Department for
Business, Energy
& Industrial Strategy

Evaluation of second Climate Change Agreements scheme

Macro-economic report

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Contents

1. Introduction

This report presents two macro-economic papers that were developed by Cambridge Econometrics for the CCA evaluation:

- Macro-level estimation of CCA impact on energy consumption
- Modelling of CCA impact on economic variables.

Macro-level estimation of CCA impact on energy consumption

During Phase 1 of the evaluation, econometric analysis was undertaken at macro-level (i.e. 2-digit Standard Industrial Classification (SIC) code level) to test whether the CCA scheme had influenced energy consumption. This analysis complemented the micro-level analysis presented in the separate micro-econometric report.

A 'difference in difference' method was used to compare changes in electricity and gas consumption, at 2-digit SIC code level, pre- and post- implementation of the second CCA scheme. Industries in other EU Member States were used as the comparison group. The methodology used in this analysis is presented in Chapter 2. The results suggested that the second CCA scheme had no additional statistically significant impact on energy consumption, for reasons explored in Chapter 4 of the main synthesis report.

Modelling of CCA impact on economic variables

During Phase 2 of the evaluation, macro-economic modelling was then undertaken using the E3ME model[1] to calculate the estimated impact of CCL and CRC discounts, and energy demand savings, on economic variables at the macro-level. Findings were calculated at 2-digit SIC code sector level.

The upper estimate for the energy impact was based on statistically significant findings from the micro-econometric workstream. The micro-econometric work found that the CCA scheme reduced electricity consumption by between 4.1% and 11.4% for Target Units in sectors that entered the scheme via Environmental Permitting Regulations (EPR) or Energy Intensity/Trade Intensity (EI) criteria, respectively. The micro-econometric work also found that the CCA scheme reduced gas consumption by between 0% and 12.6% for the EPR and EI sectors respectively. The upper estimate for energy savings in the macro-economic modelling work used a weighted

[1] The E3ME model is an input-output model of the UK, Europe and global economy, developed by Cambridge Econometrics. It was selected, on the basis of a model review by Professor Paul Ekins in 2018, as the most appropriate model to assess CCA impacts on UK economic and environmental variables at macro-level.

average of these figures (i.e. 6.3% reduction in electricity use and 1.9% reduction in gas use) across CCA sectors.

The lower estimates for energy impact assumed that the CCA scheme had no statistically significant impact on energy demand, which was consistent with the lack of statistically significant findings from the macro-level economic work (see Chapter 2). While the lower estimate assumed that the CCA scheme did not reduce energy consumption directly, there were still some economic effects because the CCA provided discounts in CCL, and for some firms, CRC elements of energy costs.

The methodology and detailed findings from this work are presented in the paper and in the accompanying spreadsheet in Chapter 3. A summary of findings is presented in the main synthesis report.

The next two chapters present the Cambridge Econometric papers which set out the methodology and findings from these two tasks.

2. Macro-level estimation of CCA impact on energy consumption

Introduction and objectives

The objective of the macro-economic modelling task is to assess the impact of the second Climate Change Agreement (CCA) scheme[2], on industry energy consumption and industry competitiveness over the period 2013-2016.

There are several factors that have affected industry energy consumption over the same period that CCAs have been in place (for example, changes in energy prices, technological progress and investments in energy-efficient equipment to improve industry competitiveness). An econometric analysis is used to ascertain the extent to which changes in energy consumption within CCA sectors are resulting from the CCA scheme itself and the extent to which these efficiency improvements would have happened anyway, in absence of the scheme, due to other exogenous factors.

This paper provides an updated summary of findings from the macro-sectoral analysis of the impact of CCAs on industry energy demand, including in response to comments from peer review on the Phase 1 analysis.

The impacts of CCAs on competitiveness (derived from impacts on energy costs and consumption) is assessed separately through use of the macro-economic model, E3ME. The estimated impacts on competitiveness (based on E3ME model results) will be discussed in a subsequent report.

Overview of approach

For the difference-in-difference analysis, trends within the CCA sectors in the UK (the target group) before and after the introduction of the second phase of the CCA scheme (in 2013) are compared with trends for a comparable group of industries, which are not covered by CCAs. The comparison group of industries are used to control for external trends in energy consumption and therefore could comprise either:

- The same industry sectors (as those that are eligible for CCAs in the UK), located in other (comparable) countries, or;

[2] The second CCA scheme involves agreement of energy efficiency targets with CCA sectors for four two-year target periods. Firms with activities in these sectors can gain a significant discount on CCL and CRC by choosing to enter an agreement with Government to improve energy or carbon efficiency, in line with the relevant sector target. Three target periods have already been completed (2013-2014, 2015-2016 and 2017-2018). From December 2014, further reliefs have applied to activities in the mineralogical and metallurgical sectors, which are exempt from both CCL and CRC even if not covered by a CCA.

- Industry sectors that are not eligible for (or do not take-up) CCAs, located in the UK.

To isolate the effects of the CCA scheme it is important that, in the countries/industry sectors that are selected for comparison, there are no external factors affecting energy demand over the same period, that do not also apply to the UK CCA industry sectors. If this criterion does not hold, the estimated effect of CCAs would be biased. The comparison group should therefore comprise countries/sectors with similar characteristics to the treatment group (which comprises CCA sectors in the UK). Where possible, other exogenous factors that could affect energy demand trends should be controlled for in the regression. The significance of the CCA scheme in explaining differences in energy consumption among industries in the UK can then be tested.

Econometric specification

The difference-in-differences approach has the advantage that, by comparing trends in other countries/sectors, it allows us to control for other external factors affecting energy demand which cannot easily be included as control variables in the regression (i.e. due to data or practical limitations). Following the difference-in-difference approach, energy consumption trends in the UK industry sectors that are eligible for CCAs are compared to other countries/sectors, where CCAs are not granted. The rationale is that the other comparison countries/sectors will capture the effects of underlying trends and external, uncontrolled-for factors. A comparison group should be made up of at least one (but ideally many more) suitably comparable countries/sectors.

The specification of the equation that is estimated is as follows:

$$\begin{aligned} Energy\ Consumption_{it} &= \beta_1 + \beta_2 TreatmentGroup_i + \beta_3 Post\ Policy_t \\ &+ \beta_4 (TreatmentGroup * Post\ Policy)_{it} \\ &+ \sum_{s=5}^{n} \beta_s Covariates_{it}^{s} + \epsilon_{it} \end{aligned}$$

i= 0,1 (treatment/comparison)

t= 0,1 (pre-policy/post-policy)

Where: ‘Treatment Group’ is a dummy variable equal to 1 if the industry is located in the UK and has a CCA, or 0 otherwise; ‘Post Policy’ is a time dummy variable equal to 1 for years after the CCA was introduced, 0 otherwise; ‘Treatment Group * Post Policy’ captures the impact of the CCAs by measuring the impact for the treatment group in the post-policy period (i.e. the difference-in-difference estimator); ‘Covariates’ is a group of exogenous variables, including gas prices, electricity prices, and GVA (or, in the alternative specification, gross output).

In addition, year-specific dummy variables are included to control for effects specific to each year.

The difference-in-differences estimator can be understood in terms of the difference between the treatment and comparison groups before and after the policy period: The estimated coefficient for the interaction variable (TreatmentGroup*Post Policy) is of most interest when considering the impact of CCAs on energy consumption. As the difference-in-difference analysis compares pre-2013 trends to post-2013 trends in energy consumption, the interpretation of the interaction term is relative to the pre-2013 policy (i.e. relative to the impact of the first phase CCAs).

$DiD\ estimator$:

$$E[Energy\ Consumption_{it} \mid i = treatment, t = before] - E[Energy\ Consumption_{it} \mid i = treatment, t = after] -$$

$$E[Energy\ Consumption_{it} \mid i = comparison\ , t = before] - E[Energy\ Consumption_{it} \mid i = comparison, t = after]$$

Where ‘before’ and ‘after’ denote time ‘t’ before and after the introduction of the Target Period 2 CCAs.

For the treatment group, the equation for i,t prior to the CCA policy being introduced is:

$$Energy\ Consumption_{it} = \beta_1 + \beta_2 TreatmentGroup_{i=1} + \beta_3 Post\ Policy_{t=0} + \beta_4 (TreatmentGroup * Post\ Policy)_{i=1,t=0} + \sum_{s=5}^{n} \beta_s Covariates_{it}^{s} + \epsilon_{it}$$

and for the treatment group the equation for i,t after the CCA policy is introduced is:

$$Energy\ Consumption_{it} = \beta_1 + \beta_2 TreatmentGroup_{i=1} + \beta_3 Post\ Policy_{t=1} + \beta_4 (TreatmentGroup * Post\ Policy)_{i=1,t=1} + \sum_{s=5}^{n} \beta_s Covariates_{it}^{s} + \epsilon_{it}$$

For the comparison group the equation for all i,t prior to the CCA policy being introduced is:

$$Energy\ Consumption_{it} = \beta_1 + \beta_2 TreatmentGroup_{i=0} + \beta_3 Post\ Policy_{t=0} + \beta_4 (TreatmentGroup * Post\ Policy)_{i=0,t=0}$$

$$+ \sum_{s=5}^{n} \beta_s Covariates_{it}^{s} + \epsilon_{it}$$

and for the comparison group the equation for i,t after the CCA policy is introduced is:

$$\begin{aligned} Energy\ Consumption_{it} \\ = \beta_1 + \beta_2 TreatmentGroup_{i=0} + \beta_3 Post\ Policy_{t=1} \\ + \beta_4 (TreatmentGroup * Post\ Policy)_{i=0,t=1} \end{aligned}$$

$$+ \sum_{s=5}^{n} \beta_s Covariates_{it}^{s} + \epsilon_{it}$$

The above model can be estimated using a fixed effects or random effects estimator. The random effects model gives a consistent and unbiased estimate only if the residuals are not correlated with the unobserved fixed effects, which is tested using the Hausman test for unobservable heterogeneity in the model.

Robustness of approach and sources of bias

There are two key challenges of the difference-in-differences approach to estimate the impact of specific energy policies within the EU:

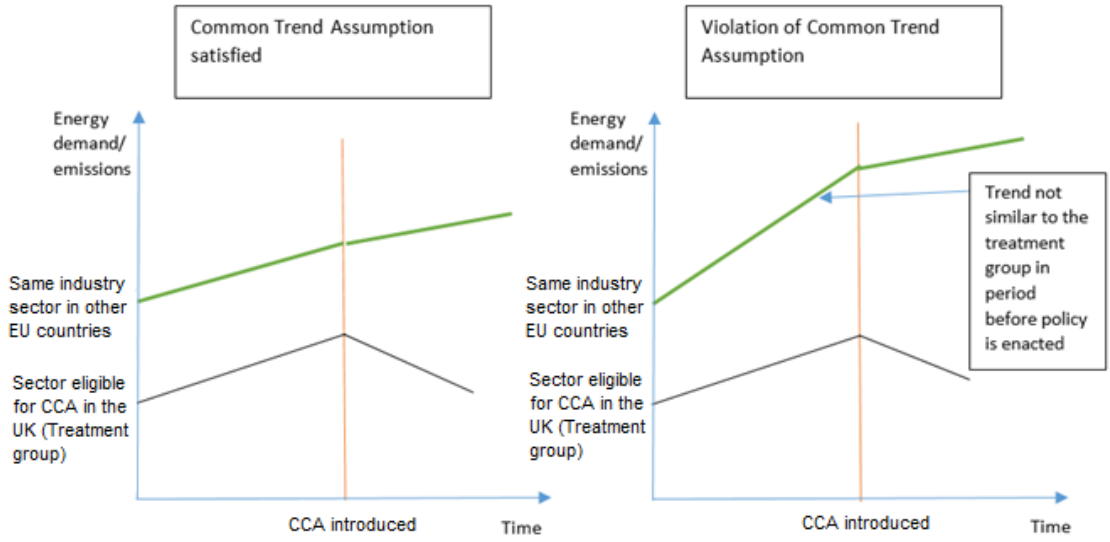
1. Being able to attribute impacts solely to the CCAs

It is important to verify that there are no factors, other than the CCAs, which could cause trends in the policy treatment group (CCA sectors in the UK) and the comparison group (sectors not covered by CCAs) to diverge. If the introduction of CCAs coincided with another reform or structural change in the UK (that was not also experienced in other countries/sectors), then the estimated impact of the other policy or structural change could be incorrectly attributed to the CCA effect.

2. Identifying a suitable counterfactual (‘the comparison group’)

The comparison group could be a single country/sector or, ideally, for a more consistent estimate, a group of countries/sectors. The difference-in-difference method only gives unbiased and consistent estimates if the common trend assumption is satisfied. According to this assumption, in the absence of the CCAs, energy consumption in the UK CCA sectors would follow a similar time trend as the comparison group (of other countries/sectors). This condition is difficult to satisfy, as there are likely to be other policies and country-specific factors and structural trends that affect countries/sectors in different ways. The assumption is tested by looking for common trends in the treatment and comparison groups over the pre-CCA period.

Figure 1 Illustrative diagram of the violation of the common trend assumption for difference-in-difference estimation



Attributing impacts to the CCAs

Policy interaction effects

For the difference-in-difference estimator to be unbiased, there must be no other policies introduced over the same period that affect energy demand in the treatment group and the comparison groups differently. If this condition does not hold, the effects of other policies will be picked up in the CCA indicator variable. The EU Emissions Trading Scheme (EU ETS) and the CRC energy efficiency scheme in the UK were both in place over the same time period as CCAs and are the two policies (alongside the CCAs) that are expected to have had the most significant direct impact on industry energy demand. A summary of these concurrent policies and the extent to which they could bias the estimates of the 'CCA effect' are discussed below.

The EU ETS

Introduced in 2005, the EU Emissions Trading System (ETS) is the foundation of energy and climate policy in Europe. The EU ETS is the largest global carbon market, operating in all EU countries (including the UK). It comprises a cap on total emissions, with companies then able to trade in emissions allowances. The carbon price is derived through demand for emissions allowances (with supply fixed to meet the emissions cap). The cap and trade system is designed to incentivise industries to decarbonise. The third trading period for the EU ETS began in January 2013.

The CRC energy efficiency scheme

Following the introduction of the CCA scheme, the CRC energy efficiency scheme started its second phase in April 2014. The CRC scheme applies to large, non-energy-intensive organisations in the public and private sector. Actions by large energy users under the CRC scheme could have an impact on industry energy efficiency that is being erroneously attributed to the effects of the CCA scheme. However, energy use that is already covered under both the EU ETS and the CCA

scheme is not included in the CRC[3]. Energy users covered under the CCA scheme and the EU ETS are typically larger industrial, energy-intensive users (such as manufacturing facilities), while the CRC applies to public bodies and large private energy users (i.e. supermarkets, hotels, water companies, local authorities, central government departments)[4].

Sources of bias

The approach we take for the difference-in-difference analysis mitigates the risk of the impact of the EU ETS and the CRC energy efficiency scheme being incorrectly attributed to the estimated 'CCA effect':

- The EU ETS is likely to have affected energy consumption behaviour across industries in the UK and the wider EU, so, by estimating industry energy consumption at the sectoral level and by using data for EU Member States in the comparison group, we control for the potential impacts of the EU ETS on industry energy demand. Due to data limitations, the comparison group is represented by 20 of the other 27 EU Member States.[5]

- The industry sectors that are covered by the CRC scheme do not substantially overlap with those industry sectors covered by CCAs. It is possible that some of the energy users included in the CCA scheme will also be subject to the CRCs (i.e. in cases where they are not included in the EU ETS) but, by estimating the 'CCA effect' at a detailed industry sector level, most of the effects of the CRC scheme (which primarily targets services and public sectors) are excluded.

Other structural changes

As well as picking up the effects of other industry energy policies, it is also possible that the CCA indicator variable will pick up the effects of industry structural change (if, for example, there was a change in the types of products that were being manufactured in the UK). To mitigate this risk, the econometric equations are estimated at the most detailed possible industry sector level (consistent with the SIC07 2-digit classification). This controls for broad industry structural change (i.e. shifts in activity between broadly defined industry sectors). Estimating at a more granular level is preferable, but not possible, due to limitations in the industry energy consumption data available for the comparison EU Member States. The estimates therefore rely on the assumption that structural changes within SIC 2-digit industries have had similar effects on energy consumption in the UK and the comparison EU Member States.

The specification of the econometric equation also controls for differences in gas and electricity price trends in the UK versus the EU, as well as differences in industry

[3] Guidance CRC Energy Efficiency Scheme: qualification and registration
[4] UK Government (2019), 'Environmental taxes, reliefs and schemes for businesses'.
[5] EU Member States that make up the comparator group include: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, and Sweden. These regions were represented in both IEA data, used for electricity and gas prices, and Eurostat data.

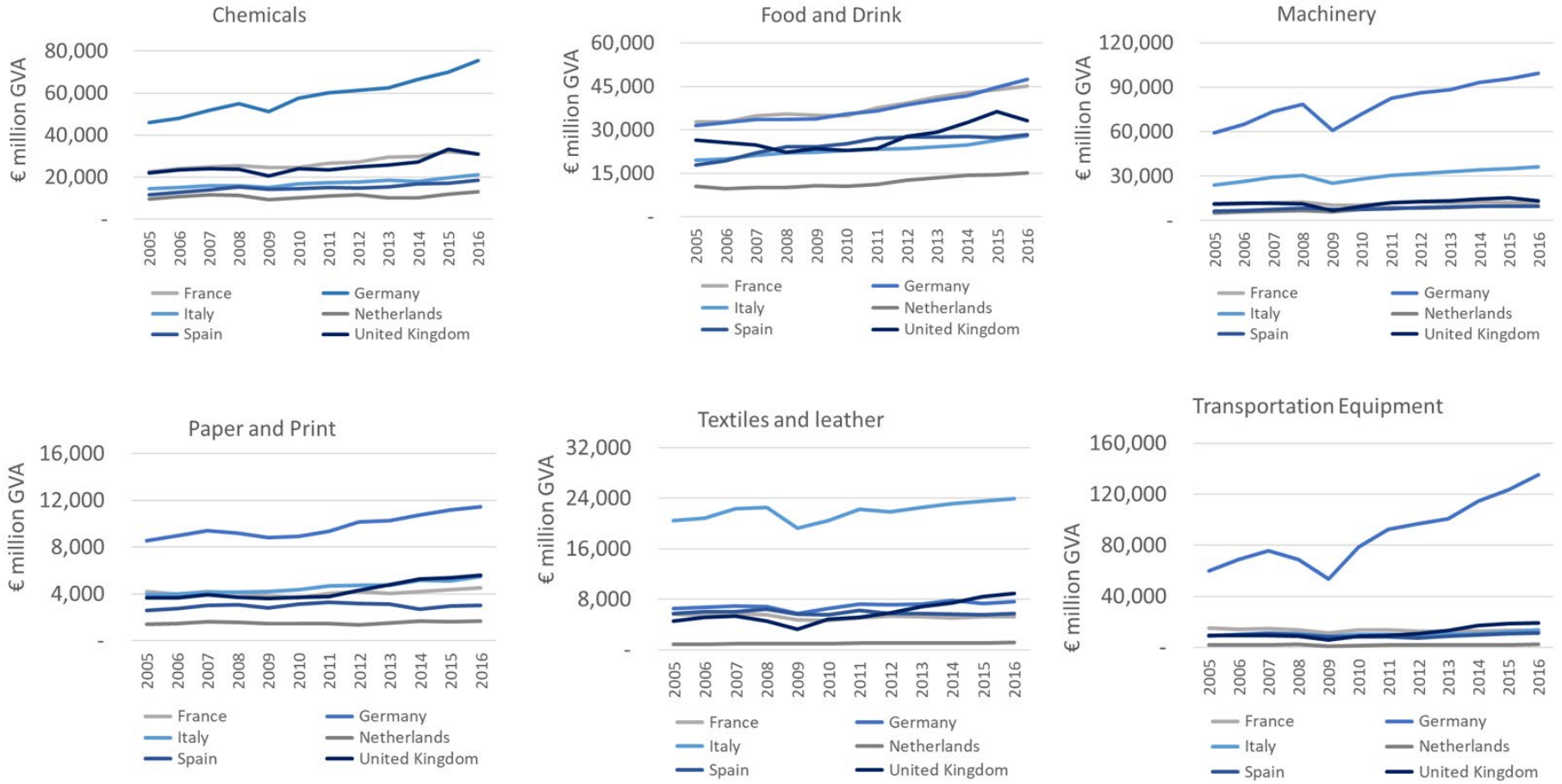
activity (GVA and gross output) by explicitly including these variables as explanatory terms in the regression.

Identifying a suitable counterfactual

Testing common trends assumption

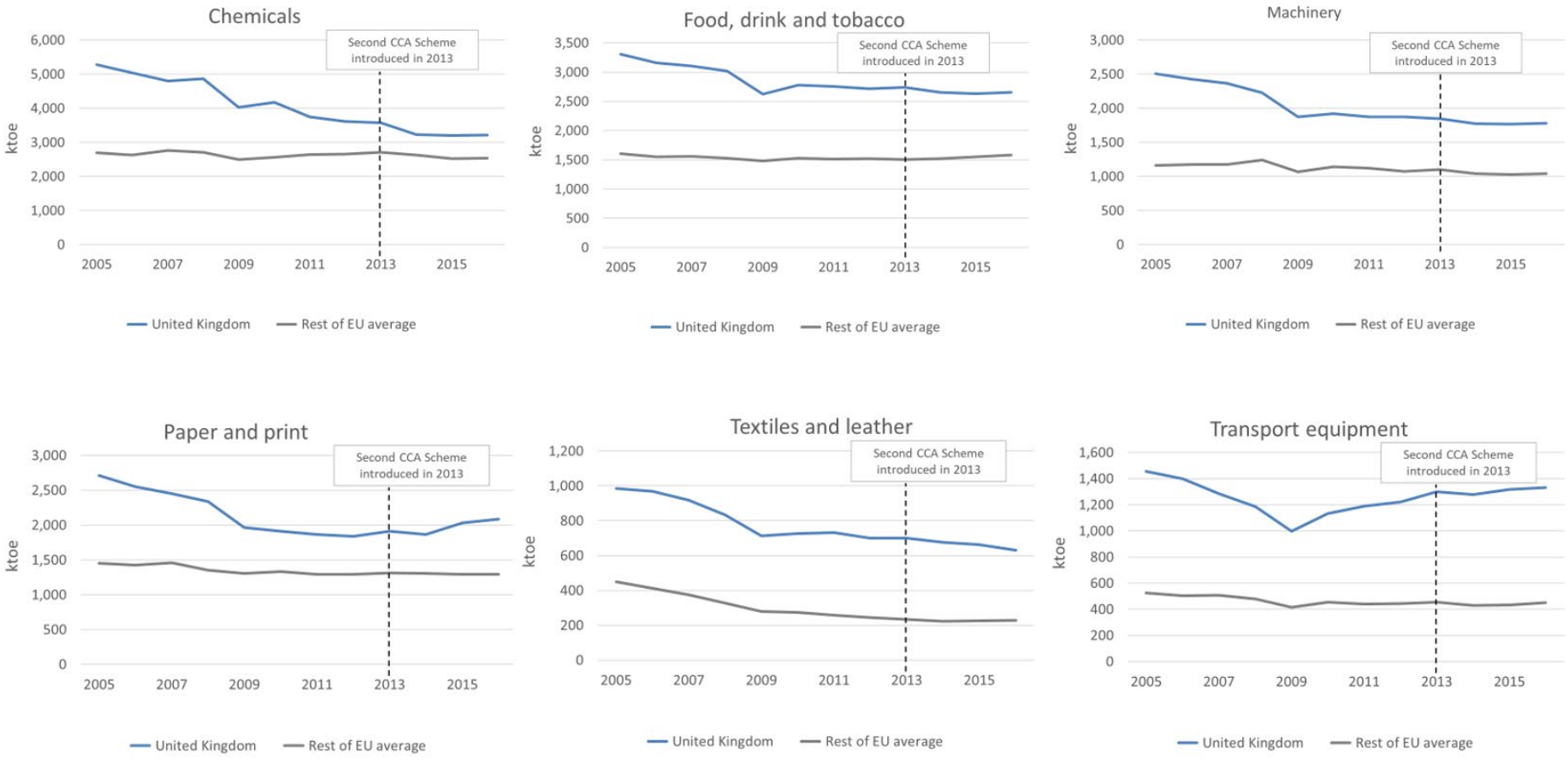
For the econometric regressions presented in this paper, industry sectors in other EU Member States form the comparison group. Industry sectors located within the EU are more likely to have experienced similar structural trends and have similar characteristics to UK-based industries, compared to those industries located outside of the EU, and therefore provide the most suitable comparison. Figure 2 summarises trends in industry GVA from 2005 to 2016 for a selection of industries. The UK (denoted by the orange plot) experiences similar trends in GVA growth as other EU countries. In many cases, the level of GVA in German industry sectors is higher than in the UK and other EU Member States but there is no immediate evidence of large systemic or structural differences in the trends reflected in these industries between countries that must be controlled for in our analysis. Furthermore, as explained above, by using industries located in the EU, we can control for the effect of EU-wide policies such as the EU ETS.

Figure 2 Comparison of industry GVA across a selection of EU states



To test that the common trend assumption holds, trends in energy consumption across CCA sectors in the UK were compared against the same sectors in other EU Member States in the period before 2013 (when the second phase CCA was introduced), as shown in the charts below.

Figure 3 Comparison of pre-2013 trends in energy consumption in industry sectors in the UK and across other EU Member States



The preliminary data analysis suggests that energy consumption is higher in the UK for the selected sectors than the EU average. In the 'Chemicals', 'Paper and print' and 'Food, drink and tobacco' sectors in particular, there are apparent differences in energy consumption trends in the UK, compared to the EU average, before 2009. Over 2010-2013, energy consumption for these sectors, and most other industry sectors considered, have followed broadly similar trends in both the UK and the comparator countries in the EU.

Divergent trends are likely driven by structural changes. For example, different responses to the global economic downturn from 2008-2009 could explain some of the differences in energy demand observed. In addition, it is possible that the effects of having a floating currency in the UK (the pound sterling) and a single currency in most comparator states (the euro) has had different effects on industry prices, output (and therefore energy demand) over the period of focus, particularly in those years where the pound - euro exchange rate has strongly fluctuated.

Although these structural and macro-economic differences exist between the UK and comparator Member States, we do not expect that they have affected the validity of our results. The period of interest for the analysis of the impact of CCAs is post-2013, and, over this period, there has not been a recession or any other major event or structural change that we would expect to have driven differing effects on energy consumption trends across countries. The 2016 EU referendum and any potential impacts subsequent to it fall outside of our sample range – the last year of data included in our analysis is for 2015. Furthermore, many of the economic drivers of changes in energy demand (e.g. due to different exchange rates and competitiveness effects of other external economic impacts) are controlled for through explicit inclusion of price and economic activity variables in the specification of the econometric equations.

In addition to visually inspecting the data, a regression was carried out to formally test the common trends assumption. To test the common trends assumption, a regression of the interaction between time dummies and the treatment indicator was tested for all industry sectors and for all years, save for the year prior to the treatment. For most sectors, the results are not statistically significant prior to the treatment period and the results of these regression tests are presented in the Appendix. For the 'Mining and Quarrying' sector, significant differences between energy consumption trends are found at the 5% level of significance and in the 'Chemicals' and 'Non-Ferrous Metals', sectors, significant differences are estimated at the 10% level. Therefore, the common trends assumption for these industries does not hold as the difference in trends between the treatment and comparison group is statistically significant in the period prior to 2013 consequentially results for these industries are biased, if the whole time series data is used. In the 'Chemicals', 'Non-Ferrous Metals', and 'Mining and Quarrying' sectors, the time series is therefore restricted to the period after 2010, which is necessary to ensure that the common trends assumption holds prior to 2013 and to derive unbiased estimates for the impact of CCAs in these sectors.

In summary, we have confirmed through visual inspection and statistical analysis that the common trends assumption holds for most industry sectors. There are several instances where there is compelling evidence that the common trends assumption does not hold. In cases where our results would be biased, we re-

estimate the results with a shorter time series where it is confirmed the common trends assumption does hold.

For results of the tests for common trends under each specification option, refer to Appendix A.

Alternative specification options

- In the Phase 1 work, different specification options were explored for the difference-in-difference analysis. In one variant, a difference-in-difference approach was tested where the comparison group comprised the mineralogical and metallurgical sectors in the UK. These are among the most energy-intensive industries but were exempted from the Climate Change Levy (CCL) and Carbon Reduction Commitment (CRC) from 2014 onwards and therefore had little incentive to agree to a CCA after that date. Including these industries in the comparison group would therefore allow us to pick up the relative impacts of the CCA targets. However, for this regression, we found that the estimated effect of CCAs on energy consumption was biased due to violation of the common trend assumption. In this case, the model was also likely to suffer from small sample bias and, therefore, the results from this regression were not considered to be sufficiently robust.

- To correct for potential bias derived from the fact that many other EU Member States also implemented industry energy efficiency policies over a similar time period as the CCAs in the UK, we also tested a regression where the group of comparison countries was limited to only include those which we identified as having either no industrial energy efficiency policy or very light industrial energy efficiency policy (i.e. voluntary agreements without financial incentives attached). This group of countries for which we identified ‘light-touch’ industry energy policy, only included three countries: Ireland, Spain and Italy. The econometric estimation using these three countries as the comparison group was found to have similar issues with violation of the common trends assumption and small sample bias and so the results of this regression are not further explored.

Data sources

The table below summarises the data sources which were used and data transformations which were carried out for the econometric analysis.

Table 1 Summary of data sources and transformations where industry sectors in other EU Member States are used for the comparator group

Data source	Description of data used
Time series	2005-2015
Comparison group	Industry sectors in the following EU Member States (for which data was available): Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.
Energy consumption (dependent variable)	Total energy demand (in ktoe). Logarithmic transformation applied for ease of interpretation of econometric results. Electricity demand (in ktoe). Logarithmic transformation applied for ease of interpretation of econometric results. Gas demand (in ktoe). Logarithmic transformation applied for ease of interpretation of econometric results. Source(s): Eurostat, 'Simplified energy balances – annual data'
Electricity and gas prices	Industry average electricity and gas price data (including all tax), taken from IEA. Converted to 2015 constant prices using industry average price deflator from Eurostat. Logarithmic transformation applied for ease of interpretation of econometric results. Source(s): International Energy Agency (IEA) – World Energy Balance and Energy prices and taxes series.
GVA	Gross value added by industry. Converted to 2015 constant prices using industry average price deflator. Logarithmic transformation applied for ease of interpretation of econometric results. Source(s): Eurostat, 'National Accounts aggregates by industry – GVA'.
Output	Output by industry. Converted to 2015 constant prices using industry average price deflator. Logarithmic transformation applied for ease of interpretation of econometric results. Source(s): Eurostat, 'National Accounts aggregates by industry – Output'.

Diagnostic tests and model re-specification

In addition to identifying an appropriate comparison group against which to carry out the differences-in-differences analysis, several statistical tests were carried out to confirm that our approach delivers efficient and unbiased estimates. This section discusses statistical tests that were carried out to validate our specification and introduces the alternative specifications used to re-estimate the effects of CCAs on industry energy demand.

Multicollinearity

Multicollinearity occurs when two or more explanatory variables are mutually dependent. The existence of multicollinearity means that it is impossible to isolate the true impact of each of the collinear variables on energy consumption, and the associated parameter estimates will be biased. To test for multicollinearity, variance inflation factors between regressors were derived. Variance inflation factors capture the severity of multicollinearity between regressors, using an index that measures how much the variance of an estimated regression coefficient is increased because of collinearity.

The variance inflation factors show that electricity prices and gas prices are collinear. This result is not particularly surprising, as gas fired CCGT plants make up an important share of the UK power generation mix and, historically in the UK, the price of gas (the marginal fuel in the electricity mix) has been an important determinant of the wholesale electricity price.

There is a methodological motivation for including both electricity and gas prices despite the presence of collinearity. Industries included in this analysis consume both electricity and gas for their energy needs and might substitute one for another to meet CCA targets. The parameters on the gas and electricity price should be interpreted with the caveat of collinearity[6]. The parameters on the gas and electricity prices variables are not of primary importance for this study and there is no evidence of collinearity affecting the estimate of the interaction term, which is the variable of most interest as it captures the policy effect.

Normality

Kernel density plots overlaid with plots for the normal distribution were used to assess the extent to which the data is normally distributed. From visual inspection of the kernel density plots, there were only a few sectors (Machinery, Mining and Quarrying, Non-Metallic Minerals) where the distribution of errors appeared normal. The Shapiro-Wilk test, which tests the null hypothesis that a sample came from a normally distributed population, was also applied. In most instances we reject the null hypothesis that data are normally distributed. Table 2 summarises the results of the test.

[6] According to estimated variance inflation factors, electricity and gas prices are highly correlated with each other, but are not perfectly colinear, as there are no instances where the variables exhibit a perfectly linear relationship.

Table 2 Summary of the results of Shapiro Wilk test of the normality/non-normality of data

Industry sector	Energy Demand	Electricity Prices	Gas Prices	GVA	Output	Common trends assumption holds?
Chemicals	Non-normal	Normal	Normal	Non-normal	Non-normal	Yes- if time-series restricted to 2010-2015
Food, drink and tobacco	Non-normal	Normal	Normal	Non-normal	Non-normal	Yes
Iron and Steel	Non-normal	Normal	Normal	Non-normal	Non-normal	Yes
Machinery	Non-normal	Normal	Normal	Non-normal	Non-normal	Yes- if time-series restricted to 2010-2015
Mining and Quarrying	Non-normal	Normal	Normal	Normal	Normal	Yes
Non-Ferrous Metals	Non-normal	Normal	Normal	Non-normal	Non-normal	No – results are biased
Non-Metallic Minerals	Non-normal	Normal	Normal	Normal	Normal	No – results are biased
Paper and print	Non-normal	Normal	Normal	Non-normal	Non-normal	Yes- if time-series restricted to 2010-2015

Industry sector	Energy Demand	Electricity Prices	Gas Prices	GVA	Output	Common trends assumption holds?
Textile and leather	Non-normal	Normal	Normal	Non-normal	Non-normal	No – results are biased
Transport equipment	Non-normal	Normal	Normal	Non-normal	Non-normal	Yes
Wood and Wood Products	Non-normal	Normal	Normal	Non-normal	Non-normal	Yes

To correct for the potential bias derived from non-normal distribution of errors, robust standard errors are used.

Endogeneity

A Hausman test was performed to check whether a random effects or fixed effects specification was appropriate for our analysis. In all cases, we find that the random effects model does not adequately capture individual (industry-level) effects, and therefore only results from the fixed effects regression specification are presented.

We performed another test checking the validity of our fixed effects specification relative to an instrumental variable (IV) specification, where lagged electricity and gas prices are used as an instrument for prices. The purpose of this test is to assess the possibility of simultaneous equations, with an ambiguous direction of causality between energy consumption and energy prices. Another Hausman test was performed to check the consistency of the IV specification against the original specification of the model.

Generally (for most sectors) we find small values for the Hausman test statistic, and so no systematic difference in the coefficients between the fixed effects model specification with instrumental variables, or without instrumental variables. This suggests that the price variables are not endogenous and so an IV regression is not needed. One exception to this was the Iron and Steel sector, where there is a large and significant Hausman test statistic, suggesting that the IV approach is appropriate and that, in this sector, prices and consumption are endogenously related. As facilities in the Iron and Steel sector are now eligible for the CCL discount without any need for a CCA, the results for this sector are of less interest, as they do not capture the effects of the CCA (only the effects of the CCL discount).

Controlling for time effects

In Phase 1 of the analysis, a time trend was included in the fixed effects econometric specifications as an indicator of technological progress. Including a time trend captures changes that are non-specific to any given year and therefore could lead to biased results. In our regression, we are more interested in capturing the specific effect in each year to account for how aggregate time trends might have impacted energy consumption year by year.

In the Phase 2 results presented below, the fixed effects differences-in-differences regression has been re-estimated with year dummies instead of a time trend, which is a more robust approach. The differences between the results and model specifications presented in Phase 1 and Phase 2, are presented in the Annex, along with the detailed estimation results

Estimating electricity and gas demand separately

In Phase 1, the focus of the analysis was on estimating total energy demand. Estimates for total energy demand do not allow us to examine to what extent industries might have chosen to substitute between electricity and gas consumption. For some sectors CCA targets are defined in terms of the carbon intensity of production which could provide incentives for substitution to fuels with lower carbon intensity.

Including this additional set of estimates allows us to estimate the extent to which industries have reduced their energy consumption overall or reduced their consumption of a specific fuel type. These regression results are discussed in more detail in the following summary of results.

Summary of results

Total energy demand specification

Results from the difference-in-difference estimation are presented in Table 3 and Table 4 below. Two alternative specifications are tested: one where GVA is included as an explanatory term in the equation and one where gross output is instead used to control for activity effects. Compared to the Phase 1 analysis, time-specific dummy variables have been used instead of a time trend, to control for year-specific effects (refer to the Appendix for a comparison of results between Phase 1 and Phase 2).

Results from the Hausman test show that the random effects model is biased, and the fixed effects specification is instead used. Results from the White test for heteroskedasticity and Shapiro-Wilk test for normally distributed data suggest that the data are both heteroskedastic and not normally distributed, so robust standard errors are also applied.

The table of results show the estimated coefficients on each of the explanatory terms included in the model. The coefficient of most interest is the interaction term, which shows the estimated effect of CCAs on industry energy consumption in the period post-2013. A coefficient of -0.01 implies that the second phase CCAs are responsible for a 1% reduction in industry energy consumption.

Because the difference-in-difference analysis compares pre-2013 trends to post-2013 trends in energy consumption, the interpretation of the interaction term is relative to the pre-2013 policy. Therefore, the regression results show the net additional impact of the second phase CCAs in each sector on energy consumption, relative to the impact of first phase CCAs.

Our starting hypothesis was that the second phase CCAs have had a small negative impact on energy demand- after all, sector associations only receive CCL discounts if they agree to energy efficiency targets and the scheme data analysis shows that there are some cases where the sector associations are not able to meet the agreed targets (suggesting that the agreed targets are stringent in some cases). Our findings do not support this hypothesis.

The coefficient on the interaction term is small and not significant in most cases, suggesting that second phase CCAs have not significantly impacted on energy consumption (compared to the pre-2013 period). Statistically significant results are identified for the ‘Food, drink and tobacco’ sector (negative impact), and in the ‘Iron and Steel’ sector (positive impact), only when gross output is included as an explanatory term in the regression. Statistically significant results are also estimated

for the ‘Non-ferrous Metals’ sector, however, in this case, the results are biased as the common trends assumption is violated.

Across both regressions, the magnitude of the estimated negative effect of CCAs on energy demand is largest in the ‘Chemicals’, ‘Food, drink and tobacco’ and ‘Paper and print’ sectors, where the mean impact of the second phase CCAs on energy demand is estimated at between 1% and 10% (depending on sector and specification) although, in most cases, is not significant.

The fact that the CCAs are found to have non-significant impacts on energy demand in most industry sectors could suggest that targets have not been stringent enough to affect firm behaviour. In most cases, when compared against observed data for other regions, the results suggest that these industry sectors are likely to have achieved similar energy efficiency improvements, in absence of the CCA scheme (e.g. they would achieved similar energy efficiency savings for other reasons, such as to reduce costs, to remain competitive in the market). This result comes with many caveats. Firstly, it is important to note that many of the other EU Member States that are used for the comparison group had some similar clean growth policies in place over the same time period. The results should therefore be interpreted as a lower bound estimate of the potential impact of CCAs on energy demand, because they are estimated relative to a group of countries where policy-induced changes in energy efficiency behaviour occurred over the same period. Another caveat to note is that our results, to some extent, could pick up the effects of confounding policies in the UK (e.g. the CRC scheme) or UK-specific responses to other policies, economic developments or structural changes. Furthermore, in many of the 2-digit industry sectors where equations were estimated, the CCA coverage is quite low, suggesting that, in some cases, our estimates are likely to be picking up noise in the data rather than any true CCA effect. Estimates for those industry sectors with below 50% CCA coverage, in particular, should be treated with caution. It is also important to emphasise that the estimated effects should be interpreted as additional impacts of the CCA scheme relative to the pre-2013 period, where phase one of the CCAs was already in place. For these reasons, it is important to consider these results in a wider context and to evaluate the results alongside the findings from other workstreams.

For the economic control variables in the regression, results are broadly in line with expectations. The results show that increases in GVA or gross output generally have had positive and significant impacts on energy demand, and there is evidence of economies of scale: a 1% increase in GVA or gross output drives less than 1% increase in energy consumption. In many cases, we estimate a negative relationship between energy prices and energy demand, which suggests that energy is a normal good, however, this is not always the case (especially for gas prices) and, across most sectors, the estimated gas and electricity price elasticities are not significant.

Table 3 Summary of results from a regression where energy use is estimated, twenty EU Member States form the comparison group and GVA is used in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	Sample size	Common trends assumption holds?
Chemicals	-0.17	-0.46	0.21	-0.06	112	Yes- if time-series restricted to 2010-2015
Food, drink and tobacco	-0.26*	-0.02	0.17	-0.03	192	Yes
Iron and Steel	-0.24	-0.17	0.00	0.24	183	Yes
Machinery	0.03	0.07	-0.12	0.00	113	Yes- if time-series restricted to 2010-2015
Mining and Quarrying	-0.35	0.17	0.18	0.07	192	Yes
Non-Ferrous Metals	-0.17	0.11	-0.07	-0.21**	183	No – results are biased
Non-Metallic Minerals	-0.23	-0.03	0.37	0.04	184	No – results are biased
Paper and print	-0.16	0.32**	0.30**	-0.04	115	Yes- if time-series restricted to 2010-2015
Textile and leather	-0.73**	-0.20	0.57**	-0.05	192	No – results are biased

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	Sample size	Common trends assumption holds?
Transport equipment	0.02	-0.27	0.40**	-0.02	184	Yes
Wood and Wood Products	-0.05	-0.36	0.22**	0.00	187	Yes

Table 3 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden

Time dummies are not reported.

Results for the Iron and Steel sector are biased due to endogeneity.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level

Table 4 Summary of results from a regression where energy use is estimated, twenty EU Member States form the comparison group and output is included in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	Output	Interaction term	Sample size	Common trends assumption holds?
Chemicals	-0.15	-0.49	0.45*	-0.06	112	Yes- if time-series restricted to 2010-2015
Food, drink and tobacco	-0.25**	-0.04	0.65**	-0.10**	192	Yes
Iron and Steel	-0.17	-0.17	-0.29	0.28*	183	Yes
Machinery	-0.01	0.05	0.02	-0.01	113	Yes- if time-series restricted to 2010-2015
Mining and Quarrying	-0.32	0.15	0.17	0.06	192	Yes
Non-Ferrous Metals	-0.11	0.11	-0.18	-0.21**	183	No – results are biased
Non-Metallic Minerals	-0.19	-0.05	0.39**	0.01	184	No – results are biased
Paper and print	-0.26*	0.36**	0.48*	-0.01	115	Yes- if time-series restricted to 2010-2015
Textile and leather	-0.83**	-0.14	0.49	0.05	192	No – results are biased

Industry sector	Electricity Price	Gas Price	Output	Interaction term	Sample size	Common trends assumption holds?
Transport equipment	0.01	-0.28**	0.39**	0.08	184	Yes
Wood and Wood Products	-0.13	-0.37	0.34**	0.01	187	Yes

Table 4 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

Time dummies are not reported.

Results for the Iron and Steel sector are biased due to endogeneity.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Electricity and gas demand specification

To test if CCAs had an impact on demand for a specific fuel type, a series of additional regressions were tested with electricity and gas demand rather than total energy demand as the dependent variable. Table 5 to Table 8 present the results from these regressions. Again, two alternative specifications were tested, one where GVA was included as an explanatory term in the estimation (Table 5 and Table 6) and one where gross output is used to control for activity effects (Tables 7 and Table 8).

Except for the changed dependent variable, this specification is identical to the previous specification for total energy demand and uses the same data. From previous testing we know that this data is heteroskedastic and not normally distributed. Again, robust standard errors are applied.

We tested the validity of the fixed effects specification relative to an instrumental variable (IV) specification, where lagged electricity and gas prices are used as an instrument for prices. For several sectors, we found that gas prices were endogenously related to demand. In those cases, the results are presented for the IV specification, where lagged gas prices are used as an instrument. The same approach is taken for the electricity use equations, with lagged electricity prices used as an instrument for electricity prices in cases where endogeneity is present. Since we are interested in looking at the potential effects of fuel switching it is important to control for this type of endogeneity or else the results will be biased.

The table of results show that the estimated coefficients for the interaction term is estimated to be very small and not significant for all industry sectors and specifications. This supports the results of the initial specification, using total energy demand as the dependent variable, where we generally found very small and non-significant effects estimated for the interaction term.

Again, the results presented here compare pre-2013 trends to post-2013 trends in electricity and gas consumption. The interaction term is relative to the pre-2013 policy. It is also possible that, in addition to picking up the effects of the CCAs, the regression is also picking up the UK-specific effects of the EU ETS scheme or other external factors that are specific to UK industries. In any case, the specifications for electricity and gas demand do not generate statistically significant estimates.

These results provide limited evidence of price-related fuel switching between electricity and gas. For example, in the specifications estimating electricity demand, increases in gas prices are associated with increases in electricity demand in some sectors (e.g. in ‘Food, drink and tobacco’, ‘Mining and quarrying’, ‘Machinery’). For the gas demand specification, there are no sectors for which increases in electricity prices are associated with increases in gas demand. Despite non-significant results for the interaction term, there is arguably some evidence of the CCAs driving fuel switching effects in some cases. For example, in ‘Chemicals’ the estimated effect of CCAs on electricity consumption is large and positive (under both the GVA and gross output specifications), whilst the gas use equations for the ‘Chemicals’ sector show an estimated negative impact associated with the CCAs (under both the GVA and gross output specification). Both estimates are not significant, but there is some tentative evidence of fuel switching (from gas to electricity) in this sector. By contrast,

in the ‘Food, drink and tobacco’ sector, the coefficient on the interaction term is negative for both the gas and electricity use equations, suggesting that the CCAs have driven reductions in overall energy demand, rather than fuel switching effects.

Table 5 Summary of results from a regression where electricity use is estimated, twenty EU Member States form the comparison group and GVA is included in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	Sample size	Common trends assumption holds?	Econometric specification
Chemicals	-3.10	-1.34	-0.38	0.45	112	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Food, drink and tobacco	-0.07	0.11	-0.16	-0.07	192	Yes	Fixed Effects
Iron and Steel	-0.42	-1.34	-0.17	0.38	183	Yes	Instrumental Variables
Machinery	0.10	-0.55	0.11	0.07	113	Yes- if time-series restricted to 2010-2015	Fixed Effects
Mining and Quarrying	-1.66	0.73	0.44	0.00	192	Yes	Instrumental Variables
Non-Ferrous Metals	0.09	0.69*	-0.17	-0.28	183	No – results are biased	Fixed Effects
Non-Metallic Minerals	1.26	-1.67	0.81**	-0.13	184	No – results are biased	Instrumental Variables

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	Sample size	Common trends assumption holds?	Econometric specification
Paper and print	0.06	-0.13	0.31**	-0.18	115	Yes- if time-series restricted to 2010-2015	Fixed Effects
Textile and leather	-0.65*	-0.08	0.55**	-0.12	192	No – results are biased	Fixed Effects
Transport equipment	1.05	-0.63	0.37	0.04	184	Yes	Fixed Effects
Wood and Wood Products	4.33	0.11	-0.42**	-0.44	187	Yes	Fixed Effects

Table 5 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden

Time dummies are not reported.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level

Table 6 Summary of results from a regression where gas use is estimated, twenty EU Member States form the comparison group and GVA is included in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	Sample size	Common trends assumption holds?	Econometric specification
Chemicals	-0.62*	-0.05	0.18	-0.5	112	Yes- if time-series restricted to 2010-2015	Fixed effects
Food, drink and tobacco	-0.84	-0.06	0.63	-0.07	192	Yes	Instrumental Variables
Iron and Steel	-2.04*	-0.34	-0.15	0.46	183	Yes	Instrumental Variables
Machinery	-1.24	-0.22	0.19	0.11	113	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Mining and Quarrying	-0.21	-0.79	0.17	0.19	192	Yes	Instrumental Variables
Non-Ferrous Metals	-0.48	-0.05	0.02	-0.22	183	No – results are biased	Fixed effects

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	Sample size	Common trends assumption holds?	Econometric specification
Non-Metallic Minerals	-0.34*	-0.24	0.44**	-0.04	184	No – results are biased	Fixed effects
Paper and print	-0.14	-0.11	0.32**	-0,10	115	Yes- if time-series restricted to 2010-2015	Fixed effects
Textile and leather	-0.58*	-0.22	0.60*	-0.16	192	No – results are biased	Fixed effects
Transport equipment	-0.20	-0.28	0.18	-0,16	184	Yes	Fixed effects
Wood and Wood Products	-0.18	-0.46	0.26**	0.06	187	Yes	Instrumental Variables

Table 6 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

Time dummies are not reported.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Table 7 Summary of results from a regression where electricity use is estimated, twenty EU Member States form the comparison group and output is included in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	Output	Interaction term	Sample size	Common trends assumption holds?	Econometric specification
Chemicals	-3.07	-1.17	-0.55	0.42	112	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Food, drink and tobacco	-0.11	0.09	0.64	-0.18	192	Yes	Fixed effects
Iron and Steel	-0.43	-1.08	0.10	0.28	183	Yes	Instrumental Variables
Machinery	-0.55	0.01	0.20	0.05	113	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Mining and Quarrying	-0.64	-0.46	0.29	0.00	192	Yes	Instrumental Variables
Non-Ferrous Metals	-0.53	2.45	-0.67	-0.36	183	No – results are biased	Fixed effects
Non-Metallic Minerals	-0.08	0.0	0.85**	-0,24	184	No – results are biased	Fixed effects

Industry sector	Electricity Price	Gas Price	Output	Interaction term	Sample size	Common trends assumption holds?	Econometric specification
Paper and print	-0.20	0.93	0.27	-0.19	115	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Textile and leather	-0.75**	-0.02	0.47	-0.03	192	No – results are biased	Fixed effects
Transport equipment	-1.46	3.39	0.71*	-0.14	184	Yes	Instrumental Variables
Wood and Wood Products	3.74	1.06	-0.79**	-0.42	187	Yes	Instrumental Variables

Table 7 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden

Time dummies are not reported.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level

Table 8 Summary of results from a regression where gas use is estimated, twenty EU Member States form the comparison group and output is included in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	Output	Interaction term	Sample size	Common trends assumption holds?	Econometric specification
Chemicals	-0.62*	-0.06	0.14	-0.04	112	Yes- if time-series restricted to 2010-2015	Fixed effects
Food, drink and tobacco	-0.25*	-0.01	0.72**	-0.17	192	Yes	Fixed effects
Iron and Steel	-2.09*	-0.09	-0.08	0.40	183	Yes	Instrumental Variables
Machinery	-1.25	-0.40	0.12	0.14	113	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Mining and Quarrying	0.19	-1.44	0.31	0.19	192	Yes	Instrumental Variables
Non-Ferrous Metals	-0.44	-0.05	-0.19	-0.19	183	No – results are biased	Fixed effects
Non-Metallic Minerals	-0.30	-0.26*	0.5**	-0.09	184	No – results are biased	Fixed effects

Industry sector	Electricity Price	Gas Price	Output	Interaction term	Sample size	Common trends assumption holds?	Econometric specification
Paper and print	0.07	-1.06	0.08	0.06	115	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Textile and leather	-0.07	-0.99	0.62**	-0.09	192	No – results are biased	Instrumental Variables
Transport equipment	3.73	-4.42	0.28	-0.11	184	Yes	Instrumental Variables
Wood and Wood Products	0.15	-0.94	0.38**	0.06	187	Yes	Instrumental Variables

Table 8 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

Time dummies are not reported.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

CCA coverage

Table 9 shows the coverage of CCAs[7], alongside the estimated impacts of CCAs at the broad industry sector level (under which the equations are estimated). There is some evidence of a relationship between CCA coverage within a sector and the estimated CCA policy effect. Although not statistically significant, the largest negative effects on energy consumption are identified in the 'Chemicals' and 'Food, drink and tobacco' sectors (-6% impact and -3% impact, respectively, in the regression where GVA is included in the model). These are among the industry sectors with the highest CCA coverage. By comparison, there is a negligible (<1% impact) in those sectors with low coverage of CCAs, such as 'Machinery' and 'Wood and wood products', and even a positive impact in the 'Mining and quarrying' sector. The 'Mining and quarrying' sector has only 30% CCA coverage and so it is possible that this estimated (positive) effect is instead picking up industry structural change that occurred over the same period.

It should be noted that during the second phase of the CCA scheme (since 2014), mineralogical and metallurgical sectors have been exempt from both CCL and CRC, even if not covered by a CCA. 'The 'Iron and Steel' sector is included within this group, which explains the low CCA coverage for this sector (estimated at 3%). Interestingly, under both specifications, we estimate that there was over 20% increase in energy consumption in the Iron and Steel sector under the second phase CCAs (which is statistically significant at the 10% level in the specification that includes output as a regressor). This suggests that the exemption of these industries from the CCL (with no CCA attached) has driven an increase in energy consumption, compared to the first phase CCAs, when controlling for other exogenous factors.

[7] The estimates of CCA coverage are based on a mapping of energy use covered by a CCA from the 4-digit SIC level to 2-digit SIC level, that was undertaken by Verco as part of this project. It differs to the mapping undertaken by UCL, which looks at the proportion of facilities in each industry sector that are covered by a CCA (as opposed to the proportion of energy consumption that is covered).

Table 9 Estimated coefficient for interaction terms across both energy demand specifications tested alongside the estimated coverage of CCAs (in terms of shares of energy consumption) across broad industry sectors, based on a mapping from 4-digit SIC codes

Industry sector	Estimated 'CCA effect' (GVA included as regressor)	Estimated 'CCA effect' (Output included as regressor)	Estimated CCA coverage	Min/Met Eligible	Biased results?
Chemicals	-0.06	-0.06	88%		
Food, drink and tobacco	-0.03	-0.10**	98%		
Iron and Steel	0.24	0.28*	3%	X	
Machinery	0.00	-0.01	18%		
Mining and Quarrying	0.07	0.06	30%		
Non-Ferrous Metals	-0.21**	-0.21**	3%	X	XX
Non-Metallic Minerals	0.04	0.01	38%	X	XX
Paper and print	-0.04	-0.01	75%		
Textile and leather	-0.05	0.05	100%		XX
Transport equipment	-0.02	0.08	100%		
Wood and Wood Products	0.00	0.01	30%		

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level. X indicates sectors covered by min-met exemption, while XX indicates where results are biased due to violation of the common trends assumption.

Given the challenges associated with finding suitable control group due to the wide adoption of industry energy efficiency policies across Europe, these results should be interpreted cautiously with the limitations of the available data in mind. The wider

synthesis compared the estimates presented in this paper with the evidence on the impact of CCAs emerging from the other workstreams.

The key take-aways from the macro-economic analysis are:

- Phase 2 CCAs have not had a statistically significant impact on energy demand in most industry sectors.

- The econometric estimates indicate that Phase 2 CCAs have had a negative impact on energy demand in the 'Chemicals' sector (-6%) and a smaller negative impact (-1% to -4%) in the 'Paper and print' sector, but these results are not statistically significant at the 10% level. In the 'Food, drink and tobacco' sector, the effect of the Phase 2 CCAs on energy demand is more ambiguous, with a large and statistically significant impact (-10%) identified in one of the specifications tested (where output is included as a regressor) but, under an alternative specification (where GVA is used as a regressor), the estimated impact is smaller (-3%) and non-significant.

- The estimations are carried out at the SIC07 2-digit level. In cases where CCA coverage at this sector level is low (<50%), the results are less robust, with estimates likely to be picking up noise in the data.

- There is some evidence that, in the 'Iron and Steel' sector, the granting of automatic exemption to the CCL (with no CCA requirement) in 2014 has driven an increase in energy demand, relative to the pre-2013 period, when controlling for other factors.

- Steps have been taken to reduce the risk of bias in the results (i.e. by estimating equations at an industry sector level and validating the suitability of the comparison group). Statistical tests have been carried out to ensure robustness. However, using the macro-level data has limitations due to the small sample size and because it involves comparing aggregated effects across a large group of heterogeneous firms. These results should therefore be interpreted within the context of the results emerging from other workstreams (in particular, from the micro-econometric analysis).

3. Modelling of CCA impact on energy and economic variables

Introduction and objectives

The objective of the macro-economic modelling task is to assess the impact of the second Climate Change Agreement (CCA) scheme[8], on industry costs and industry competitiveness over the period 2013-2017.

The second CCA scheme involves agreement of energy efficiency targets with CCA sectors for four two-year target periods. Firms with activities in these sectors are able to gain a significant discount on the Climate Change Levy (CCL)[9] and Carbon Reduction Commitment (CRC)[10] that is paid on energy use, by choosing to enter an agreement with Government to improve their energy or carbon efficiency, in line with the relevant sector target. Three target periods have already been completed (2013-2014, 2015-2016 and 2017-2018). From December 2014, further reliefs have applied to activities in the mineralogical and metallurgical sectors, which are now exempt from both CCL and CRC, even if not covered by a CCA.

A counterfactual scenario was developed, where it was assumed that sector associations were not able to take advantage of the second CCA scheme, and this counterfactual was compared to scenarios and sensitivities that captured the impact of the CCA on energy prices and costs. The scenarios were implemented in the macro-economic model, E3ME, to assess impacts on industry costs and competitiveness. The key findings from our analysis are:

- Across most of the sector associations, the Phase 2 CCA scheme contributed to around 0.2%-0.6% cost savings for those firms that would not otherwise have been subject to the CRC, and around 0.6%-1% cost savings for those firms that would have otherwise have been subject to the CRC as well as the CCL.

- Across most sectors, the CCAs are associated with a 0%-0.6% positive impact on GVA. This is due to a combination of (i) higher margins per unit of output, due to a reduced cost base and (ii) increases in gross output, as lower

[9] The CCL is a tax that is charged on energy use by industry. The full rate of CCL (in the 2018/19 tax year) is 0.583p/kWh for electricity use, and 0.203p/kWh for gas use. In the same year, Sector associations that sign up to a CCA are eligible for a 90% discount on the CCL rate paid on electricity and up to 65% discount on the CCL rate paid on gas, coal and LPG.

[10] The CRC Energy Efficiency Scheme aims to incentivise large energy users in the UK public and private sectors to reduce emissions, by requiring them to monitor and report their energy use and purchase allowances for each tonne of CO2 emitted. The last year of the scheme is in 2018/19, where the allowance price is £17.20/tCO2, if allowances are bought in advance at the 'forecast price', or £18.30/tCO2 if allowances are purchased at the end of year 'compliance price'.

production costs improve industry competitiveness, driving an increase in net exports.

This note briefly describes the macro-economic modelling approach that was applied, the scenarios that were run and the results that emerge from the analysis.

Overview of approach

To assess the impact of the CCA scheme on industry costs and competitiveness, we use a macro-economic modelling approach, applying the E3ME model. As a macro-econometric model, E3ME uses an extensive historical database and was therefore well suited to carry out ex-post economic analysis.

E3ME is built around an input-output structure with a detailed representation of industry interdependencies. The input-output framework in E3ME shows, for each industry sector[11] in the UK, the cost of energy relative to total production costs. The input-output framework thus reflects industry-specific exposure to competitiveness risks from higher energy prices and costs. It can also show how reductions in energy prices and taxes can improve industry competitiveness (due to reduced production costs). The E3ME model includes a series of price equations (estimated for each sector and country) which reflect different cost pass-through rates among sectors and reflect how energy costs ultimately affect prices of the goods and services produced. Import and export prices and bilateral trade equations are also estimated in each sector and country. More information about E3ME is available in Annex 1.

Scenarios

A counterfactual was developed to represent the case where industries were not covered by CCA agreements and therefore faced the full cost of the CCL (and, where applicable, the CRC).

A series of scenarios were then constructed that, when compared against the counterfactual, show the impact that CCAs have had on industry unit costs, prices and Gross Value Added (GVA). The scenarios are summarised in Table 10 below.

[11] Based on a classification that is broadly consistent with the SIC 2-digit classification.

Table 10 Overview of scenarios modelled

Scenario name	Description
S1: CCL discount	S1 tests the impact of the CCL discount only in those sector associations that were signed up to Phase 2 CCAs, over the period 2014-2017.
S1a: CCL discount + CRC exemption	S1a tests the combined impact of the CCL discount and the CRC exemptions (for those firms that would otherwise be subject to this payment) in Phase 2 CCAs, over the period 2014-2017.
S2: CCL discount + electricity savings	S2 is as S1, but, in addition to the CCL discount, it includes an estimated 6.3% average reduction in electricity use and 1.9% average reduction in gas use associated with the CCAs over the Phase 2 CCA period (2014-2017). The energy savings are assumed to accumulate over time.
S2a: CCL discount + CRC exemption + electricity savings	S2a tests the combined impact of the CCL discount and CRC exemption, in addition to an estimated 6.3% average electricity savings and 1.9% average gas savings over the period 2014-2017.

Scenario inputs

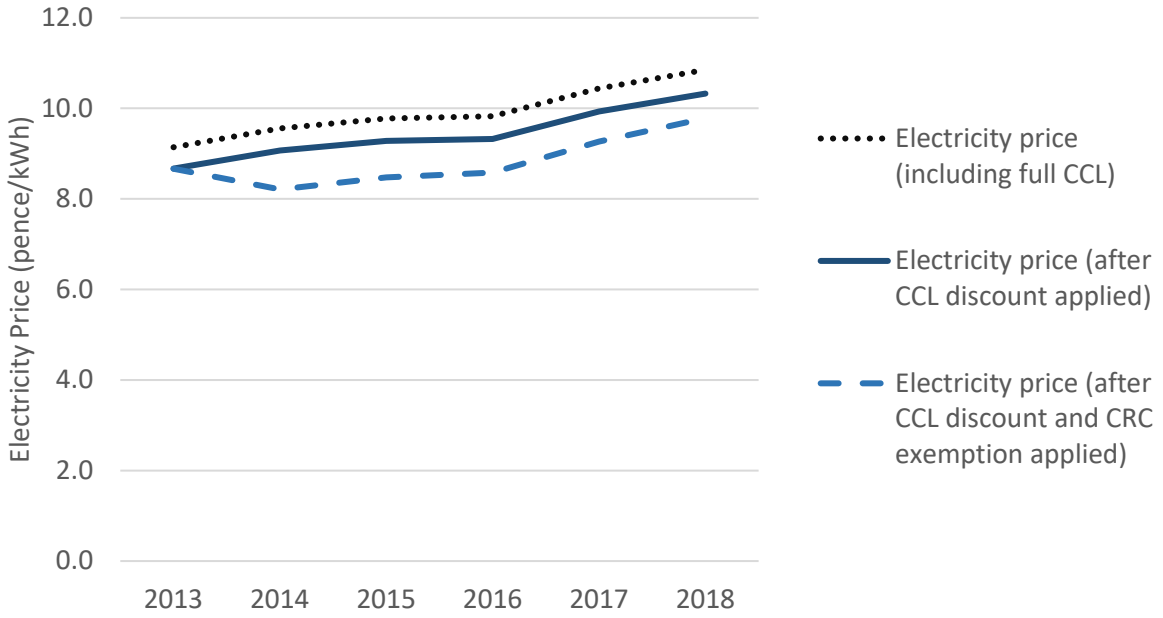
Energy prices

The CCL discount on energy prices reflects the direct effect of the CCA scheme and is the only input that is common across all scenarios modelled. It is input to the model as a reduction in the tax paid on gas and electricity use. In addition, the scheme data analysis identified several sector associations that, in absence of a CCA, would also be covered by the CRC scheme. In these cases, the CCA scheme provided both a CCL discount and an exemption to CRC payments. The impact of the CCA on this subset of sector associations is tested in S1a and S2a.

Figure 4 and Figure 5 below show the impact of the CCL discount and (where applicable) the CRC discount on industry electricity and gas prices, respectively. Firms with higher energy use are typically able to negotiate lower electricity and gas prices. The charts below show the impact of the CCL and CRC discounts on large consumers of electricity and gas (i.e. consuming 20-70GWh of electricity per year and 27.8-277.8GWh gas per year, respectively). The CCL rate increased slightly over the period (on average, by 2.2% per year), but there was no change to the percentage discount applied for those firms that sign up to a CCA. The CRC scheme has a larger impact on electricity prices than gas prices in absolute terms (p/kWh), due to the higher carbon intensity of electricity, which averaged 397g/kWh, compared to an average carbon intensity of 183g/kWh for gas over the 2014-2018

period. In relative terms, the impact of the CRC scheme on gas prices is larger than electricity prices, because of the lower price of gas.

Figure 4 Industry electricity price (with and without CCA discounts on CCL and CRC)



Source: BEIS, CE calculations

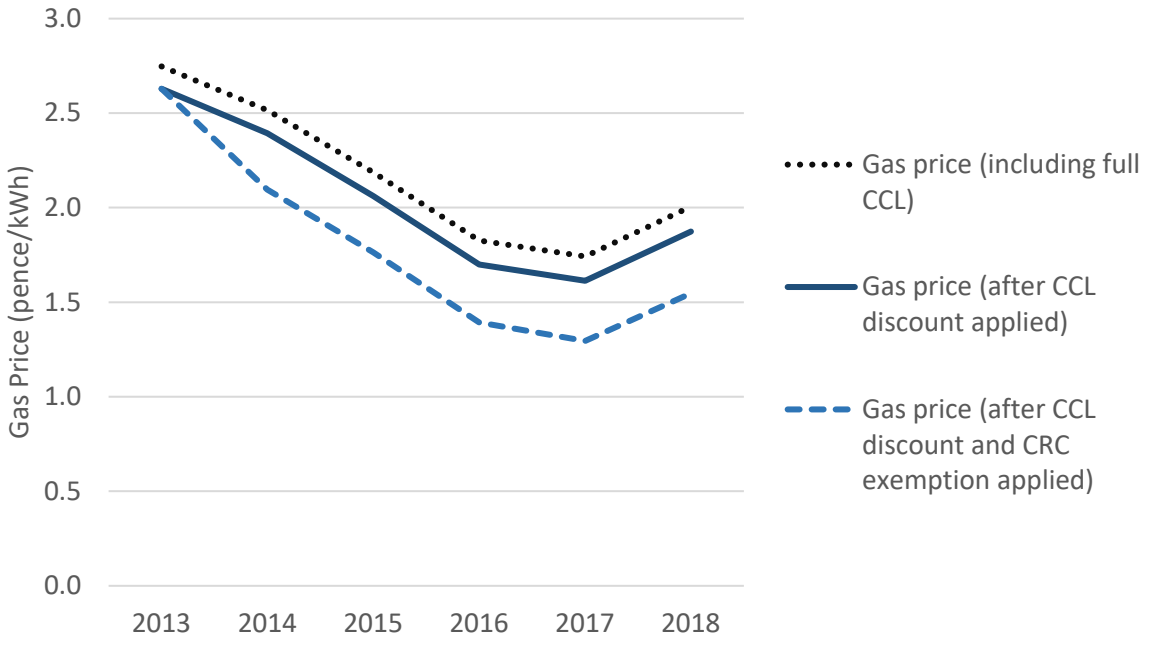
Note: Prices are reported for a large electricity consumer, with annual electricity consumption of 20 GWh - 70 GWh; prices are exclusive of VAT; the blue line indicates the price discount for those industries that are only subject to the CCL discount; the green line indicates the price discount for those industries that would have otherwise been subject to both the CRC and the CCL.

Table 11 Electricity prices faced by large electricity consumers, with and without CCL discounts and CRC exemptions (p/kWh)

Electricity price	2013	2014	2015	2016	2017	2018
Electricity price (including full CCL)	9.14	9.56	9.78	9.83	10.44	10.85
Electricity price (after CCL discount applied)	8.67	9.07	9.28	9.33	9.93	10.33
Electricity price (after CCL discount and CRC exemption applied)	8.67	8.21	8.48	8.58	9.27	9.78

Note: Prices are reported for a large electricity consumer, with annual electricity consumption of 20 GWh - 70 GWh; prices are exclusive of VAT.

Figure 5 Industry gas price (with and without CCA discounts on CCL and CRC)



Source: BEIS, own calculations

Note: Prices are reported for a large gas consumer, with annual gas consumption of 27.8 GWh - 277.8 GWh; prices are exclusive of VAT; the blue line indicates the price discount for those industries that are only subject to the CCL discount; the green line indicates the price discount for those industries that would have otherwise been subject to both the CRC and the CCL.

Table 12 Gas prices faced by large electricity consumers, with and without CCL discounts and CRC exemptions (p/kWh)

Gas Price	2013	2014	2015	2016	2017	2018
Gas price (including full CCL)	2.65	2.41	2.08	1.72	1.63	1.89
Gas price (after CCL discount applied)	2.54	2.29	1.95	1.59	1.50	1.76
Gas price (after CCL discount and CRC exemption applied)	2.54	1.99	1.66	1.29	1.18	1.43

Table 12 Note: Prices are reported for a large gas consumer, with annual gas consumption of 27.8 GWh - 277.8 GWh; prices are exclusive of VAT.

Energy consumption

The impact of the CCA scheme on gas and electricity consumption was assessed in both the micro-econometric and macro-economic workstreams for this project.

The macro-economic workstream found no statistically significant impact of the CCA scheme on gas and electricity demand across almost all of the industry sectors tested. The assumption that the CCA scheme had no significant impact on gas and electricity consumption is taken as a lower-bound estimate (and is tested in S1 and S1a).

By comparison, the micro-econometric analysis did find a statistically significant impact on energy consumption, associated with the CCA scheme. The micro-econometric analysis found that, in one sample of data i.e. those sectors that entered the CCA through the Environmental Permitting Regulations (EPR) route, participation was associated with a 4.1% reduction in electricity use, but no significant impact on gas use. For the other sample of data i.e. those sectors that entered the scheme based on energy and trade intensity criteria (EI), the micro-econometric analysis found that the CCA scheme was associated with a 11.4% reduction in electricity use and a 12.6% reduction in gas use.

The estimated energy savings from each sample of data in the micro-econometric workstream were multiplied by the share of electricity and gas use that the EPR and EI sectors represent, to derive weighted average impacts, that are used as inputs to the macro-economic modelling. These are taken as upper-bound estimates of the magnitude of the impact of CCA's on energy demand (and tested in S2 and S2a).

Table 13 Inputs to the modelling of S2 and S2a (and derivation from micro-economics results)

	Share of electricity use (Target Period 3)	Share of gas use (Target Period 3)
Sectors that entered CCA scheme via EPR route	70.3%	84.9%
Sectors that entered CCA scheme via EI route	29.7%	15.1%
	Estimated impact of CCAs of electricity use	Estimated impact of CCAs of gas use
Sectors that entered CCA scheme via EPR route	-4.1%	Statistically non-significant
Sectors that entered CCA scheme via EI route	-11.4%	-12.6%

	Share of electricity use (Target Period 3)	Share of gas use (Target Period 3)
Weighted average impact of the CCA scheme on energy use (used as an input to the macro-economic modelling)[12]	-6.3%	-1.9%

Source: Scheme data analysis (CAG Consultants); Micro-econometric analysis (UCL); Cambridge Econometric calculations.

Results

A comparison of the counterfactual scenario (which assumes no CCAs) against the CCA scenarios shows the impacts that the CCAs have had on industry costs, competitiveness and output.

In S1 and S1a, it is assumed that the CCA scheme benefited sector associations solely because of the impact on energy prices (i.e. through CCL discount and CRC exemption). In S2 and S2a, it is assumed that the CCA scheme reduced industry energy costs due to the benefits of both energy tax discounts/exemptions (as in S1 and S1a) and due to electricity savings. It is assumed that these energy savings have come about through behavioural changes and energy efficiency investments[13] as a result of the sector-specific energy and carbon reduction targets that were agreed to as part of the CCA.

Costs of production

- Figure 3 below shows the impact of the CCA scenarios on industry unit costs[14]. The impact of changes in the level of energy tax on industry unit costs depends on the relative proportion of energy costs in total production costs for each sector. E3ME uses broad sector definitions (as shown in Figure 3) and therefore, the energy intensity of the sector associations is approximated based on the energy intensity (and structure of costs more generally) in the broader industry sector that it falls into (refer to Annex 2). To further refine these estimates of energy expenditure shares, results from the quantitative surveys were drawn upon.

[12] These are calculated as a weighted average, weighted using the proportion of TP3 energy use arising from EPR and EI sectors based on scheme data analysis): -6.3% = (70.3% *-4.1%) +(29.7% *-11.4%); -1.9% = (84.9% *0%) +(15.1% *-12.6%)

[13] Energy efficiency investments are not explicitly modelled. To the extent that the CCAs drove firms to invest in energy efficiency measures, the costs of the energy efficiency investments are not taken into account. GVA figures, by definition, do not take account of the cost of investments or capital depreciation.

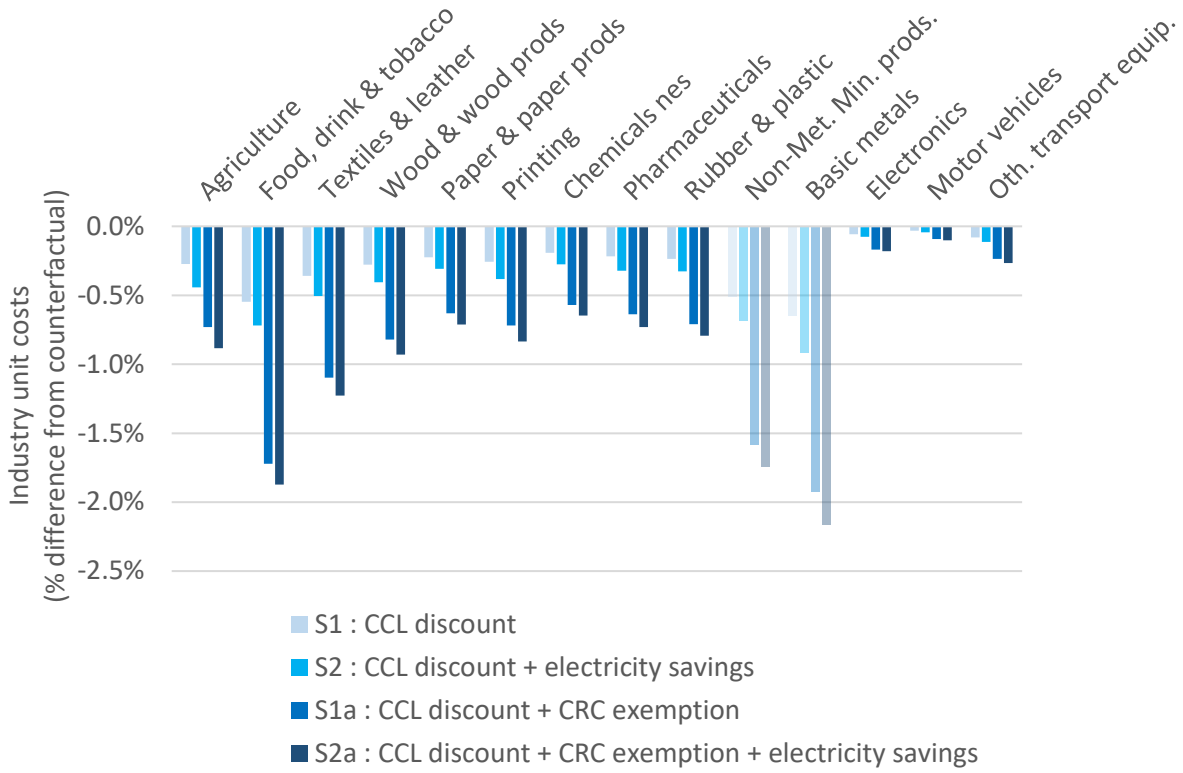
[14] Industry unit costs refer to the costs of production per unit of output produced (i.e. the sum of material costs, energy costs and labour costs).

- As shown in Figure 3, ‘Non-metallic minerals’ and ‘Basic metals’ are the sectors that would be most affected by the CCL discounts, as these are the sectors that are most energy intensive. However, most of the sector associations classified within ‘Non-metallic minerals’ and ‘Basic metals’ would have automatically qualified for a CCL exemption over the Phase 2 CCA scheme, as they would have been classified as mineralogical and metallurgical processes. For this reason, the impacts on these sectors are shaded out, as they are unlikely to have signed up to, or been affected by, the Phase 2 CCAs[15].

- Across most of the other sector associations, the CCA scheme contributes to around 0.2%-0.6% cost savings for those firms that would not otherwise have been subject to the CRC[16], and to around 0.6%-1% cost savings for those firms that would have otherwise been subject to the CRC as well as the CCL[17]. Three exceptions to this are the sector associations that fall within ‘Electronics’, ‘Motor vehicles’ and ‘Other transport services’, which are considerably less energy intensive. Because energy costs account for a lower proportion of total production costs in these cases, the impact of the CCAs on industry unit costs are considerably lower, compared to other sectors analysed.

[15] Results presented in the charts show the CCL rebate under the CCA only, although it is noted that mineralogical and metallurgical processes were entitled to a full CCA exemption over the Phase 2 CCA scheme.
[16] Refer to results for S1 and S2, which provide the upper and lower bound estimates for the impact of the Phase 2 CCA scheme on sectors that would not otherwise have been subject to the CRC.
[17] Refer to results for S1a and S2a, which provide the upper and lower bound estimates for the impact of the Phase 2 CCA scheme on sectors that would have otherwise been subject to the CRC as well as the CCL.

Figure 6 Impact of CCAs on industry costs of production



Source: E3ME, Cambridge Econometrics.

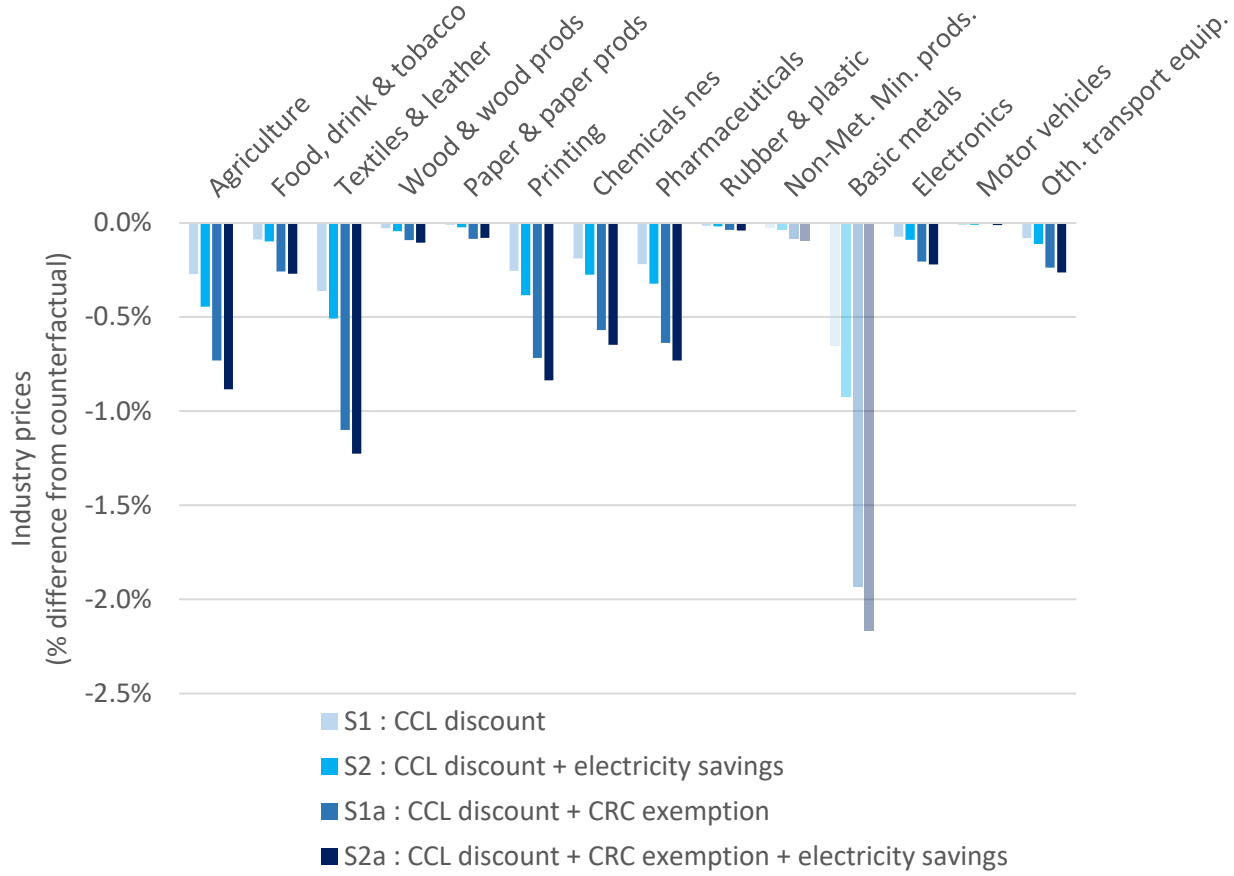
Note: Results are presented at a broad sector level but should be interpreted as the impact of CCAs on those facilities that belong to each broad industry sector. Most firms classified within 'Non-metallic Minerals' and 'Basic Metals' qualified for automatic CCL exemptions from 2014 and therefore had no incentive to sign up to a CCA after this date. Only some of the firms that had a CCA would have otherwise been subject to the CRC scheme as well as the CCL.

Industry prices

- The effect of lower unit costs on industry sales prices in the CCA scenarios is shown in Figure 4. The ratio between industry sales price and unit cost reductions shows the extent to which cost reductions are passed on to consumers in lower sales prices (the cost pass-through rate). The results suggest wide variation in these cost pass-through rates. In the 'Food, drink and tobacco' sector, for example, sales prices are barely affected by the CCAs, despite lower industry unit costs, reflecting a low, or zero, cost pass-through rate in the short term. By comparison, 'Agriculture', 'Textiles' and 'Printing' sectors reflect much higher cost pass-through rates (close to 100%). The reason for the differences in cost pass-through across sectors is explained by differences in the market structure of different industries. In the most competitive market structures, with many homogeneous firms, margins are low, and firms are price takers, indicating high rates of cost pass-through. By comparison, in markets where there is greater product differentiation and

fewer firms, individual firms can choose the extent to which they pass on costs.

Figure 7 Impact of CCAs on industry prices (average over period 2014-2017)



Source: E3ME, Cambridge Econometrics.

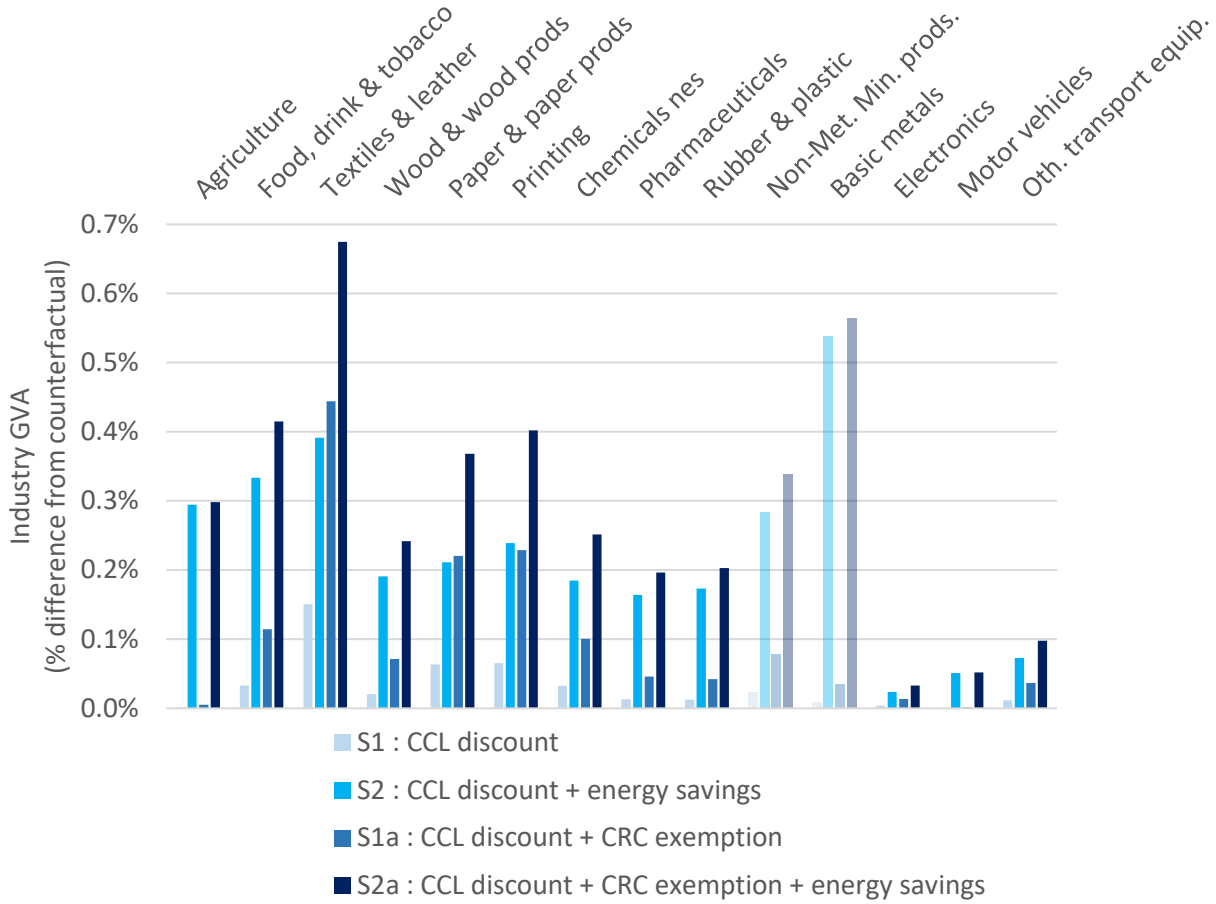
Note: Results are presented at a broad sector level but should be interpreted as the impact of CCAs on those facilities that belong to each broad industry sector. Most firms classified within Non-metallic Minerals and Basic Metals qualified for automatic CCL exemptions from 2014 and therefore had no incentive to sign up to a CCA after this date. Only a portion of firms that had a CCA would have otherwise been subject to the CRC scheme as well as the CCL.

Gross Value Added

- Finally, E3ME was used to assess the impacts of the CCAs on Gross Value Added (GVA). Figure 5 shows the impact of the various scenarios on GVA at the sector level. Across most sectors, the CCAs are associated with a 0%-0.6% positive impact on GVA. In addition to the relative energy intensity of industries (which affects the impact of CCAs on production costs), the impact of CCAs on GVA in each sector also depends on (i) the estimated cost reduction pass-through rate and (ii) the impact on domestic demand and international competitiveness.

- In sectors where there is a larger differential between costs of production and sales prices, cost savings associated with the CCA can be retained and drive an increase in operating margins (and profits), therefore directly contributing to GVA. Those firms that are operating in the most competitive market structures, however, are forced to pass on cost savings to consumers and so are less able to benefit from the energy cost savings in this way.[18] Despite this, those firms that do pass on cost savings to consumers are more likely to benefit from an increase in demand and a boost to their internationally competitive position, due to the lower prices that they are now able to offer.

Figure 8 Impact of CCAs on Gross Value Added (average over period 2014-2017)



Source: E3ME, Cambridge Econometrics.

Note: Results are presented at a broad sector level but should be interpreted as the impact of CCAs on those facilities that belong to each broad industry sector. Most firms classified within Non-metallic Minerals and Basic Metals qualified for automatic CCL exemptions from 2014 and therefore had no incentive to sign up to a CCA after this date. Only a portion of firms that had a CCA would have otherwise been subject to the CRC scheme as well as the CCL.

[18] The level of cost-pass through is determined through empirically estimated equations, using industry unit cost and price data at the NACE 2-digit level (NACE is the European standard for 'Nomenclature of Economic Activities', similar to SIC codes). The results from these econometric equations implicitly indicate the degree of competitiveness across different industry sectors.

Caveats and limitations

The results presented in this paper are subject to two key caveats and limitations that are presented in the table below.

Limitation	Explanation	Impact on results
Fuel coverage	The modelling accounts for the impact of the CCA scheme on electricity and gas prices (and electricity consumption in S2 and S2a). It is noted that the CCA discount on the CCL also applied to other fuels that have not been considered within the scope of this task.	Possible underestimate of the full benefits of the CCAs (because the analysis only considers the impact on gas and electricity use). The significance of this underestimate is likely to be small, as expenditure on other fuels that are covered by the CCL and CCA (coal and oil) is small, representing less than 20% of total energy expenditures in most cases.
Cost structure of sector associations	As detailed supply chain and energy cost information is not available for the industry sector associations that are covered by a CCA, all results are presented at a broad industry sector level. Results should be interpreted as the specific impact on sector associations that belong to the corresponding broad sector (see mapping in Annex 2).	Could underestimate or overestimate the impact of CCAs. However, as most sector associations covered by a CCA are expected to be more energy intensive than the broader sector average (that has been used for this analysis), it is likely that this leads to an underestimate of the full benefits in terms of production costs and competitiveness for the specific sectors covered. In addition to the broad sector-level energy statistics and input-output data, results from the quantitative surveys were drawn upon to tailor the energy expenditure assumptions to reflect the specific information that CCA sectors were reporting.

Appendix A – Energy consumption results

Results from regression-based testing of the common trends assumption

Table 14 Summary of results from a regression that tests the validity of the common trends assumption (in the case where 20 EU Member States are included in the comparison group)

Industry sector	2005 & UK	2006 & UK	2007 & UK	2008 & UK	2009 & UK	2010 & UK	2011 & UK	2013 & UK	2014 & UK	2015 & UK	Common trends assumption holds?
Chemicals	-	-	-	-	-	0.34	0.26	0.12	-0.03	-0.25	Yes- if time-series restricted to 2010-2015
Food, drink and tobacco	0.35	0.33	0.35	0.42	0.23	0.32	0.28	0.06	-0.08	-0.20	Yes
Iron and Steel	0.58	0.43	0.30	0.47	0.81	0.38	0.21	0.20	0.15	-0.18	Yes
Machinery	-	-	-	-	-	0.35	0.11	0.00	-0.13	-0.18	Yes- if time-series restricted to 2010-2015
Mining and Quarrying	0.48	0.20	0.64	-0.18	0.12	0.00	-0.22	0.12	0.19	-0.08	Yes
Non-Ferrous Metals	0.69**	0.45	0.28	0.42	0.88*	0.54	0.47	-0.09	-0.15	-0.48	No – results are biased

Industry sector	2005 & UK	2006 & UK	2007 & UK	2008 & UK	2009 & UK	2010 & UK	2011 & UK	2013 & UK	2014 & UK	2015 & UK	Common trends assumption holds?
Non-Metallic Minerals	0.41	0.31	0.23	0.35	0.51*	0.39	0.30	0.25	0.08	-0.09	No – results are biased
Paper and print	-	-	-	-	-	0.25	0.21	-0.01	-0.12	-0.05	Yes- if time-series restricted to 2010-2015
Textile and leather	0.85**	0.72*	0.63	0.69*	0.85**	0.48	0.43	0.11	-0.02	-0.17	No – results are biased
Transport equipment	0.57	0.53	0.44	0.41	0.67	0.36	0.36	0.09	-0.18	-0.24	Yes
Wood and Wood Products	0.0	0.0	0.0	0.0	0.0	0.30	0.23	-0.18	-0.33	0.06	Yes

Note: Data from 2008 to 2015 for all sectors except ‘Chemicals’, ‘Machinery’ and ‘Paper and Print’ where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

Time dummies are not reported.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

Time dummies are not reported.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Table 15 Summary of results from a regression that tests the validity of the common trends assumption (in the case where 3 EU Member States with light-touch industry energy policy are included in the comparison group)

Industry sector	2005 & UK	2006 & UK	2007 & UK	2008 & UK	2009 & UK	2010 & UK	2011 & UK	2013 & UK	2014 & UK	2015 & UK	Common trends assumption holds?
Chemicals	0.67*	0.56**	0.49	0.51	0.46	0.34	0.26	0.12	-0.03	-0.25	No – results are biased
Food, drink and tobacco	0.35	0.33	0.35	0.42	0.23	0.32	0.28	0.06	-0.08	-0.20	Yes
Iron and Steel	0.58	0.43	0.30	0.47	0.81	0.38	0.21	0.20	0.15	-0.18	Yes
Machinery	0.47	0.41	0.38	0.34	0.72**	0.35	0.11	0.00	-0.13	-0.18	No – results are biased
Mining and Quarrying	0.48	0.20	0.64	-0.18	0.12	0.00	-0.22	0.12	0.19	-0.08	Yes
Non-Ferrous Metals	0.69**	0.45*	0.28	0.42	0.88	0.54	0.47	-0.09	-0.15	-0.48	No – results are biased
Non-Metallic Minerals	0.41**	0.31*	0.23	0.35	0.51**	0.39**	0.30	0.25	0.08	-0.09	No – results are biased

Industry sector	2005 & UK	2006 & UK	2007 & UK	2008 & UK	2009 & UK	2010 & UK	2011 & UK	2013 & UK	2014 & UK	2015 & UK	Common trends assumption holds?
Paper and print	0.62**	0.55**	0.44*	0.45*	0.31	0.25	0.21	-0.01	-0.12	-0.05	No – results are biased
Textile and leather	0.85**	0.72*	0.63	0.69*	0.85**	0.48	0.43	0.11	-0.02	-0.17	No – results are biased
Transport equipment	0.57**	0.53*	0.44	0.41	0.67	0.36	0.36	0.09	-0.18	-0.24	No – results are biased
Wood and Wood Products	0.00	0.00	0.00	0.00	0.00	0.30	0.23	-0.18	-0.33	0.06	Yes

Table 15 Note: Data from 2008 to 2015

Countries included in the comparison group are: Italy, Spain and Ireland

** indicates statistically significant at 5% level; * indicates statistically significant at the 10%

Comparison of econometric results from Phase 1 and Phase 2

These tables compare econometric results for CCA influence on energy consumption that were undertaken during Phase 1 and Phase 2 of the evaluation.

Table 16 Phase 1 and 2 econometric results for the GVA specification, including a time trend in Phase 1 (biased results) and time dummies in Phase 2

Industry sector	Interaction term (Phase 1 results)	Interaction term (Phase 2 results)	Common trends assumption holds?	Reason for different estimated coefficients
Chemicals	-0.14**	-0.06	Yes- if time-series restricted to 2010-2015	Inclusion of time dummies in Phase 2 results leads to unbiased estimates (Phase 1 results only included a time trend as proxy for technological innovation, which lead to biased estimates)
Food, drink and tobacco	-0.07**	-0.03	Yes	
Iron and Steel	0.09	0.24	Yes	
Machinery	0.02	0.00	Yes- if time-series restricted to 2010-2015	
Mining and Quarrying	-0.14**	0.07	Yes	
Non-Ferrous Metals	-0.33**	-0.21**	No – results are biased	
Non-Metallic Minerals	0.02	0.04	No – results are biased	
Paper and print	0.00	-0.04	Yes- if time-series restricted to 2010-2015	

Industry sector	Interaction term (Phase 1 results)	Interaction term (Phase 2 results)	Common trends assumption holds?	Reason for different estimated coefficients
Textile and leather	-0.07	-0.05	No – results are biased	
Transport equipment	-0.06	-0.02	Yes	
Wood and Wood Products	-0.07	0.00	Yes	

Table 17 Phase 1 and 2 econometric results for the Output specification, including a time trend in Phase 1 (biased results) and time dummies in Phase 2

Industry sector	Interaction term (Phase 1 results)	Interaction term (Phase 2 results)	Common trends assumption holds?	Reason for different estimated coefficients
Chemicals	-0.12**	-0.06	Yes- if time-series restricted to 2010-2015	Inclusion of time dummies in Phase 2 results leads to unbiased estimates (Phase 1 results only included a time trend as proxy for technological innovation, which lead to biased estimates)
Food, drink and tobacco	-0.11**	-0.10**	Yes	
Iron and Steel	0.12	0.28*	Yes	
Machinery	0.00	-0.01	Yes- if time-series restricted to 2010-2015	
Mining and Quarrying	-0.19**	0.06	Yes	
Non-Ferrous Metals	-0.30**	-0.21**	No – results are biased	
Non-Metallic Minerals	-0.03	0.01	No – results are biased	
Paper and print	0.03	-0.01	Yes- if time-series restricted to 2010-2015	
Textile and leather	0.02	0.05	No – results are biased	
Transport equipment	0.04	0.08	Yes	
Wood and Wood Products	-0.07	0.01	Yes	

Detailed model result

Table 18 Complete regression results, where energy use is estimated, twenty EU Member States form the comparison group and GVA is used in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?
Chemicals	-0.17	-0.46	0.21	-0.06	-	-	0.33**	0.40**	0.44**	0.31**	0.11	112	Yes- if time-series restricted to 2010-2015
Food, drink and tobacco	-0.26*	-0.02	0.17	-0.03	0.06	0.01	0.02	0.04	0.00	0.02	-0.03	192	Yes
Iron and Steel	-0.24	-0.17	0.00	0.24	0.30**	-0.01	0.11	0.17*	0.07	0.03	0.00	183	Yes
Machinery	0.03	0.07	-0.12	0.00	-	-	0.07	0.07	-0.02	-0.04	-0.03	113	Yes- if time-series restricted to 2010-2015
Mining and Quarrying	-0.35	0.17	0.18	0.07	-0.04	-0.13	-0.04	-0.12	0.00	-0.10	-0.06	192	Yes
Non-Ferrous Metals	-0.17	0.11	-0.07	-0.21**	0.12	-0.10	-0.01	0.02	-0.03	-0.05	-0.04	183	No – results are biased

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?
Non-Metallic Minerals	-0.23	-0.03	0.37	0.04	0.37**	0.21*	0.22**	0.23*	0.13	0.11	0.03	184	No – results are biased
Paper and print	-0.16	0.32**	0.30**	-0.04	-	-	0.03	-0.02	-0.01	-0.06	-0.04	115	Yes- if time-series restricted to 2010-2015
Textile and leather	-0.73**	-0.20	0.57**	-0.05	0.63**	0.51**	0.45**	0.43**	0.40**	0.30**	0.07	192	No – results are biased
Transport equipment	0.02	-0.27	0.40**	-0.02	0.22	0.14	0.12	0.09	0.11	0.07	-0.01	184	Yes
Wood and Wood Products	-0.05	-0.36	0.22**	0.00	0.22*	0.09	0.14	0.18	0.18	0.17	0.12	187	Yes

Table 18 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Table 19 Complete regression results, where energy use is estimated, twenty EU Member States form the comparison group and output is used in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	Output	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?
Chemicals	-0.15	-0.49	0.45*	-0.06			0.29**	0.31**	0.33**	0.22**	0.07	112	Yes- if time-series restricted to 2010-2015
Food, drink and tobacco	-0.25**	-0.04	0.65**	-0.10**	0.16**	0.15**	0.13**	0.10	0.02	0.04	-0.02	192	Yes
Iron and Steel	-0.17	-0.17	-0.29	0.28*	0.30**	-0.16	0.07	0.17**	0.04	0.01	0.00	183	Yes
Machinery	-0.01	0.05	0.02	-0.01			0.08	0.07	-0.02	-0.05	-0.03	113	Yes- if time-series restricted to 2010-2015
Mining and Quarrying	-0.32	0.15	0.17	0.06	-0.03	-0.12	-0.02	-0.10	0.02	-0.08	-0.06	192	Yes
Non-Ferrous Metals	-0.11	0.11	-0.18	-0.21**	0.12*	-0.15	-0.01	0.03	-0.03	-0.06	-0.04	183	No – results are biased
Non-Metallic Minerals	-0.19	-0.05	0.39**	0.01	0.37**	0.20*	0.20*	0.21	0.12	0.11	0.03	184	No – results are biased

Industry sector	Electricity Price	Gas Price	Output	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?
Paper and print	-0.26*	0.36**	0.48*	-0.01			0.03	-0.04	-0.03	-0.07	-0.07**	115	Yes- if time-series restricted to 2010-2015
Textile and leather	-0.83**	-0.14	0.49	0.05	0.63**	0.52**	0.45**	0.43**	0.38**	0.29**	0.07	192	No – results are biased
Transport equipment	0.01	-0.28**	0.39**	0.08	0.20	0.13	0.12	0.08	0.11	0.07	-0.02	184	Yes
Wood and Wood Products	-0.13	-0.37	0.34**	0.01	0.27**	0.16	0.19	0.24	0.23	0.20	0.13	187	Yes

Table 19 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level

Table 20 Complete regression results, where electricity use is estimated, twenty EU Member States form the comparison group and GVA is used in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?	Econometric specification
Chemicals	-3.10	-3.10	-3.10	-3.10			-0.62	-0.05	1.99	1.72	0.72	112	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Food, drink and tobacco	-1.34	-1.34	-1.34	-1.34	-0.12	-0.11	-0.04	-0.02	-0.09	-0.06	-0.04	192	Yes	Fixed Effects
Iron and Steel	-0.38	-0.38	-0.38	-0.38	0.23**	-0.39	-0.33	-0.04	0.89	0.79	0.35	183	Yes	Instrumental Variables
Machinery	0.45	0.45	0.45	0.45			0.00	0.06	0.25	0.17	0.11	113	Yes- if time-series restricted to 2010-2015	Fixed Effects
Mining and Quarrying	-1.66	0.73	0.44	0.0	-0.15	0.12	0.07	0.16	0.21	0.03	-0.03	192	Yes	Instrumental Variables
Non-Ferrous Metals	-0.07	-0.07	-0.07	-0.07	-0.04	0.14	0.31	0.19	-0.88	-0.81	-0.36	183	No – results are biased	Fixed Effects

Industry sector	Electricity Price	Gas Price	GVA	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?	Econometric specification
Non-Metallic Minerals	0.11	0.11	0.11	0.11	0.08	0.04	0.12	0.08	0.08	0.05	-0.06	184	No – results are biased	Instrumental Variables
Paper and print	-0.16	-0.16	-0.16	-0.16			0.08	0.01	0.09	0.08	0.07	115	Yes- if time-series restricted to 2010-2015	Fixed Effects
Textile and leather	-0.07	-0.07	-0.07	-0.07	0.32**	0.20**	0.11	0.08*	0.26**	0.18	-0.01	192	No – results are biased	Fixed Effects
Transport equipment	1.05	-0.63	0.37	0.04	0.26**	0.05	-0.09	-0.09	-0.01	-0.11	-0.27	184	Yes	Fixed Effects
Wood and Wood Products	4.33	0.11	-0.42	-0.44	0.26	0.03	0.39	0.05	-1.18	-1.30	-0.48	187	Yes	Fixed Effects

Table 20 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Table 21 Complete regression results, where gas use is estimated, twenty EU Member States form the comparison group and GVA is used in the regression as measure of industry activity

Industry Sector	Electricity Price	Gas Price	GVA	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?	Econometric specification
Chemicals	-0.62*	-0.05	0.18	-0.5	-	-	-0.01	0.00	0.32*	0.26*	0.09	112	Yes- if time-series restricted to 2010-2015	Fixed effects
Food, drink and tobacco	-0.84	-0.06	0.63	-0.07	0.00	0.17	0.22	0.07	-0.14	-0.13	-0.06	192	Yes	Instrumental Variables
Iron and Steel	-2.04*	-0.34	-0.15	0.46	0.26	-0.15	-0.12	0.17	0.97	0.93	0.42	183	Yes	Instrumental Variables
Machinery	-1.24	-0.22	0.19	0.11	-	-	-0.04	0.14	0.54	0.48	0.14	113	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Mining and Quarrying	-0.21	-0.79	0.17	0.19	0.07	-0.19	-0.12	-0.08	0.40	0.29	0.04	192	Yes	Instrumental Variables
Non-Ferrous Metals	-0.48	-0.05	0.02	-0.22	0.12	-0.15	-0.06	0.04	0.14	0.11	0.00	183	No – results are biased	Fixed effects

Industry Sector	Electricity Price	Gas Price	GVA	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?	Econometric specification
Non-Metallic Minerals	-0.34*	-0.24	0.44**	-0.04	0.12**	0.00	-0.04	0.01	0.23**	0.21**	0.05	184	No – results are biased	Fixed effects
Paper and print	-0.14	-0.11	0.32**	-0,10	-	-	-0.04	-0.03	0.11	0.09	0.01	115	Yes- if time-series restricted to 2010-2015	Fixed effects
Textile and leather	-0.58*	-0.22	0.60*	-0.16	0.13	0.02	0.02	0.01	0.32**	0.22**	0.04	192	No – results are biased	Fixed effects
Transport equipment	-0.20	-0.28	0.18	-0,16	0.00	-0.12	-0.13	-0.04	0.08	0.05	-0.05	184	Yes	Fixed effects
Wood and Wood Products	-0.18	-0.46	0.26**	0.06	0.10	-0.11	-0.11	-0.04	0.27	0.19	0.04	187	Yes	Instrumental Variables

Table 21 Note: Data from 2008 to 2015 for all sectors except 'Chemicals', 'Machinery' and 'Paper and Print' where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Table 22 Complete regression results, where electricity use is estimated, twenty EU Member States form the comparison group and output is used in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	Output	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?	Econometric specification
Chemicals	-3.07	-1.17	-0.55	0.42	-	-	-0.65	-0.06	1.93	1.65	0.67	112	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Food, drink and tobacco	-0.11	0.09	0.64	-0.18	0.00	0.03	0.06	0.02	-0.02	0.00	-0.01	192	Yes	Fixed effects
Iron and Steel	-0.43	-1.08	0.10	0.28	0.18	-0.24	-0.24	-0.03	0.78	0.69	0.29	183	Yes	Instrumental Variables
Machinery	-0.55	0.01	0.20	0.05	-	-	0.11	0.12	0.21	0.14	0.09	113	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Mining and Quarrying	-0.64	-0.46	0.29	0.00	-0.16	-0.06	-0.13	0.05	0.47	0.29	0.08	192	Yes	Instrumental Variables
Non-Ferrous Metals	-0.53	2.45	-0.67	-0.36	-0.05	-0.24	0.06	0.11*	-0.49**	-0.45**	-0.13*	183	No – results are biased	Fixed effects

Industry sector	Electricity Price	Gas Price	Output	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?	Econometric specification
Non-Metallic Minerals	-0.08	0.0	0.85**	-0,24	0.11	0.08	0.12	0.07*	0.06	0.04	-0.05	184	No – results are biased	Fixed effects
Paper and print	-0.20	0.93	0.27	-0.19	-	-	0.28	0.08	-0.28	-0.26	-0.11	115	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Textile and leather	-0.75**	-0.02	0.47	-0.03	0.34**	0.22**	0.13	0.10*	0.24	0.17	-0.02	192	No – results are biased	Fixed effects
Transport equipment	-1.46	3.39	0.71*	-0.14	0.25	0.67	0.64	0.14	-1.16	-1.19	-0.86	184	Yes	Instrumental Variables
Wood and Wood Products	3.74	1.06	-0.79**	-0.42	0.25	0.08	0.49	0.08	-1.43	-1.49	-0.54	187	Yes	Instrumental Variables

Table 22 Note: Data from 2008 to 2015 for all sectors except ‘Chemicals’, ‘Machinery’ and ‘Paper and Print’ where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Table 23 Complete regression results, where gas use is estimated, twenty EU Member States form the comparison group and output is used in the regression as measure of industry activity

Industry sector	Electricity Price	Gas Price	Output	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?	Econometric specification
Chemicals	-0.62*	-0.06	0.14	-0.04	-	-	0.00	0.01	0.28	0.24	0.08	112	Yes- if time-series restricted to 2010-2015	Fixed effects
Food, drink and tobacco	-0.25*	-0.01	0.72**	-0.17	0.05	0.08*	0.06	0.03	0.01	0.04	-0.03	192	Yes	Fixed effects
Iron and Steel	-2.09*	-0.09	-0.08	0.40	0.23**	-0.09	-0.06	0.18	0.90	0.85	0.38	183	Yes	Instrumental Variables
Machinery	-1.25	-0.40	0.12	0.14	-	-	-0.09	0.12	0.64	0.57	0.19	113	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Mining and Quarrying	0.19	-1.44	0.31	0.19	0.06	-0.28	-0.23	-0.13	0.57	0.45	0.10	192	Yes	Instrumental Variables
Non-Ferrous Metals	-0.44	-0.05	-0.19	-0.19	0.13	-0.24	-0.08	0.05	0.11	0.09	-0.01	183	No – results are biased	Fixed effects
Non-Metallic Minerals	-0.30	-0.26*	0.5**	-0.09	0.13**	0.03	-0.04	0.01	0.23**	0.21**	0.06*	184	No – results are biased	Fixed effects

Industry sector	Electricity Price	Gas Price	Output	Interaction term	2008	2009	2010	2011	2013	2014	2015	Sample size	Common trends assumption holds?	Econometric specification
Paper and print	0.07	-1.06	0.08	0.06	-	-	-0.25	-0.09	0.49	0.46	0.17	115	Yes- if time-series restricted to 2010-2015	Instrumental Variables
Textile and leather	-0.07	-0.99	0.62**	-0.09	0.12**	-0.11	-0.13	-0.05	0.38	0.28	0.00	192	No – results are biased	Instrumental Variables
Transport equipment	3.73	-4.42	0.28	-0.11	-0.02	-0.72	-0.81	-0.37	0.71	0.59	0.19	184	Yes	Instrumental Variables
Wood and Wood Products	0.15	-0.94	0.38**	0.06	0.12	-0.12	-0.15	-0.05	0.36	0.27	0.06	187	Yes	Instrumental Variables

Note: Data from 2008 to 2015 for all sectors except ‘Chemicals’, ‘Machinery’ and ‘Paper and Print’ where data over 2010-2015 is used.

Countries included in the comparison group are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden.

** indicates statistically significant at 5% level; * indicates statistically significant at the 10% level.

Appendix B: About E3ME

Overview

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment, for forecasting and for research purposes.

This model description provides a short summary of the E3ME model. For further details, please read the full model manual available online from www.e3me.com.

Applications of E3ME

Although E3ME can be used for forecasting, the model is more commonly used for evaluating the impacts of an input shock through a scenario-based analysis. The shock may be either a change in policy, a change in economic assumptions or another change to a model variable. The analysis can be either forward looking (ex-ante) or evaluating previous developments in an ex-post manner. Scenarios may be used either to assess policy, or to assess sensitivities to key inputs (e.g. international energy prices).

For ex-ante analysis a baseline forecast up to 2050 is required; E3ME is usually calibrated to match a set of projections that are published by the European Commission and the International Energy Agency, but alternative projections may be used. The scenarios represent alternative versions of the future (or past) based on a different set of inputs. By comparing the outcomes to the baseline (usually in percentage terms), the effects of the change in inputs can be determined.

Model-based scenario analyses often focus on changes in price because this is easy to quantify and represent in the model structure. Examples include:

- changes in tax rates including direct, indirect, border, energy and environment taxes
- changes in international energy prices.

All of the price changes above can be represented in E3ME's framework reasonably well, given the level of disaggregation available. However, it is also possible to assess the effects of regulation, albeit with an assumption about effectiveness and cost. For example, an increase in vehicle fuel-efficiency standards could be assessed in the model with an assumption about how efficient vehicles become, and the cost of these measures. This would be entered into the model as a higher price for cars and a reduction in fuel consumption (all other things being equal). E3ME could then be used to determine:

- secondary effects, for example on fuel suppliers

- rebound effects[19]
- overall macro-economic impacts.

Comparison with CGE models and econometric specification

E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, underlying this there are important theoretical differences between the modelling approaches.

In a typical CGE framework, optimal behaviour is assumed, output is determined by supply-side constraints and prices adjust fully so that all the available capacity is used. In E3ME the determination of output comes from a post-Keynesian framework and it is possible to have spare capacity. The model is more demand-driven and it is not assumed that prices always adjust to market clearing levels.

The differences have important practical implications, as they mean that in E3ME regulation and other policy may lead to increases in output if they are able to draw upon spare economic capacity. This is described in more detail in the model manual.

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2020) and rebound effects[20], which are included as standard in the model's results.

Strengths and limitations of E3ME

In summary the key strengths of E3ME are:

- the close integration of the economy, energy systems and the environment, with two-way linkages between each component
- the detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios
- its global coverage, while still allowing for analysis at the national level for large economies
- the econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to CGE models

[19] In the example, the higher fuel efficiency effectively reduces the cost of motoring. In the long run this is likely to lead to an increase in demand, meaning some of the initial savings are lost. Barker et al (2009) demonstrate that this can be as high as 50% of the original reduction.
[20] Where an initial increase in efficiency reduces demand, but this is negated in the long run as greater efficiency lowers the relative cost and increases consumption. See Barker et al (2009).

- the econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends

As with all modelling approaches, E3ME is a simplification of reality and is based on a series of assumptions. Compared to other macro-economic modelling approaches, the assumptions are relatively non-restrictive as most relationships are determined by the historical data in the model database. This does, however, present its own limitations, for which the model user must be aware:

- The quality of the data used in the modelling is very important. Substantial resources are put into maintaining the E3ME database and filling out gaps in the data. However, particularly in developing countries, there is some uncertainty in results due to the data used.

- Econometric approaches are also sometimes criticised for using the past to explain future trends. In cases where there is large-scale policy change, the 'Lucas Critique' that suggests behaviour might change is also applicable. There is no solution to this argument using any modelling approach (as no one can predict the future) but we must always be aware of the uncertainty in the modelled results.

- The other main limitation to the E3ME approach relates to the dimensions of the model. In general, it is very difficult to go into a level of detail beyond that offered by the model classifications. This means that sub-national analysis is difficult[21] and sub-sectoral analysis is also difficult. Similarly, although usually less relevant, attempting to assess impacts on a monthly or quarterly basis would not be possible.

E3ME basic structure and data

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2014 and the model projects forward annually to 2050. The main data sources for European countries are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using customised software algorithms.

The main dimensions of E3ME are:

- 59 countries – all major world economies, the EU28 and candidate countries plus other countries' economies grouped

[21] If relevant, it may be possible to apply Cambridge Econometric's E3-India or E3-US (currently under development) models to give state-level analysis.

- 44 or 70 (Europe) industry sectors, based on standard international classifications
- 28 or 43 (Europe) categories of household expenditure
- 22 different users of 12 different fuel types
- 14 types of air-borne emission (where data are available) including the 6 GHG's monitored under the Kyoto Protocol

As a general model of the economy, based on the full structure of the national accounts, E3ME is capable of producing a broad range of economic indicators. In addition there is range of energy and environment indicators. The following list provides a summary of the most common model outputs:

- GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and international trade)
- sectoral output and GVA, prices, trade and competitiveness effects
- international trade by sector, origin and destination
- consumer prices and expenditures
- sectoral employment, unemployment, sectoral wage rates and labour supply
- energy demand, by sector and by fuel, energy prices
- CO2 emissions by sector and by fuel
- other air-borne emissions
- material demands

This list is by no means exhaustive and the delivered outputs often depend on the requirements of the specific application. In addition to the sectoral dimension mentioned in the list, all indicators are produced at the national and regional level and annually over the period up to 2050.

Appendix C: Mapping sector associations to E3ME sectors

Sector association (for CCA)	Sector ID	Corresponding broad industry sector (E3ME)
Aerospace	ADS	Other transport equip.
Agricultural Supply	AIC	Agriculture
Aluminium	AFED	Basic metals
Bakers	NAMB	Food, drink & tobacco
Brewing	BLRA	Food, drink & tobacco
Calcium Carbonate	BCCF	Chemicals N.E.S. (Not Elsewhere Specified)
Cement	BCA	Non-Met. Min. prods.
Ceramics	BCC	Non-Met. Min. prods.
Chemicals	CIA	Chemicals N.E.S.
Cold Storage	CSDF	Chemicals N.E.S.
Compressed Gases	BCGA	Chemicals N.E.S.
Dairy	DIAL	Food, drink & tobacco
Data Centres*	DATC	-
Egg Processing	BEPA	Food, drink & tobacco
Eggs & Poultry Meat	NFU5	Food, drink & tobacco
Food and Drink	FDF1	Food, drink & tobacco
Foundries	CAST	Basic metals
Geosynthetics Non-Woven	BNMA	Textiles & leather
Glass	BGMC	Non-Met. Min. prods.
Horticulture*	NFU4	-

Sector association (for CCA)	Sector ID	Corresponding broad industry sector (E3ME)
Kaolin and Ball Clay	KABC	Non-Met. Min. prods.
Laundries*	TSA	-
Leather	UKLF	Textiles & leather
Malting	MAGB	Food, drink & tobacco
Meat	BMPA	Food, drink & tobacco
Metal Packaging	MPMA	Basic metals
Metalforming	CBM	Basic metals
Motor Manufacturing	SMMT	Motor vehicles
Non-Ferrous Metals	NFA	Basic metals
Packaging & Industrial Films	PIFA	Chemicals N.E.S.
Paper	CPI	Paper & paper prods
Pigs	NFU1	Agriculture
Plastics	BPF	Rubber & plastic
Poultry Meat Processing	BPC2	Food, drink & tobacco
Poultry Meat Rearing	BPC1	Agriculture
Printing	BPIF	Printing
Rendering	UKRA	Non-Met. Min. prods.
Sawmills	CONF	Wood & wood prods
Semiconductors	NMI	Electronics
Spirits	SEEC	Food, drink & tobacco
Steel	UKSA	Basic metals
Supermarkets*	FDFS	-
Surface Engineering	SEA	Chemicals N.E.S.

Sector association (for CCA)	Sector ID	Corresponding broad industry sector (E3ME)
Surface Engineering Heat Treatment	SEHT	Chemicals N.E.S.
Textiles	BATC	Textiles & leather
Textiles Energy Intensive	BATE	Textiles & leather
Tyres	BTMA	Rubber & plastic
Wallcoverings	AWM	Paper & paper prods
Wood Panels	WPIF	Wood & wood prods

Note: An asterisk indicates those sector associations that were not possible to match closely to a corresponding E3ME sector. The closest corresponding sectors in E3ME are service sectors that are heterogenous in terms of the nature of activities and structure of firms. These are not suitable for modelling the impacts of the CCA sector associations. Results for these sectors are therefore not presented.

Appendix D: Macro-economic modelling results

Table 24 Electricity Prices

Electricity price (p/kwh)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Electricity price (including full CCL)	6.2	6.2	7.3	8.3	6.9	7.4	8.4	9.1	9.6	9.8	9.8	10.4	10.9
Electricity price (after CCL discount applied)	6.2	6.2	7.3	8.3	6.9	7.4	8.4	8.7	9.1	9.3	9.3	9.9	10.3
Electricity price (after CCL discount and CRC exemption applied)		6.2	7.3	8.3	6.9	7.4	8.4	8.7	8.2	8.5	8.6	9.3	9.8

Table 25 Gas Prices

Gas price (p/kwh)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Gas price (including full CCL)	2.0	1.6	2.2	2.1	1.8	2.1	2.4	2.7	2.4	2.1	1.7	1.6	1.9
Gas price (after CCL discount applied)	2.0	1.6	2.2	2.1	1.8	2.1	2.4	2.5	2.3	2.0	1.6	1.5	1.8
Gas price (after CCL discount and CRC exemption applied)		1.6	2.2	2.1	1.8	2.1	2.4	2.5	2.0	1.7	1.3	1.2	1.4

Table 26 Industry costs of Production

S1: CCL Discount

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	-0.2%	-0.4%	-0.3%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.4%	-0.6%	0.0%	0.0%	-0.1%
2015	-0.2%	-0.4%	-0.3%	-0.2%	-0.2%	-0.2%	-0.1%	-0.2%	-0.2%	-0.4%	-0.5%	-0.1%	0.0%	-0.1%
2016	-0.2%	-0.5%	-0.3%	-0.3%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.5%	-0.6%	-0.1%	0.0%	-0.1%
2017	-0.4%	-0.8%	-0.5%	-0.4%	-0.3%	-0.4%	-0.3%	-0.3%	-0.3%	-0.8%	-0.9%	-0.1%	0.0%	-0.1%
Average (2014-2017)	-0.3%	-0.5%	-0.4%	-0.3%	-0.2%	-0.3%	-0.2%	-0.2%	-0.2%	-0.5%	-0.7%	-0.1%	0.0%	-0.1%

S1a: CCL discount + CRC exemption

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	-0.7%	-1.3%	-1.0%	-0.7%	-0.5%	-0.6%	-0.5%	-0.6%	-0.6%	-1.3%	-1.7%	-0.1%	-0.1%	-0.2%
2015	-0.6%	-1.3%	-0.8%	-0.7%	-0.5%	-0.6%	-0.4%	-0.5%	-0.6%	-1.2%	-1.5%	-0.1%	-0.1%	-0.2%
2016	-0.7%	-1.7%	-1.0%	-0.8%	-0.6%	-0.6%	-0.5%	-0.6%	-0.7%	-1.5%	-1.8%	-0.2%	-0.1%	-0.2%
2017	-1.0%	-2.6%	-1.6%	-1.2%	-0.9%	-1.0%	-0.8%	-0.9%	-1.0%	-2.3%	-2.7%	-0.2%	-0.1%	-0.3%
Average (2014-2017)	-0.7%	-1.7%	-1.1%	-0.8%	-0.6%	-0.7%	-0.6%	-0.6%	-0.7%	-1.6%	-1.9%	-0.2%	-0.1%	-0.2%

S2: CCL discount + electricity savings

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	-0.4%	-0.6%	-0.5%	-0.3%	-0.2%	-0.3%	-0.2%	-0.3%	-0.3%	-0.5%	-0.8%	0.0%	0.0%	-0.1%
2015	-0.5%	-0.7%	-0.5%	-0.4%	-0.3%	-0.4%	-0.3%	-0.3%	-0.3%	-0.7%	-0.9%	0.0%	0.0%	-0.1%
2016	-0.7%	-1.0%	-0.7%	-0.6%	-0.4%	-0.5%	-0.4%	-0.5%	-0.5%	-0.9%	-1.3%	-0.1%	-0.1%	-0.2%
2017	-0.8%	-1.2%	-0.8%	-0.7%	-0.6%	-0.7%	-0.5%	-0.6%	-0.6%	-1.2%	-1.6%	-0.2%	-0.1%	-0.2%
Average (2014-2017)	-0.6%	-0.9%	-0.6%	-0.5%	-0.4%	-0.5%	-0.3%	-0.4%	-0.4%	-0.8%	-1.1%	-0.1%	-0.1%	-0.1%

Table 27 Industry Prices

S2a: CCL discount + CRC exemption + electricity savings

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	-0.8%	-1.5%	-1.1%	-0.8%	-0.6%	-0.7%	-0.6%	-0.7%	-0.7%	-1.4%	-1.9%	-0.1%	-0.1%	-0.2%
2015	-0.8%	-1.6%	-1.0%	-0.8%	-0.6%	-0.7%	-0.6%	-0.7%	-0.7%	-1.5%	-1.9%	-0.1%	-0.1%	-0.2%
2016	-1.0%	-2.1%	-1.3%	-1.1%	-0.8%	-0.9%	-0.7%	-0.8%	-0.9%	-1.9%	-2.4%	-0.2%	-0.1%	-0.3%
2017	-1.4%	-2.9%	-1.8%	-1.4%	-1.1%	-1.3%	-1.0%	-1.1%	-1.2%	-2.7%	-3.3%	-0.3%	-0.2%	-0.4%
Average (2014-2017)	-1.0%	-2.0%	-1.3%	-1.0%	-0.8%	-0.9%	-0.7%	-0.8%	-0.9%	-1.9%	-2.4%	-0.2%	-0.1%	-0.3%

S1 : CCL discount

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	-0.2%	-0.1%	-0.3%	0.0%	0.0%	-0.2%	-0.2%	-0.2%	0.0%	0.0%	-0.6%	0.0%	0.0%	-0.1%
2015	-0.2%	-0.1%	-0.3%	0.0%	0.0%	-0.2%	-0.1%	-0.2%	0.0%	0.0%	-0.5%	-0.1%	0.0%	-0.1%
2016	-0.3%	-0.1%	-0.3%	0.0%	0.0%	-0.2%	-0.2%	-0.2%	0.0%	0.0%	-0.6%	-0.1%	0.0%	-0.1%
2017	-0.4%	-0.1%	-0.5%	0.0%	0.0%	-0.4%	-0.3%	-0.3%	0.0%	0.0%	-0.9%	-0.1%	0.0%	-0.1%
Average (2014-2017)	-0.3%	-0.1%	-0.4%	0.0%	0.0%	-0.3%	-0.2%	-0.2%	0.0%	0.0%	-0.6%	-0.1%	0.0%	-0.1%

S1a : CCL discount + CRC exemption

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	-0.7%	-0.2%	-1.0%	-0.1%	0.0%	-0.6%	-0.5%	-0.6%	0.0%	-0.1%	-1.7%	-0.1%	0.0%	-0.2%
2015	-0.6%	-0.2%	-0.8%	-0.1%	-0.1%	-0.6%	-0.4%	-0.5%	0.0%	-0.1%	-1.5%	-0.2%	0.0%	-0.2%
2016	-0.7%	-0.3%	-1.0%	-0.1%	-0.1%	-0.7%	-0.5%	-0.6%	0.0%	-0.1%	-1.8%	-0.2%	0.0%	-0.2%
2017	-1.0%	-0.4%	-1.6%	-0.1%	-0.1%	-1.0%	-0.8%	-0.9%	0.0%	-0.1%	-2.7%	-0.3%	0.0%	-0.3%
Average (2014-2017)	-0.7%	-0.3%	-1.1%	-0.1%	-0.1%	-0.7%	-0.6%	-0.6%	0.0%	-0.1%	-1.9%	-0.2%	0.0%	-0.2%

S2 : CCL discount + electricity savings

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	-0.4%	0.0%	-0.5%	0.0%	0.0%	-0.3%	-0.2%	-0.3%	0.0%	0.0%	-0.8%	0.0%	0.0%	-0.1%
2015	-0.5%	-0.1%	-0.5%	0.0%	0.0%	-0.4%	-0.3%	-0.3%	0.0%	0.0%	-0.9%	0.0%	0.0%	-0.1%
2016	-0.7%	-0.1%	-0.7%	-0.1%	0.0%	-0.5%	-0.4%	-0.5%	0.0%	0.0%	-1.3%	-0.1%	0.0%	-0.2%
2017	-0.8%	-0.2%	-0.8%	-0.1%	-0.1%	-0.7%	-0.5%	-0.6%	0.0%	-0.1%	-1.6%	-0.1%	0.0%	-0.2%
Average (2014-2017)	-0.6%	-0.1%	-0.6%	-0.1%	0.0%	-0.5%	-0.3%	-0.4%	0.0%	0.0%	-1.1%	-0.1%	0.0%	-0.1%

S2a : CCL discount + CRC exemption + electricity savings

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	-0.8%	-0.2%	-1.2%	-0.1%	0.0%	-0.7%	-0.6%	-0.7%	0.0%	-0.1%	-1.9%	-0.1%	0.0%	-0.2%
2015	-0.8%	-0.2%	-1.0%	-0.1%	-0.1%	-0.7%	-0.6%	-0.7%	0.0%	-0.1%	-1.9%	-0.1%	0.0%	-0.2%
2016	-1.0%	-0.3%	-1.3%	-0.1%	-0.1%	-0.9%	-0.7%	-0.8%	0.0%	-0.1%	-2.4%	-0.1%	0.0%	-0.3%
2017	-1.4%	-0.5%	-1.8%	-0.2%	-0.2%	-1.3%	-1.0%	-1.1%	-0.1%	-0.1%	-3.3%	-0.2%	0.0%	-0.4%
Average (2014-2017)	-1.0%	-0.3%	-1.3%	-0.1%	-0.1%	-0.9%	-0.7%	-0.8%	0.0%	-0.1%	-2.4%	-0.1%	0.0%	-0.3%

Table 27 Gross Value Added

S1 : CCL discount

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2015	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2016	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2017	0.0%	0.1%	0.2%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Average (2014-2017)	0.0%	0.0%	0.2%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

S1a : CCL discount + CRC exemption

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	0.0%	0.1%	0.5%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
2015	0.0%	0.1%	0.3%	0.1%	0.2%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
2016	0.0%	0.1%	0.4%	0.1%	0.2%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
2017	0.0%	0.2%	0.6%	0.1%	0.3%	0.4%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%
Average (2014-2017)	0.0%	0.1%	0.4%	0.1%	0.2%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%

S2 : CCL discount + energy savings

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	0.2%	0.3%	0.4%	0.1%	0.1%	0.2%	0.2%	0.1%	0.1%	0.2%	0.4%	0.0%	0.0%	0.1%
2015	0.5%	0.5%	0.5%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.4%	0.8%	0.1%	0.1%	0.1%
2016	0.7%	0.8%	0.7%	0.5%	0.4%	0.5%	0.4%	0.4%	0.4%	0.7%	1.3%	0.1%	0.1%	0.2%
2017	0.7%	0.8%	0.7%	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%	0.7%	1.4%	0.0%	0.1%	0.2%
Average (2014-2017)	0.5%	0.6%	0.6%	0.3%	0.3%	0.4%	0.3%	0.3%	0.3%	0.5%	1.0%	0.1%	0.1%	0.1%

S2a : CCL discount + CRC exemption + energy savings

Year	Agriculture	Food, drink & tobacco	Textiles & leather	Wood & wood prods	Paper & paper prods	Printing	Chemicals N.E.S.	Pharma-ceuticals	Rubber & plastic	Non-Met. Min. prods.	Basic metals	Electronics	Motor vehicles	Other transport equip.
2014	0.2%	0.3%	0.7%	0.2%	0.2%	0.3%	0.2%	0.2%	0.2%	0.3%	0.4%	0.0%	0.0%	0.1%
2015	0.5%	0.6%	0.7%	0.3%	0.4%	0.5%	0.3%	0.3%	0.3%	0.5%	0.9%	0.1%	0.1%	0.1%
2016	0.7%	0.8%	0.9%	0.5%	0.6%	0.7%	0.4%	0.4%	0.4%	0.7%	1.3%	0.0%	0.1%	0.2%
2017	0.7%	0.9%	1.1%	0.6%	0.7%	0.8%	0.5%	0.4%	0.5%	0.8%	1.4%	0.1%	0.1%	0.2%
Average (2014-2017)	0.5%	0.7%	0.9%	0.4%	0.5%	0.5%	0.4%	0.3%	0.3%	0.6%	1.0%	0.1%	0.1%	0.2%

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