Lynemouth (2012). There is only one remaining primary smelter, Rio Tinto Alcan Lochaber. In addition to aluminium, the organic chemicals sector was also not analysed for this study, due to the unavailability of appropriate data.*

Source: *DECC, ONS, Vivid Economics*

2.2 Detailed sector models

Estimating overseas competition

2.2.1 Introducing the sector models

Vivid Economics has an Industrial Market Model (IMM) which analyses the interaction between rival firms and consumers within asset-intensive industries, such as an electro-intensive goods market. The model is well-suited to industrial sectors in which firms have high fixed costs, such as electro-intensive industries. The model shares the same underlying economic pedigree as the qualitative Porter's Five Forces model, widely used in corporate strategy analysis, and Cournot's model of oligopoly, familiar to academic economists.

The model comes in two forms: the Full Industrial Market Model (FIMM), which incorporates information on individual facilities within the market, and the Reduced Industrial Market Model (RIMM), which takes a more aggregated approach. These may be referred to collectively as the 'IMMs'.

2.2.2 Markets are identified before applying the models

Before either version of the model can be applied, it is necessary to define the economic market. Markets do not necessarily coincide with sector definitions in public statistical sources. For instance, as noted before, the ceramics sector contains types of ceramics that are not in competition with each other. Further, markets are defined not solely by the substitutability of their outputs, but also by geographical scope. In particular, products which are expensive to transport relative to their value are best treated from a modelling perspective as involving competition only within a particular area.

Some sectors, such as ceramics, were narrowed down to heavy clay ceramics, for the purpose of modelling a market. Paper, another example, was split into four subsectors to ensure appropriate product scope. Each market was classed as being UK or EU. This was determined either with reference to European Commission judgments on competition cases (which make use of the 'hypothetical monopolist' test, that is, considering the scope of the market to be defined as no wider than the widest definition necessary for a monopolist of that market to be able profitably raise prices by some reference level) or by examining the share of imports and exports as a proportion of the UK and EU markets. The outcome by sector is summarised in Table 3.

Table 3. **Market scope by sector**

UK-level sectors (full detail):	Cement	Heavy clay ceramics	Sanitary				
EU-level sectors (full detail):	Fertilisers	Flat glass	Printing & writing	Newsprint	Steel (long and flat)	Packaging	
UK-level sectors (less detail):	Ice cream	Beer	Clay	Gravel	Lime	Oils	Salt
EU-level sectors (less detail):	Veneer sheets	Copper products	Carpets	Petroleum products	Poly-propylene	Rubber products	Malt

Source: Vivid Economics

2.2.3 The model incorporates behaviour of firms and consumers

The model encompasses Cournot competition, where firms have market power and firms decide what quantities of goods to produce, and extends to Bertrand competition, featuring price competition. Real world firm behaviour can be difficult to reconcile with the narrow predictions of either of these pure conceptions of markets.

Traditional economic models assume that firms act to maximise profit, but in reality firms often diverge from this model. Executives may be incentivised, through their contracts, to maximise market share or sales instead. Aggressive firms may temporarily pursue market share to force competitors out of the market and create permanent competitive advantage. The IMMs capture these alternative behaviours.

To introduce this flexibility, the model is calibrated to the competitive outcomes observed in the sector. A parameter is adjusted until the profit margins match observed conditions. The parameter value reveals the aggressiveness of competition, which, among other things, shows the degree to which firms pursue maximisation of market share as against maximisation of profits. In this way, the model reflects behavioural differences between sectors.

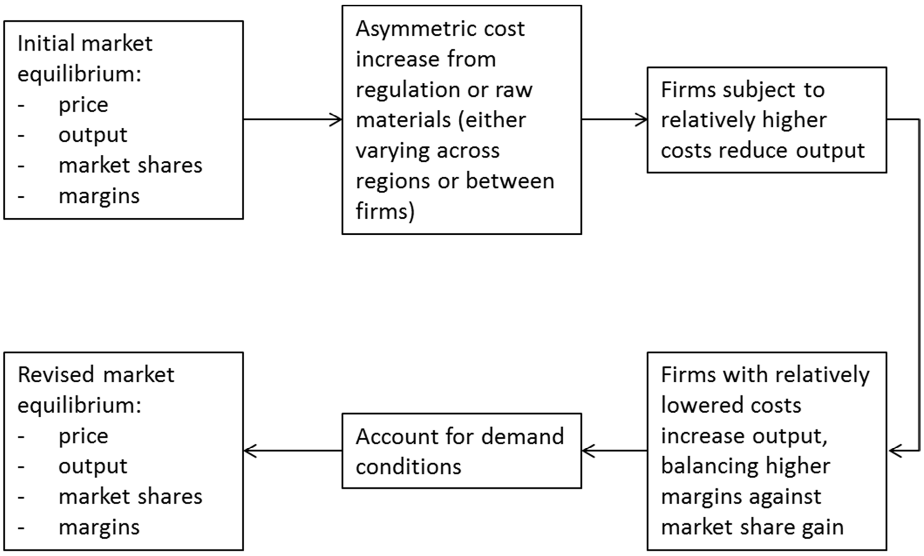
2.2.4 The FIMM depicts market conditions for individual installations

FIMM analysis proceeds in three broad steps, which are depicted graphically in Figure 8:

- first, for the selected market, data is compiled on market prices, quantities sold, the market shares of individual productive installations within the market and the intensity of electricity use. The model uses this information to estimate the marginal costs of production at each plant, which can be calibrated against information obtained elsewhere;
- second, an estimate is made of the impact of exemptions from CfD support charges on firms' production costs using data on electricity intensity;
- third, a new equilibrium is calculated, reporting any changes in market share, price and quantity. This process is undertaken for each market in 2016, 2020 and 2030 and is illustrated in Figure 8.

Some steps of the process may be simplified to suit available data. Projections made by MDM-E3 were used to inform scenarios of future market conditions. As the sector definitions in MDM-E3 are more aggregated, the projections used were in many cases for more aggregate sectors. For example, future production in the steel sector was given by MDM-E3's 'Basic metals' sector projections.

Figure 8. **FIMM involves shifts between static equilibria; the process for RIMM is the same, but without reference to individual firms**



Source: Vivid Economics

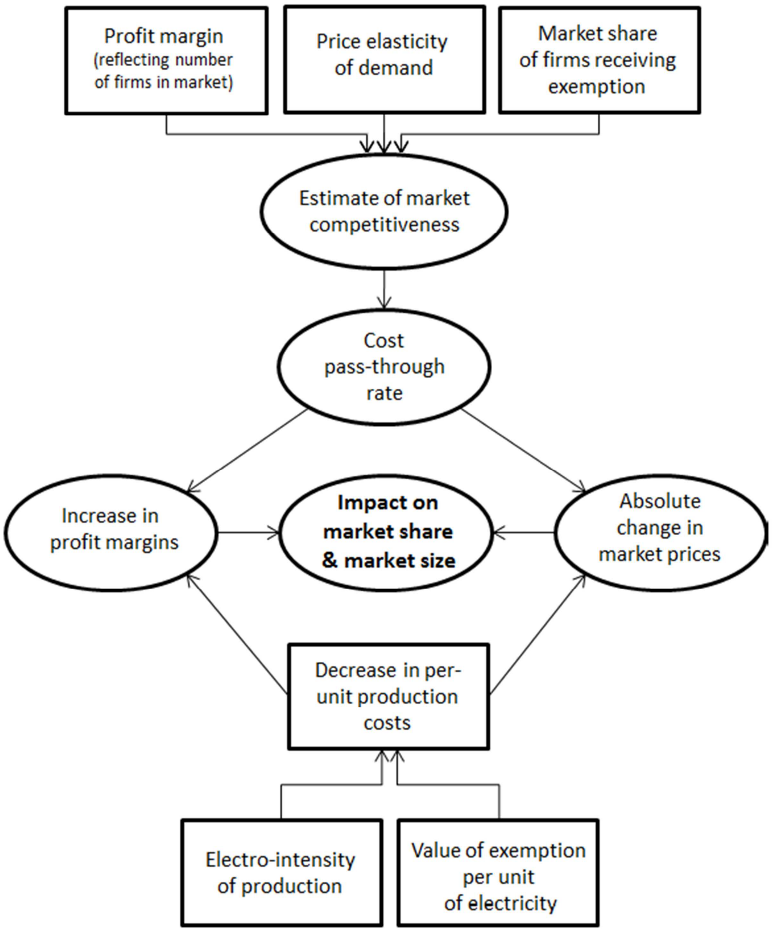
Figure 9 provides a graphical depiction providing more detail on how firms respond to cost shocks in the model. The change in market prices and total quantities of production are a result of the cost pass-through rate and the production decisions of individual firms. Note that the 'cost pass-through rate' is defined as the relative extent to which the benefit of the exemption is passed on to consumers in the form of lower prices (that is, a cost pass-through rate of 25 per cent would suggest that for every £1 reduction in per-unit costs resulting from the exemption, the sale price of the product would reduce by 25p).

Figure 9 shows that parameters such as market share, demand elasticity, and profit margins are used to calibrate the model's estimation of the degree of competitiveness in a market, which then determines the cost pass-through rate. That is to say, ultimately, cost pass-through is determined by:

- the market share of UK producers (a strong import presence suggests UK producers have less influence on the market price, and cost pass-through will be lower);
- profit margins (high UK profit margins suggest that the domestic market is less competitive, with lower cost pass-through);
- the elasticity of demand (the more responsive are consumers to price, the lower the cost pass-through rate).

This is discussed further in Section 5.3.1. Cost pass-through in turn influences the change in profit margins and the absolute size of the change in market prices. In conjunction with the absolute size of the exemption, the impact on production is driven both by increased demand (as a result of lower prices) and rising market share (as exempt producers enjoy greater profitability). Additional complexity, such as the closure of individual installations, is not included in Figure 9's depiction. A more detailed explanation is contained in Appendix I.

Figure 9. **Simplified depiction of Industrial Market Model structure**



Source: *Vivid Economics*

2.2.5 The approach has advantages and disadvantages

To summarise the key features of the model:

- it explicitly represents firm-to-firm (in FIMM) and consumer-to-firm interactions encompassing a range of profit-maximising and sales-maximising behaviours
- it allows for changes in output within existing firms or assets as well as entry or exit (in FIMM);
- it allows consumer behaviour, whether price sensitive or insensitive, to be included;
- it considers each firm or major asset individually (in FIMM), allowing differences in unit cost or behaviour on a firm by firm basis;

- it is based upon the well understood Cournot quantity competition economic framework, with flexibility to encompass a full spectrum of competitive dynamics, including Bertrand price competition;
- it allows for cost differentials across national or administrative boundaries;
- it uses input data which is generally publicly available, which is particularly useful in public sector analysis where commercially confidential data is not available;
- it produces a wide range of output metrics which are of interest; and
- it can be calibrated, audited, and subject to sensitivity and scenario analysis.

In the context of the project at hand, the approach has several key advantages:

- it finds the destination and magnitude of output and emissions leakage; and
- it can integrate qualitative information gathered during expert interviews.
- it explicitly accounts for strategic interactions between firms (in FIMM) when determining cost pass-through, rather than relying on aggregate relationships.

Note that output leakage refers to replacement of domestic production with foreign production. Emissions, or carbon, leakage refers to the offsetting of declines in domestic emissions by increases in emissions elsewhere. It is possible to refer to both through the use of a percentage rate; for instance, an output leakage rate of 60 per cent implies that for every 100 units of lost UK production, imports into the UK increase by 60 units.

In contrast to RIMM, the application of FIMM requires the collection of firm level data. This renders its application to a large number of sectors prohibitively time-consuming.

The models also assume that the market is in equilibrium before the cost shock is introduced. This implies that all firms are optimally responding to the production strategies of their competitors, and that, in the absence of a cost shock, firms would not adjust their production plans. This may not be the case; firms may be in the midst of expanding capacity, or on the verge of shutting down. Information gained from interviews may be useful in anticipating these changes.

An assumption is made about the shape of the demand curve. For simplicity, in the context of this research, demand is assumed to be linear; in conjunction with estimates of demand elasticities and market size, this results in a full specification of the demand curve. The inaccuracies induced by this assumption are likely to become larger as any investigated shock increases in size. Other specifications – such as constant elasticity – are possible.

The model does not attempt to capture wider knock-on effects of exemption. The Industrial Market Model implicitly holds overall demand constant, with consumers altering which goods and services they purchase due to changes in relative prices rather than changes in income. Yet any change in prices, quantities, and employment levels at the sector level will have consequences elsewhere in the economy, especially in the sector's supply chain.

The analysis concentrates on the larger players within a sector. Small firms or assets are likely to produce more specialised products and will be unable to realise the economies of scale enjoyed by larger consumers. In the absence of detailed firm specific data, it is harder to take the smaller firms into account, and their inclusion may make sectors appear more competitive than, in reality, they are.

2.2.6 RIMM is similar to FIMM, with some simplifications

The RIMM approach enables estimation of the industrial impacts of exemption using simplified data. Additional discussion of the details of RIMM analysis, besides that found in Appendix I, is provided in Ritz (2009).

As before, firms within a market face an asymmetric cost increase. Cost changes occur due to the exemption affecting electro-intensive firms within the UK, but not firms outside the UK.

A key advantage of the RIMM is its lower data requirement. It generates close approximations to FIMM outputs under some simplifying assumptions:

- the electricity intensity of production is the same across all firms in the UK; and
- the electricity intensity of production is the same across all firms outside the UK

2.2.7 Basic outputs are the same across the Industrial Market Models

In both FIMM and RIMM the key model outputs are:

- cost pass-through;
- total change in UK sector output;
- total change in foreign output; and
- changes in market prices

These outputs lead to estimates of a number of additional effects, including:

- change in employment;
- change in consumer welfare;
- carbon leakage; and
- change in profits.

FIMM estimates allow for some additional precision in these outputs. For instance, with regards to output leakage: FIMM calculates distinct changes in production for each import partner; RIMM calculates changes at the level of aggregate imports, which then must be assigned to import partners after the modelling process. In this work, the aggregate change was assigned proportionally to each import partner's share of sector imports into the UK.

2.3 The whole economy model

A full macro-econometric model of the UK with energy and trade

2.3.1 MDM-E3 has various useful features

Cambridge Econometrics' multi-sector dynamic model of the UK economy, MDM-E3, is designed to answer a range of policy questions concerning energy, the environment, and the economy. MDM-E3 was originally developed as part of the Cambridge Growth Project by the University of Cambridge. In 1985, Cambridge Econometrics was set up to provide commercial access to the model and to develop it further.

The model captures and represents the impacts at the macro, industrial, regional and energy system levels simultaneously within a single framework. The model is demand-driven, based on post Keynesian macroeconomics. MDM-E3 emphasises empirical relationships, using time-series data sets underpinned by economic theory. It is based on the structure of the national accounts and provides a coherent, empirically validated framework for analysis, including feedback and multiplier effects and well-defined links between economic sectors. MDM-E3 was recently reviewed by the National Audit Office, which described it as one of the most sophisticated macroeconomic models of the UK available (National Audit Office, 2007).

Notable elements of MDM-E3 include:

- it models the UK economy in sector detail, distinguishing 87 sectors;
- it splits the UK into 12 regions, corresponding to the 9 former government office regions of England, plus Wales, Scotland and Northern Ireland.
- it is 'general' rather than 'partial' in nature, that is, it aims to capture second and third round effects as other parts of the economy adjust to a change in one sector;
- it combines some of the features of a Keynesian macroeconomic model (the expenditure components of final demand are modelled, but disaggregated by sector products) with an input-output structure (which is used to determine intermediate demand for products and also to calculate the unit cost of production in each industry from the prices of the inputs that are purchased);
- it has a specialised treatment of energy use and distinguishes between forms of energy;
- it is solved in annual time steps;
- it is particularly well-suited to analysing issues surrounding carbon emissions; and
- it models the economy in disequilibrium, with dynamic adjustment from one year to the next.

2.3.2 Several steps are involved in modelling the impact of CfD exemptions

MDM-E3 is used in the following way to estimate the effects of exemptions from CfD support costs:

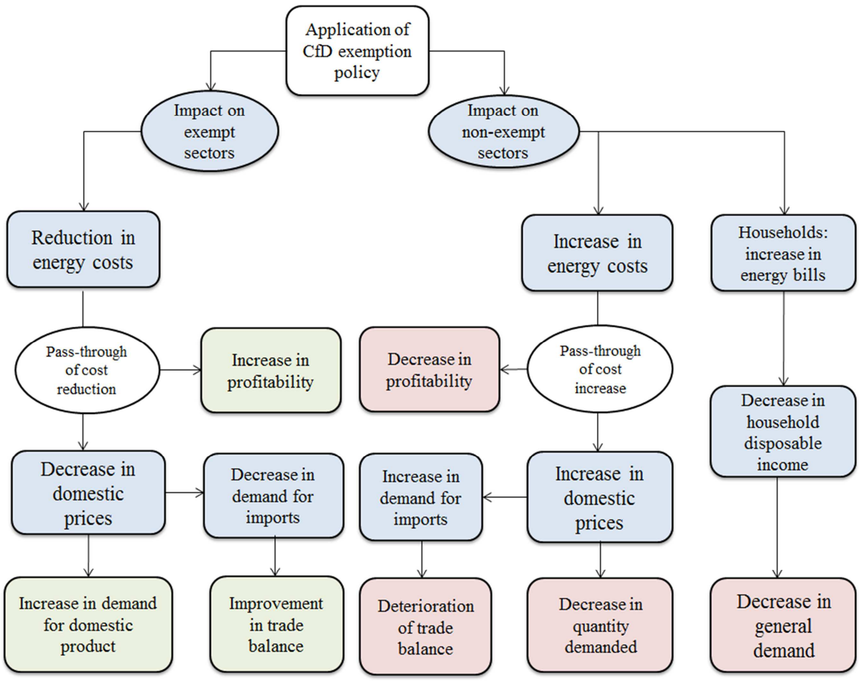
- initially, a baseline (or counterfactual) is estimated with reference to DECC energy projections;
- UK electricity prices faced by energy-intensive industries and other electricity consumers are changed to reflect the CfDs exemption and the compensating price increase to non-exempt consumers required to fund it;
- energy users adjust their use of electricity and other fuels in response to the changing price;

– the net impact of changed electricity prices and changed volume of electricity (and other energy types) used is reflected in changes to the unit costs of production of each industry;
– the extent to which those changes in unit costs are passed through into the prices of industry output is calculated, reflecting the extent to which the industry is a price taker in a market where there is international trade;
– changes in industry prices affect the costs of non-energy inputs to production, and so unit costs and output prices of each industry are further affected;
– households respond to changes in consumer prices (distinguished by product, including the price of electricity) with both income and substitution effects;
– the exports and imports of each product are affected by the change in price competitiveness;
– each industry's output and employment are affected by the net effect of the changes in demand and the penetration of imports;
– the dynamic nature of the modelling means that short and medium-term effects are distinguished.

Note 'second-round' effects, that is, the impact on CfD support costs resulting from changes in electricity consumption after the initial cost estimates are applied, are not considered, as they were considered relatively small in scale. The estimated values of CfD support costs are reported in Table 5 in Section 3.1.

A stylised representation of how exemptions flow through the economy is depicted in Figure 10.

Figure 10. **Exemptions in MDM-E3 impact exempt industrial sectors, non-exempt productive sectors, and households**



Source: *Cambridge Econometrics*

Sectors receive individual rates of exemption under the policy scenarios. The more aggregated sectors in MDM-E3 do not align perfectly with the relevant 4-digit SIC codes identified in the policy scenarios. Thus, it was necessary to calculate effective exemption rates, based on the exempt sectors' share of production within each MDM-E3 category. Table 4 illustrates the resulting rates for a selected subset of sectors.

Table 4. **Specific exemption rates calculated for sectors in MDM-E3 (selected sectors)**

	Option						
MDM-E3 sector	**1a**	**1b**	**2a**	**2b**	**3a**	**3b**	**4**
Food products	0%	0%	2%	1%	0%	0%	100%
Textiles	0%	0%	34%	21%	0%	0%	100%
Wearing apparel	0%	0%	7%	5%	0%	0%	100%
Paper, printing, publishing	40%	33%	51%	47%	40%	33%	100%
Coke & petroleum	0%	0%	80%	50%	0%	0%	100%
Chemical products	57%	48%	77%	71%	39%	33%	100%
Rubber and plastic	3%	3%	3%	3%	0%	0%	100%
Other non-metallic mineral products	26%	22%	33%	30%	0%	0%	100%
Basic metals	49%	41%	56%	53%	49%	41%	100%

Source: Cambridge Econometrics

The more aggregated sectors in MDM-E3 do result in a loss of some detail, but it is not clear that it necessarily biases the overall results in one way or the other, except that it may miss large movements (either positive or negative) that would occur in small subsectors.

2.3.3 Various macro-level outputs are produced, including CfD support cost estimates

MDM-E3 provides a wide range of macroeconomic and sector outputs including GDP, gross value added, production, exports, imports, incomes, employment, energy use, carbon emissions, tax revenues, the fiscal budget deficit and the balance of payments. In the context of the current research, the attention is on output, GVA and employment measures. MDM-E3 includes projections of consumer prices in considerable detail, and these inform an analysis of impacts on poorer households through a version of the Consumer Price Index with weights reflecting the patterns of expenditure of those households.

Crucially, MDM-E3 also produces estimates of the CfD support costs that will be required at each time horizon. These costs are then used in the sectoral modelling with IMM. CfD costs can be estimated as

MDM-E3 includes electricity price projections, which in combination with other variables allow the necessary size of the electricity price change to be determined.

2.3.4 MDM-E3 has various advantages and disadvantages

MDM-E3 has several advantages:

- it estimates wider macroeconomic and dynamic effects;
- it requires little additional data to be collected;
- it includes the downstream effects of an exemption, which is especially important when considering industries, such as chemicals, that form essential inputs into other industrial sectors; and
- it allows the separate impacts on exempt and non-exempt electricity users (whether industries or households) to be modelled.

On the other hand, there are disadvantages relevant to this project:

- there is a limitation in the sector detail available for energy intensive industries within MDM-E3. The model's energy demand analysis cannot incorporate further disaggregation than is available in DUKES (the Digest of UK Energy Statistics). The detail available for the analysis of impacts on costs and prices, trade effects and carbon leakage is limited by the industry classification in the modelling;
- MDM-E3 relies on econometrically estimated aggregate relationships for industries, but reveals little about the underlying firm-level dynamics. It provides no understanding of which firms and assets within an industry are likely to be threatened by higher electricity prices, and therefore who are the likely beneficiaries of an exemption;
- while effects on domestic production and emissions are identified, the model cannot be used to determine the magnitude or destination of leakage. The model only incorporates production within the UK. Exports and imports are to and from the 'rest of the world'.

At the level of the sectors examined, these limitations are addressed by the use of Vivid Economics' Industrial Market Models.

2.3.5 Steps taken to increase inter-model comparability

Effort was made to achieve comparability between the sector and macro model results. For instance, to obtain projections for 2016, 2020, and 2030, the sectors investigated by the IMMs are assumed to grow at rates implied by the MDM-E3, as are their import shares. As sector definitions in MDM-E3 are more aggregate, this involves some degree of approximation.

Some areas of difference were not forcibly aligned: for instance, the rates of cost pass-through and import elasticities were not harmonised between the sector and macro models. These differences were left in place, allowing the models to function in the way they were designed to, making best use of the data available.

2.4 Data sources

Data for both the industrial market and macro models

2.4.1 The Industrial Market Models are relatively data-demanding

The FIMM and RIMM approaches require the following data for each sector analysed:

- total number of firms in market;
- total number of UK firms in market;
- market share of UK firms;
- elasticity of demand across the entire market;
- electricity intensity of UK and foreign firms;
- emissions intensity of UK and foreign firms;
- average profit margin of UK firms;
- average price per unit (tonne) of produced goods;
- electricity cost decreases when exemption in place;
- individual installation output (FIMM only);
- sources of imports (FIMM only);
- any relevant variations in electro-intensity across installations (FIMM only) or nations.

Relevant estimates come from a variety of sources, including economic reports, national statistical services, industry association publications and industry association bespoke data. A comprehensive list of the sources is listed in Appendix H.

Interviews with industry associations and representatives of industry firms for the six sectors investigated in detail were of considerable assistance. Interviewees provided data and helpful review of draft results. Interviewees also identified sector features that deserved attention in the modelling approach. They supplied qualitative information concerning their industries and the outlook for growth in coming years, as well as quantitative estimates of the usage of electricity. Prior to submission of the final report, key input and output figures for the sectors investigated in full detail were shown to industry associations and they were invited to comment.

Where possible, data was taken from consistent sources, but this was not always possible. For instance, no single comprehensive source exists to provide estimates of demand elasticities. Estimates of profit margins can be made consistently from IBISWorld and ONS data, but in several instances alternative numbers supplied by industry associations were considered more appropriate. Similarly, the Office for National Statistics collects trade data for all sectors, but in some cases, sector associations have data which is specific to the market of interest.

The use of data from multiple sources leads to some risk of inconsistency of definitions. For instance, electro-intensity is, in some instances, calculated using DECC projections of sector electricity use combined with PRODCOM information concerning UK production levels. Average prices per tonne of production is taken from industry associations in some cases, possibly using a slightly different scope of production. It is expected that these issues do not cause significant bias in the results.

2.4.2 MDM-E3 data requirements are comparatively light, though some calibration is necessary

The bulk of the data required to operate MDM-E3 was held by Cambridge Econometrics prior to commencement of the project. The principal data inputs are:

- social accounting matrices and input-output tables which describe the interactions between parts of the economy;
- econometric estimation of elasticities showing the response of consumers to changes in price and income and the response of exports and imports to changes in price and market demand;
- assumptions about world prices of fossil fuels and the growth in activity and prices in the parts of the world that are not within the scope of the model;
- energy-specific data relating to energy demand and power supply from specialist statistical sources, mainly DUKES; and
- in cases where future behaviour is unlikely to be captured by econometric methods, for example, in the take-up of technologies in electricity generation, behavioural rules based on economic theory and expert judgement.

The MDM-E3 model was calibrated to be consistent with other projections regarding future states of the world. In particular, it was aligned to the Updated Energy and Emissions Projections (UEP) produced by DECC in November 2012. For each manufacturing sector identified in the UEP, economic growth assumptions were applied to the MDM-E3 projections to set the outcomes derived from the model equal to the published projections. The same treatment was applied to final energy demand by sector.

Projections of energy prices (fossil fuel prices, wholesale electricity prices and retail prices) were supplied by DECC. The projections are similar to those used in the UEP, but account for the most recent policy analysis. Wholesale prices are exogenous, while retail prices are calibrated in a similar manner to energy demand. This treatment allows retail energy prices in the model to change with the impact of exemptions on final electricity prices.

2.4.3 Sector definition to ensure appropriate market scope

Several of the SIC 4-digit sectors selected for detailed analysis were not immediately suitable for analysis with the Industrial Market Models due to lack of homogeneity. The issue is not whether two subsectors are direct substitutes for each other, but whether the manufacturing equipment used in one subsector can produce goods from another subsector. For the six sectors investigated in detail, these issues arose:

- within the ceramics sector, brick production, for instance, is distinct from porcelain fixtures such as sinks, or from advanced technical ceramics which may involve substantially different levels of electricity usage;
- various major fertiliser types are produced using different chemical processes;
- shaping of steel is a capital-intensive process; and combined with variations in steel quality, this means that the UK's steel output as a whole cannot be seen as a single commodity.

To address these issues:

- the focus in the ceramics sector was narrowed to heavy-clay based products; that is, predominantly bricks. These make up well over a quarter of total ceramics sector GVA, and more than half of sector electricity use;
- the focus in fertilisers was narrowed to nitrogen-based fertilisers, specifically ammonium nitrate and urea; which can be considered practical substitutes for each other, with the market price for ammonium nitrate generally tracking the urea price;
- the steel industry was split into long steel and flat steel, which were modelled separately.

These distinctions should be borne in mind when interpreting the results: for instance, the results for heavy clay ceramics are not indicative of the ceramics sector overall.

The sector 'paper manufacturing' was originally to be modelled using the FIMM; however, in discussion with the industry association it became clear that it would be prohibitively difficult to obtain the necessary data. Consequently, paper manufacturing was split into four subsectors: packaging, newsprint, sanitary, and stationery. Together, these make up more than 95 per cent of paper production in the UK, by value and tonnage. Each subsector was analysed separately with the RIMM, and the results aggregated to produce sector-wide estimates.

Heavy clay ceramics and cement were considered, due to transport costs, to be unambiguously a UK market. Due to the low volume of exports from the UK, nitrogenous fertilisers were also analysed at the UK level. The steel subsectors, paper subsectors and flat glass were analysed at the EU level, as were several of the RIMM sectors.

2.5 The estimation of carbon leakage

Changes in carbon emissions outside the UK

The FIMM estimates changes in both the level of UK production, and of the quantity of imports by source. RIMM analysis only includes variation in domestic production and aggregate imports, where the latter can be retrospectively assigned to import partners' share of total imports. Note that, as discussed in Section 4.5, only the net change in carbon emissions within the UK is relevant for the purposes of cost-benefit analysis; however, the broader impact on EU and global emissions is investigated for interest.

The carbon leakage estimates combine modelled changes in output and the IEA's estimates of the carbon intensity of sectors:

- it is assumed with RIMM sectors that direct emissions intensity is the same across the UK and all import partners; variations in direct emissions are thus solely driven by variations in production. If there is reason to believe that UK installations are more carbon efficient than their foreign counterparts then benefits will be underestimated;
- indirect emissions from RIMM sectors are calculated using the UK's electro-intensity of production and applying it to the UK's import partners combined with the IEA's national electricity emissions factors. Again, if the UK's electro-intensity is, in fact, lower than that of its competitors, then the benefits will be underestimated;
- the procedure for FIMMs is similar, except that in several instances the IEA produces relevant emissions factors for the sector by region.

Note that in the emissions measures based on the IMM outputs, there is no accounting for potential decarbonisation of the electricity supply or sectoral carbon-intensity abatement measures over the modelled time horizon. This is largely to ensure consistency in projections across countries, as international rates of decarbonisation are difficult to estimate. In practice, some degree of decarbonisation will occur (indeed, partly driven by the CfD policy), and consequently the absolute levels of changes in carbon emissions based on the IMM outputs should be treated as an upper bound.

The presence of the EU ETS, and consequently an annual cap on emissions in the EU from participating sectors, complicates the question of estimating carbon leakage rates, as movements in emissions between EU member states would not change overall EU emissions.

- where a sector is under the EU ETS, the output leakage from nations covered by the EU ETS to the UK does not result in a change in global carbon emissions.
- further, for sectors not covered by the EU ETS, it is assumed that output leakage from nations covered by the EU ETS to the UK does not result in carbon leakage through the indirect channel: that is, through electricity use, because electricity production is covered by the EU ETS.
- for sectors not covered by the EU ETS, it remains possible to have carbon leakage through direct emissions.

Decreased output in nations not covered by the EU ETS, while output in the UK increases, may result in a decline in net global emissions. This is a result of the increase in UK emissions being offset by decreases elsewhere in the EU (due to the emissions cap), while emissions in nations not covered by the EU ETS decline.

MDM-E3 has full coverage of UK GHG emissions, sourced from the National Air Emissions Inventory. Carbon dioxide emissions within the model change in response to energy production and consumption.

3 Results

A negligible impact on the whole economy, potentially significant impacts on individual sectors

Section contents:

An uncertain scale of effects on sectors

The impacts on sectors vary greatly. Some are much more sensitive than others: a consequence of differences in competition from imports, margins and electricity intensity.

The whole economy impacts are indisputably small; mere fractions of a percent of output. They are marginally negative overall, with the cost of raising funds exceeding the value of exemptions to their beneficiaries.

The two modelling methods estimate quite different magnitudes of impact. The Industrial Market Models indicate quite dramatic changes in output, consistent with the change in margin. The macro-econometric model states the aggregate effects will be small, in line with statistically estimated sensitivities.

3.1 Results for individual sectors

Some examples of low cost pass-through and large output effects

3.1.1 Contract for Difference support costs

The incremental charge on electricity prices that will be necessary to support CfDs was estimated using MDM-E3 in combination with DECC projections. The resulting figures, to which the impact of exemptions at different percentage rates were then considered with modelling, are recorded in Table 5. While low in the near term, they increase substantially out towards 2030, with a consequent increase in the value of being the recipient of an exemption.

Table 5. **Both CfD support costs and electricity prices are expected to rise out to 2030**

Year	CfD support cost (2012 £/MWh)	Typical electricity prices faced by EIIs in counterfactual (including CfD support costs) (2012 £/MWh)
2016	0.90	110.30
2020	9.80	120.70
2030	16.20	134.40

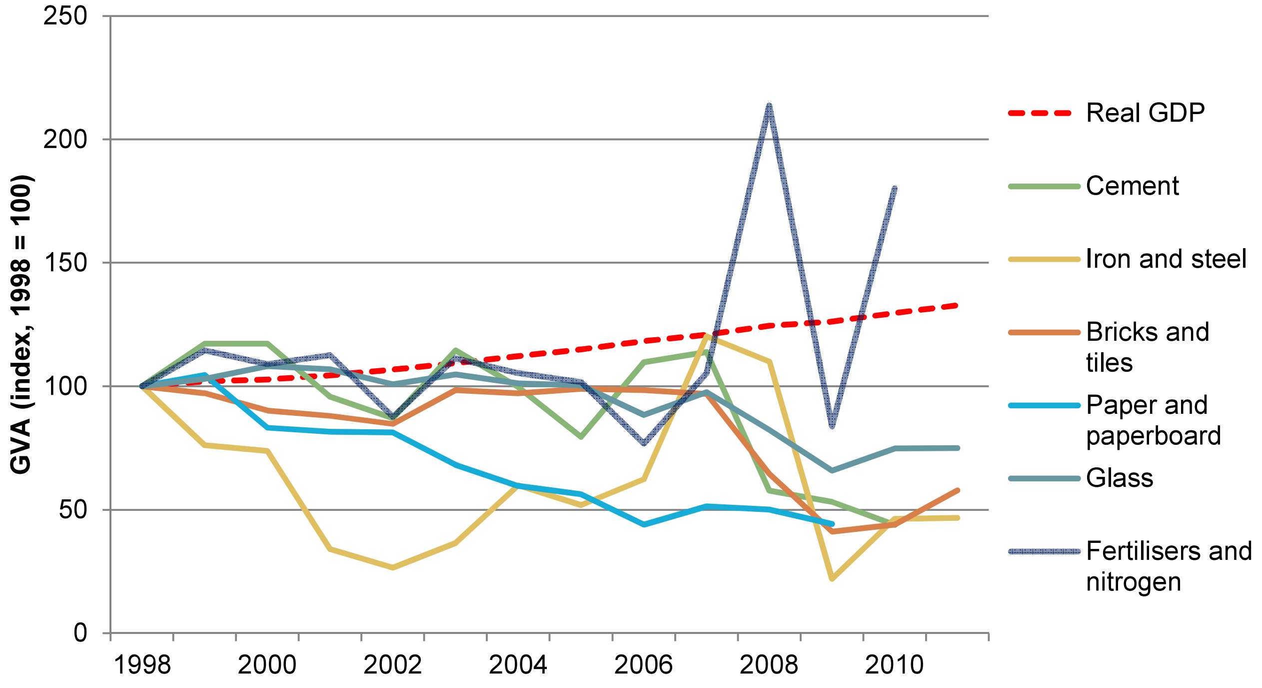
Note: Not all sectors face the electricity costs identified, due to variations in sectoral pricing. Original MDM-E3 estimates were in £2009, adjusted to £2012 using the UK GDP deflator.
Values rounded to nearest £0.10.
Source: DECC, Cambridge Econometrics

In both IMM and MDM-E3 analysis, the same CfD support cost figures were used across all policy and upside, downside, and central scenarios.

3.1.2 Results for six sectors investigated in detail

The six sectors investigated in detail are all relatively heavy electricity users. These sectors have seen declining output or have been experiencing slow growth compared with the rest of the British economy, and all except fertilisers were diminished by the global financial crisis from 2008, see Figure 11. Heavy clay ceramics, for instance, was particularly hard-hit, with a sharp down-turn in brick and tile demand resulting in a decline in the number of operating facilities from around 100 in 2006 to 65 in 2012 (BCC, 2013). The paper industry is another which has experienced a relatively large number of installation closures.

Figure 11. **The sectors investigated in full detail have mostly underperformed the broader British economy**



Notes: GVA for glass includes the whole manufacturing of glass sector, not just flat glass. This is due to suppression of GVA for flat glass to avoid disclosure.

Source: ONS, Vivid Economics

The sectors show variety in their size and in the value of key inputs, between goods that have relatively low prices per tonne to those that have high prices per tonne (cement, at £71/tonne, to steel, at around £450-475/tonne), and a substantial range in electro-intensity (from heavy clay ceramics, at 0.07MWh/t, to nitrogenous fertilisers, at 0.34MWh/t, and higher still for steel produced using the Electric Arc Furnace (EAF) process).

Referring to 2020 results for convenience, the rate at which the exemption is passed through to customers ranges from around 2 per cent in steel to 78 per cent in heavy clay ceramics. There are also substantial variations in the impact on domestic production, from 3 per cent in flat glass to almost 20 per cent in long steel. This range of variation is driven by:

- differences in the competitive structure of the markets: the degree of trade exposure, the level of profitability, and the consumer response (the influence of these variables is discussed further in Section 5);
- differences in the relative size of the decrease in costs, as compared to the retail price of the product in question.

In terms of output, cement responds strongly to the exemption, as does steel. In the case of cement, this is largely due to its low price compared to the electro-intensity of production, and consequently the proportionately large size of the shock as seen from the perspective of producers. The shock is less intense for steel, but UK steel production is only a small share of the total EU market. Consequently, UK steel producers retain the bulk of the benefit of the exemption – that is, the cost pass-through rate is low – and take market share from other producers. Conversely, sectors that combine a relatively small size for the value of the exemption with high gross profit margins (such as flat glass) or high market share for UK producers (such as ceramics) see a relatively smaller impact. However, some of the uncertainties here should be noted: gross profit margin is difficult to identify with precision (see Section 5 for further discussion) while the aggregate import exposure for heavy clay ceramics may miss variations in the import share for heavy clay subsectors. For instance, roof tiles are substantially more trade exposed than house bricks, but as bricks make up the bulk of heavy clay ceramic production by volume they tend to determine the results of the model; this is an inevitable result of data limitations.

Regarding heavy clay ceramics, it is worth noting that the British Ceramic Confederation (BCC) has projected an increase in imports of heavy clay ceramics from 280kt in 2012 to 450kt (or higher) in 2013, based on import figures over the first half of 2013. The BCC expects this higher import level to be sustained. If this is the case, then the relative decrease in UK market share would likely substantially increase the impact of the CfD exemption on the ceramics sector.

Table 6. **Summary inputs and outputs for sectors investigated in full detail (80% exemption rates, 2020)**

	Variable	Flat glass	Cement	Steel	Nitrogenous fertilisers	Heavy clay ceramics
Model inputs	Electro-intensity (MWh/tonne)	0.19	0.12	0.31 – 0.55	0.34	0.07
	Price (£/tonne)	380	71	456 – 473	294	£98
	Value of exemption as proportion of price	0.4%	1.3%	0.5 – 0.9%	0.9%	0.6%
	Gross profit margin	12%	5%	8%	10%	3%
	Price elasticity	-0.3	-0.27	-0.3	-0.37	-0.3
	Domestic production ('000t)	380	6,328	2,500 (flats); 2,925 (longs)	1,200	3,181
	Market share	3%	64%	1 - 3%	41%	83%
Outcome of exemption	Increase in domestic production	3.2%	17.9%	9.5 – 19.5%	7.5%	7.7%
	Cost pass-through rate	4%	49%	1.6 - 5%	18%	78%

Notes: *Some values for steel and paper are excluded because of variation within the sector. For instance, multiple values of electro-intensity are used for steel depending on product and production technology, and cost pass-through rates vary by subsector.*

Source: *Vivid Economics; see Appendix H*

In addition to the disclaimers above, it is also worth noting that:

- although steel flats and longs were treated separately, there are additional grades of steel, related to quality and intended final purpose. Steel may thus be more heterogeneous than considered here, which would soften the impact of the exemptions;
- a small yet significant share of cement imports are comprised of 'white cement', in contrast to the grey cement manufactured in the UK. The former is for decorative use and is thus not a direct substitute for grey cement; thus, the effective import share may be overstated;
- besides that, the analysis conflates bricks with tiles, not accounting for further distinctions within heavy clay products.

As discussed, all sectors were investigated using FIMM except for paper manufacture, which was split into four subsectors, each investigated with RIMM. These subsector results are presented in Table 7. Note that newsprint, stationery, and packaging were all treated as EU markets, while sanitary paper was treated as a UK market.

Except for sanitary paper, paper manufacture exhibits a cost pass-through rate of less than 10 per cent, which is low. This is because these three markets are EU-wide, and UK manufacture constitutes a small fraction of market production. The exemption triggers increases in output of between 16 and 50 per cent.

Box 1. **Production expansions, investment, and installation capacity, in models and in reality**

As noted, where data is available the Full Industrial Model takes account of production decisions down to the installation level. In instances where industries are subject to negative shocks, the model may make predictions regarding the likelihood of individual installation closure. In this case, the cost shock is positive, and the model in turn estimates different degrees of benefit for different producers.

This level of detail is not included in the results. However, it is worth discussing the production changes identified here. The Industrial Market Models involve shifts from one equilibrium to another, with full adjustment of all capital stocks. In the short-term, depending on capacity utilisation within the sector, it may be difficult to expand output further. The models' results emerge over longer time periods, at a minimum over the time frame which would be necessary to either expand capacity or construct new facilities.

Whether change in output occur 'smoothly' or in a step-wise fashion may depend on the size of installations: whether the change is large enough to require either construction of new installations or closure of old ones. Where individual installations make up small shares of total output, such as in ceramics, the adjustment is likely to be smoother. For sectors such as steel, the opposite is the case.

In reality, some of the benefits of the exemption will be realised through higher investment in these sectors than would otherwise be the case, as long as access to the exemption is seen as a long term commitment. Closure of installations may have social impacts beyond the simple loss in output, including employment effects, which may be regionally concentrated.

Table 7. **Paper sector summary inputs and outputs for sectors investigated in full detail (80% exemption rates, 2020, core scenario)**

	Variable	Newsprint	Printing and writing	Packaging	Sanitary
	Electro-intensity (MWh/t)	0.91	0.98	0.56	1.30
	Price (£/tonne)	375	685	685	800
	Value of exemption as proportion of price	1.9%	1.1%	0.6%	1.3%
	Gross margin	3%	3%	3%	3%
	Price elasticity	-0.38	-0.25	-0.16	-0.16
	Domestic production (‘000t)	982	366	1,496	682
	Market share	9%	1%	3%	63%
Outcome of exemption	Increase in domestic production	49.5%	31%	17.1%	16.5%
	Cost pass-through rate	9%	1%	3%	62%

Source: Vivid Economics

3.1.3 Results for sectors analysed in less detail, with RIMM

The effects on domestic production in the RIMM sectors are generally substantially smaller, which for the most part is due to considerably lower electro-intensities of production. Table 8 shows results for 2020 under the core scenario.

However, there is nonetheless substantial variation amongst the RIMM sectors. Copper products, for example – which includes manufacture of fixtures, pipes, and cable – has the highest electro-intensity of any sector studied, including those examined using FIMM, but the cost shock represented by the exemption is small relative to the sector’s average retail price. However, combined with UK producer’s low share of the UK market, and the consequent exposure to foreign competition, the impact on production, of around 6 per cent, is still large among the RIMM sectors. Indeed, the only RIMM sector more strongly affected in terms of the impact on production is veneer panels and sheeting, which combines moderate electro-intensity with a low price of produce per tonne and a high trade exposure.

Several sectors benefit from having very low electro-intensities, or from being UK-level markets with limited trade exposure, and are expected to have high levels of cost pass-through and consequently small output responses. These include ice-cream, gravel, clay, oils and salt. Overall, the RIMM sectors indicate the potential diversity of impacts of exemptions on the UK manufacturing sector.

Table 8. **Summary inputs and outputs for sectors investigated in less detail (80% exemption rates, core scenario, 2020)**

Full sector name	Market scope	UK production ('000t)	Price (£/t)	Electro-intensity (MWh/t)	Cost shock / price	Gross margin	Elasticity	Market share	Increase in domestic production	Cost pass-through rate	Brief commentary
Manufacture of ice cream	UK	830	868	0.12	0.11%	11%	1.0	87%	0.2%	79%	High domestic market share, partly due to high cost of trading frozen dairy products, means little foreign competition.
Manufacture of malt	EU	1,206	152	0.15	0.77%	9%	0.8	17%	7.3%	16%	Strong effect due to low market share and large electro-intensity
Manufacture of beer	UK	4,576	4322	0.01	0.00%	12%	0.6	78%	0.0%	73%	Low electro-intensity and high value per tonne leaves the relatively large sector unaffected.
Production of clay	UK	962	113	0.34	2.38%	8%	0.8	85%	5.3%	80%	Large response is driven by a relatively large cost shock in proportion to price, despite low trade exposure
Production of gravel	UK	66,971	34	0.01	0.25%	8%	0.8	95%	0.3%	89%	Very low trade exposure and low emissions intensity result in a small impact on production overall

Full sector name	Market scope	UK production ('000t)	Price (£/t)	Electro-intensity (MWh/t)	Cost shock / price	Gross margin	Elasticity	Market share	Increase in domestic production	Cost pass-through rate	Brief commentary
Manufacture of lime	UK	1,173	69	0.04	0.42%	13%	0.9	87%	0.7%	78%	High domestic market share and a relatively low cost shock, along with high gross profit margins, result in only a moderate response in production.
Manufacture of oils and fats	UK	4824	223	0.01	0.04%	5%	0.8	51%	0.5%	49%	A minimal cost shock for a product with high value per unit of weight results in a small impact on domestic production.
Production of salt	UK	6,381	50	0.01	0.12%	44%	0.1	97%	0.0%	93%	Salt production, having low electro-intensity and high UK market share, is largely unaffected by the exemption.
Manufacture of veneer sheets, plywood, laminboard, particle board, fibre board and other panels and boards	EU	1,605	258	0.51	1.55%	5%	0.8	46%	16.8%	45%	A relatively large cost shock, coupled with significant exposure to foreign trade, results UK producers gaining substantial market share

Full sector name	Market scope	UK production ('000t)	Price (£/t)	Electro-intensity (MWh/t)	Cost shock / price	Gross margin	Elasticity	Market share	Increase in domestic production	Cost pass-through rate	Brief commentary
Manufacture of copper products (pipes, cables)	EU	84	9,356	5.92	0.49%	5%	0.2	1%	7.4%	1%	A high-value product, but nonetheless sufficiently electro-intense to be strongly affected, due particularly to the UK's small market share
Manufacture of carpets and rugs	EU	90	10,800	4.83	0.35%	10%	1.2	16%	2.6%	15%	The cost decline per unit of value is quite small, but low margin and high elasticity results in low CPT and relatively large output increase
Manufacture of refined petroleum products	EU	67,600	715	0.05	0.06%	3%	0.7	7%	1.6%	7%	The largest sector examined by value. Exposure to EU trade amplifies the impact of the exemption, though the proportional cost shock is small.
Manufacture of polypropylene	EU	398	943	1.89	1.56%	20%	0.4	4%	6.2%	3%	Similar to the broader refined petroleum products, polypropylene production increases due to opportunity for capturing market share from foreign producers

Full sector name	Market scope	UK production ('000t)	Price (£/t)	Electro-intensity (MWh/t)	Cost shock / price	Gross margin	Elasticity	Market share	Increase in domestic production	Cost pass-through rate	Brief commentary
Manufacture of rubber tyres and tubes	EU	671	3,353	0.84	0.20%	9%	1.2	9%	1.6%	8%	A high value product with relatively elastic demand and low UK market share, rubber products are reasonably responsive to the exemption

Source: Vivid Economics

3.2 Scenario discussion

Exploring uncertainty around the core scenario results

3.2.1 Market scenarios for sectors analysed in full detail, with FIMM

As described in Section 1.2.4, market scenarios are used to examine upside and downside outcomes to the CfD exemption at the sectoral level. Upside scenarios incorporate more rapid growth rates in UK domestic production combined with the positive influence of a natural gas price decrease for EU producers, while downside scenarios involve the opposite situation.

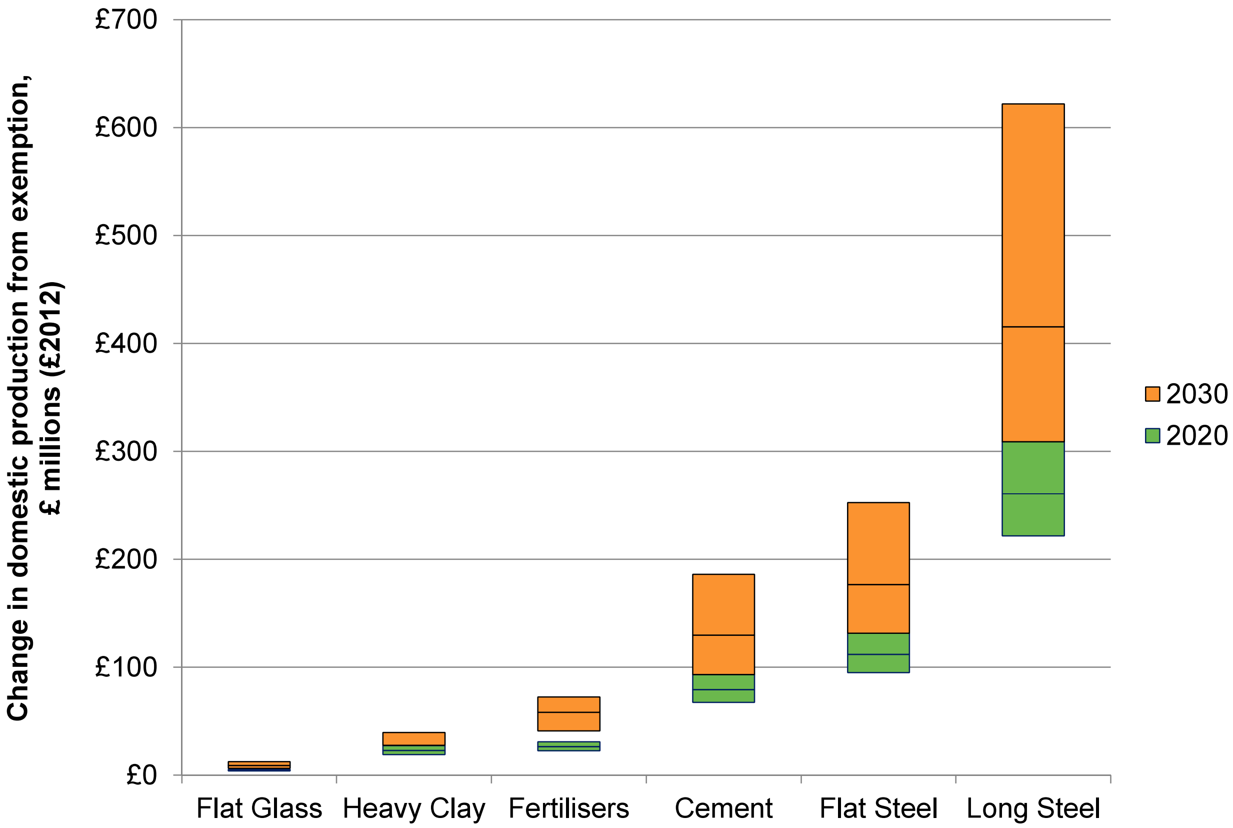
The effect of the scenarios is to vary the pre-exemption market share and the overall size of the market. This has two significant consequences:

- the changes in market share change the competitiveness of the sector; a higher market share translates to greater profitability;
- the changes in market size imply greater changes in absolute terms. That is, the same percentage change in production in a larger market will have a higher market value, and consequently a bigger impact in cost-benefit terms.

Figure 12 illustrates the scale of the impact on production, expressed in £2012, for sectors analysed using FIMM. Note the ordering in terms of the absolute value of the impact is not the same as the proportionate change in production, due to differences in sizes of the sectors.

Figure 12 also shows the range covered by the upside and downside scenarios. Note that larger value increases, in absolute terms, occur in the upside scenario: that is, the exemption is worth more in a scenario of high UK domestic growth and relatively low gas prices. This is partly a consequence of there being ‘more to lose’ the larger the domestic market is. However, larger *proportional* changes typically occur in the downside scenario, where sectors are more exposed to imports. Ceramics, for instance, is an exception, where the increase in market share under the upside scenario is such that, with lower import exposure, the response of production to imports is more muted and thus the largest change occurs under the core scenario. Out to 2030, the value change in the upside scenario can be several hundred million pounds for the most affected sectors, or more than twice the impact recorded in the downside scenario.

Figure 12. **For the change in the value of domestic production, the sectors investigated in detail show wide ranges of outcomes roughly symmetrical around the core scenarios**



Notes: *Each bar shows the highest, lowest and central estimate of the value of the exemption. Note that for all sectors and years the highest value changes occur in the upside scenario, and the lowest occur in the downside scenario. An exception is heavy clay ceramics in 2030 ,where the largest value change occurs in the core scenario, and the lowest occurs in the upside scenario.*

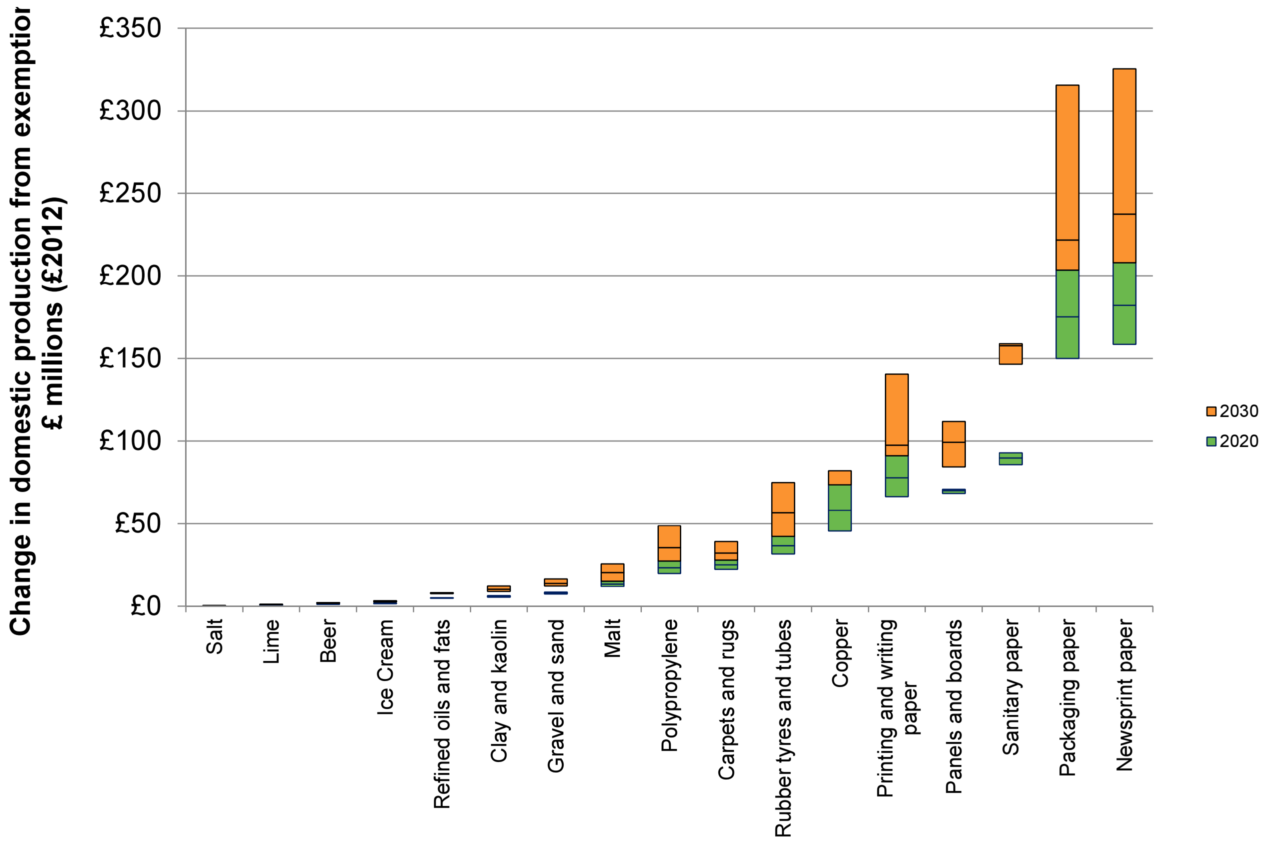
Source: *Vivid Economics*

3.2.2 Scenarios for sectors analysed with RIMM

A similar dynamic holds in the scenario analysis for sectors investigated with RIMM as it does for those investigated with FIMM (Figure 13). Corresponding to the generally smaller size of the sectors investigated with RIMM, as well as the lower average proportionate impact of the exemption on domestic production, the impact expressed in terms of £2012 is also generally lower; for the non-paper sectors, only exceeding £100 million in the upside scenario for panels and boards.

Some sectors show substantially less variation between the upside and downside scenarios than others. Such sectors tend to be those that start with UK producers having a large share of production. This is largely because, over the time frame examined, the differential in growth rates is not sufficient for the UK producers' market shares to be substantially eroded: that is, sectors where UK producers have very large shares of production in 2012 also tend to have at least relatively large shares of production in 2030. Without a major alteration in the extent of the threat posed by foreign producers, there is less difference in the outcome between scenarios.

Figure 13. **Change in domestic production in 2020 and 2030 under non-policy scenarios for sectors analysed with RIMM**



Note: *The petrochemicals sector is not shown on the chart for scaling reasons; in 2030, the change in the value of petroleum production ranges from around £550m to over £1,050m. This is due to the substantially larger size of the petrochemicals sector compared to other sectors examined.*

Source: *Vivid Economics*

3.3 Discussion of IMM sector-level results

The sample of sectors spans a wide range of responsiveness to CfD exemption

The similarity of the RIMM and FIMM approaches allows the results to be presented together and compared. This is done in this section, allowing a consideration of the extent of differences across sectors. Section 2.2 will likely be of assistance in understanding the pattern of results across sectors.

3.3.1 Cost pass-through rates vary widely across sectors

As discussed in Section 2.2.4, the drivers of the cost pass-through rate are:

- the price elasticity of demand;
- the gross profit margin; and
- the market share of UK producers.

Of these three, the most significant is UK market share. This shown in Figure 14, where the relationship shown is broadly linear: that is, 100 per cent UK market share would be approximately associated with 100 per cent cost pass-through, and equivalently for different percentages. At the level of individual installations, this relationship might be different, and there would also be additional complicating factors in reality.

Note that, as shown in Figure 15, the cost pass-through rate is independent of the size of the exemption. Note that Figure 15 measures the size of the electricity price reduction relative to the average price of goods sold. This is calculated as:

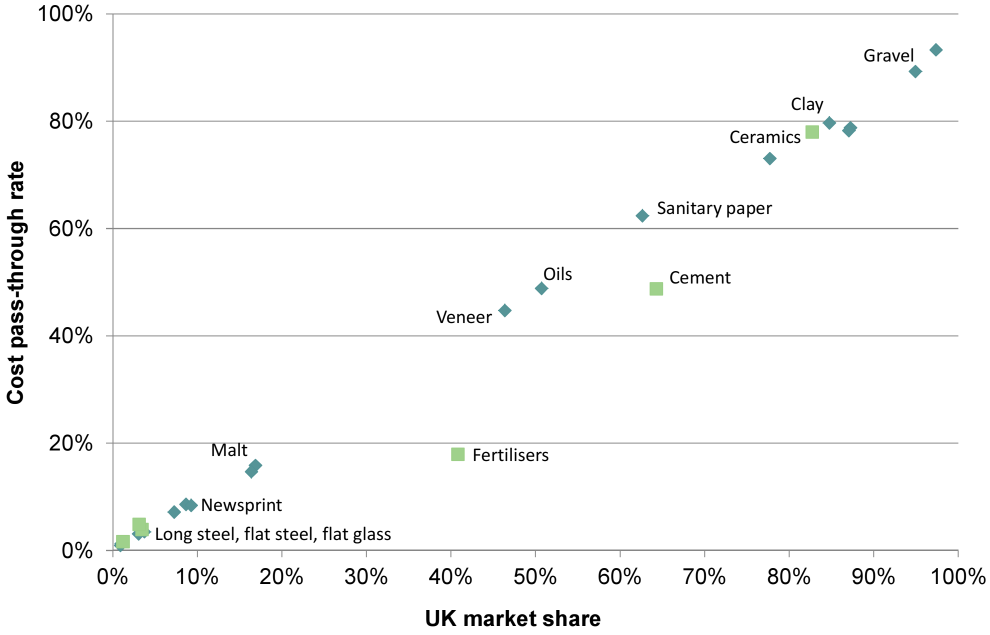
$$\frac{CfD\ support\ cost\ (£/MWh) \times\ Exemption\ rate\ (\%) \times\ Electro\text{–}\ intensity\ of\ production\ (MWh/t)}{Sale\ price\ of\ product\ (£/t)}$$

The significance of this is that the importance of electricity in the production costs of different sectors can vary substantially. This is true even for sectors with the same electro-intensity of production: if profit margins (expressed as percentages) are the same, the impact of the exemption will be much stronger on a sector which sells its product for £100 per tonne rather than one which sells for £1,000 per tonne, even if both have an electro-intensity of 0.5MWh per tonne, as the relative share of electricity in production costs for the former is higher.

However, it is worth noting the potential scale of the cost shock as a share of price for some sectors. A shock of around 2.5 per cent, in the case of clay, or even around 1 per cent, in the case of cement and fertilisers, might reasonably be considered significant.

As an example, the cement sector features relatively high domestic market share (64 per cent), moderate profit margins, and relatively low demand elasticity (-0.3). This results in a cost pass-through rate around the middle of the range identified, at approximately 50 per cent.

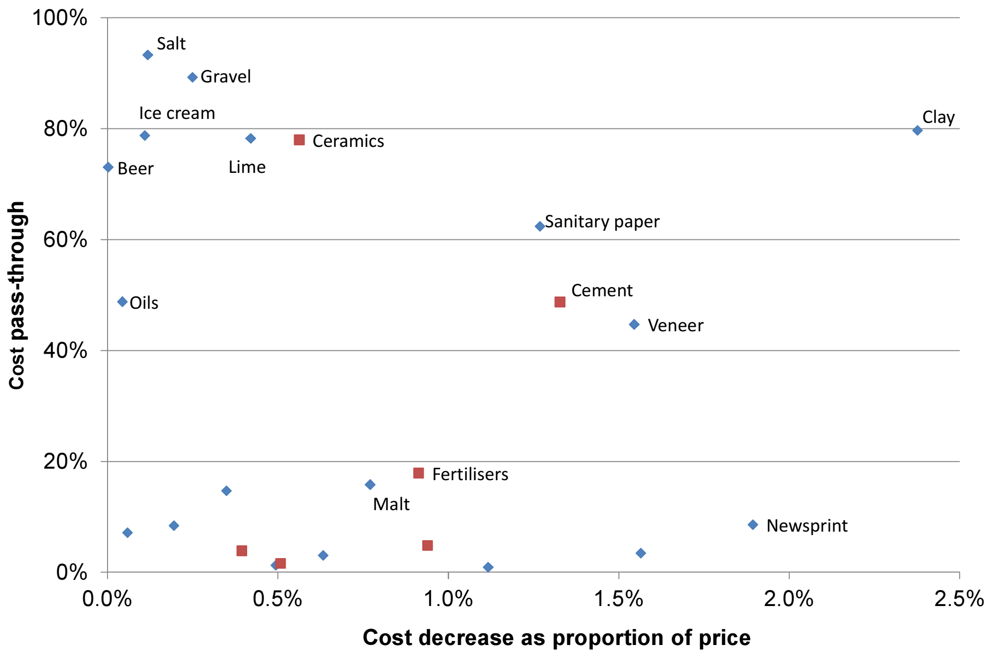
Figure 14. **UK market share is the most significant determinant of cost pass-through rates (2020, core scenario)**



Notes: *Data labels are excluded from the bottom left for presentational purposes*

Source: *Vivid Economics*

Figure 15. **The cost pass-through rate is not a function of the size of the decrease in production costs (2020, core scenario)**



Notes: *Data labels are excluded from the bottom left for presentational purposes*

Source: *Vivid Economics*

In addition, the electro-intensity of production of cement is around 0.12MWh/t, while the sale price is around £70/t. An exemption of 80 per cent applied to the estimated CfD support costs of £9.8/MWh in 2020 suggests that the exemption represents somewhat over 1 per cent of cement's sale price.

The gross profit margin used for the cement sector modelling was around 5 per cent. Applying the cost pass-through rate to the size of the exemption suggests that the cement sector retains a 0.5 per cent reduction in per-unit costs associated with the exemption. This translates into a 10 per cent increase in the level of profit margin.

The cost pass-through rate is tied to output decisions, which are influenced through two channels:

- market share, where, due to the exemption, lower costs and greater rewards per unit of production (that is, a larger profit margin) encourage domestic firms to expand production and attract market share away from importers;
- market growth, where, due to the share of exemption passed to consumers in lower prices, total consumption increases.

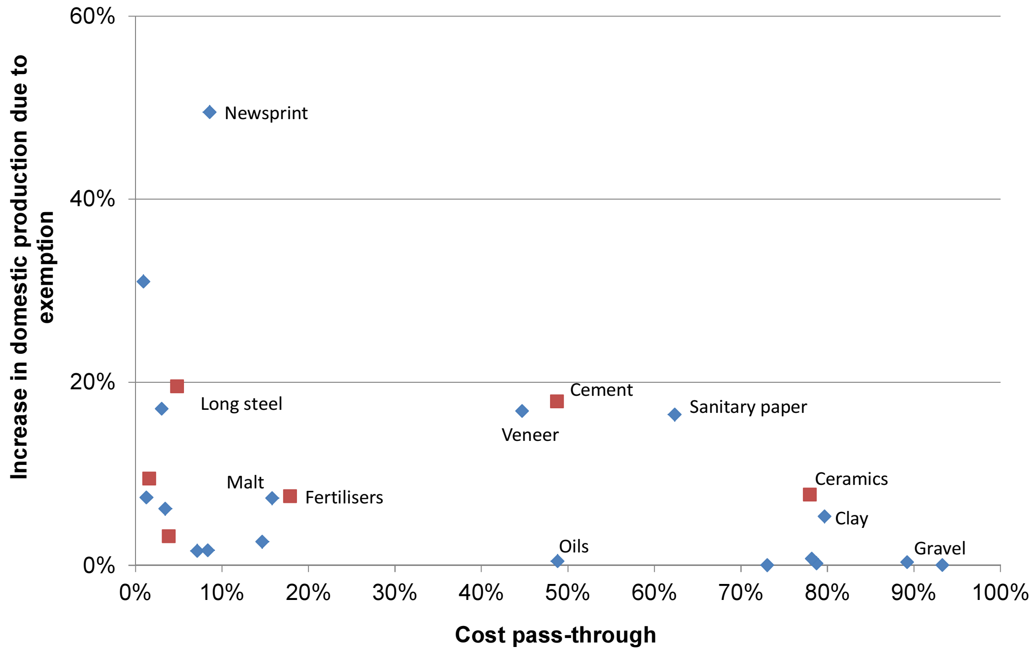
The former is generally the principal effect in the sectors examined here, as the scale of the cost shocks is relatively small and demand is generally inelastic. Low cost pass-through rates tend, broadly, to be associated with higher impacts on domestic production, as shown in Figure 16. In the case of cement, the 10 per cent increase in profit margins provides a mechanism for UK producers to capture additional market share. The increase in market cement consumption, however, is relatively muted: a 0.5 per cent reduction in price increases demand by around 0.15 per cent. Since the overall increase in domestic cement production in 2020 is nearer 20 per cent, it can be seen that movements in market share are driving the bulk of the response.

From a firm's perspective, the resulting impact on profits decomposes into two elements:

- the impact of a change in quantity produced;
- the impact resulting from incomplete pass-through of the reduction costs, that is, the increase in profit margins following an exemption.

The former is the change in total profits arising from the change in quantity of production if profit margins are held constant; the latter is the profits arising from the change in profit margin applied to the post-shock output level. The former effect tends to account for most of the change in sector profits.

Figure 16. **High cost pass-through implies smaller increases in profit margins, and is associated with smaller changes in domestic production (2020, core scenario)**

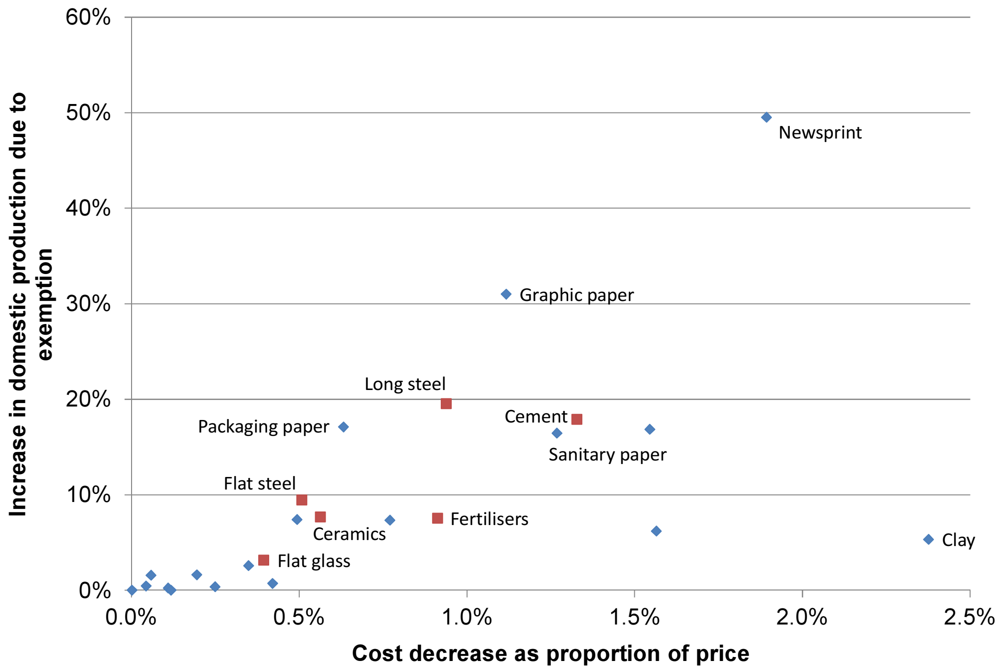


Notes: *Data labels are excluded from the bottom left for presentational purposes*

Source: *Vivid Economics*

The relationship between cost pass-through and output changes is obscured somewhat, however, by variations in the relative size of the cost shock. While large relative price shocks may not influence the cost pass-through rate, they do translate into a larger increase in industrial production. This is shown in Figure 17, which also illustrates the underlying similarity in the functioning of the RIMM approach as compared to FIMM. The major outlier on the FIMM side, long steel, has a disproportionately large production impact due to the UK occupying a small share of the relevant market; correspondingly, on the RIMM side, clay has a disproportionately low production change due a high domestic market share, while the converse holds for newsprint.

Figure 17. **The bigger the price shock, the larger the impact on domestic production, mediated through the variables describing the structure of the market (2020, core scenario)**



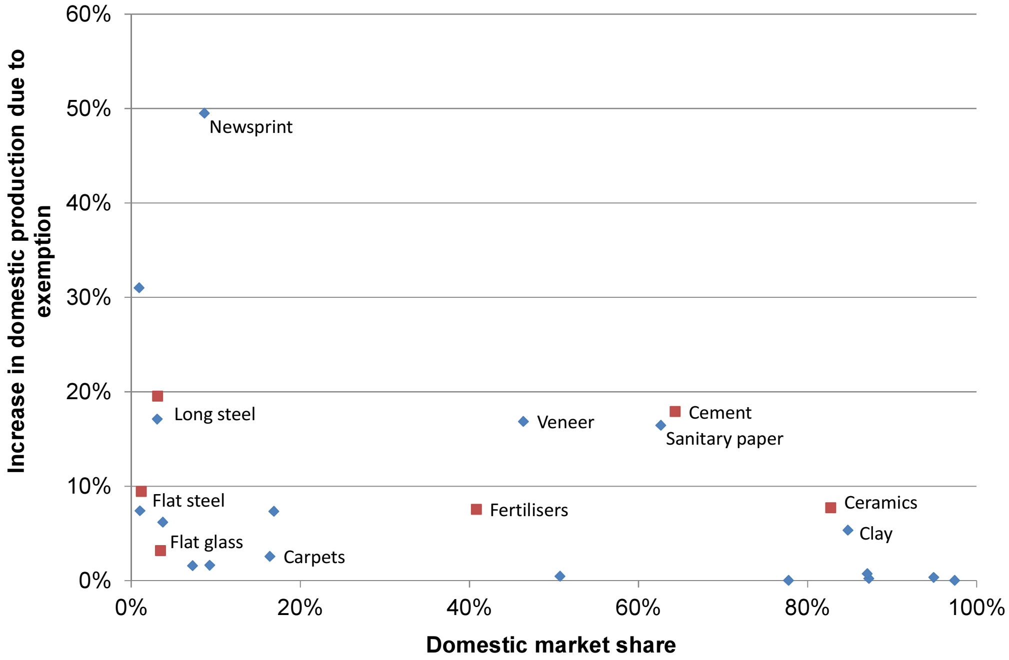
Notes: *Graphic paper and newsprint excluded for scaling purposes.*

Source: *Vivid Economics*

Figure 18 examines the relationship between domestic market share and the impact of the exemption. The relationship is not entirely unambiguous, but the generally lower impact on production that accompanies higher domestic market share is clear. Again, the relationship is confused by other factors not shown: as well as the relative scale of the shock, there is also the demand elasticity and profit margins.

Note that Figure 17 and Figure 18 are approximately analogous to the criteria employed by the EU when considering the level of potential sectoral carbon leakage, that is, trade intensity and carbon costs as a share of GVA.

Figure 18. **Percentage change in domestic production against domestic market share (2020, core scenario)**



Notes: *Data labels are excluded from the bottom left and bottom right for presentational purposes*

Source: *Vivid Economics*

3.4 Sector-level results in MDM-E3

Sector level impacts are small in MDM-E3

3.4.1 Small cost changes lead to small changes in output

MDM-E3 estimates production changes at the sector level, though MDM-E3 sectors are more aggregated than the IMM sectors. Sector-level changes in MDM-E3 are much smaller than in the IMMs. This section discusses the MDM-E3 sector-level results, while Section 3.5 compares the results from the different streams of modelling and identifies the mechanics of what drives them.

Consider the basic metals sector in MDM-E3 under Option 2a, which applies an 80 per cent exemption rate to a broad range of SIC 4-digit codes. Basic metals in MDM-E3 is equivalent to SIC sector 24, and covers the energy users represented by iron and steel and non-ferrous metals.

The implied overall exemption for iron and steel, after using an adjusted weighting for subsectors that do and do not receive exemptions, is 76 per cent. The following subsectors are those that receive the full 80 per cent exemption:

- manufacture of basic iron and steel and of ferro-alloys;
- cold drawing;
- cold rolling of narrow strip;
- casting of iron.

Similarly, the implied exemption for non-ferrous metals is 46 per cent, with the following sub-sectors receiving 80 per cent exemptions:

- aluminium production;
- lead, zinc and tin production;
- copper production;
- other non-ferrous metal production;
- casting of light metals.

The average exemption at the level of the MDM-E3 sector basic metals is around 56 per cent. Before the exemption rates but including CfD costs, electricity prices in these sectors are around £134.40/MWh by 2030 in £2012. The exemption reduces this to £123.60/MWh for iron and steel and £128.70/MWh for non-ferrous metals, relative reductions in electricity prices of 8 per cent and 4 per cent respectively.

The overall impact on production unit cost for the basic metals sector is to reduce it by just 0.02 per cent, while output prices remain almost unchanged, declining by 0.01 per cent. This reflects the difficulty the sector has in passing on cost changes. Industrial gross output and value added are, therefore, relatively unchanged between scenarios.

A similar result is found for most other sectors. The largest price response is in leather goods, which shows a price reduction of 1.36 per cent in Option 2a; paper, printing and recording, and other non-metallic minerals also show relatively strong price decreases. Non-exempt industries are negligibly affected by the marginally higher electricity prices; to some degree, electricity prices are offset by reductions in costs for inputs sourced from exempt sectors.

Table 9 shows the effect of the exemption schemes on output for the most adversely affected sectors in MDM-E3. Most sectors show a negative impact; of the 87 sectors in MDM-E3, 64 decline under Option 1a.

Table 9. **Impact on UK output (measured by quantity of production) for most adversely affected sectors in MDM-E3 (2020)**

	Policy Option					
Sector	**1a (%)**	**1b (%)**	**2a (%)**	**2b (%)**	**3a (%)**	**3b (%)**
Tobacco	-0.34	-0.28	-0.38	-0.37	-0.25	-0.21
Textiles	-0.18	-0.15	-0.11	-0.14	-0.13	-0.11
Pharmaceuticals	-0.12	-0.09	-0.16	-0.14	-0.09	-0.08
Other mining	-0.08	-0.06	-0.11	-0.1	-0.08	-0.06
Rubber & plastic	-0.08	-0.06	-0.11	-0.1	-0.07	-0.06
Accommodation	-0.06	-0.05	-0.08	-0.07	-0.04	-0.03
Miscellaneous transport equipment	-0.05	-0.04	-0.06	-0.06	-0.04	-0.03
Coke & petroleum	-0.04	-0.03	-0.05	-0.04	-0.03	-0.02
Furniture	-0.03	-0.03	-0.05	-0.04	-0.03	-0.02
Metal products	-0.03	-0.02	-0.04	-0.03	-0.02	-0.02
Beverages	-0.03	-0.02	-0.03	-0.03	-0.02	-0.02

Note: *Sectors that experience a less than 0.03 per cent reduction under Option 1a are excluded.*

Source: *Cambridge Econometrics*

3.5 Comparison of results between models

The two models exhibit quite different sensitivities to cost changes

3.5.1 Models of fundamentally different structure produce contrasting results

Given the differences in sector definitions, it is not straightforward to compare results between MDM-E3 and the IMMs. Some of the sectors analysed with RIMM and FIMM make up only a small proportion of the more aggregated sectors in MDM-E3. The exemption rates applied to more aggregated sectors in MDM-E3 differ from those applied in the IMMs.

However, with some adjustments, it is possible to arrive at broadly comparable numbers, which generally indicate that the impact of the exemption as estimated by MDM-E3 is substantially smaller than the impact as estimated by RIMM or FIMM. For instance, the adjusted change in domestic output for a standardised exemption rate of 80 per cent on 'non-metallic minerals' in MDM-E3 is not even 0.01 per cent; the estimated impact on the lime sector is over two orders of magnitude higher using RIMM, and the impact on cement is more than another order of magnitude higher still. The absolute value of the impact on the rubber and plastic sector in MDM-E3 is, in absolute terms, stronger than the equivalent IMM sector, but in the other direction: rubber and plastic output declines in MDM-E3, while rubber tyres and tubes output increases due to the exemption in the IMMs (Table 10 shows the sectors where the most direct comparisons are possible). In sum, the IMM impacts are substantially larger than their MDM-E3 equivalents.

Table 10. **The change in domestic production is substantially larger in the industrial models than in MDM-E3 (2020, core scenario)**

MDM-E3 sector	Adjusted change in domestic output in MDM-E3, %	Relevant RIMM and FIMM sectors	Estimated change in domestic output in IMMs, %
Rubber and plastic	-2.93	Rubber tyres and tubes	1.6
Non-metallic minerals	0.005	Cement	17.9
		Lime	0.7
Basic metals	-0.03	Long steel	19.5
		Steel flats	9.5

Notes: *The issue is further complicated because the sector-wide exemption rates applied in MDM-E3 are adjusted from their values in the original policy scenarios. In order to produce numbers that can be compared across models, the sector-wide effects in MDM-E3 were adjusted in proportion to their exemption size under Option 2a, which broadly applies an 80 per cent exemption rate.*

Source: *Cambridge Econometrics, Vivid Economics*

The remainder of this section addresses these differences in more detail, showing how a cost shock is processed in the models. In both models, the application of a production cost decrease to industry is partially transmitted to market prices. Associated with the price change, there is a substitution towards domestic production at the expense of imports (the import elasticity). The discussion that follows covers:

- similarities in the scale of the cost shocks applied (Section 3.5.2);
- theoretical and practical differences in the determination of cost pass-through rates (Section 3.5.3);
- theoretical and practical differences in the determination of import elasticities (Section 3.5.4);
- miscellaneous other factors which might lead to differences in the results (Section 3.5.5);
- summary points (Section 3.5.6).

3.5.2 The size of cost shocks in the model are similar

As would be expected, the magnitude of the decreases in production costs are similar in both models (Table 11), with identical CfD support costs applied in both cases. The underlying values for the electro-intensity of production do differ in some instances, but not sufficiently to explain the divergence in outcomes.

Table 11. **Comparison of cost changes across models**

MDM-E3 sector	Exemption as proportion of price for MDM-E3 sectors, %	Relevant IMM sectors	Exemption as proportion of price for IMM sectors, %
Mineral products	0.83	Cement	1.3
		Flat glass	0.4
		Heavy clay ceramics	0.6
Basic metals	1.08	Long steel	0.9
		Steel flats	0.5

Notes: *The issue is further complicated because the sector-wide exemption rates applied in MDM-E3 are adjusted from their values in the original policy scenarios. In order to produce numbers that can be compared across models, the sector-wide effects in MDM-E3 were adjusted in proportion to their exemption size under Option 2a, which broadly applies an 80 per cent exemption rate.*

Source: *Cambridge Econometrics, Vivid Economics*

3.5.3 The method for determining cost pass-through rates differs

Cost pass-through rates in the IMMs are determined from the various competitive factors that the model considers in the decisions of firms. In MDM-E3, cost pass-through rates are estimated empirically from historic data sets or are assumed to be equal to 100 per cent where empirical estimates are not available.

This results in the models' cost pass-through rates differing significantly in some instances, as shown in Table 12. For instance, in the IMMs, the small share of UK steel production in the EU market results in very low cost pass-through rates; in MDM-E3, however, the rate is 30.4 per cent. For other non-metallic minerals, the MDM-E3 cost pass-through is 100 per cent (a rounding down of the empirical estimate, which was greater than 100 per cent). The IMM estimates for the relevant sectors are, again, substantially smaller than this.

Table 12. **There is substantial variation in sector cost pass-through rates between IMMs and MDM-E3 (2020, core scenario)**

MDM-E3 sector	Cost pass-through rate, %	IMM sector	Cost pass-through rate, IMMs, %
Other non-metallic minerals	100	Flat glass	4
		Ceramics	78
		Fertilisers	18
		Cement	49
Basic metals	30	Steel flat	1.6
		Long steel	5

Source: Cambridge Econometrics, Vivid Economics

3.5.4 Import elasticities differ greatly and have different origins

The cost pass-through rates interact with substantially higher responsiveness to prices on the part of imports in the IMMs than in MDM-E3. As shown in Table 13, the inferred IMM elasticity estimates range from around 7 to 83 while the MDM-E3 econometrically estimated elasticities are less than unity.

Table 13. **The sensitivity of imports to price changes is 10 to 100 times larger in the IMMs than MDM-E3 (2020, core scenario)**

IMM sector	Imports pre-exemption, '000t	Percentage change in imports	Price pre-exemption, £/t	Percentage change in price	Elasticity of imports with regard to price, %	MDM-E3 sector	Elasticity of imports with regard to price, %
Flat glass	10,550	-0.1	380	-0.02	7.1	Other non-metallic minerals	0.50
Ceramics	664	-36.1	98	-0.43	83.0		
Fertilisers	1,733	-5.1	294	-0.16	31.2		
Cement	3,509	-31.8	71	-0.65	49.1		
Steel flat	203,333	-0.1	473	-0.01	13.9	Basic metals	0.84
Long steel	90,965	-0.6	456	-0.04	14.9		

Source: Cambridge Econometrics, Vivid Economics

The IMM import elasticities may seem large, but they reflect the basic premise that a reduction in domestic margin to zero would result in a complete departure of domestic production from the market in the long run. Compared to MDM-E3, the IMMs places greater emphasis on the potential for domestic producers to increase their market share at the expense of importers, given sustained differences in production costs. Box 2 explains how such high import elasticities can come about.

Box 2. **Hypothetical illustration of high import sensitivity**

The IMMs results exhibit an intuitively sensible pattern in which a reduction in domestic profit margins to zero would result in a complete departure of domestic production from the market in the long run. Less obvious is that, in the absence of the closure of installations, this decrease is linear, that is, a reduction in profit margins results in a proportional decrease in output. Within the model, this linearity is ultimately driven by the assumption of the linearity of demand, a common assumption in models of this type. In reality, differing demand curve shapes, as well as other factors beside installation closures, may complicate this relationship. CfD support cost exemptions involve an increase in profit margins, resulting in proportional increases in output, but a negative cost shock example will be used for illustration.

Let domestic margins start at 10 per cent, and import penetration at 10 per cent. To this situation, apply a negative cost shock of 2 per cent of sale price, assuming the cost pass-through rate is 50 per cent. The market price of the product will increase by 1 per cent of the current price, while the profit margin reduces to 9 per cent.

Assuming no installation closures, the IMMs would suggest a proportionate decline in domestic production of 10 per cent. There may be a change in market size, as consumers reduce consumption in the face of the new market price. However, if demand elasticity is, say, -0.5, then the 1 per cent increase in costs will translate to a 0.5 per cent reduction in consumption, which can be ignored in this analysis. Consequently, after the cost shock, domestic production must now make up 81 per cent of the market. The gap is filled by imports, which rise from 10 per cent to 19 per cent of the market: thus, the quantity of imports increases by 90 per cent.

Thus a 1 per cent increase in market price results in a 90 per cent increase in imports: the elasticity of imports with respect to prices is 90.

However, the empirical import elasticities used within MDM-E3 are valid: that is, they are highly significant in statistical terms. They are estimated over a long period in which there have been some price changes and shifts in import penetration and margins have been at plausible levels. Ultimately, the theoretically-produced and empirically-observed elasticities lie very far apart, but draw attention to the range of potential consequences of the policy.

3.5.5 Additional notes on drivers of difference in the models

There are further factors which may lead to differences between the models. The greatest of these factors might be homogeneity, which is a key assumption in the IMMs, implying that the output of any installation in the market is a perfect substitute for the output of any other. The assumption increases the effective competitiveness of markets, inducing a larger response to a price shock applied to a group of producers. For some sectors, this assumption may involve more of a departure from reality than for others. The possible reasons for non-homogeneity include:

- vertical market integration creating sticky demand;
- operational cooperation between suppliers and customers;
- specialisation;
- branding;
- portfolio ownership of installations to hedge risks across regions.

The other factors are:

- decision makers are not perfectly informed, which may make the import reaction more or less price sensitive;
- unlike MDM-E3, no attempt is made in the IMMs to allow for changes in the efficiency of energy use over time;
- parameter variables in the industrial models were set, for the most part, to be equal to the most recently available data, or to an average of the most recent three years of data. However, growth in the UK's economy has been below trend for almost five years now; and, by projecting forward variables calibrated to a relatively difficult time period, the problems faced by firms in the future may be overstated;
- MDM-E3 includes an increase in the general price level and changes in income.

3.5.6 Summary and additional notes

The impact of exemptions being greater in the IMMs can mostly be attributed to the combination of:

- lower cost pass-through rates, resulting in producers obtaining greater benefits from the exemptions;
- greater responsiveness to competition from imports, resulting in substantial output-driven profit gains.

These differences, in turn, are driven by fundamental differences between the models. The IMMs are theoretically driven, particularly by the rule that production is unsustainable if profit margins are zero, and in the absence of closures they produce an approximately linear relationship between domestic output and margin. This assumption is derived from the underlying construction of market equilibrium, and is intuitively reasonable. MDM-E3 reflects history, as measured by empirical analysis in statistical models. These differences cannot be directly reconciled, as they reflect fundamental differences in economic modelling methodology. However, given that declines in sectoral output may not be easily reversible, and may induce significant social costs (see Section 4), a cautious policymaker might wish to interpret the IMMs as a warning of a potential downside outcome.

3.6 Aggregate macroeconomic results

The impact of CfD exemptions at the whole-economy level is negligible

3.6.1 A very small rise in price indices, very small dips in GDP and consumption

It is necessary to consider the effect of exemptions from the broader perspective of the aggregate UK economy. The focus so far has been on sectors that are recipients of the exemption. However, funding the exemption has an offsetting negative impact on non-exempt sectors and consumers through higher electricity prices and changes in product prices that occur as a result of the exemption. For households, the former effect is likely to be greater than the latter, noting that cost pass-through rates will blunt household exposure to product cost rises and falls and that, for instance, the exempt sectors do not generally represent a large share of household expenditure.

As seen in MDM-E3's sectoral results, the inspection of major macroeconomic variables suggests that the exemption scenarios have a very small impact, see Table 14. The change in consumer spending and GDP is a decrease of a few thousandths of a percent. The impact on imports, exports, and price indices is similarly muted.

The small impact is unsurprising: the manufacturing sectors subject to exemptions in the broader policy scenarios constitute less than 0.5 per cent of total UK GDP. Furthermore, the net effect is the growth impact from exempt sectors offset by contraction in non-exempt sectors. That is, exemptions improve the competitiveness of industry, which stimulates mild increases in output. The exemption is funded by non-exempt electricity consumers. The resulting aggregate effects are the net sum of all the gains and losses. The overall outcome is broadly neutral almost to the point of negligible, with a very small net negative impact.

Table 14. **The outcomes of major macroeconomic variables in 2020 are largely invariant across the scenarios (£2009)**

Variable	No exemptions	Percentage difference in outcome relative to the no exemptions case: Option 1a	Option 1b	Option 2a	Option 2b	Option 3a	Option 3b
Consumer spending	£1,070 bn	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Exports	£540 bn	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01
Imports	£564 bn	-0.01	-0.01	-0.01	-0.01	0	0
GDP	£1,680 bn	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Index of average housing cost (2009=1)	1.35	0.11	0.09	0.14	0.13	0.08	0.06
Consumer prices index (2009=1)	1.41	0.12	0.1	0.16	0.15	0.09	0.07
Domestic electricity prices (£/MWh)	201.7	0.26	0.21	0.35	0.31	0.19	0.16

Source: Cambridge Econometrics

4 Costs and benefits

Value for money and distribution of impacts

Section contents:

Some sectors are more deserving of exemption than others
Sectors examined in detail individually are likely, in current market conditions, to show value for money from exemptions, in some cases strongly so. Somewhat conflicting evidence emerges from the macroeconomic modelling level, where the costs of the policy appear to very slightly outweigh the benefits, although because the scale of the policy is modest, neither costs nor benefits are large.

Most of the benefit that is generated comes from changes in UK firm profits. Some additional benefit flows outside the UK economy to purchasers of exports. Meanwhile, the costs of the policy fall more heavily on low income than high income households, probably because the former spend more of their income on electricity.

There are some employment effects, in the order of a small number of thousands of jobs over a period of years. Additional aspects of employment effects, such as regional distribution, are also touched on.

4.1 Introduction

A cost benefit analysis supported with other information

4.1.1 A standard economic welfare analysis

Throughout the report so far, the focus has been on the variations in output in tonnes and turnover in money. These variables do not equate directly, however, to the costs and benefits of the policy, which this section addresses.

The two building blocks of cost and benefit analysis are the consumer and producer surplus in the UK, that is, an approximation of the change in welfare of domestic consumers and producers resulting from the policy. For individual sectors analysed with the industrial models, the benefits of exemptions tend to outweigh the costs. Sectors can be ranked by the relative value for money of their exemptions. However, the macroeconomic results in Section 4.3, albeit containing very different scales of impact on individual sectors, suggest that, in aggregate, the costs of the exemption just outweigh the benefits, although the net impact is very small.

4.1.2 Supplementary information on employment, distributional impact and environmental effect

A policymaker may consider additional outcomes as costs and benefits besides producer and consumer surplus. This section also addresses the impact on employment; including aggregate, sector, and regional employment effects. It looks too at the impact across the household income distribution and at environmental impact in the form of carbon leakage.

4.1.3 A subset of results is presented here

Due to the large volume of results across 20 sectors, three time horizons and both scenario and sensitivity analysis, the Industrial Market Model results shown here are all for an exemption rate of 80 per cent. The data books supplied to DECC and BIS provide more comprehensive datasets, including the application of an exemption rate of 50 per cent. As the only other rate applied in the policy scenarios considered in MDM-E3 is 67 per cent, and the relationship between the size of the exemption and the impact on key variables is linear, this is sufficient information to enable the calculation of the impact on production from any exemption rate. Where MDM-E3 results are presented, they are presented for all policy scenarios because there are fewer variations.

4.2 Individual sector costs and benefits

The variation in value for money across sectors is modest

4.2.1 The welfare analysis

Producer surplus refers to welfare gained by producers in a market. It is commonly taken as equivalent to total profits. Wages earned by employees are not included as it assumed that labour markets are unaffected by small changes in sector employment.

Consumer surplus refers to the gain in welfare that consumers obtain from consumption of a product. Following an exemption, so long as cost pass-through rates are not equal to zero, consumers enjoy a lower price for the exempt product relative to the price there would have been without the exemption. There will also generally be a larger quantity of product consumed, which results in additional surplus.

Both types of surplus are measured in pounds sterling. There are criticisms of the extent to which these definitions relate objectively to welfare, but nonetheless their usage is standard in cost-benefit analysis. The focus is on the direct benefit to UK producers and consumers only. Hence, the benefits enjoyed by purchasers of UK exports, or the profits enjoyed by any producer based outside of the UK, are ignored, as is any recycling of such profits back into the UK economy.

4.2.2 Measuring surplus

Within the context of the results of the Industrial Market Model:

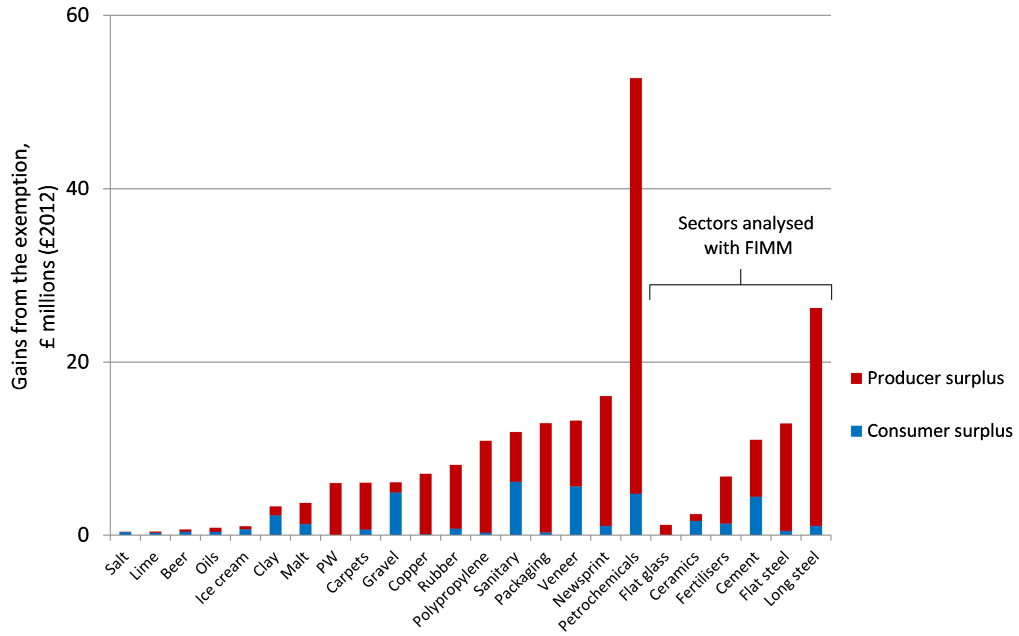
- the change in producer surplus is calculated as simply the change in firm profits, which result both from wider profit margins and higher levels of output (typically the latter is the larger contributor);
- as the demand curve is assumed to be linear, consumer surplus is calculated as the change in the price of the good multiplied by the pre-exemption market quantity, *plus* one-half of the change in price multiplied by the change in quantity. This is then discounted in proportion to the share of UK consumers in the market.

In MDM-E3, a change in the macro-economic variable *consumption* is used as a proxy for change in consumer surplus.

4.2.3 Estimates of surplus

Estimates of changes in consumer and producer surplus are shown in Figure 19. In all cases, the producer surplus benefits are substantially greater than the gains in consumer surplus. This is largely driven by cost pass-through: where cost pass-through rates are low, such as in the steel sector, producers are able to retain the bulk of the exemption.

Figure 19. **The gains from the exemption mostly benefit firms rather than consumers (2020, core scenario)**



Source: *Vivid Economics*

4.2.4 Surplus-based estimates of value for money

Value for money (VfM) is calculated as the ratio of benefits to costs. Thus, a high value for money ratio indicates high returns for the resources employed; a value for money below unity indicates that the benefits are less than the resources employed. Value for money estimates have to be used with great care since they can require a sometimes subjective classification of what is a cost and what is a benefit.

Here, the explicit value for money analysis is restricted to the consumer and producer surplus measures:

- the benefit is the sum of producer and consumer surpluses from those in receipt of the exemption;
- the cost is simply the funds raised elsewhere to pay for the exemption, as measured by the value of the exemption per MWh multiplied by the quantity of sectoral electricity use after the application of the exemption.

Expressed as an equation, the calculation is:

$$VfM = \frac{(\Delta UK\ profits) + (\Delta market\text{-}wide\ consumer\ surplus) \times (\%\ of\ UK\ consumers\ in\ market)}{(Value\ of\ exemption\ per\ MWh) \times (electricity\ use\ post\text{-}exemption, in\ MWh)}$$

In reality, the cost is not merely the funds raised to pay for the exemption: it is the funds raised multiplied by some factor to reflect the additional loss in surplus incurred through raising those funds. That is, a pound of funding costs more than a pound to raise, because it triggers additional loss of surplus as the fund-providing sector reduces output and raises prices in response to higher electricity costs, while consumers incur welfare losses from increased electricity costs.

Note that, due to the lack of accounting for additional costs associated with fund-raising, it is impossible for the VfM ratio at the sectoral level to be below 1: any pound sterling given to industry via the exemption must be distributed among either firm profits or consumer surplus. This would be true even if the quantity of production remained unchanged after the exemption.

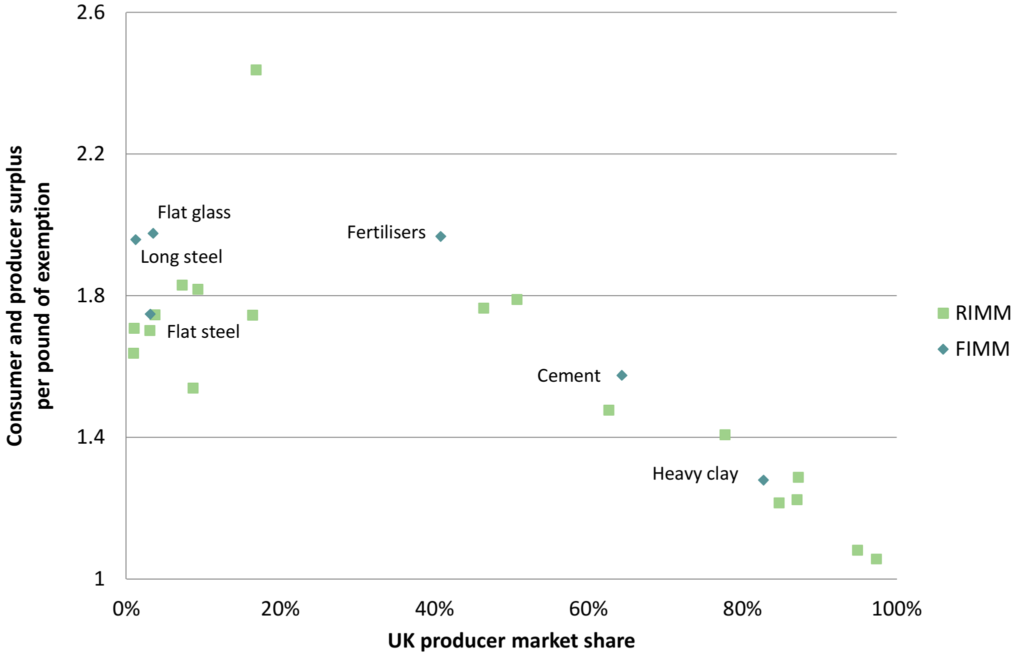
The value for money of exempting the various sectors is shown in Figure 21. As defined here, relatively higher values of VfM are largely driven by the responsiveness of the sector in terms of output changes; not necessarily the largest absolute output change, but the largest change per pound of exemption. Variations across sectors are driven by:

- differences in market share of UK producers, insofar as this is the largest single driver of the responsiveness of output to exemptions. Other factors driving responsivenesss – profit margins and price elasticity of demand – will also influence VfM;
- differences in the market share of UK consumers, affecting the share of consumer surplus that is included in the VfM numerator.

This is discussed further in Section 5.2. The first of the factors – exposure to imports – tends to have the stronger effect. It can be expected, then, that sectors with high import penetration, and especially where export rates are low, will achieve the highest value for money ratio. Figure 20 indicates the importance of UK producer market share alone in driving variation in VfM ratios. Thus, elasticity, gross profit margins, and the share of UK consumers in the market account for the unexplained share of the variation.

The rate of cost pass-through is not directly involved in determining the VfM ratio. As noted and shown in Figure 19, it does drive the split between consumer and producer surplus, but as both these variables are included in the numerator of VfM, it is correct to consider that cost pass-through’s involvement in determining VfM ratios is mediated through its association with the impact on production decisions.

Figure 20. **High UK producer market shares are associated with lower VfM estimates**



Source: *Vivid Economics*

For the sectors investigated in full detail, in most cases, the VfM ratio is close to 2. The exceptions are heavy clay ceramics, at around 1.29, and cement, at 1.57. If adjusted for the cost of raising funds, ceramics is most at risk of having a value for money below unity. Some sectors investigated in less detail have similarly low value for money, namely salt, gravel, clay, ice cream, lime and beer. Malt shows the highest estimated value for money of all sectors, combining reasonable electro-intensity with a high degree of trade exposure.

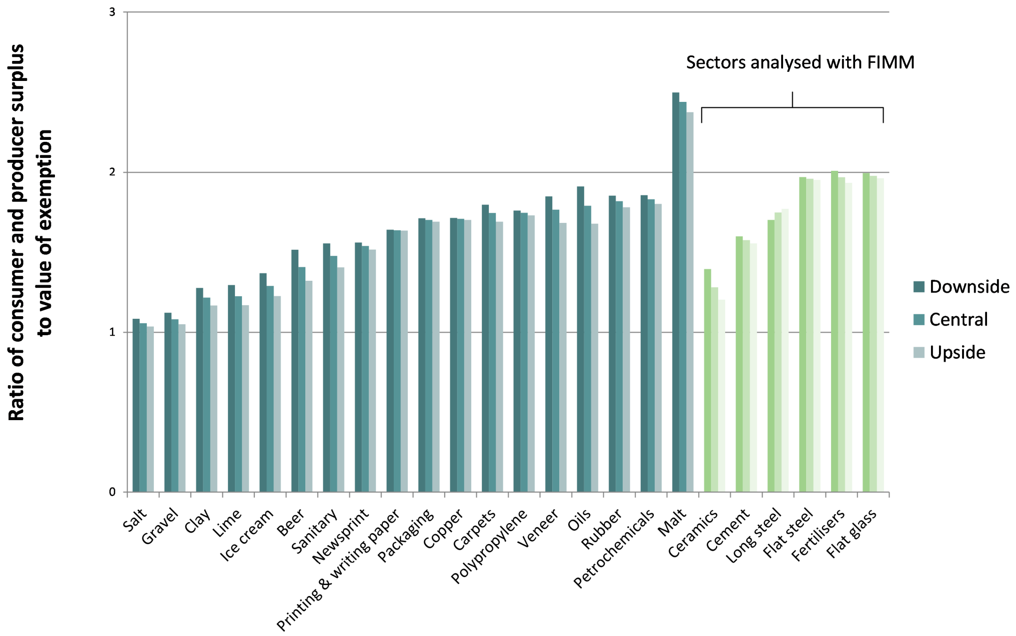
Figure 21 also shows the variation in VfM across different the upside, central, and downside scenarios. Two observations are notable:

- for all sectors, the VfM ratios are similar across the scenarios. This is contrast to the variation in the absolute value of production shown in Figure 1 and Figure 2. The difference is that VfM is a ratio reflecting relative sectoral responsiveness, while the absolute value of a proportional change under the scenarios varies due to changes in the absolute size of the sector. Sectors in which market share varies strongly across the scenarios (which changes the sector's competitive position) or in which consumer demand is responsive to price, show stronger variations in VfM;
- the VfM ratios are consistently highest in the downside scenario, which occurs because the benefit of an exemption is higher when margins are squeezed and markets behave more competitively.

An exception to the latter point is long steel products, which have the highest VfM in the upside scenario, and have a lower average intensity of natural gas use in the UK as compared to the EU. Within the model, the UK sector loses market share disproportionately when gas prices decrease, and consequently, and unintuitively, experiences relatively greater disadvantage in the upside scenario.

At the current time, all of the seven sectors examined in full detail show likely net benefits of exemption. As economic and market conditions change, the value for money metrics can be expected to change too, see the sensitivity analysis conducted in Section 5. This is also true for the sectors investigated in less detail, which, as shown, also span a wide range of VfM ratios.

Figure 21. **Many sectors show value for money above 1.5 under exemptions, with the exception of salt, gravel, heavy clay ceramics, clay, ice cream and lime (2020, core scenario)**



Source: *Vivid Economics*

4.3 Economy-wide costs and benefits

Exemptions impose a net cost on the economy

4.3.1 Costs and benefits across the economy

At the macroeconomic level, the exemption of sectors to the support costs for CfDs leads to two direct effects:

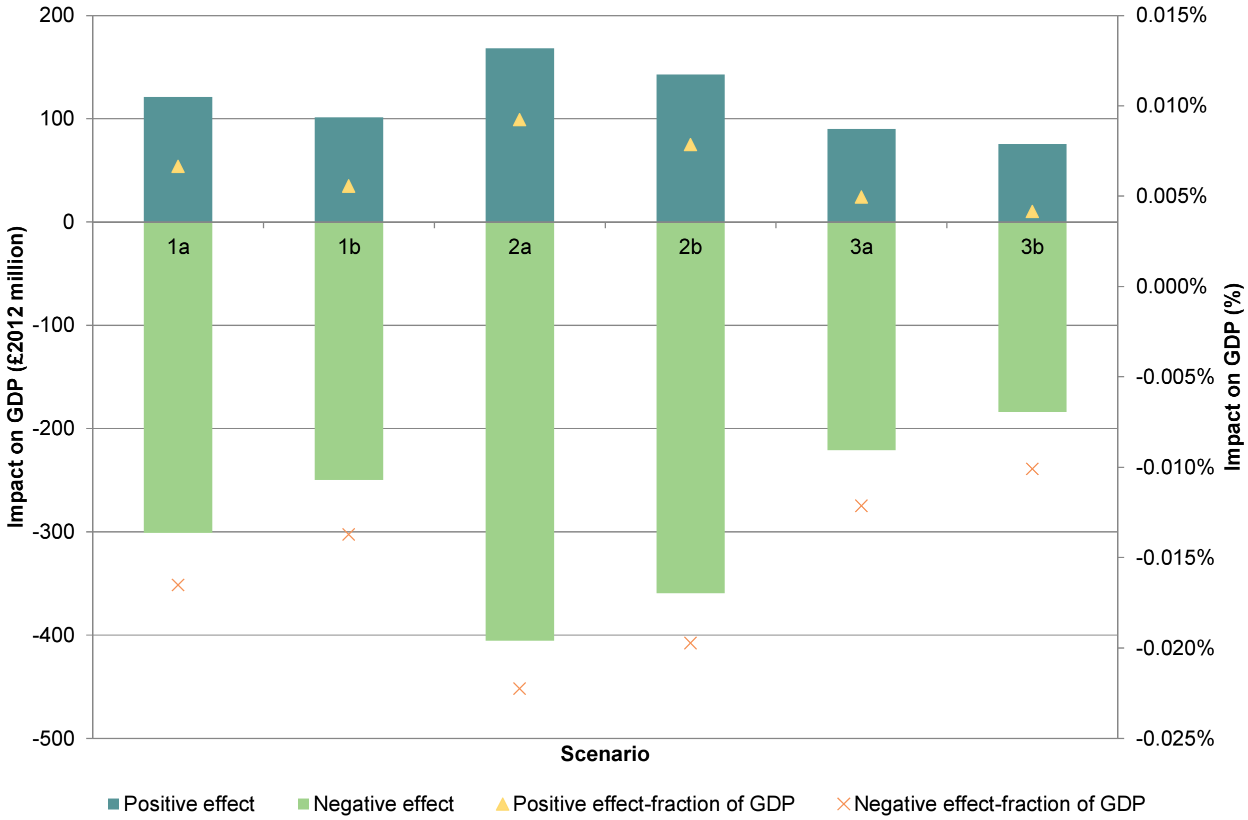
- businesses receive an exemption, increasing profits, while customers of those businesses face lower prices: a benefit;
- businesses and sectors not receiving an exemption face higher electricity costs to support those exempt, as well as higher general costs through increases in the price of goods of non-exempt sectors: a cost.

The macroeconomic modelling captures both effects.

The exempt sectors experience lower costs, passed on to some extent as lower prices. The demand response to the price change is met by increased output, with resulting higher turnover. The demand response in MDM-E3 primarily takes place through exports, and is generally small, resulting in the impact of the exemption also being small. Export purchasers are not counted in the overall cost and benefit calculations, which means that most of the benefit is excluded and hence the total benefit of the exemptions is reported as small. This is shown in Figure 22.

Industrial sectors which do not receive exemptions, as well as households and services, face higher costs, both on their electricity bills and through purchases of goods from non-exempt sectors. This effect generally outweighs the purchases of lower-priced goods from exempt sectors, as much of these latter are directed overseas. That is, sectors subject to the exemption tend, on average, to export more of their production than non-exempt sectors; consequently, the cost to households of higher electricity prices and higher priced goods from non-exempt sectors is not outweighed by the lower cost of goods from exempt sectors. This contributes to the negative impact slightly outweighing the positive GDP impact in all scenarios, though, in the context of the expected size of the UK economy in 2020, the difference is small (note that the 'exporting of price decreases' occurs less in sectors with low cost pass-through rates).

Figure 22. **Negative effects outweigh positive effects in all scenarios modelled in MDM-E3 (impact in 2020)**



Source: *Cambridge Econometrics*

4.3.2 Total employment impact

Estimates were made of the net effect on employment using MDM-E3. As for the other aggregate macroeconomic impacts, and for similar reasons, the estimated impact is very small, see Table 15. Total economy wide employment changes by a negligible amount, in all exemption options increasing by less than 0.05 per cent. Corresponding decreases in unemployment reduce the claimant count by around 1 in 250 of claimants, that is 0.3 to 0.5 per cent of claimants. This employment change is thinly spread over the sectors of interest. Note that with its Keynesian heritage, MDM-E3 tends to suggest that labour (and capital) disequilibria are somewhat more persistent than, for example, might be suggested by a Dynamic Stochastic General Equilibrium (DSGE) model, which involves more rapid price adjustments. Such differences in the pace of market clearing under different macroeconomic modelling techniques may result in different estimates of the net impact of an exemption.

Table 15. **Aggregate employment outcomes in 2020 are largely invariant across the scenarios**

Variable	No exemption	Option 1a	Option 1b	Option 2a	Option 2b	Option 3a	Option 3b
Total employment ('000s)	33,227	0.02%	0.02%	0.03%	0.03%	0.02%	0.02%
Unemployment (claimant count; '000s)	1,755.6	-0.47%	-0.39%	-0.62%	-0.55%	-0.34%	-0.29%

Source: *Cambridge Econometrics*

Note that wages are not included in the measures of producer surplus in Section 4.2. The economic assumption in the analysis presented here is that employees in manufacturing sectors would, in a situation of macroeconomic equilibrium, mostly be able to find employment elsewhere, and consequently there is not a strong opportunity cost if they fail to find employment in a specific sector due to an absence of exemptions.

In practice, however, frictions, such as underemployment or regional concentration of industry may mean that there are employment-based social benefits to exemptions. Many of the sectors examined are capital intensive and involve skilled employment; there may effectively be human capital losses if such workers are not able to deploy their skills elsewhere. A thorough analysis of this issue is not attempted, though it may be useful to note, for reference, that average annual full-time wage in the manufacturing sector are around £32,000 (ONS, 2013b), which serves as a broad indicator of the potential productivity and other losses that could be caused by unemployment. Potential regional employment effects are discussed further in Section 4.3.4.

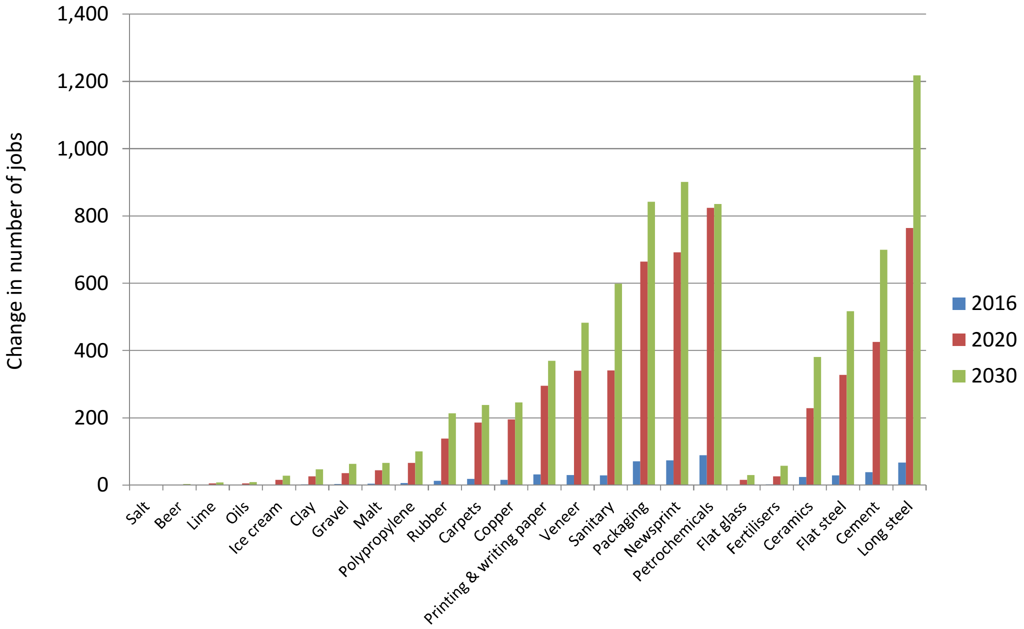
4.3.3 Sector employment impact

Returning to the sectoral results produced by the IMMs, the variations in turnover that result from exemptions could result in changes in sector employment. For this analysis, it is assumed the relationship between turnover and employment is linear: that is, a 1 per cent increase in sector output corresponds to a 1 per cent increase in employment. In practice, this is unlikely to be true: it would imply, for instance, that employment also decreases linearly as output drops, when in practice firms would maintain a minimum number of staff to keep a plant operating, at least until market exit occurred.

The sector labour to turnover ratio is obtained from ONS data between 2008 and 2011. It is assumed this ratio remains constant over time, that is, no changes in the capital-labour ratio occur.

In general, the sectors have a reasonably high capital-labour ratio. Representing only a small share of UK GDP, the absolute employment gains are small relative to the broader economy, though they amount to several thousand jobs by 2030, see Figure 23.

Figure 23. **Estimated employment gains associated with exemptions are small in the near-term, though for some sectors they are somewhat more substantial by 2030**



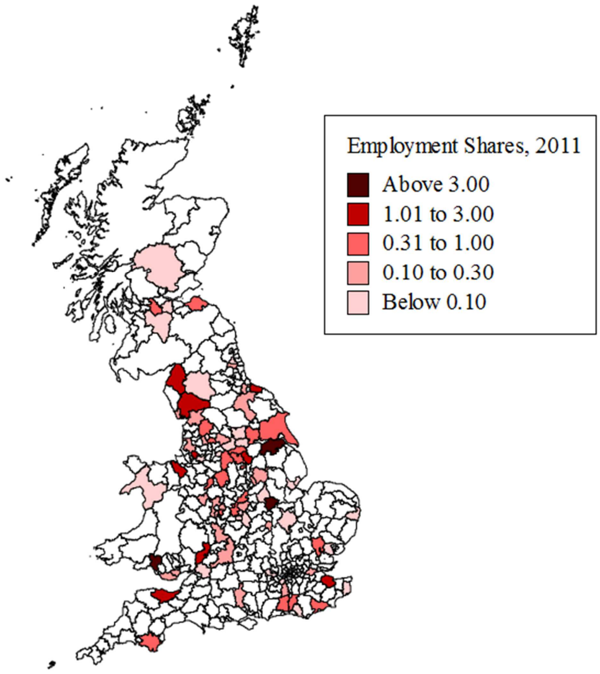
Source: *Cambridge Econometrics; Vivid Economics*

4.3.4 Regional employment: concentration and dependence

It is worth considering that there may be additional social costs incurred if installation closure results in concentrated rises in unemployment in particular areas. The estimated local dependencies of employment on the six energy intensive industries assessed in full detail, as expressed by share of local employment, are shown in Figure 24. In 2011, twelve local authorities had employment dependency ratios above 1 per cent for these sectors as a whole and, within that, three had dependency ratios that were over 3 per cent. That is, in twelve cases, more than 1 in 100 people in employment work in these sectors and in three cases more than 1 in 30 people work in them:

- Neath Port Talbot, 9.1 per cent;
- North Lincolnshire, 6.2 per cent;
- Rutland, 4.0 per cent.

Figure 24. **Local employment dependencies for the six sectors investigated in detail**

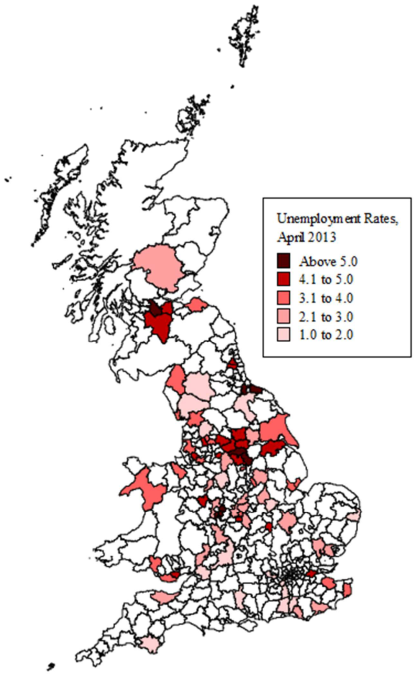


Source: *Cambridge Econometrics; Vivid Economics*

However, a local area's vulnerability to the continuation of particular sectors is not solely determined by its dependency on these sectors. Other factors should be considered, such as employment growth, unemployment growth, and unemployment levels relative to the UK average, since these factors relate to an area's capacity to absorb employment losses.

Figure 25 shows that of the three local authorities most affected, the first two, Neath Port Talbot and North Lincolnshire are, at 4.0 and 4.6 per cent respectively, facing unemployment rates slightly above the UK average of 3.7 per cent.

Figure 25. **Local unemployment rates vary substantially across the UK**



Source: *Cambridge Econometrics*

Overall, then, if exemptions were not sufficient to maintain economic production in these sectors, the impact might be disproportionately felt in these local authority areas.

4.4 Distributional impacts

Very small alterations in consumer price distributions

4.4.1 Mechanism of action on consumer prices

In MDM-E3, the exemptions are processed by industry as follows:

- the majority of the exemption is passed through to purchasers, with some proportion absorbed as extra profit;
- a sizeable portion of sales is directed to exports, so foreign purchasers benefit from the lower prices;
- before reaching final consumers, output is processed, to varying degrees, through intermediate industries, which may also export or absorb a proportion of the price decrease.

Households additionally face higher electricity prices to pay for the exemption. The service industry similarly faces higher electricity costs, relatively more of which are passed to final consumers due to lower export rates; thus the net overall increase in consumption price indices.

4.4.2 Prices rise overall, net impact is negligibly regressive

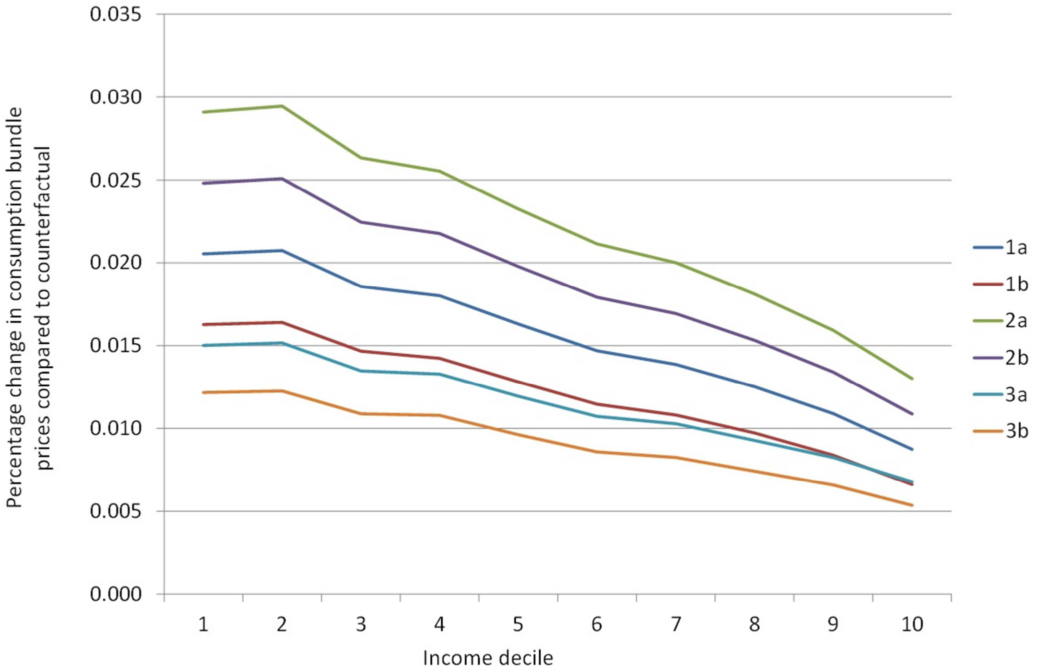
The prices of typical consumption bundles across income groups change, indicating the effects of the policy scenarios on households by income group. There is a somewhat larger percentage increase in the price of the consumption bundles of lower income households than higher income deciles. The relative effects on low and high income households appear stable across the policy options.

This is unsurprising:

- low-income households spend a higher proportion of their income on electricity;
- there are no obvious factors that would lead either relatively high- or low-income individuals to be purchasers of the output of electro-intensive industries;
- the exemptions are designed to be revenue neutral, price decreases in some areas will be offset by increases elsewhere, blunting the net impact.

The changes in prices of consumption bundles by income decile are shown in Figure 26.

Figure 26. **Consumers face slightly higher consumer prices in 2030 and the policy is negligibly regressive under all policy options**



Source: *Cambridge Econometrics*

4.5 Carbon leakage

The exemption fractionally reduces global carbon emissions

4.5.1 Emissions in exempt sectors fall with the exemption because the UK is less carbon-intensive than rivals

IMM estimates suggest that global carbon savings within individual sectors subject to exemptions range from minimal to over 500,000 tonnes annually by 2030, see Figure 27. This is largely a consequence of the accounting treatment of changes in carbon emissions discussed in Section 2.5: if output in non-EU countries decreases to the benefit of production within the UK, it is assumed that there is no net change in EU-wide emissions due to the EU ETS cap, while there is a saving in emissions due to the non-EU production declines.

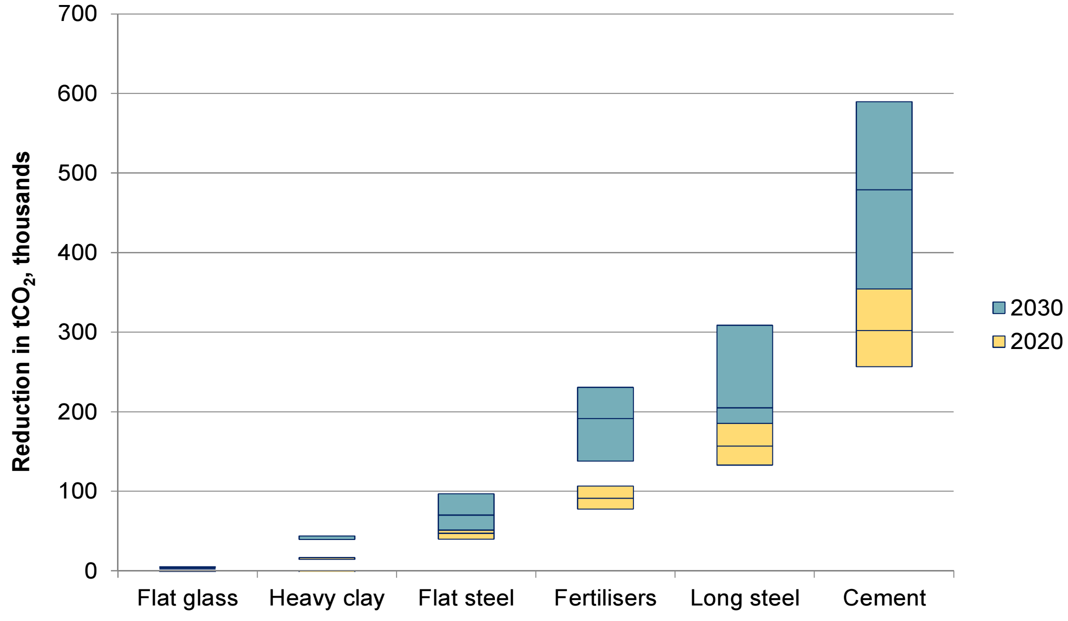
The pattern of savings here is broadly similar to Figure 12, which showed the change in the value of domestic production. However, there are some differences: for instance, carbon savings in the cement sector are relatively higher compared to steel. This is due to the proportionately higher carbon intensity of cement compared to steel, as measured by tonnes of CO_2 required per unit value of production, as well as due to the higher carbon intensity of production for the UK's trading partners for cement as compared to its trading partners for steel.

Note, however, that from the perspective of cost-benefit analysis, UK government guidelines indicate that the key issue is the net change in carbon emissions specifically within the UK, not the net global changes within particular sectors discussed above. This involves reference to the MDM-E3 results.

The UK government's valuation per tonne of carbon in traded sectors in 2016, 2020, and 2030 is £4, £5, and £76/tCO_2, respectively (DECC, CCC, & ONS, 2013). However, MDM-E3 results suggest that the overall impact on CO_2 emissions across the UK economy is fairly negligible. There are three reasons why emissions savings both at the level of exempt sectors, and across the overall economy, are likely to be small:

- overall emissions are little changed because increases in electricity consumption by exempt industries are more or less offset by decreases in electricity consumption in non-exempt sectors;
- the impact on emissions from an increase in imports from within the EU is close to zero, because EU plant have similar emissions intensities and may be operating under the cap of the EU ETS;
- MDM-E3 follows the DECC Updated Energy Projections, and consequently the carbon intensity of electricity is low by 2030. Thus, the changes in electricity consumption due to exemption do not have a large impact on emissions.

Figure 27. **The estimated quantity of carbon savings varies widely across sectors investigated with FIMM**



Notes: *Each bar shows the highest, lowest and central estimate of the value of the exemption. Note that for all sectors, the highest value changes occur in the upside scenario, and the lowest occur in the downside scenario. 2020 numbers are layered on top of 2030 numbers, and thus in some instances the low estimate for 2030 is not visible.*

Source: *Vivid Economics*

5 Sensitivity analysis and model behaviour

There is a range of plausible estimates of impact

Section contents:

Results are driven by the size of the exemption relative to profits and by parameters describing the competitive environment

Value for money is influenced by the assumed profit margin, price elasticity of demand and exemption rate. Value for money in the cement and steel sectors, for example, is sensitive to reductions in profit margins and changes in the other assumptions. The impacts on sectoral VfM are driven by the starting levels of the input variables.

The sensitivity of firm profits and output helps further explain the economic dynamics. For instance, sectors which exhibit lower long-run profit margins characteristically have more aggressively competing firms, where firms use cost advantage more vigorously to obtain greater market share.

The estimates of domestic firm output respond non-linearly to changes in profit margin, while domestic firm output responds linearly to changes in the size of the exemption. The price elasticity of demand exhibited by consumers has little influence in most sectors, while, as discussed previously, changes in market share have a strong influence on the impact of exemptions. Thus, speaking broadly, inter-firm interactions are more important than interactions with consumers in driving output changes for domestic firms for a given CfD exemption.

5.1 Introduction

Sensitivity analysis illustrates the model and sector dynamics

The sector-level results in Section 3 and Section 4 reflect the Industrial Market Model's response to the various inputs that describe the competitive state of a sector.

This section aims to demonstrate the robustness of those results towards key areas of uncertainty, and to provide a more detailed illustration of the model's behaviour. This will help the reader to interpret the sector results and the background information in the Appendices. The results of the sensitivity analysis serve to illustrate the discussion.

Sensitivity analysis refers to the practice of examining the scale of response of a model to perturbations in input parameters. It can be conducted in various ways; the approach here is as follows:

- for sectors analysed with both RIMM and FIMM, the models are run multiple times over a series of small steps of specific inputs, such as demand elasticity, holding other variables constant. This allows inspection of the variation in key outputs, such as VfM ratios, cost pass-through, and the change in domestic production;
- within MDM-E3, the sensitivity focuses on variation in fossil fuel prices, with both central, high, and low fuel price variations considered.

For the most part, the results are robust to input variations, though the degree of response varies depending on the setting of other inputs.

The idea is not to demonstrate every possible input combination, which would be overwhelming: the presentation is limited to parameters of particular interest to assist the reader develop intuition regarding the behaviour of the models and thus the sectors themselves.

5.2 Value for money sensitivities

VfM does not vary strongly with changes in input variables

5.2.1 Principal drivers of value for money results

This section shows how the headline VfM estimates presented in Section **4** respond to variations of profit margins, demand elasticity, UK market share, and the scale of the exemption, focusing on the sectors analysed with FIMM, though sectors analysed with RIMM would show similar results.

Profit margin and elasticity are relatively difficult to estimate empirically, and thus sensitivity towards them is of particular importance. Industry preference is generally to keep precise profit margins obscure, and further the model ideally requires long-run equilibrium profit margins, which are difficult to define from real-world data in a fluctuating macroeconomic environment.

Elasticity of demand, meanwhile, is notoriously hard to estimate in general, requiring detailed data sets and econometric techniques. It can be difficult to obtain estimates for individual subsectors.

Fortunately, the results appear robust to reasonable variations in either of these parameters; VfM estimates do not change enough to suggest revision to the narrative described in Section 4. Note that while trade exposure is also a key driver of output variations, it is generally much less uncertain than these other variables.

As noted in Section 4.2, in the IMMs, it is impossible for the VfM ratio to fall below unity: one pound sterling provided as electricity support cost must be divided in its entirety between firm profits and declines in price, where the latter translates directly into consumer surplus.

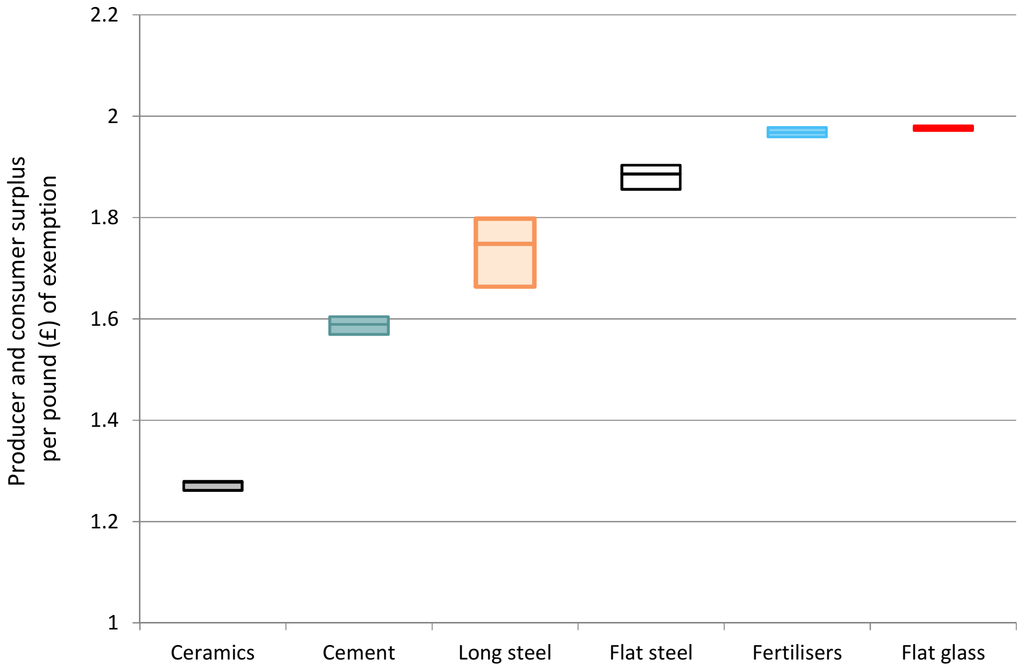
VfM sensitivities for the RIMMs are not shown, though other sensitivity tests are applied to the RIMMs in Section 5.3. The behaviour of the RIMMs with regards to VfM sensitivity is not substantially different to the relationships shown here because it shares the same underlying economic framework with FIMM.

5.2.2 VfM sensitivity to profit margins, demand elasticity, market share, and size of exemption

Figure 28 shows the responsiveness of the approximate VfM ratio to variations in domestic gross profit margin, noting again that the denominator in this measure of VfM is only the ‘raw expenditure’ on the exemption, not accounting for further negative impacts on industries and domestic consumers that experience electricity price rises.

The chart shows that a sizable variation in profit margin of plus or minus 2 percentage points does little to sway the VfM estimates, and nothing to alter the ranking of VfM between sectors. The largest variation is shown by long steel, which moves between a VfM ratio of 1.66 to 1.80 as the estimated gross profit margin moves between 6 to 10 per cent, while the smallest variation is found in flat glass, probably partly due to the relatively large profit margin employed to start with (that is, the absolute variation of 2 percentage points is a smaller proportional movement).

Figure 28. **Varying the estimated UK profit margin by +/-2 percentage points has little effect on VfM ratios (2020, core scenario)**

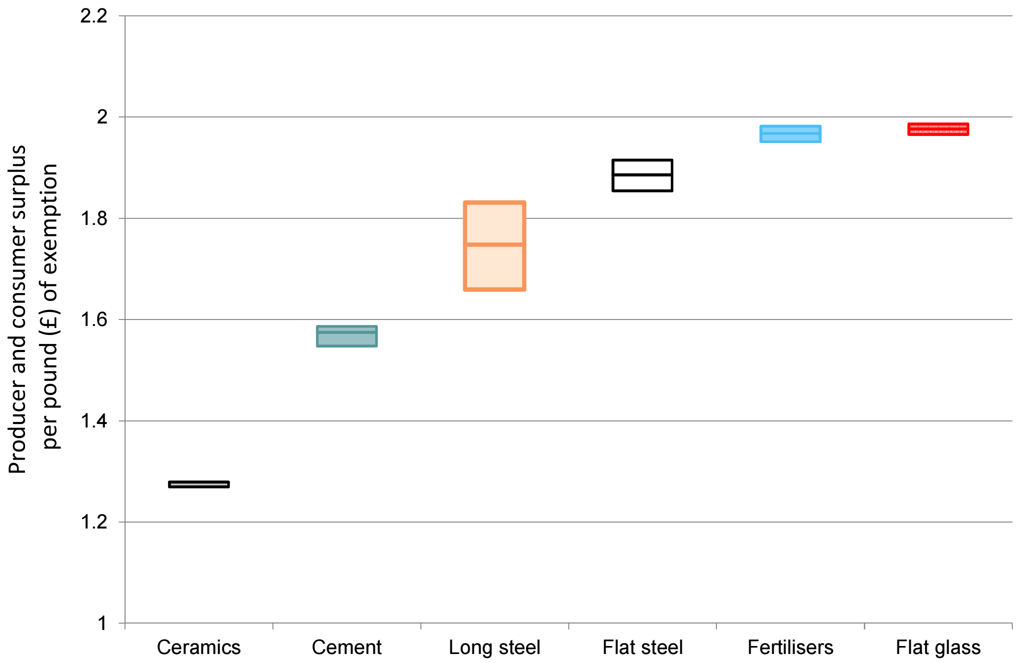


Source: Vivid Economics

Similarly, the sensitivity of the VfM ratio to the value used for demand elasticity suggests that the results are fairly robust to variation of this parameter (Figure 28). Varying the elasticity of demand for cement, for instance, from -0.2 to -0.4 per cent results in the estimated VfM ranging from 1.57 to 1.60.

Inspection of the underlying data suggests that, for instance, doubling the range of variation to plus or minus 4 percentage points in the case of profit margins, or plus or minus 0.2 percentage points for demand elasticity, would still leave the broad narrative of the results unaffected.

Figure 29. **Similarly, varying the elasticity of demand by +/-0.1 percentage points does not substantially vary VfM ratios (2020, core scenario)**



Source: *Vivid Economics*

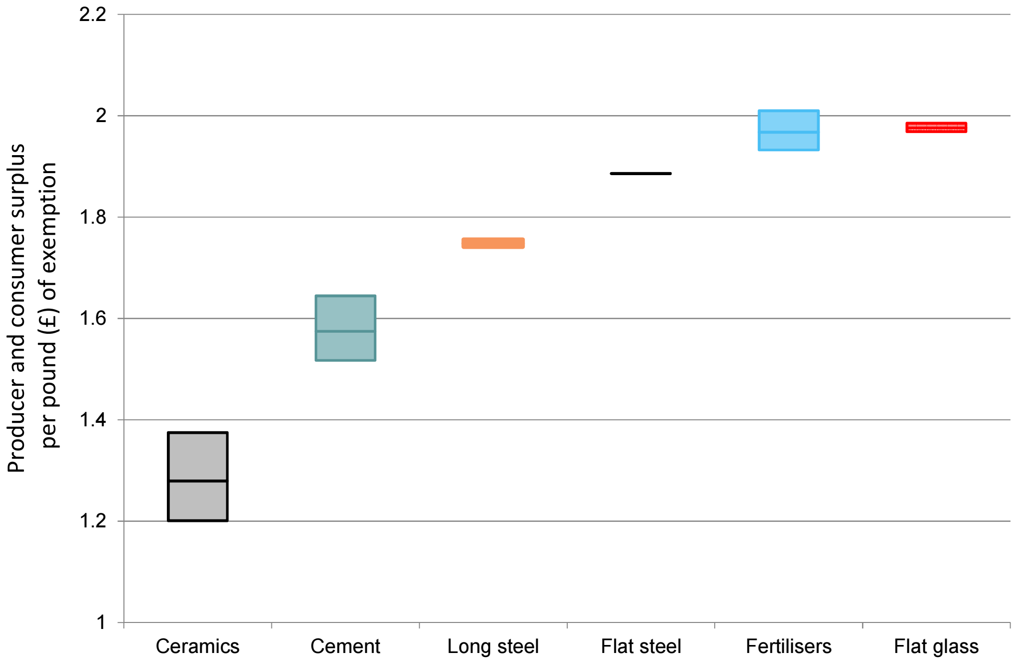
Figure 30 shows the responsiveness of VfM to 10 per cent variations in UK producer market share (noting that this implies a market share of 90 per cent would be varied between 81 and 99 per cent). This results in changes in VfM ratios that are significantly larger, though note that there is no natural comparison point for the relative size of the variation in market share and other input variables. In contrast to their responsiveness to demand elasticity and profit margins, the change in VfM in the steel sectors when market share is varied is small. This is largely because the UK's share of the steel market was low to start with; this is also true for flat glass.

There is a conceptual issue with the isolation of a variation in market share in the IMMs in this manner. It requires an assumption of how the change in production level is divided between producers, which in turn impacts the model's estimate of competitiveness.

The limited variation for at least some sectors shown in Figure 28, Figure 29, and Figure 30 might seem surprising. For instance, the VfM for flat glass changes only fractionally in response to changes in profit margin, demand elasticity and market share. The explanation is that VfM is driven by the responsiveness of output per pound of exemption. Referring to Figure 32, for instance, it can be seen that flat glass has a relatively high profit margin, whereas output sensitivity to changes in the profit margin only becomes high when profit margins are relatively low. Consequently, it would take quite substantial variation in the profit margin estimated for flat glass for the underlying production to change, and hence for the VfM ratio to change substantially.

Figure 35 suggests that sensitivities to variations in demand elasticity are fairly weak, becoming more pronounced only if other factors contribute, such as, in the case of the steel sectors, greater trade exposure, resulting in their relatively greater sensitivity to demand elasticity, see Figure 29.

Figure 30. **The impact on VfM ratios of varying market shares by +/- 10 per cent**



Note: *A '10 per cent' variation is applied proportionally, not in percentage point terms; that is, a market share of 90 per cent would be varied between 81 per cent and 99 per cent.*

Source: *Vivid Economics*

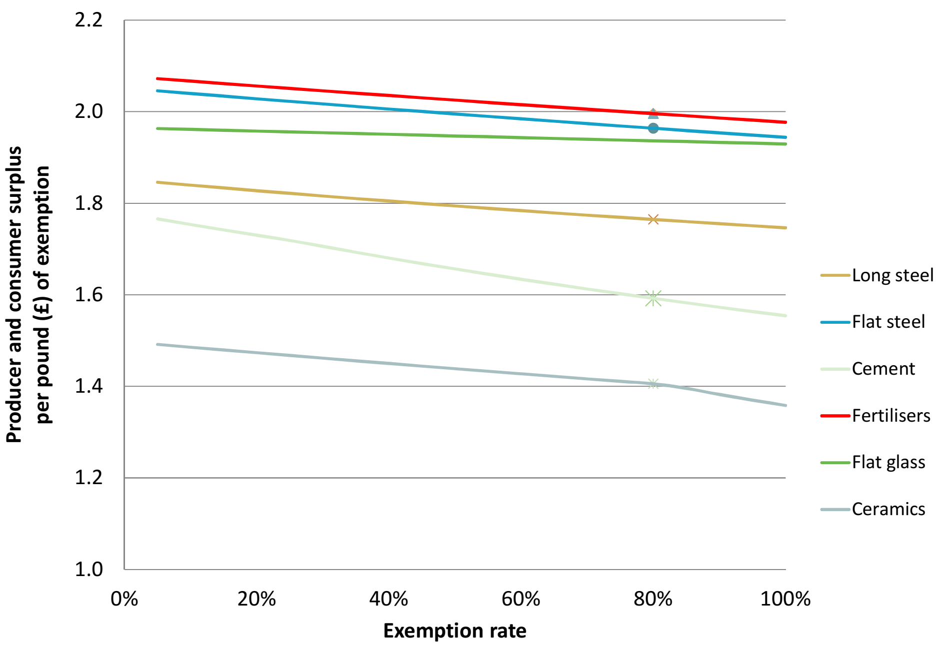
The impact on VfM of combining the variations in profit margin, demand elasticity and market share shown in the above charts is expected to be approximately the sum of the individual effects. This is a consequence of there not being significant discontinuities in response from these sensitivities, evidenced by the figures in Section 5.3. However, as noted, there are non-linearities: thus, for instance, the impact of higher market share, lower profit margins and higher demand elasticity will be larger than the sum of each individual effect, as the overall worsening of the competitive position of the sector amplifies the individual impacts.

Finally, as shown in Figure 31, the responsiveness of VfM to the size of the exemption is close to linear. The VfM ratio is is at its maximum as soon as the exemption rate is strictly positive, and declines as the exemption rate increases. Between an exemption rate of 0 and 100 per cent, the ranking of the sectors by VfM remains the same.

This chart should be interpreted carefully. It does not indicate, for instance, an optimal rate of exemption, only that the benefits per pound of expenditure are lower at higher exemption rates. It could still be the case that the optimal public policy is to offer a 100 per cent exemption, or any other value, depending on what is considered an appropriate VfM threshold, or how other costs and benefits are weighted.

The slight downward slope can be explained by reference to the linear demand curve. For each increment in exemption rate, a similar additional increase in consumer and producer surplus occurs, but the incremental cost of the exemption rises. The economic intuition is straightforward: additional marginal expenditure providing electricity price discounts shows diminishing marginal returns. The slope of the curve for each sector is determined by the parameters that govern the output response for that sector.

Figure 31. **VfM ratios respond linearly to changes in the exemption rate (2020, core scenario)**



Note: *Marker points on data series indicate estimated profit margins used to produce the reported modelling results*

Source: *Vivid Economics*

5.3 Underlying Industrial Market Model behaviour

Several variables drive the scale of change in domestic firm output

5.3.1 The scale of cost shock and competitive environment matter most to output

Within the Industrial Market Model, the proportion of the exemption UK firms pass on determines the extent to which output expands due to the exemption. If firms retain most of the exemption, that is, if they have a low cost pass-through rate, their margin will increase and their output expands. If the bulk of the exemption passes on to consumers, firms' margins and output are relatively unaffected. In this latter case, the reduction in price may translate into slightly increased demand. The size of the cost decrease relative to the sector margin drives the competitiveness effects between firms, while the size of the price decrease of the product relates to the scale of the potential impact on consumers. Overall, the extent to which output increases is closely linked to the VfM estimates: sectors which are quite responsive to exemptions will generate higher VfM ratios.

Within the model, three factors drive the ability of firms to retain the exemption, or phrased alternatively, determine the cost pass-through rate: domestic market share, gross profit margins, and demand elasticity. Low margins, high elasticities and low market share of domestic firms all increase the effect of the exemption on output:

– low domestic firm market share implies that price is influenced by the production choices of overseas firms, and that UK firms will therefore be unable to pass the exemption on;
– low margins indicate competitive markets, with all firms subject to the exemption bidding the price down until the exemption is passed on;
– the elasticity has more of an effect where firms have market power, which means that there have to be relatively few firms and relatively fat margins: in this case, high elasticity discourages firms from passing on cost increases as they wish to avoid dampening total demand, while the converse holds for cost decreases

The interaction between market variables is non-linear. The models' equations show that the relationship of the change in output to market parameters is, approximately, as follows:

$$\%\ output\ change \approx \left[\frac{(1 - inside\ market\ share)}{inside\ market\ share}\right]\left[\frac{price\ elasticity\ of\ demand}{theta}\right]\left[\frac{cost\ change}{price}\right]$$

This is a simplification in order to give a clear impression of the key drivers of output change within the model. The parameter *theta* represents the competitiveness of the sector (see Figure 9), where a higher value is associated with firms exhibiting more aggressive behaviour. The functionality of the IMMs is discussed further in Appendix I.

Note market share is *not* subject to sensitivity analysis in this section, due to the technical difficulties in varying market share within the models. The importance of market share as an input is demonstrated by Figure 18.

5.3.2 Sensitivity analysis for sectors with FIMM

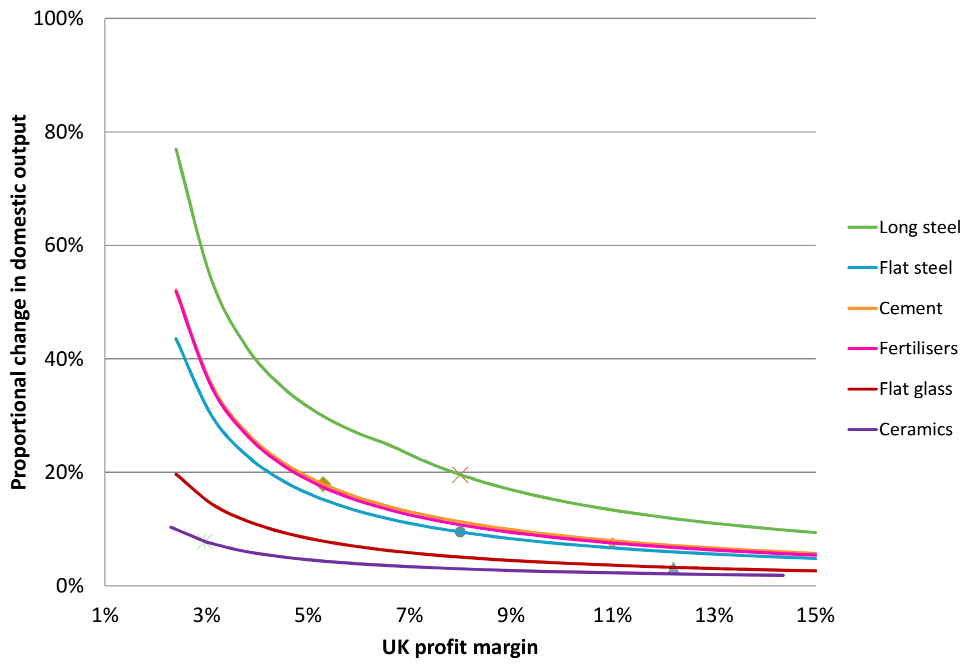
The sensitivities shown across the sectors are directionally similar but different in degree. These are shown in Figure 32, Figure 33, Figure 34 and Figure 35.

Figure 32 shows the sensitivity of domestic output to changes in the profit margin of the sector. The response is non-linear, and as the profit margin decreases output becomes increasingly responsive to exemptions. The overall pattern is largely the result of two factors:

- as the profit margin declines, any given change in costs represents a greater proportion of the profit margin. This results in the given change in costs having a larger impact;
- as the profit margin declines, the IMMs' estimation of the competitiveness of a sector increases, making production decisions more responsive to changes in costs.

Figure 33 shows the responsiveness of output to changes in the exemption rate, where the relationship is largely linear. This is a typical outcome in the FIMMs, so long as producer entrance and exit is not occurring. It is a result of the structure of the model in combination with the assumption of linear demand.

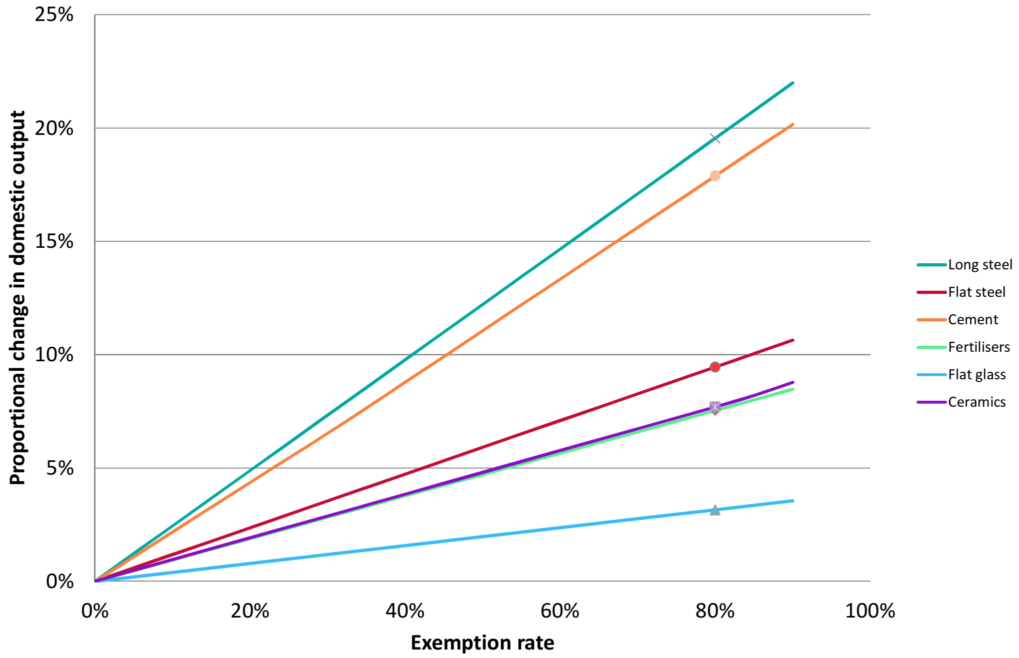
Figure 32. **Lower UK profit margins increase the sensitivity of output (2020, core scenario)**



Note: *Marker points on data series indicate estimated profit margins used to produce the reported modelling results*

Source: *Vivid Economics*

Figure 33. **Output responds fairly linearly to variations in the exemption rate, with exceptions caused by firm exit (2020, core scenario)**



Notes: *Markers denote 80 per cent exemption rate*

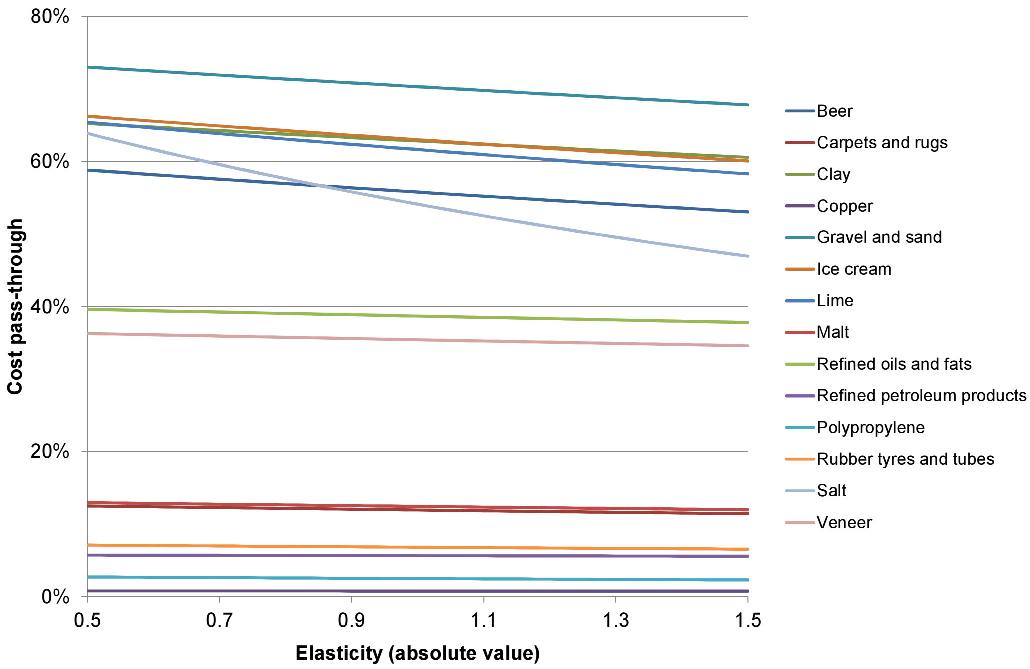
Source: *Vivid Economics*

5.3.3 Sensitivity analysis in sectors studied in less detail

As noted before, the cost pass-through rate is not an assumption in the Industrial Market Models, but is determined by the combination of various inputs, including market share and also demand elasticity, which is shown in Figure 34. Here, cost pass-through rates for UK firms decrease smoothly as demand becomes more elastic: the higher the sensitivity of consumers, the more firms will be forced to absorb production cost shocks themselves.

Salt shows a relatively steep relationship compared to the other sectors: this is partly a result of there being few imports for domestic producers to take market share from, which results in the demand response being the main determining factor in domestic production decisions. Furthermore, if margins are high, as in the salt sector, the value of the elasticity has a strong effect on observed change in production. Sectors where the output response is driven by low margins are less affected by elasticity.

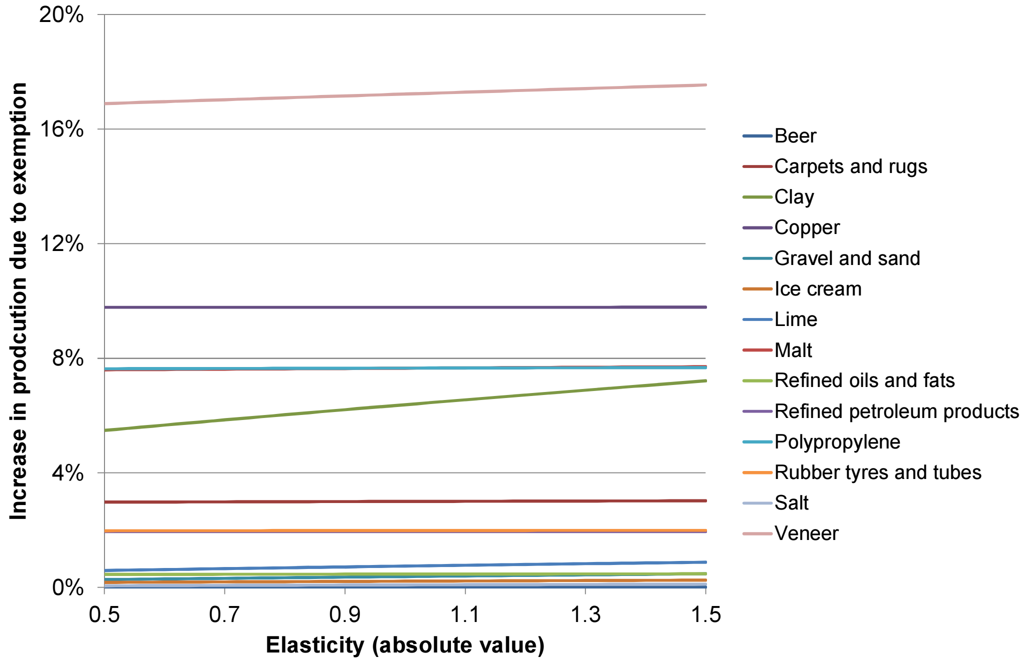
Figure 34. **Cost pass-through rates decrease as demand becomes more elastic (2020, core scenario)**



Source: *Vivid Economics*

While the cost pass-through rate is important, it is of a secondary concern compared to the variables which are tied to costs and benefits, such as changes in domestic production or profit. Figure 35 shows the change in domestic production across sectors as a function of elasticity. As would be expected, with increasing price sensitivity of consumers a given cost shock has a larger impact on domestic production. For the most part, however, the responsiveness is quite muted, because the change in price is small. Most of the impact on domestic producers comes through competition with rivals rather than through consumer response.

Figure 35. **As demand becomes more sensitive, the impact on domestic production increases (2020, core scenario)**

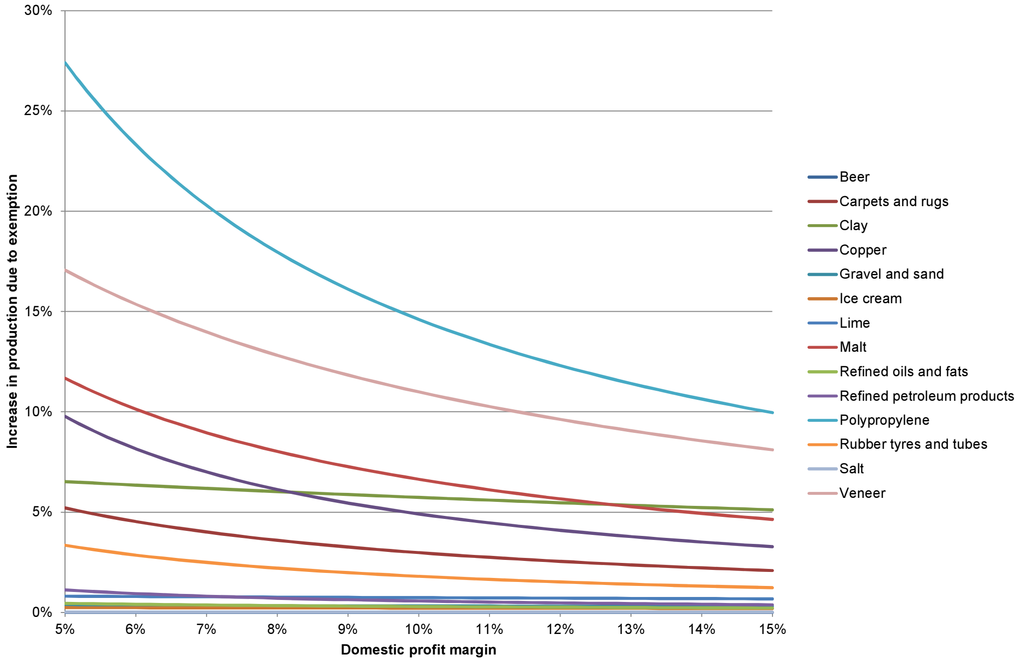


Note: *Paper subsectors excluded for scaling purposes.*

Source: *Vivid Economics*

Figure 36 and Figure 37 demonstrate the influence of domestic and foreign profit margins on domestic output following the cost shock. In Figure 36, higher domestic profit margins result in a smaller level of responsiveness of domestic output; in Figure 37, the same holds true of foreign profit margins. This is the same pattern seen for FIMM sectors, as shown in Figure 32, and holds for the same reasons.

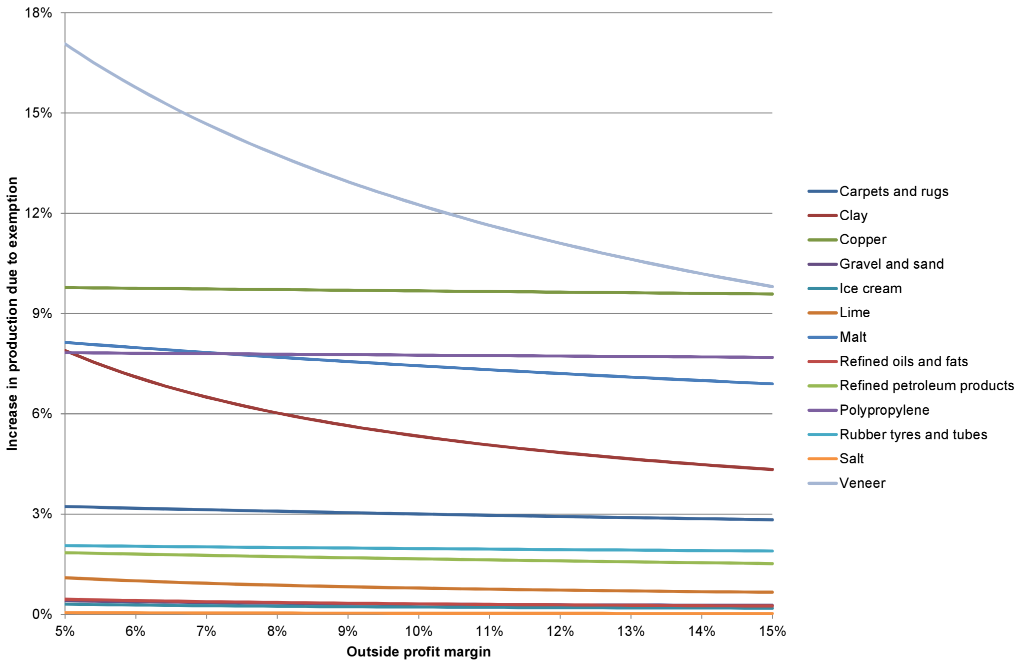
Figure 36. **High domestic profit margins result in smaller changes in domestic output (2020, core scenario)**



Note: *Paper subsectors excluded for scaling purposes.*

Source: *Vivid Economics*

Figure 37. **High foreign profit margins also cause smaller changes in domestic output (2020, core scenario)**

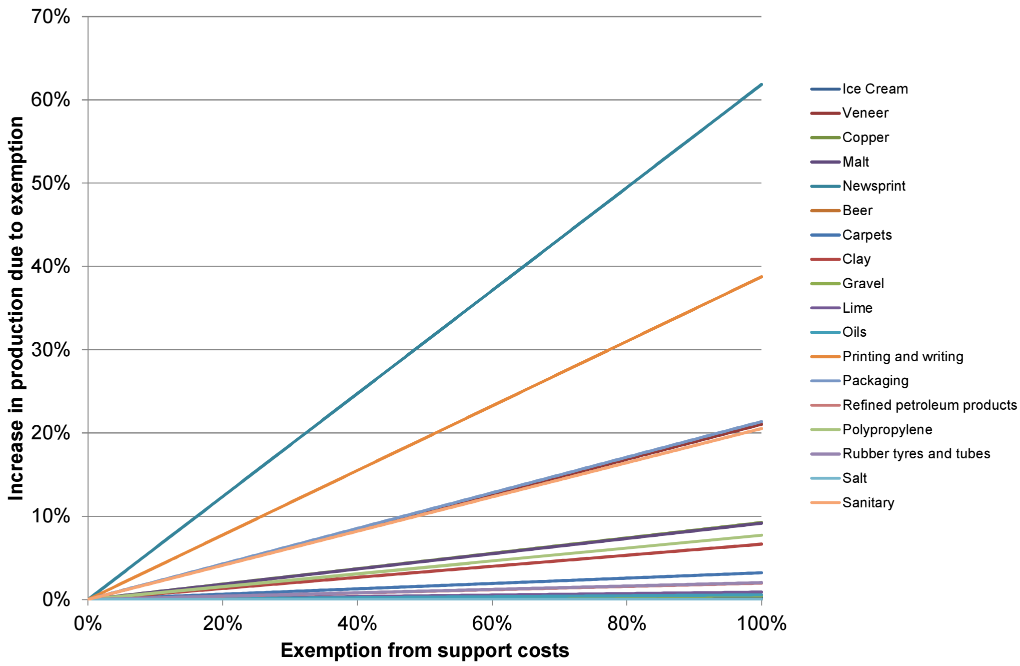


Note: *Paper subsectors excluded for scaling purposes.*

Source: *Vivid Economics*

Finally, Figure 38 demonstrates the impact on domestic production from a change in the exemption rate. The relationship is linear, with variation in slopes caused by each sector's characteristics; the straight lines are an artefact of the linearisation within the algebra of the model.

Figure 38. **Variations in the exemption rate have a linear relationship with increases in output (2020, core scenario)**



Source: *Vivid Economics*

5.3.4 Sensitivity analysis in MDM-E3

For the macroeconomic modelling, a particular set of sensitivity to energy prices was conducted, where high and low energy price scenarios were considered in addition to the central projections. Prices in the high scenario were around 17 per cent greater than in the low scenario.

The impact of these variations proved minimal. Table 16 reports ranges of changes in production under the high versus low energy price scenarios. In most cases, the variation is under 0.02 percentage points.

Table 16. **Varying energy prices in MDM-E3 does little to change the impact of the exemptions (2020)**

	Range of variation in percentage change in output compared to counterfactual, under high to low energy price scenarios					
Sector	**Option 1a**	**Option 1b**	**Option 2a**	**Option 2b**	**Option 3a**	**Option 3b**
Paper	0.05 to 0.07	0.03 to 0.05	0.06 to 0.08	0.03 to 0.05	0.06 to 0.09	0.05 to 0.07
Other non-metallic minerals	--	--	--	--	0 to -0.01	--
Basic metals	-0.01 to -0.02	-0.1 to -0.02	-0.02 to -0.04	-0.01 to -0.03	-0.01 to -0.01	-0.01 to -0.01
Total GDP	--	0 to -0.01	--	--	--	--

Notes: *'--' denotes changes smaller than 0.01 percentage point, which can be considered negligible*

Source: *Cambridge Econometrics*

6 Conclusions

The exemption offers value for money in some sectors and imposes negligible costs on the economy as a whole

Findings which support the selective application of exemptions

This is a small policy in the context of the whole UK economy, but it is significant in the economics of some of individual sectors. If the exemption is well targeted and not too broad, it may bring a net benefit to the economy, but if exemptions are too broad, the costs might outweigh the benefits.

Value for money is found where sectors cannot pass on costs to customers without losing market share to overseas rivals. These sectors have high electro-intensity, low margin and high overseas market share in the economic market (whether that is UK, EU or global).

The exemption may be good value for money if targeted at electricity-intensive sectors exposed to aggressive, international rivalry

The CfD exemptions generate benefits for exempt sectors and their customers and impose costs on other electricity consumers and their customers. Detailed investigations of the impacts on individual sectors, based on theory calibrated to actual market conditions, suggest that there is value for money in exempting sectors most exposed to international competition. In these sectors, a benefit of up to £2 may be obtained for every £1 of exemption. Other sectors exhibit lower value for money, closer to £1.

Most of this benefit occurs through increases in UK firm profits, rather than in benefits to consumers. Indeed, for exports, the consumers who benefit lie outside the UK, and would not counted as a benefit at all. Two elements drive the increase in firm profits: the increase in profit margin resulting from the portion of the exemption retained by producers, and the increase in production resulting from the capture of market share from foreign rivals and greater market demand.

There is evidence from the sector models that cost pass-through rates vary greatly from almost zero to close to 100 per cent. This implies a wide range of impacts on firm profitability and, in turn, competitiveness. Due ultimately to the (not especially restrictive) assumption of linear demand, the percentage change in profitability is associated with a similar percentage change in output, the intuition being that firms making no earnings before interest and taxes will, in the long run, exit the sector. The theoretical model suggests these changes in competitiveness are large enough to trigger significant changes in output, especially in markets which are geographically extensive, where goods are widely traded across the EU or beyond.

The impact on profits and on output is much more strongly a consequence of rivalries, of foreign rival's market shares, profit margins and the aggressiveness of competition in the sector, than it is about consumers' responsiveness to price changes. Consumer behaviour will only begin to determine the impact of the exemption on profits and outputs where within-sector rivalry is weak.

The sector-level changes estimated using an alternative model, macro-econometric in structure, are substantially smaller. In this model, empirical estimates of cost pass-through are significantly higher, while empirical estimates of the response of imports to changes in UK prices are substantially smaller. A weak import response critically drives the result that UK firm output is not exposed to displacement by imports, contradicting the findings of the sector models. It has been possible to identify reasons explaining the differences between the macro- and micro-economic modelling, but not to reconcile the two approaches. The differences are a product of the model structures themselves, not the input parameters.

The macro-econometric model finds the exemption policy's impact on the whole economy is negligible. This is a function of the small scale of funding mobilised by the policy and the weak import response within the model. Regarding the effect on income distributions, the cost of supporting the CfD exemptions falls on all consumers. It happens that those on low incomes tend to have a greater amount of electricity embodied in their expenditure. These low income households lose a greater fraction of their purchasing power than richer households: the exemption policy is regressive, but only slightly.

The value of modelling at the whole economy level has been to understand the scale of benefits and costs of the policy and to track its distributional effects through the economy. The individual sector models have provided insight into the drivers of impacts for individual sectors and the relative importance of different drivers, as well as providing specific estimates for individual sectors and showing the diversity of impacts likely to be experienced across the manufacturing sector.

Considering all the evidence together, in the round, there is a value for money case for exempting some, but not all, electro-intensive sectors from CfD support costs. While the results from the different approaches to modelling indicate different levels of concern about competitiveness impacts, a cautious policymaker might judge that the costs to the economy will be negligible and the benefits from preserving competitiveness are potentially significant.

References

BBC News Wales. (2012). Steel giant Tata announces £800m Welsh investment. Retrieved from http://www.bbc.co.uk/news/uk-wales-17724818

BCG. (2013). The Cement Sector : A Strategic Contributor to Europe's Future.

Borealis. (2008). *Addressing climate change: Borealis' approach to climate change and its polyolefin carbon footprint*. Retrieved from http://www.borealisgroup.com/pdf/global-challenges/IN0159_GB_BOR_2008_09_B.pdf

British Beer and Pub Association. (2013). British Beer and Pub Association Statistics. Retrieved from http://www.beerandpub.com/statistics

British Ceramics Confederation. (2013). Personal communication with industry association.

British Geological Survey. (2013). Mineral Planning Factsheet Kaolin.

British Glass Manufacturers Confederation. (2013). Personal communication with industry association.

British Lime Association. (2013). About the BLA. Retrieved from http://www.britishlime.org/about/the_bla.php

British Steel. (2013). Personal communication with industry association.

C.G.Davis, D.P.Blayney, S.T.Yen, & J.Cooper. (2009). An analysis of at-home demand for ice cream in the United States. *Journal of Dairy Science*, (92), 6210–6216. Retrieved from http://naldc.nal.usda.gov/download/38425/PDF

Cambridge Econometrics. (2010). *Assessment of the degree of carbon leakage in light of an international agreement on climate change Department of Energy and Climate Change*.

Comite Permanent des Industries du Verre Europeenes. (2010). CPIV position paper on the design of CO2 benchmarks and fall back options under the ETS for the glass sector ., *32*(January), 1–21.

DECC. (2011a). *Estimated impacts of energy and climate change policies on energy prices and bills*.

DECC. (2011b). Industrial data tables. *Energy Consumption in the United Kingdom*. Retrieved March 15, 2012, from http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx

DECC. (2012). Industrial data tables. *Energy Consumption in the United Kingdom*.

DECC. (2013). *Data provided for modelling purposes*.

DECC, & BIS. (2013). *Electricity market reform: eligibility for an exemption from the costs of Contracts for Difference*.

DECC, CCC, & ONS. (n.d.). Using evidence and analysis to inform energy and climate change policies. Retrieved October 5, 2013, from https://www.gov.uk/government/policies/using-evidence-and-analysis-to-inform-energy-and-climate-change-policies/supporting-pages/policy-appraisal

DEFRA. (2013). Statistics at Defra.

Euromalt. (2012). EU Malt production capacity. Retrieved from http://www.euromalt.be/data/13621459342011 malt production CAPACITY.pdf

European Commission. (1993). Commission Decision of 21 December 1993 declaring a concentration to be compatible with the common market (Case No IV/M.358 - Pilkington- Techint/SIV) Council Regulation (EEC) No 4064/89 (Text with EEA relevance). Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994D0359:EN:HTML

European Commission. (2010). *Draft reference document on Best Available Techniques in the Pulp and Paper Industry*.

European Commission. (2013a). International trade and production data, Eurostat.

European Commission. (2013b). European Union Community Independent Transactions Log. Retrieved from http://ec.europa.eu/environment/ets/

FAO. (2009). Agribusiness handbook: Barley Malt beer.

FAO. (2012). FAOStat. Retrieved from http://faostat.fao.org/site/612/DesktopDefault.aspx?PageID=612#ancor

Forestry Commission. (2013). UK Wood production and trade statistics 2012. Retrieved from http://www.forestry.gov.uk/news1/D93B5F2BB48A779480257B6D002E82E4

Global Cement Magazine. (2013a). Cement price trends in the UK. Retrieved from http://www.globalcement.com/magazine/articles/643-cement-price-trends-in-the-uk

Global Cement Magazine. (2013b). The British cement industry in 2011 and 2012. Retrieved from http://www.globalcement.com/magazine/articles/706-the-british-cement-industry-in-2011-and-2012

Graham, D. J., & Glaister, S. (2002). The Demand for Automobile Fuel A Survey of Elasticities. *Journal of Transport Economics and Policy*, *36*(September 2000), 1–26.

GrowHow. (2013). GrowHow manufacturing sites and capacity. Retrieved from http://www.growhow.co.uk/content.output/182/182/Find Us/Find Us/Location Map.mspx

Gwartney, J. D., & Stroup, R. L. (1997). *Economics: private and public choice*.

HMRC. (2010). Econometric analysis of alcohol consumption in the UK.

IBISWorld. (2012). *Lime & Plaster Manufacturing in the UK report*.

IBISWorld. (2013a). *Fertiliser & nitrogen compound manufacturing in the UK.*

IBISWorld. (2013b). Flat glass manufacturing in the UK industry report.

IBISWorld. (2013c). Copper production in the UK industry report.

IBISWorld. (2013d). Gravel, sand & clay extraction in the UK industry report.

IBISWorld. (2013e). Oil & fat production in the UK industry report.

IBISWorld. (2013f). Beer production in the UK industry report.

IBISWorld. (2013g). Ice cream production in the UK industry report.

IBISWorld. (2013h). Carpet & rug manufacturing in the UK industry report.

IBISWorld. (2013i). *Primary plastics manufacturing in the UK report*.

IBISWorld. (2013j). *Veneer sheet & wood-based panel manufacturing in the UK industry report*.

IBISWorld. (2013k). *Tyre manufacturing in the UK industry report*.

IBISWorld. (2013l). Malt Manufacturing in the UK industry report, (March).

IBISWorld. (2013m). Petroleum Refining in the UK industry report.

IBISWorld. (2013n). *Salt extraction in the UK industry report*.

ICF International, & Cambridge Econometrics. (2013). Assessment of competitiveness impacts of carbon budgets on electro-intensive sectors to 2030. Retrieved from http://www.theccc.org.uk/wp-content/uploads/2013/04/ICF-and-CE-2013-Assessment-of-Competitiveness-Impacts-of-Carbon-Budgets-on-Electro-intensive-Sectors-to-2030.pdf

IEA. (2007). *Tracking Industrial Energy Efficiency and CO2 Emissions*.

IEA. (2012). IEA Data Services.

IndexMundi. (2013). Price of hot-rolled steel. Retrieved from http://www.indexmundi.com/commodities/?commodity=hot-rolled-steel&months=60

International Copper Study Group. (2008). International Copper Study Group Statistical Yearbook.

Ivanova, N. (2005). Estimation of own- and cross-price elasticities of disaggregated imported and domestic goods in Russia, (05), 2–5.

La Cour, L. F., & Mollgaard, H. P. (2002). Meaningful and measurable market domination. *Copenhagen Business School Department of Economics Working Paper*, (09-2002).

MEPS. (2013). Price of long steel products. Retrieved from http://www.meps.co.uk/flat&longcarbonprice1.htm

Mineral Products Association. (2012). Progress and Challenges... continuing to deliver: Summary Sustainable Development Report.

Mineral Products Association. (2013). *Personal communication with industry association*.

Minerals UK. (2013). United Kingdom mineral statistics. Retrieved from http://www.bgs.ac.uk/mineralsuk/statistics/ukStatistics.html

National Audit Office. (2007). *The Climate Change Levy and Climate Change Agreements*. Retrieved from http://www.eurosaiwgea.org/Environmental audits/Air/Documents/2007-UK-The Climate Change Levy and Climate Change Agreements.pdf

OECD. (2010). Demand Growth in Developing Countries. *OECD Food, Agriculture and Fisheries Working Papers, No. 29*. Retrieved from http://dx.doi.org/10.1787/5km91p2xcsd4-en

ONS. (2012a). Annual Business Survey. *Survey: Annual Business Survey (ABS)*. Retrieved from http://www.ons.gov.uk/ons/guide-method/surveys/list-of-surveys/survey.html?survey=Annual+Business+Survey+(ABS)

ONS. (2012b). *Annual Business Inquiry*.

ONS. (2012c). Business Register and Employment Survey. *Survey: Business Register and Employment Survey (BRES)*. Retrieved from http://www.ons.gov.uk/ons/guide-method/surveys/list-of-surveys/survey.html?survey=Business+Register+and+Employment+Survey+(BRES)

ONS. (2013a). UK National Statistics.

ONS. (2013b). UK National Statistics. Retrieved February 1, 2013, from http://www.statistics.gov.uk/

Platts. (2013). Platts Global Polypropylene (PP) Price Index. Retrieved from http://www.platts.com/news-feature/2012/pgpi/polypropylene

PricewaterhouseCoopers. (2009). *Destination 2030: How the UK economy could fare*.

Ritz, R. A. (2009). Carbon leakage under incomplete environmental regulation : An industry-level approach. *University of Oxford, Department of Economics, Discussion Paper Series*, (461).

The Beer Tutor. (2013). Beer statistics. Retrieved from http://www.thebeertutor.co.uk/statistics/

The Economist. (2010). Salt sellers. Retrieved from http://www.economist.com/node/15276675

UK Steel Association. (2013). *Key statistics*.

UKPIA. (2013). Statistical review 2012 UKPIA.

UN. (2011). UN Comtrade Database. Retrieved November 17, 2011, from www.comtrade.un.org/db/

UNECE. (2003). *Econometric modelling and projections of wood products demand, supply and trade in Europe*.

UNECE. (2010). *Policy Refroms for Energy Efficiency Investments*.

UNECE. (2012). Value-added wood products markets, 2011-2012, 2011–2012.

USGS. (2011). *US Geological Survey, Mineral Commodity Summaries*.

Wood, S., & Cowie, A. (2004). A review of greenhouse gases for fertiliser production; for IEA Bioenergy Task 38, (June).

Worrell, E., Phylipsen, D., Einstein, D., & Martin, N. (2000). *Energy Use and Energy Intensity of the U.S. Chemical Industry*.

Zhu, Z. (2012). *Identifying Supply and Demand Elasticities of Iron Ore*. Duke University. Retrieved from http://econ.duke.edu/uploads/media_items/thesis-zhirui-zhu.original.pdf

Appendix A Cement

Introduction

Cement is a relatively homogenous product. It is expensive to transport relative to its value, but there is still an active import market and so UK producers face competition from overseas as well as from other construction materials. There are three large producers in the UK.

Production process

Almost all UK production is Portland cement from limestone, although other types exist. Manufacture is in four steps:

- limestone is quarried close to the cement works;
- the rock is pulverized, along with some sand and clay;
- the powder is heated to 1,450 °C, to form glass-like clinker;
- the clinker is mixed and ground with additional materials, such as gypsum, to produce cement.

Types of cement

The main relevant product differentiation in cement in this context is between white and grey cement. White cement is extremely low in impurities and is used for decorative work. White cement is generally not produced in Great Britain due to lack of suitable limestone.

Emissions

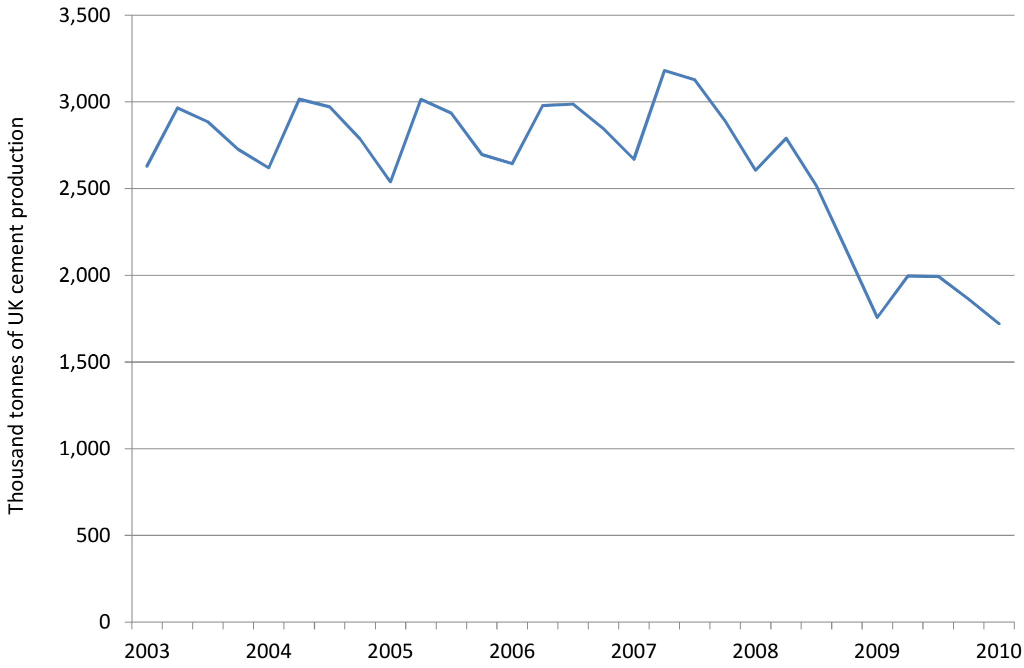
The majority of emissions occur during clinker production from the calcining process, and not from fossil fuel combustion or electricity use. Nevertheless, the process is energy intensive:

- energy is around 40 per cent of cost of production in EU;
- ONS data shows that in 2007, 15 per cent of energy use was electricity, with the remainder coal;
- electricity intensity of 90–50 kWh/tonne cement.

Prices

Prices in the UK have increased around 35 per cent between 2005 and 2011, even while demand has fallen. Demand fell sharply in 2008 caused by decreased demand from the construction sector, and production followed suit, see Figure 39.

Figure 39. **Cement production in the UK**

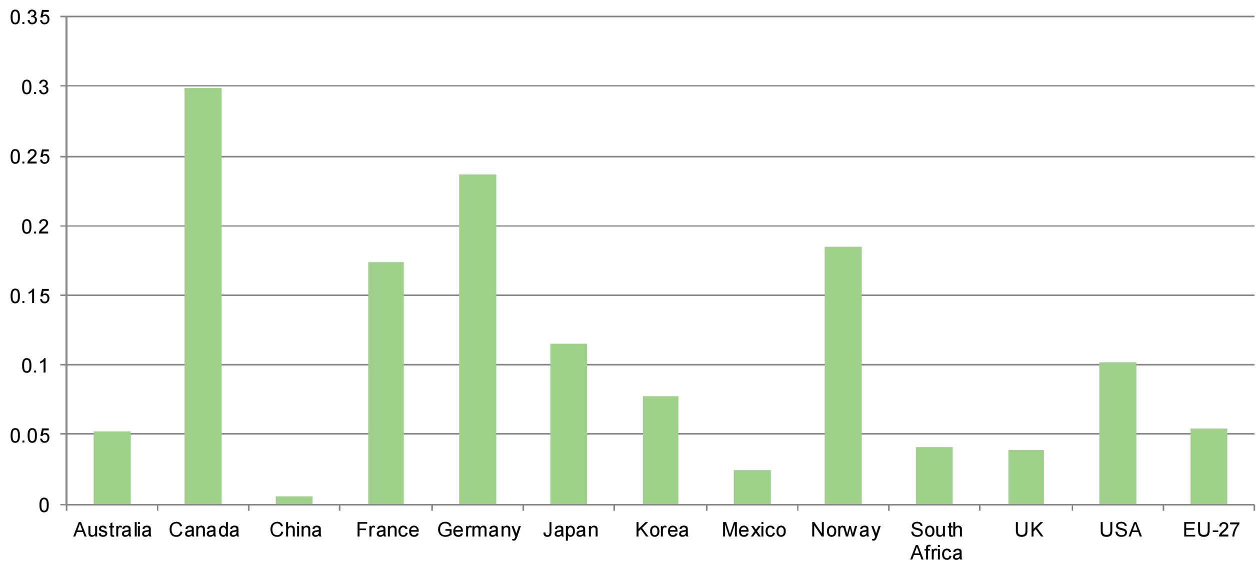


Source: Mineral Products Association, 2013

Not only has cement suffered from the decline in construction activity over the last five years. It has underperformed the wider economy for a decade, having missed out on the economic boom between 1998 and 2007 (Figure 11), and being hit hard by the decline in construction following the global financial crisis.

The trade intensity of cement in the UK is low relative to international comparators. This is because relatively high transport costs result in cement being traded over short distances only. However, the higher levels of trade seen in other countries suggests that there may be greater potential for trade in the UK if the economic situation changed.

Figure 40. **Trade intensities by country (2010)**



Note: *trade intensity is the volume of imports and exports divided by the total volume of both domestic production and imports*

Source: *UN, 2011, Vivid Economics*

Market structure

The domestic UK market is highly concentrated, reflecting the capital-intensive nature of the industry: the cost of a new cement plant is around three years' sales from the plant. Three firms make over 90 per cent of UK output, namely Lafarge/Tarmac, Hanson and CEMEX across 14 facilities. Employment has been around 5,000 persons over the last decade (ONS, 2012a, 2012b). The employment and plant are located across the UK.

Appendix B Ceramics

Introduction

Ceramics is a diverse sector, encompassing many separate markets whose products do not directly compete with each other. The brick subsector forms the largest ceramics market and generates the majority of emissions: it is thus the focus of the analysis.

Brick manufacture is emissions intensive, especially relative to the value of the product. Emissions can vary between 120 kg CO_2 per tonne and 320 kg CO_2 per tonne. Electricity accounts for a relatively small proportion of total energy used, most of which is natural gas. Trade in bricks is limited due to high transport costs relative to their value and, consequently, the majority of trade partners are within the EU.

Employment, profit margins and GVA within the bricks and roof tiles sector has declined considerably in the last few years, reflecting depressed construction demand, particularly in house building.

Sector definition

Ceramics is a diverse sector, encompassing a wide variety of subsectors. The European Commission distinguishes nine main subsectors in its Best Available Techniques reference document (European Commission, 2010):

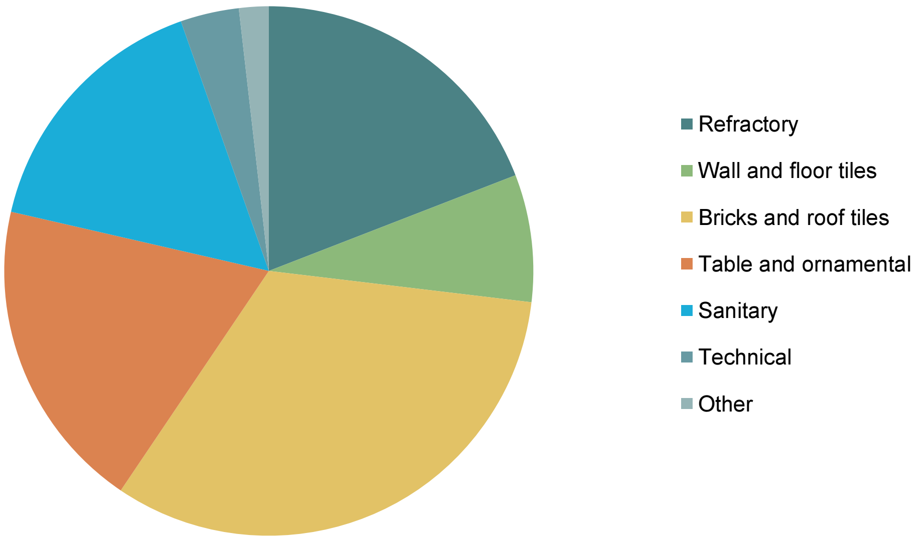
- wall and floor tiles;
- bricks and roof tiles;
- table- and ornamental-ware;
- refractory products;
- sanitaryware;
- technical ceramics;
- vitrified clay pipes;
- expanded clay aggregates;
- inorganic abrasives.

Some of the subsectors plausibly contain multiple markets. For instance, technical ceramics have a wide variety of physical characteristics, which is likely to render them poor substitutes for each other, and are based on many different raw materials.

Total GVA was approximately £825 million in 2011 of which bricks and roof tiles contribute over one quarter. This analysis focuses on one subsector – bricks and roof tiles. There are three reasons for this choice:

- brick and roof tiles appears to be the largest ceramics subsector in the UK, both in terms of employment and GVA, see Figure 41;
- brick and roof tiles are responsible for the majority of EU ceramics emissions (BREF, 2007);
- the latest available DECC data suggests that manufacture of bricks and tiles accounts for 52 per cent of the ceramics sectors electricity use.

Figure 41. **Bricks and tiles, refractory, sanitary and tableware are the major subsectors in the UK**



Source: ONS, 2013

Within this subsector, bricks eclipse roof tiles in value. For instance, revenue from brick sales in the United Kingdom was approximately 5.5 times greater than revenue from roof tile sales. As a result, much of the available literature focuses on bricks rather than roof tiles.

Bricks appear to be a separate market to roof tiles:
– the European Commission found that bricks as a whole formed a single product market (EC, 1994);
– the OFT adopted all bricks as the relevant product market when considering the acquisition of Baggeridge by Wienerberger (OFT, 2006);
– the UK Competition Commission found that non-Fletton clay bricks formed a single product market (Competition Commission, 2007).

The analysis therefore focuses on bricks.

Production process

There are three main production processes for bricks, resulting in three product categories:
– extruded bricks;
– soft mud bricks;
– Fletton bricks.

Each differs in both raw material and shaping process. For instance, Fletton bricks are made from lower Oxford clay, traditionally favoured because its high carbon content reduces the firing temperature. Production for each follows similar basic steps (TBE, 2012);

- raw clay material is extracted from a quarry;
- the raw material is crushed to produced the required grain size and water may be added to obtain the right consistency;
- clay is extruded or moulded to shape and cut to size;
- formed clay is dried and loaded into kilns for firing;
- the brick is allowed to cool and is then packaged and dispatched.

Emissions

The majority of emissions are produced in the firing and drying stage, where high temperatures are necessary to produce a durable product suitable for construction. Natural gas, LPG and fuel oil are the most common sources of energy (BREF, 2007). Ecofys (2009) finds that across the EU, emissions vary between around 120 kg CO_2 per tonne and 320 kg CO_2 per tonne. According to the Best Available Techniques Reference Document, the share of energy costs in total production costs generally varies between 17 per cent and 30 per cent, with maximum values up to 40 per cent. Based on 2007 DECC statistics, electricity use seems to comprise around 10 per cent of total energy use in the bricks and tiles sector.

Market structure

In 2009, there were around 70 ceramics installations in the UK (Ecofys, 2009). The largest UK manufacturers of brick and roof tiles include Wienerberger of Austria, Hanson, Ibstock Brick, and Marley Eternit. Hanson produces most of the Fletton Bricks, with the other manufacturers focussing on extruded and soft clay bricks.

Brick manufacturing is scattered across Britain, reflecting the significant costs to transportation relative to the value of the product. The production of Fletton bricks requires access to Oxford clay and is centred in the Midlands. The main production centres are Peterborough and Bedford. Meanwhile, the production of non-Fletton occurs throughout the country.

International trade in bricks is small, reflecting the high costs of transport. For instance, the costs of transporting one thousand bricks from Belgium or the Netherlands to the UK is estimated to be between £50 and £75 (Competition Commission, 2007). By comparison, the price of one thousand imported bricks in 2010 was around £300. The vast majority of the domestic consumption is served through local production. Prodcom data shows that in 2010, 95 per cent of UK consumption was served by domestic suppliers, with slightly under 5 per cent by imports. Less than one per cent of UK production by value was exported.

Almost all brick imports and exports are intra-EU and the few trading partners the UK has are geographically close by. The value of intra-EU imports was 40 times higher in 2010 than the value of extra-EU imports. The same pattern holds in exports; intra-EU exports were five times higher than extra-EU exports. This is reflected in the major trading partners listed in Table 17. Import partners are compiled for the bricks and roof tiles subsector, while export partners are compiled for the wider clay building materials sector, due to the data available.

Table 17. **Top five import and export partners for bricks and tiles**

Imports (brick and roof tiles)	Exports (clay building materials)
Belgium	Ireland
Netherlands	France
Germany	The Netherlands
France	USA

Note: Table shows top 5 export and import partners, according to value, for 2010.
Source: European Commission, 2013

Recent history

Brick and roof tile employment declined significantly following the recession. This is probably due to fall in house building, which is the main driver of demand. Real GVA fell by 50 per cent between 2007 and 2009 (Figure 11), but is showing signs of recovery recently.

Prices

The average price of bricks has been £96 – 121 per tonne in recent years. The wholesale price depends on volume, distance from production and brick type (Competition Commission, 2007). Firms only recently began posting listed public prices, and it appears that customers rarely pay full price. An average price per kg can be estimated using the Prodcom database, which includes weight and revenue measures aggregated across all bricks sold in the UK. Price appears to be £170 – 220 per m^3. Taking the density of Fletton bricks, which is around $1.8t/m^3$, the price per kg appears to be between £90 – £120 per tonne. The estimates for 2009, 2010 and 2011 are shown in Table 2. Discussions with the industry association suggest that figures at the bottom end of the range are appropriate in the current market.

Table 18. **Estimated price for bricks produced in the UK**

Year	Price, £/tonne
2009	96
2010	100
2011	121

Source: European Commission, 2013; Vivid Economics

Margins

Profit margins a few years ago were between six and eleven per cent. Average margins for the available years are around eight per cent. Accounting information for Ibstock and Baggeridge, released during an acquisition (Competition Commission, 2007), allows for the estimation of profit margins within the sector. Five years are available for Ibstock, six for Baggeridge. As far as possible, 'fixed costs', such as interest payments, are excluded from our calculations so that the profit margin captures only the variables relevant to production decisions. Profit margins for both firms fluctuated between around 6 per cent and 11 per cent. Mean profit margin was 8.4 per cent for Ibstock, and 7.8 per cent for Baggeridge.

However, recent research commissioned by the sector suggests that average profit margins have been below 5 per cent since 2008 and that may have dipped below zero for one year. There have been widespread closures. Most recent trading seems to have been taking place in the range 3 to 5 per cent. The differences in margin before and after 2007/08 are consistent with a sharp contrast in the balance of demand and supply.

Demand elasticity

Demand for bricks is highly inelastic but there appear to be no reliable quantitative estimates of elasticity available. Cambridge Econometrics has previously attempted to estimate the price elasticity of domestic demand for bricks and tiles (DECC, 2010). It found the overwhelming determinant of domestic consumption to be construction output, which alone explained almost all variation in demand. This suggests there are few substitutes for bricks, and that price elasticity is likely to be low. In its work, attempts to estimate price elasticity of demand were unable to return an effect significantly different from zero. This is, itself, is suggestive of a low elasticity.

The European Commission (EC, 1994) found that price elasticities in this sector are low, but did not published a quantitative estimate. It argues that demand for bricks represent 'only two to three per cent of the cost of a building' and that consequently 'there is very little or no elasticity of demand with respect to price levels in the short or medium term'.

Appendix C Fertiliser

Introduction

Fertilisers can be subdivided into straight, compound and organic types. One straight fertilizer does not tend to compete with another, but each competes with various compound and organic alternatives.

The production of nitrogen fertilisers is energy intensive, requiring significant natural gas and electricity inputs. The cost of production reflects energy prices, and the price of fertilisers is volatile.

It does not appear that fertilisers is experiencing a decline in demand similar to other energy intensive manufacturing sectors. Demand for fertiliser is unresponsive to price, reflecting the lack of substitutes within agriculture. The UK imports a large quantity of fertiliser, largely from the Netherlands, Germany, Lithuania and Russia. Cheap shale gas in the US has the potential to represent a significant competitive threat.

Definition

Fertilisers can be broadly divided into three main types:
- straight fertilisers;
- compound and blended fertilisers;
- organic fertilisers.

All non-organic fertilisers are based on a combination of the compounds nitrogen (N), phosphate (P) and potash (K). Straight fertilisers consist of just one primary chemical element, whereas compound and blended fertilisers are a combination of N, P and K.

Fertiliser plants will often produce chemicals which are inputs or by-products of fertiliser production. They include nitric acid, anhydrous ammonia and aqueous ammonia.

Straight fertilisers provide the majority of revenue for the fertiliser industry. Organic and compound fertilisers jointly supply 45 per cent of revenue (IBIS World).

Straight and compound fertilisers do not seem to comprise separate product markets. Individual straight fertilisers, however, do not compete with each other. The OFT found that straight nitrogen fertilisers, such as urea, ammonium nitrate (AN), and calcium ammonium nitrate (CAN), are substitutable and form a single product market (OFT, 2007). The OFT has found that the switching costs between liquid and solid fertilisers is likely to be low, which implies that the products compete with each other (OFT, 2007). The OFT left the distinction between complex and straight fertilisers unsettled, but found some evidence that they were substitutes. The EC has previously distinguished between N, P and K straight fertilisers, but also found evidence that compound fertilisers were competitively constrained by straight fertilisers, and vice versa (EC, 2004).

Production process

The production process differs between each of the three elements of non-organic fertiliser. Ammonium nitrate is produced as follows:

- ammonia is produced through steam reformation of natural gas;
- ammonia is converted into nitric acid by reacting ammonia with water in the presence of a catalyst;
- nitric acid and ammonia are combined to produce ammonium nitrate.

Phosphorus-based fertiliser is produced using sulfuric acid to isolate phosphorus from phosphate rock, and potassium based fertilisers are produced from potassium chloride. Each of the components can then be granulated and combined to produce complex fertilisers.

Energy and emissions

Estimates of the emissions intensity of fertiliser production vary. Wood and Cook (2004) review literature on the emissions factors for fertiliser production. They find that ammonium nitrate and calcium ammonium nitrate fertilisers have emissions intensities of between 1.5 and 2.6 tonnes CO_{2e} per tonne of product. The main source of emissions in this case is the burning of natural gas in the production of ammonia. Ecofys (2009) found similar values of between 1 and 3 tonnes CO_{2e} per tonne of ammonia. Urea, another nitrogen fertiliser, is found to have slightly lower emissions intensities of between 0.5 and 1.8 tonnes CO_{2e} per tonne of product.

Phosphate fertilisers have a low emissions intensity: the reactions involved themselves release heat. As a result, best practice emissions intensities can be negative, and generally vary between -0.2 and +0.7 tonnes CO_{2e} per tonne of product.

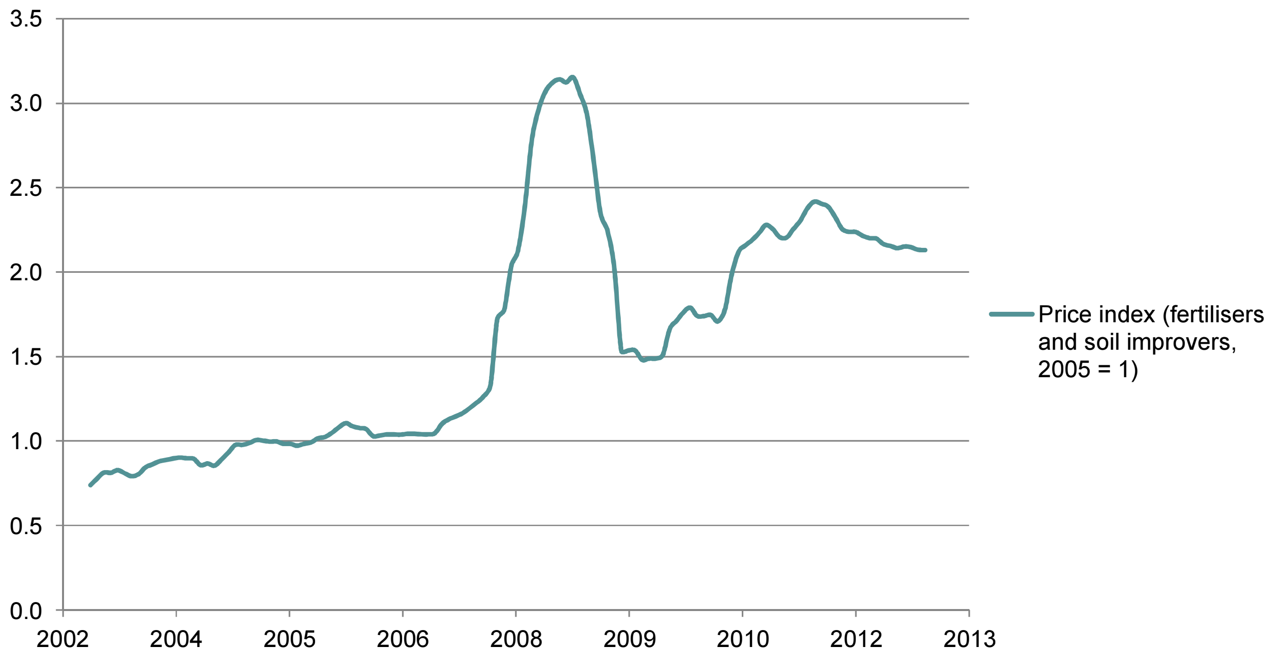
There is little information on the electricity intensity of fertiliser production. Department of Energy and Climate Change statistics suggest that in 2007, electricity use comprised 30 per cent of total energy use within the sector. Given that natural gas comprises around 70 per cent of the cost of producing nitrogen, this implies significant electricity use. However, Ecofys (2009) suggests that some ammonia plants within integrated chemical sites make use of imported electricity to generate greater steam exports. Seemingly high electricity consumption may therefore not always reflect the normal underlying production process, but rather exist to realise additional profitable opportunities.

Activity

GVA was around £330 million in 2010, and has varied significantly in recent years (Figure 11). Unlike the other selected energy intensive industries, fertilisers have not been in decline.

The volatility of GVA is partially driven by underlying volatility of fertiliser prices, see Figure 42. The price of gas, which is a key input to production, is particularly important.

Figure 42. **Price of fertilisers and soil improvers, index**



Source: *DEFRA, 2013*

Demand appears to be unresponsive to price, reflecting the lack of substitutes for mineral and organic fertilisers. Breen et al. (2012) estimated the price elasticity of demand for calcium ammonium nitrate in Ireland. They found that demand was reasonably inelastic, with a value of -0.4. This result was estimated with high statistical confidence. There is little reason to suspect that the price elasticity of demand will vary significantly between countries or by product. Other estimates of the price elasticity of demand, such as Dholakia and Majumdar's estimate for Indian fertiliser demand (1995), are also inelastic.

Employment has steadily declined since 1998 even while output has remained steady. The fertiliser sector currently employs around 2,000 people (ONS, 2012a).

Market structure

There are two large players in the UK market, alongside many smaller firms (IBIS World, 2013). The major firms are:

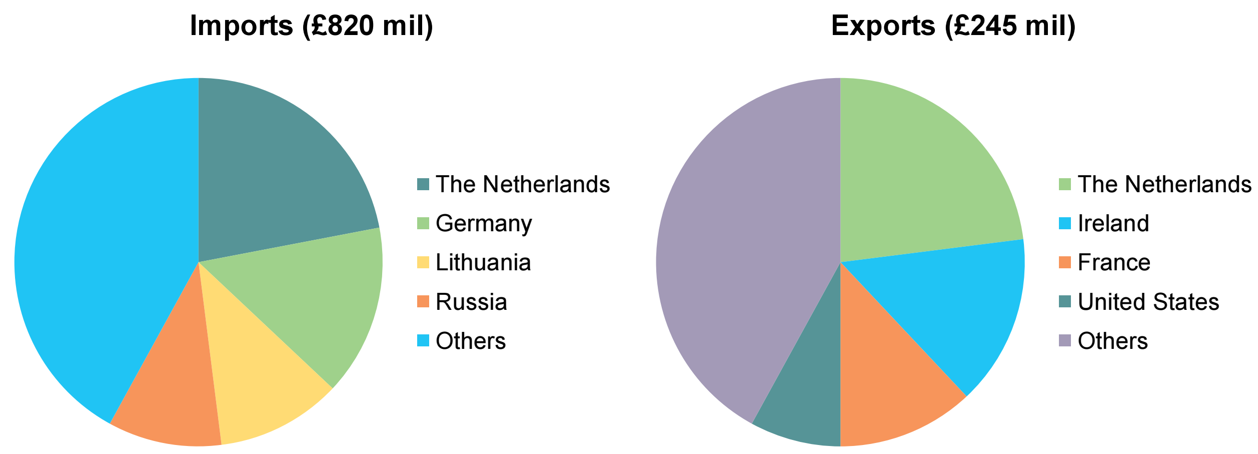
– Yara UK, with approximately 21 per cent market share;
– J & H Bunn, with approximately seven per cent market share.

In addition, Yara International and Terra Industries jointly run GrowHow UK. GrowHow is the only remaining producer of ammonium nitrate in the UK and states that it supplies around 40 per cent of total UK fertiliser consumption. There are a large number of smaller players, often producing organic or specialist fertilisers, tailored to use for particular agricultural products or soil types.

Production is concentrated in Scotland and the north of England (IBISWorld). This reflects the benefits of being located in established chemical clusters. GrowHow, for instance, locates a significant proportion of its production in Teesside, a traditional location for chemicals production within the UK.

The value of imports is four times higher than the value of exports, and most exports are to the EU. The Netherlands is a major trading partner, providing 23 per cent of UK imports.

Figure 43. **The Netherlands is the single largest trading partner**



Source: IBISWorld, 2013a

At least two major sources of future competitive threat can be identified, both of which relate to cheap gas. Cheap shale gas may drive investment in fertiliser production in the US. The lead-time for major fertiliser investment is estimated at around 4 years. Thus, this threat could come into play during Phase III of the EU ETS. Imports from Russia enjoy state-subsidised gas prices and any future removal of anti-dumping tariffs has the potential to harm UK producers.

Appendix D Flat glass

Production

Flat glass is mostly used in buildings and the automotive industry, and increasingly in other specialist areas. The automotive sector is by far the biggest consumer of flat glass.

The main flat glass production process in the UK is the float process:

- melting, refining, and homogenisation in a furnace;
- glass from the furnace flows over a refractory spout on to a surface of molten tin, leaving the float bath as a solid ribbon at 600˚C;
- various coatings can be applied to vary the optical properties of the glass;
- annealing to relieve cooling stresses in another furnace;
- cutting to order.

Energy and emissions

Flat glass has high emissions and electricity intensity. Ecofys (2009) in its benchmarking study for the EC estimates the emissions and electricity intensity for flat glass production in Europe:

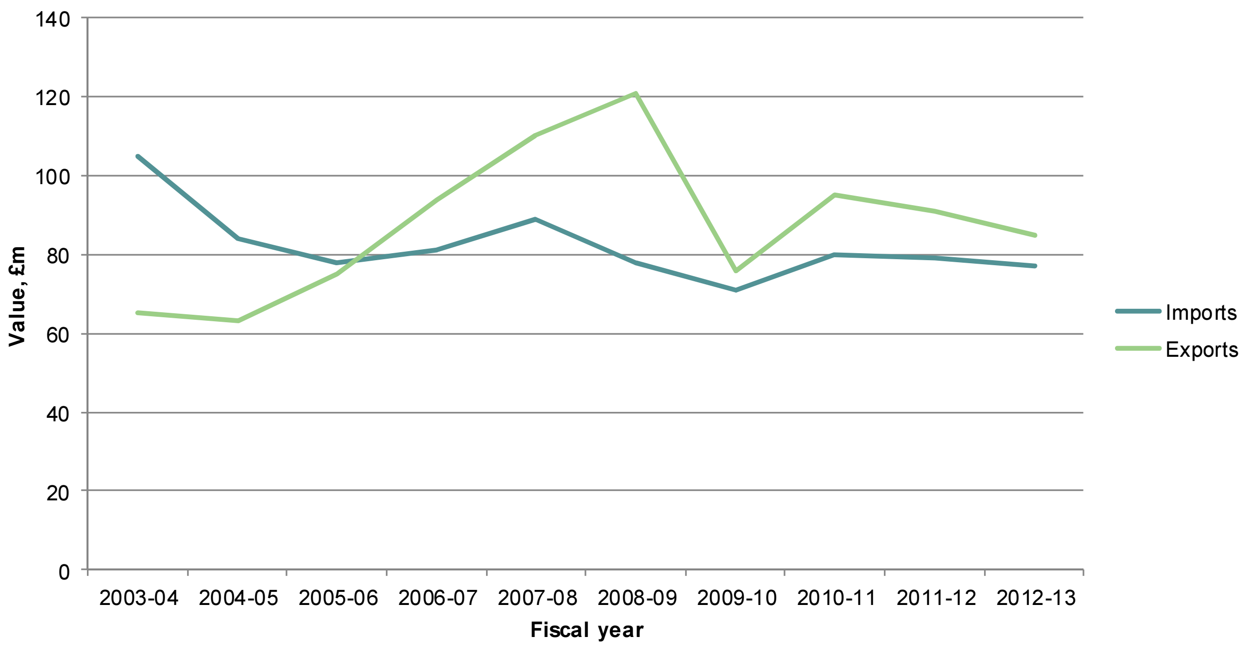
- the emissions intensity of flat glass production is estimated to be 677 kg CO_2/tonne of product;
- the electricity intensity of flat glass production is estimated to be 203 kWh/tonne of product.

Activity

Total flat glass value of production was £338m in 2012/13, with industry output of 2.2mt per annum. Ninety per cent of flat glass is produced on float lines, with the rest in Pilkington's rolled glass plant.

Flat glass value added has fallen by more than 30 per cent since 2007 and employment has fallen by a third since 2004, reflecting the trend in declining production (Figure 11; ONS, 2012b). UK flat glass exports were £85m and imports £77m in 2012/13. The value of imports and exports is volatile.

Figure 44. **The value of flat glass trade is variable but total trade is now roughly equal to 2003/04 levels**



Source: *ONS, 2012a*

The demand elasticity, or own-price elasticity, is hard to estimate due to data limitations and difficulties in specifying a satisfactory econometric model. Cambridge Econometrics (2010) estimates the own-price elasticity of domestic flat glass demand to be -0.65.

Market structure

There are five float lines producing flat glass in the UK, owned by three companies: NSG, Saint-Gobain and Guardian. There are many more flat glass plant in continental Europe.

The firms and their plants focus on specific market segments and their product mix changes over time. The Saint Gobain plant (established in 1999) and Guardian (established in 2004) are relatively new, but no major investments have been announced recently. The main recent product developments and uplift in value comes from new coating materials. New coating materials enhance product performance, for example in environmental control in buildings.

Flat glass production is highly capital intensive, with energy and raw input each as significant as factory labour in total costs.

Flat glass plants cost around €70-200m to build, and have run campaigns of 10-15 years, after which a major rebuild/upgrade programme is needed. The plants becomes profitable once a fairly high capacity utilisation rate is reached, typically around 70 per cent. It is expensive to switch between composition and thickness of flat glass product.

Glass is heavy and comparatively cheap, with 200km of transportation seen as the norm and an economic limit at 600km for most products. Transport costs are typically 15 per cent of total costs (British Glass Manufacturers Confederation, 2013).

Appendix E Pulp and paper

Introduction

Paper is a highly diverse set of markets, with large differences in production process, emissions intensity and price. In contrast, pulp is generally treated as a single market, despite some limits in product substitutability.

All pulp production in the UK uses either a mechanical process or recycled feedstock. Neither generate significant direct emissions. Paper production is more emissions intensive, requiring large amounts of heat.

Both employment and GVA have declined significantly in the last decade and 50 UK paper mills have closed down since 2000. There are still a large number of small producers in the market. Demand is neither responsive nor unresponsive to price, with a price elasticity of demand of around -0.5.

Definition

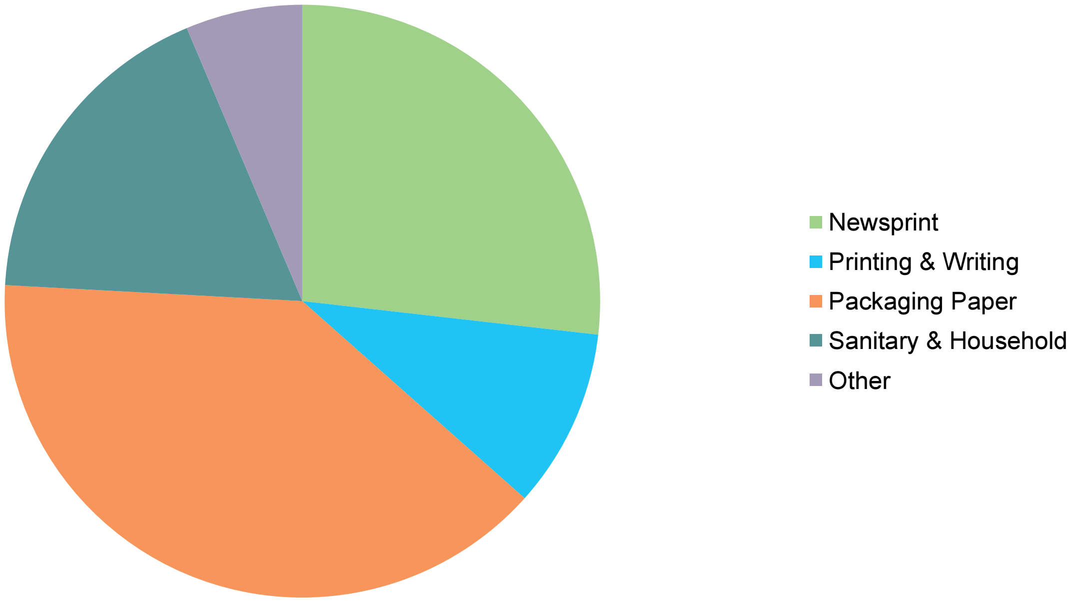
Pulp is the raw material in the manufacture of various paper products. There are four main production processes for pulp: mechanical, semi-chemical, sulphite, sulphate. The pulp from each of these processes has distinctive properties and is used to produce particular categories of paper product. Even so, the European Commission has found that it comprises a single market (EC, 2002).

Paper, on the other hand, is composed of many markets. The main subsectors of paper distinguished within the Best Available Techniques Reference document (EC, 2001) are:
- newsprint;
- uncoated printing and writing papers;
- coated printing and writing papers;
- packaging papers;
- tissue;
- speciality papers.

This is broadly consistent with the definitions used by the European Commission in competition cases, though it has also tended to distinguish between some further submarkets within each subsector. For instance, the Commission has occasionally distinguished between wood-free and wood-containing paper types, and between paper provided in reels and paper provided in sheets (EC, 2002).

Approximately 4.4 million tonnes of paper were produced in the UK in 2012. Packaging paper and newsprint comprise the two largest subsectors by production weight.

Figure 45. **Printing paper and sanitary products comprise a low proportion of production weight, but are generally higher value**



Note: *Subsector production measured by weight*

Source: *ONS, 2013*

Production

Paper plants either purchase virgin pulp or used recovered paper feedstock. To produce pulp from recovered paper:

- the recovered paper is combined with hot or white water within a pulper;
- the paper is decomposed into fibres using mechanical and hydraulic processes;
- impurities are removed from the pulp by spinning and a variety of pressurised screens;
- the pulp may then be deinked or bleached, depending on the end use.

All types of paper and paperboard follow the same basic production steps:

- pulp is mixed with water to produce a pulp slurry, which is subsequently refined, cleaned and screened
- the slurry is sprayed onto a flat wire screen;
- the web of slurry is pressed at high speed between large rolls that squeeze out water;
- the pressed sheet is passed to heated cylinders that are used to dry the slurry;
- the paper is rolled in the 'calender' (a series of high-pressure rollers) to provide finish and uniform consistency;
- the paper is cut and prepared for shipment.

Paper production is capital intensive. A 'paper machine', which performs the forming, pressing, drying and smoothing, is an expensive asset with a lifespan measured in decades.

Energy and emissions

Emissions from paper manufacture vary with the feedstock, product and type of fuel used, as well as with the application of specific energy efficiency technologies. In particular, co-generation of heat and power (CHP) is widely applied within the paper industry, and has a significant effect on energy efficiency. The fuel used in the UK paper industry is predominantly gas, accounting for 88 per cent in 2005 to 2007 (Ecofys, 2009).

Best practice mechanical pulp manufacture generates no direct emissions. While heat is necessary to produce pulp, enough heat can be recovered as a by-product of mechanical pulping to ensure that no combustion of fossil fuels is necessary (Ecofys, 2009). Recovered paper processing generates a small quantity of direct emissions, with an EU-ETS benchmark of 19kg CO_2 per air dried tonne (ADT).

Paper production is more emissions intensive, with benchmarks ranging form 0.32 tCO_2 per ADT to 0.46 tCO_2 per ADT, depending on the product (Ecofys, 2009). Each benchmark was generated using natural gas as the reference fuel, and therefore seems likely to be applicable in the context of UK production. In addition, DECC statistics suggest that around 40 per cent of total energy use in the UK paper industry is in the form of electricity. These indirect emissions have previously been estimated to be around 0.1 tCO_2 per ADT (EC, 2001).

Activity

All pulping within the UK is fully integrated with paper production. There are two pulp plants that produce virgin pulp through the mechanical process, while the remaining paper facilities use recycled paper feedstock to produce their pulp or import virgin pulp.

The number of paper mills in the UK has declined substantially over the last decade. In 2000, there were around 90 mills. Ecofys (2009) found 63 registered ‘paper, pulp and board’ installations in the UK.

Real GVA has also been in decline, reflected by static nominal GVA of around £700 million since 2007 (Figure 11). As in other manufacturing sectors, employment in pulp and paper manufacture has fallen significantly since 1998 and there have been widespread closures.

Profit margins have stayed relatively stable over the last few years. Independent analysis of company accounts suggests a margin of around six per cent. Publically available accounts indicate that profit margins in pulp and paper, measured as operating profits with interest payments excluded, are around four to six per cent. This is broadly compatible with CEPI data which indicates average European EBITDA margins of around 10 to 13 per cent. EBITDA margins exclude tax, which is included as a variable cost of production within our model.

The majority of UK trade is with EU countries and imports are far larger than exports. In 2010, the value of imports was over three times greater than the value of exports.

In 2010 the value of intra-EU imports was approximately four times the value of extra-EU imports. Exports were more evenly distributed between EU and non-EU countries. Intra-EU exports generated around 50 per cent higher revenues than extra-EU exports in 2010.

Table 19. **Top import and export partners for paper**

Imports	Exports
Germany	Germany
Finland	Ireland
Sweden	France
The Netherlands	United States
France	The Netherlands

Note: Table shows top five export and import partners for paper and paperboard, according to value, for 2010

Source: European Commission, 2013

Cambridge Econometrics has previously estimated elasticities for the responsiveness of domestic consumption, imports and exports of paper to price (DECC, 2010). The estimates are -0.5, -0.16 and -0.7 respectively.

Of the three elasticities, only the domestic price elasticity was estimated with a high degree of statistical confidence. An elasticity of -0.5 suggests that demand will be relatively unresponsive to price, indicative of the paucity of substitutes for many paper applications. Import PED is plausibly lower due to imports being composed of a greater degree of speciality products, with low substitutability.

Appendix F Steel

Definition

UK production was 9.5mt in 2011. The steel industry in the UK overall is split by two production processes, which tend to produce differentiated goods.

There are two main production processes for crude steel:
- basic oxygen furnace (BOF), 73 per cent of UK output;
- electric arc furnace (EAF), 27 per cent of UK output.

Analysis from the European Commission argues that the overall steel sector is further split into several subsectors, including construction, engineering and aeronautical steels.

BOF production takes place in large integrated steel mills, with capacities above 2,000,000 tonnes per year. It is generally used for high quality 'flat products' such as plates, sheets and tubes, used in automotive industry and oil and gas transmission.

EAF production largely takes place in mini-mills, with lower capacities of between 200,000 and 400,000 tonnes per year. It is generally used for lower quality 'long products', bars, rods and structural sections, used in construction and mechanical engineering.

Production

BOF production has four stages:
- iron ore is prepared in form of sinter and pellets;
- coke (dry distillate of coal), iron ore, pellets, sinter, limestone are combined in a blast furnace to produce liquid iron and slag;
- liquid iron is transported to a BOF to form steel;
- liquid steel is cast into ingots or via some type of continuous casting.

EAF production has three stages:
- some combination of scrap metal, direct reduced iron and pig iron are loaded into the furnace;
- electrodes are lowered onto the scrap, and an electric arc is created; simultaneously, oxygen is blown into the scrap to speed scrap meltdown and a foaming slag is formed to increase energy efficiency and arc stability;
- steel is tapped out into a ladle, and then cast into a variety of products.

Both the BOF and EAF production processes lead to the production of liquid steel, which is then processed into a 'semi-finished' product, generally by pouring the steel directly into casting machines. Semi-finished products include ingots, blooms, billets, and slabs.

While there is some trade in semi-finished products, most are then subsequently rolled into flat or long steel products. There are three major subdivisions of flat steel product: hot-rolling; cold-rolling and coating. In addition, there are at least five types of finished long product: wire rod; drawn wire products; reinforcing bars; merchant bars and sections. The EC has found that most of these products form distinct markets, and has also found some further markets within the products.

Energy and emissions

The emissions and electricity intensity of steel production are high. The electricity intensity of EAF production is high whereas BOF uses mainly natural gas.

In BOF production, direct carbon emissions result from fuel used for the blast furnace. In addition, some carbon content from coke and coal input for the blast furnace is released. In EAF production, direct carbon emissions result from fuel and carbon from electrodes and scrap that is oxidised in the EAF.

Market structure

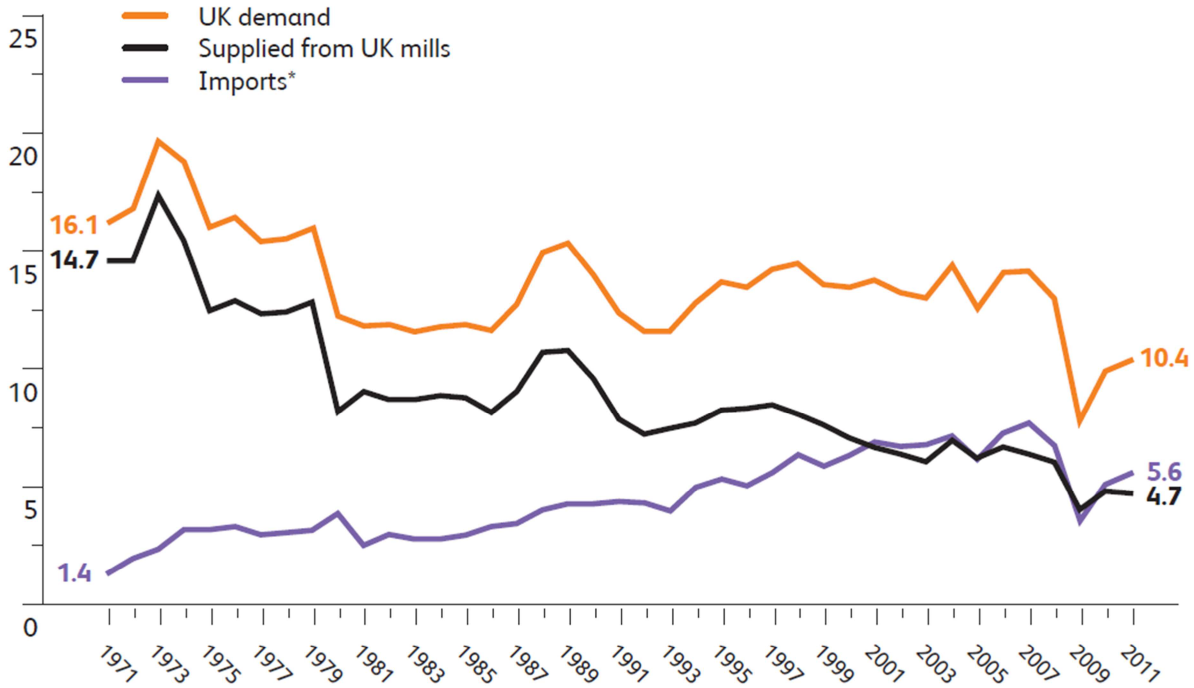
There are three BOF and six EAF plant in the UK. Total crude steel production in the UK in 2011 from the nine active production plants amounted to 9.5mt. Of this total, 6.9mt was produced in BOF plant and 2.5mt in EAF plant.

The UK crude steel industry consists of nine production sites, owned by five companies. The Teesside BOF plant was bought by Thai steel giant SSI and reopened in 2012. The largest UK player, Tata Steel recently announced a major investment package to improve production quality (BBC News Wales, 2012).

Activity

Total crude steel demand of 10.4mt in 2011 was covered by 4.7mt of UK production and 5.6mt of imports. By contrast, in 1971 the share of imports was only 9 per cent.

Figure 46. **Imports have overtaken UK production in the 21st century (numbers in tonnes millions)**

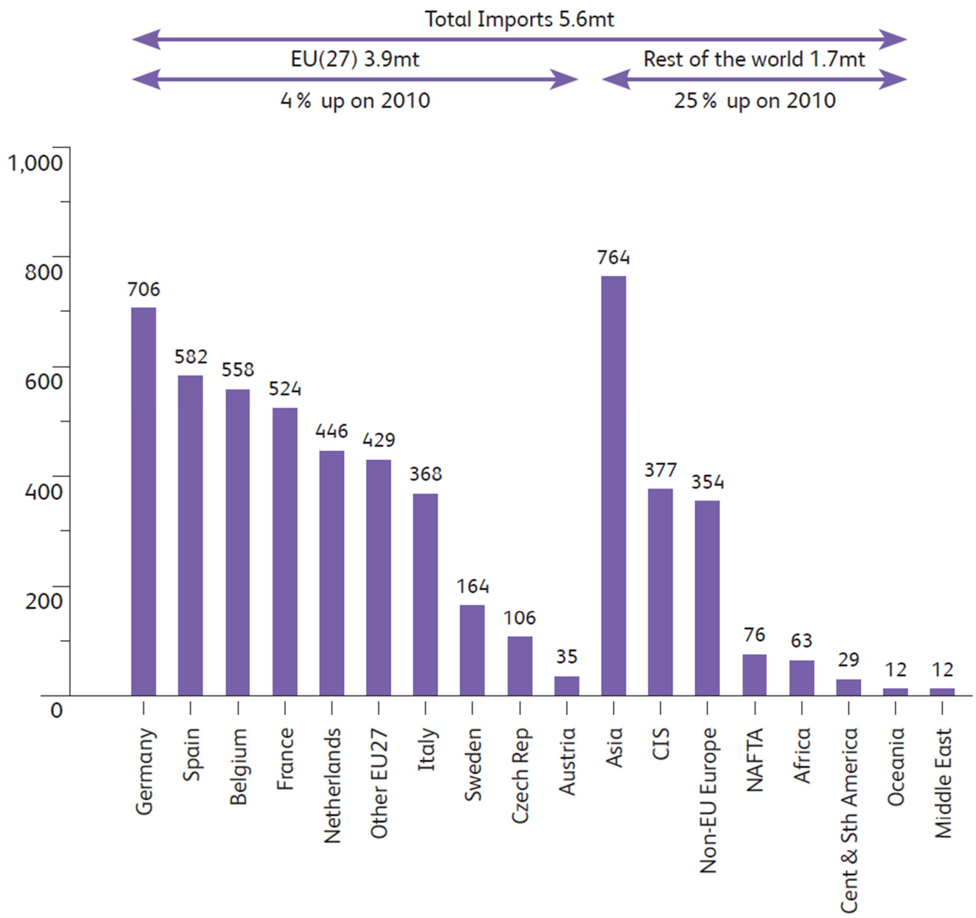


Note: *Excludes any imports by steel producers*

Source: *UK Steel Association, 2013b*

In 2011, 70 per cent of UK steel imports originated from EU countries. Imports from elsewhere were mainly from Asia.

Figure 47. **In 2011, seventy per cent of UK steel imports were sourced from the EU**



Source: UK Steel Association, 2013b

Faced with falling domestic demand, iron and steel gross value added (GVA) to the economy has fallen by almost 50 per cent since 1998. Employment in the sector has fallen by more than half, from 45,000 in 1991 to 18,500 in 2011.

UK exports have, however, been increasing over the last decade, more than compensating for the domestic encroachment of imports. Crude steel exports reached a value of 5 mt, up from 3.5 mt in 2001.

Appendix G Exemptions tested

Table 20 lists the exemption rates and scope employed in MDM-E3.

Table 20. **Proposed sectoral exemption rates under different policy scenarios tested in MDM-E3**

		Option					
SIC	Sector	1a	1b	2a	2b	3a	3b
1310	Mining of iron ores	80%	67%	80%	80%	80%	67%
1430	Mining of chemical and fertiliser minerals	80%	67%	80%	80%	80%	67%
1711	Preparation and spinning of cotton-type fibres	80%	67%	80%	80%	80%	67%
1810	Manufacture of leather clothes	80%	67%	80%	80%	80%	67%
2111	Manufacture of pulp	80%	67%	80%	80%	80%	67%
2112	Manufacture of paper and paperboard	80%	67%	80%	80%	80%	67%
2413	Manufacture of other inorganic basic chemicals	80%	67%	80%	80%	80%	67%
2414	Manufacture of other organic basic chemicals	80%	67%	80%	80%	80%	67%
2415	Manufacture of fertilizers and nitrogen compounds	80%	67%	80%	80%	80%	67%
2416	Manufacture of plastics in primary forms	80%	67%	80%	80%	80%	67%
2470	Manufacture of man-made fibres	80%	67%	80%	80%	80%	67%
2710	Manufacture of basic iron, steel, and ferro-alloys	80%	67%	80%	80%	80%	67%
2742	Aluminium production (adjusted)	80%	67%	80%	80%	80%	67%
2743	Lead, zinc and tin production	80%	67%	80%	80%	80%	67%
2744	Copper production	80%	67%	80%	80%	80%	67%
2020	Manufacture of veneer sheets, plywood, laminboard, particle board, etc	80%	67%	80%	80%	0%	0%
2411	Manufacture of industrial gases	80%	67%	80%	80%	0%	0%
2613	Manufacture of hollow glass	80%	67%	80%	80%	0%	0%
2621	Manufacture of ceramic household and ornamental articles	80%	67%	80%	80%	0%	0%
2651	Manufacture of cement	80%	67%	80%	80%	0%	0%
2511	Manufacture of rubber tyres and tubes	80%	67%	80%	80%	0%	0%
1715	Throw & prepared silk, synthetic etc	0%	0%	80%	50%	0%	0%
1753	Manufacture of non-wovens and articles made from non-wovens, except apparel	0%	0%	80%	50%	0%	0%
1542	Manufacture of refined oils and fats	0%	0%	80%	50%	0%	0%
1713	Preparation and spinning of worsted-type fibres	0%	0%	80%	50%	0%	0%
2122	Manufacture of household and sanitary goods and of toilet requisites	0%	0%	80%	50%	0%	0%
1450	Other mining and quarrying n.e.c.	0%	0%	80%	50%	0%	0%
2320	Manufacture of refined petroleum products	0%	0%	80%	50%	0%	0%
1422	Mining of clays and kaolin	0%	0%	80%	50%	0%	0%
1716	Manufacture of sewing threads	0%	0%	80%	50%	0%	0%

		Option					
SIC	**Sector**	**1a**	**1b**	**2a**	**2b**	**3a**	**3b**
2417	Manufacture of synthetic rubber in primary forms	0%	0%	80%	50%	0%	0%
2732	Cold rolling of narrow strip	0%	0%	80%	50%	0%	0%
1597	Manufacture of malt	0%	0%	80%	50%	0%	0%
2412	Manufacture of dyes and pigments	0%	0%	80%	50%	0%	0%
2522	Manufacture of plastic packing goods	0%	0%	80%	50%	0%	0%
1724	Silk-type weaving	0%	0%	80%	50%	0%	0%
2611	Manufacture of flat glass	0%	0%	80%	50%	0%	0%
2751	Casting of iron	0%	0%	80%	50%	0%	0%
1760	Manufacture of knitted & crocheted fabrics	0%	0%	80%	50%	0%	0%
1712	Preparation and spinning of woollen-type fibres	0%	0%	80%	50%	0%	0%
2465	Manufacture of prepared unrecorded media	0%	0%	80%	50%	0%	0%
2731	Cold drawing	0%	0%	80%	50%	0%	0%
2753	Casting of light metals	0%	0%	80%	50%	0%	0%
1440	Production of salt	0%	0%	80%	50%	0%	0%
2745	Other non-ferrous metal production	0%	0%	80%	50%	0%	0%
1910	Tanning and dressing of leather	0%	0%	80%	50%	0%	0%

Source: Cambridge Econometrics

Appendix H Data sources

Data is obtained across a wide range of sources

A wide variety of data sources were used in obtaining and deriving input estimates for RIMM and FIMM analysis, spanning from data collected directly from industry to websites, academic papers, and international organisations. These are identified in Table 21, Table 22, and Table 23.

Table 21. **Data sources used in FIMM analysis**

	Price		Gross profit margins		Elasticity		UK production quantity		External production quantity	
Sector	Value (£/t)	Source	Value (%)	Source	Value (%)	Source	Value (t)	Source	Value (t)	Source
Cement	90	Global Cement Magazine, 2013a	5.3	BCG, (2013)	-0.27	la Cour & Mollgaard, 2002	8,403,000	Global Cement Magazine, 2013b	1,670,328	Mineral Products Association, 2013, European Commission, 2013
Ceramics	97	British Ceramics Confederation, 2013	3	British Ceramics Confederation, 2013	-0.3	Ivanova, 2005	3,739,622	British Ceramics Confederation, 2013, European Commission, 2013	217,921	British Ceramics Confederation, 2013, European Commission, 2013
Flat glass	380	British Glass Manufacturers Confederation, 2013	12.5	IBISWorld, (2013a)	-0.3	European Commission, 1993	428,759	British Glass Manufacturers Confederation, 2013,IBISWorld, 2013b	8,334,831	British Glass Manufacturers Confederation, 2013, IBISWorld, 2013b, European Commission, 2013

	Price		Gross profit margins		Elasticity		UK production quantity		External production quantity	
Sector	Value (£/t)	Source	Value (%)	Source	Value (%)	Source	Value (t)	Source	Value (t)	Source
Fertilisers	293	IBISWorld, 2013a	11	(IBISWorld, 2013a)	-0.37	ICF International & Cambridge Econometrics, 2013	1,100,000	IBISWorld, 2013a, GrowHow, 2013 (note is a closer approximation to capacity than output)	1,501,842	IBISWorld, 2013a, European Commission, 2013
Flat steel	473	IndexMundi, 2013	8	British Steel, (2013)	-0.3	Zhu, 2012	2,199,356	British Steel, 2013; European Commission, 2013	211,087,943	British Steel, 2013, European Commission, 2013
Long steel	456	MEPS, 2013	8	British Steel, (2013)	-0.3	Zhu, 2012	4,116,805	British Steel, 2013; European Commission, 2013	107,313,437	British Steel, 2013, European Commission, 2013

Source: *Vivid Economics*

Table 22. **Electro- and emissions-intensity of production data sources used in FIMM analysis**

	Electro-intensity of production (£/MWh)		UK emissions intensity		EU emissions intensity		Non-EU emissions intensity	
Sector	Value (£/t)	Source	Value (tCO_2e/t)	Source	Value (tCO_2e/t)	Source	Value (tCO_2e/t)	Source
Cement	0.13	DECC (2011); European Commission, (2013)	0.72	Mineral Products Association (2012)	0.7	Mineral Products Association (2012); IEA (2012); IEA, (2007)	0.8	IEA (2012); IEA, (2007)

	Electro-intensity of production (£/MWh)		UK emissions intensity		EU emissions intensity		Non-EU emissions intensity	
Sector	**Value (£/t)**	**Source**	**Value (tCO_2e/t)**	**Source**	**Value (tCO_2e/t)**	**Source**	**Value (tCO_2e/t)**	**Source**
Ceramics	0.07	British Ceramics Confederation, 2013	0.21	British Ceramics Confederation, 2013; European Commission (2013b)	0.21	British Ceramics Confederation, 2013; European Commission (2013b); IEA (2012)	0.23	British Ceramics Confederation, 2013; European Commission (2013b); IEA (2012)
Flat glass	0.19	British Glass Manufacturers Confederation, 2013,	0.51	Comite Permanent des Industries du Verre Europeenes, (2010)	0.51	Comite Permanent des Industries du Verre Europeenes, (2010)	0.51	Comite Permanent des Industries du Verre Europeenes, (2010)
Fertilisers	0.34	DECC (2011); European Commission, (2013)	2.54	Wood & Cowie, (2004)	2.59	Wood & Cowie, (2004)	3.1	Wood & Cowie, (2004)
Flat steel	0.31	British Steel, (2013)	1.5	IEA (2007)	1.02	IEA (2007)	1.3	IEA (2007)
Long steel	0.55	British Steel, (2013)	0.87	IEA (2007)	1.04	IEA (2007)	1.25	IEA (2007)

Source: *Vivid Economics*

Table 23. **Data sources used in RIMM analysis**

	Price		Elasticity		UK production quantity		External production quantity	
Sector	**Value (£/t)**	**Source**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**
Copper production	9,356	International Copper Study Group, 2008, IBISWorld, 2013c	0.2	Cambridge Econometrics, 2010	98,800	International Copper Study Group, 2008	374,287	European Commission, 2013
Polypropylene	977	Platts, 2013	0.41	Cambridge Econometrics, 2010	614,600	European Commission, 2013	516,787	European Commission, 2013
Veneer sheets	258	UNECE, 2010, UNECE, 2012	0.75	UNECE, 2003	1,948,947	Forestry Commission, 2013	2,315,416	European Commission, 2013
Rubber tyres and tubes	3,353	European Commission, 2013	1.2	Gwartney & Stroup, 1997	646,063	ONS, 2012a	578,176	European Commission, 2013
Mining of clays and kaolin	113	IBISWorld, 2013d, British Geological Survey, 2013	0.8	Cambridge Econometrics, 2010	1,000,000	British Geological Survey, 2013	162,535	European Commission, 2013, IBISWorld, 2013d
Malt	300	FAO, 2009	0.56	HMRC, 2010	1,567,000	Euromalt, 2012	267,479	European Commission, 2013
Lime	31	USGS, 2011	0.87	Cambridge Econometrics, 2010	1,200,000	BLA, 2013	164,010	European Commission, 2013
Petroleum products	715	ONS, 2012a	0.7	Graham & Glaister, 2002	75,000,000	UKPIA, 2013	28,233,081	European Commission, 2013
Salt	50	The Economist, 2010	0.1	Gwartney & Stroup, 1997	6,666,000	Minerals UK, 2013	161,574	European Commission, 2013
Refined oils and fats	223	FAO, 2012	0.805	OECD, 2010	4,932,735	IBISWorld, 2013e	4,409,141	European Commission, 2013
Beer	4,332	British Beer and Pub Association, 2013	0.56	HMRC, 2010	4,727,933	IBISWorld, 2013f, The Beer Tutor, 2013	1,098,637	European Commission, 2013
Ice cream	3,325	IBISWorld, 2013g	1	C.G.Davis, D.P.Blayney, S.T.Yen, & J.Cooper, 2009	223,806	European Commission, 2013	90,756	European Commission, 2013
Gravel and sand pits	34	IBISWorld, 2013d	0.8	Cambridge Econometrics, 2010	69,222,400	IBISWorld, 2013d	3,370,828	European Commission, 2013
Carpets	10,800	IBISWorld, 2013h	1.2	Gwartney & Stroup, 1997	81,325	IBISWorld, 2013h	366,855	European Commission, 2013

Source: *Vivid Economics*

Table 24. **Profit margin and electro-intensity sources used in RIMM analysis**

	Gross profit margin		Electro-intensity	
Sector	**Value**	**Source**	**Value (£/t product)**	**Source**
Copper production	5.0%	IBISWorld, 2013c	5.92	DECC, 2012; International Copper Study Group, 2008
Polypropylene	19.8%	IBISWorld, 2013i	1.89	DECC, 2012; Worrell, Phylipsen, Einstein, & Martin, 2000; European Commission, 2013
Veneer sheets	5.0%	IBISWorld, 2013j	0.51	DECC, 2012; Forestry Commission, 2013
Rubber tyres and tubes	9.0%	IBISWorld, 2013k	0.84	DECC, 2012; ONS, 2012
Mining of clays and kaolin	8.0%	IBISWorld, 2013d	0.34	British Geological Survey, 2013; DECC, 2012
Malt	8.5%	IBISWorld, 2013l	0.15	Euromalt, 2012; DECC, 2012
Lime	13.0%	IBISWorld, 2012	0.04	British Lime Association, 2013; DECC, 2012
Petroleum products	2.8%	IBISWorld, 2013m	0.05	UKPIA, 2013; DECC, 2012
Salt	44.0%	IBISWorld, 2013n	0.01	Minerals UK, 2013; DECC, 2012
Refined oils and fats	4.9%	IBISWorld, 2013e	0.01	IBISWorld, 2013e; DECC, 2012
Beer	11.5%	IBISWorld, 2013f	0.01	IBISWorld, 2013f; The Beer Tutor, 2013; DECC, 2012
Ice cream	10.8%	IBISWorld, 2013g	0.12	European Commission, 2013; DECC, 2012
Gravel and sand pits	8.0%	IBISWorld, 2013d	0.01	IBISWorld, 2013d; DECC, 2012
Carpets	9.9%	IBISWorld, 2013h	4.83	IBISWorld, 2013h; DECC, 2012

Note: *Emissions-intensity data was obtained from the same source as the electro-intensity data in all instances, with the exception of polypropylene, which was obtained from Borealis, (2008)*

Source: *Vivid Economics*

Appendix I The economics of the Industrial Market Models

This Appendix provides both graphical intuition regarding the functionality of the model and explicitly identifies dependencies between variables. Theoretical background is covered first, followed by a detailed discussion of the mechanics of the RIMM approach, and then some additional commentary on the differences in FIMM.

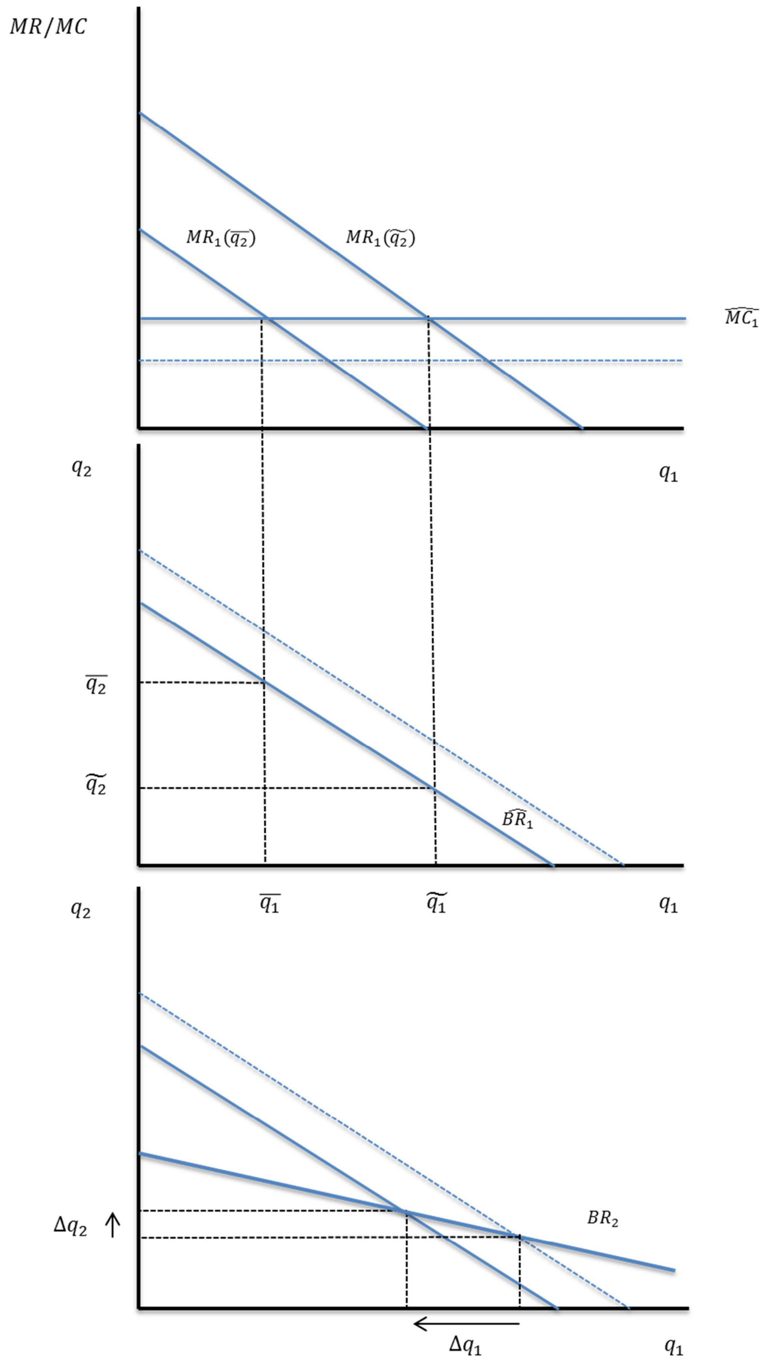
Underlying the Industrial Market Models are various assumptions regarding optimising firm behaviour, largely based around Cournot competition. Some insight can thus be obtained by considering a simplified two-firm, pure Cournot model, where the analysis would proceed as follows:

- a best response curve for each firm is derived as the intersection of the firm's marginal revenue and marginal cost curves at different levels of production for their opponent;
- the initial equilibrium is defined by the intersection of the firms' best response curves;
- the marginal cost of one of the firms is increased. This results in an inward shift of their best response curve;
- a new equilibrium is derived. Production in the new equilibrium is higher for the firm whose marginal cost remains unchanged and lower for the firm whose marginal cost has increased.

This process is depicted in Figure 48. The first chart shows how the marginal revenue curve for Firm 1 changes as Firm 2 varies its production quantity (q_2). The intersection of the marginal revenue and marginal cost curve then defines the best response for Firm 1. This allows the derivation of the best response curve shown in the second chart. The first and second charts also show how Firm 1's best response curve shifts in response to a change in marginal costs.

The third chart then depicts both the best response curve of Firm 1 and the best response curve of Firm 2. Where these curves intersect, that is, where each firm's output is the best response to the other firm's output, defines the equilibrium. When Firm 1's best response curve moves inwards in response to a change in production costs, q_1 falls and q_2 rises.

Figure 48. **An asymmetric cost increase in a two-firm Cournot model**



Source: *Vivid Economics*

Modelling with RIMM

Analysis under the RIMM approach proceeds in a broadly analogous manner to the above, but with two additions:

– it integrates a broad array of competitive strategies beyond Cournot (quantity) competition, including price competition; and
– it extends the analysis to a large number of firms.

As a simplifying assumption, RIMM requires that all firms that are affected by a change in costs experience an identical unit cost increase or decrease. In the context of this report, this implies that all firms within the relevant industry in the UK have identical electro-intensity to each other.

The conceptual structure of the RIMM model is depicted in Figure 9, Section 2.2.4. The functional form of the model can be broken down into five steps, which are broken down, including explicit functional notation for formality (where Δ signifies 'change in'):

Market competitiveness is estimated as a function of market share, price elasticity of demand and domestic profit margin:

$$theta = f(price\ elasticity\ of\ demand, profit\ margin, domestic\ market\ share)$$

Market competitiveness, referred to as 'theta', measures the extent to which firms prioritise market share over profit in their objective function. At one extreme, firms care only about market share and outcomes are identical to Bertrand price competition. At the other extreme, firms act to maximise profit and outcomes are identical to classic Cournot competition.

Cost pass-through rate is estimated as a function of competitiveness:

$$Cost\ passthrough\ rate = f(market\ competitveness)$$

Absolute cost shock is a function of the cost shock per unit of electricity and the electro-intensity of domestic production:

$$absolute\ cost\ shock = f(electro\text{–}\ intensity\ of\ production, value\ of\ exemption\ per\ MWh)$$

Absolute cost shock combined with cost pass-through rate determines both change in profit margins and absolute change in market prices:

$$\Delta profit\ margins = f(cost\ pass\ through\ rate, absolute\ cost\ shock)$$

Finally, change in market share, total market size, and market price are also determined as a function of cost pass-through rate, absolute cost shock and market shares:

$$\Delta domestic\ production = f(market\ share, cost\ pass\ through\ rate, absolute\ cost\ shock)$$

$$\Delta market\ price = f(cost\ pass\ through\ rate, absolute\ cost\ shock)$$

Conceptually, firms can be thought of as trading-off their profit margins, which are maximised by keeping production at the pre-shock level, and market share, which is maximised by increasing production. Increased production will lower prices, which both increases total market size and drives down competitors profit margins. Lower profit margins for competitors imply that they will reduce their output, with domestic producers benefiting from both the larger total market and from 'stealing' some of their competitor's market share.

Distinctions in FIMM

The FIMM model works in an analogous way, but relaxes some of the simplifying assumptions in RIMM. For instance:

- as discussed in Section 2.2, rather than splitting total market production into two regions, it accounts for production via individual firms or installations, which can be assigned specific electro-intensity levels;
- consequently, in the face of a cost shock, the relative impact on different firms varies. In the case of a regulatory-induced shock, the FIMM allows for market share reallocation not just between regulated and unregulated regions, but within the set of regulated firms;
- including individual firm profit margins, estimated in relation to their share of the market, it allows for firm exit when margins drop to zero, which can result in significant non-linearities in production responses.

As FIMM includes the behaviour of individual firms or installations in the markets, it takes into account not just the fraction of regulated firms or assets, but the distribution of asset sizes and cost shocks. A market with one large regulated asset and several small unregulated ones will produce different dynamics (usually, for instance, more muted output responses) compared to a market with several equally-sized regulated and unregulated firms, even if the fraction of total production that falls under regulation is the same in both. For instance, suppose regulated firms make up 20 per cent of market production. In one case, there is only one regulated firm, but the firm has 20 per cent of the market-share. In another, there are 20 regulated firms, each with 1 per cent of the market-share. The latter case would usually display more output responsiveness than the former.

FIMM also derives estimations of firm unit costs, based on observed market shares and industry average profit margins: firms with larger market shares are assumed to have lower unit costs. On imposition of a cost shock, as market share reallocates both between regulated firms, and from regulated to unregulated firms, FIMM recalculates market share, unit costs and margins. In RIMM, the change in unit cost of regulated firms is simply the per-tonne regulation cost paid by firms, but not in FIMM, since unit costs are recalculated upon the imposition of the cost shock both before and after firms exit.

Additional notes

The results from each model approximately follow the following equation, which is derived from algebraic manipulation of the model:

$$\% \; output \; change \approx \left[\frac{(1 - inside \; market \; share)}{inside \; market \; share}\right] \left[\frac{price \; elasticity \; of \; demand}{theta}\right] \left[\frac{cost \; change}{price}\right]$$

Note that both the electricity intensity of production and the price of electricity outside the UK do not appear in any of the equations shown here, and thus are not relevant to the modelling. This is a consequence of the IMM's assumption that the initial input data describe a market equilibrium; all electricity costs are assumed to have already been absorbed by foreign firms in their production decisions. As the CfD exemption does not affect production costs for foreign firms, foreign electro-intensities are not relevant.

Contact us:
Vivid Economics Limited
The Media Village
131-151 Great Titchfield Street
London W1W 5BB
United Kingdom

T: +44 (0)844 8000 254
E: enquiries@vivideconomics.com

Company Profile

Vivid Economics is a leading strategic economics consultancy with global reach. We strive to create lasting value for our clients, both in government and the private sector, and for society at large.

We are a premier consultant in the policy-commerce interface and resource- and environment-intensive sectors, where we advise on the most critical and complex policy and commercial questions facing clients around the world. The success we bring to our clients reflects a strong partnership culture, solid foundation of skills and analytical assets, and close cooperation with a large network of contacts across key organisations.

:vividenomics

cambridge econometrics