Department of Energy & Climate Change

CRC Energy Efficiency Scheme Evaluation

Appendix 3: Stage 2 econometric report

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Acronyms

CRC	CRC Energy Efficiency Scheme
CCA	Climate Change Agreement
BSD	Business Structure Database
UKDS	UK Data Service
IDBR	Interdepartmental Business Register
EU ETS	European Union Emissions Trading System
CCL	Climate Change Levy
InfoDec	Information Declarer
DiD	Difference-in-differences

Executive summary

In 2010, the UK government introduced the CRC Energy Efficiency Scheme (CRC) to reduce greenhouse gas (GHG) emissions and energy consumption in sectors that were not already covered by policy instruments such as the EU Emissions Trading System (EU ETS) and Climate Change Agreements (CCAs). Phase 1 of the scheme ran from April 2010 to the end of March 2014. Organisations with half hourly electricity meters and combined annual electricity consumption exceeding 6,000 MWh (in the 2008 base year) were included in the scheme. The original CRC scheme involved a levy on emissions and revenue recycling to the participating organisations on the basis of their performance in a Performance League Table (PLT). In October 2010 the Government simplified the scheme and removed the recycling element. In the 2012 Autumn Statement, the Government removed the PLT and the Chancellor stated that "the Government will review the effectiveness of the CRC in 2016 [...] the tax element of the CRC introduced at Spending Review 2010 will be a high priority for removal when the public finances allow."

This report presents the first econometric evaluation study of the CRC scheme. Its purpose is to estimate the actual causal impact of the scheme on energy consumption and intensity, using data for the period 2010 to 2012. Our methodology compares the 'difference–in-differences' in energy consumption before and after the introduction of the CRC scheme, between participating organisations and organisations in suitable control groups.

We draw control organisations from the group of so called 'information declarers': organisations that had a least one settled half-hourly meter in 2008, and were required to submit their electricity consumption for 2008 to the Environment Agency, but were below the threshold of 6,000 MWh annual consumption set for CRC registration.

The first section of the report explains how using difference-in-differences (DiD) regression analysis allows us to isolate the causal effect of the CRC. A thorough description of the datasets then follows, showing how the five different levels of aggregation of the data can bring additional angles of analysis:

i. At the most disaggregate level, the meter level provides precise electricity consumption data.

ii. Aggregating at the building level provides information on gas consumption and on building type by matching to the non-domestic National Energy Efficiency Data-Framework (NEED) dataset.

iii. At the postcode level of aggregation, nearly the full sample of CRC and information declarers can be combined with other business level data from the Office of National Statistics' Business Structure Database (BSD). In particular this provides information on the sector of activity and employment at that postcode.

iv. A more precise merging of meter data with BSD data datasets that exploits postcode information and organisation names leads us to the establishment level; i.e. the activities of

a particular organisation in a particular location (identified by the postcode). However, this comes at the cost of a reduced sample size.

v. Finally, aggregation at the organisation level makes the computation of energy intensity in terms of both employment and turnover possible.

In addition to these five aggregation levels, the analysis is performed for two different samples reflecting different definitions of scope with respect to including meters where consumption may have been influenced by other schemes. In all cases, meters belonging to organisations with full exemptions from CRC on the grounds of Climate Change Agreements (CCAs) are excluded from the CRC sample, as are meters located at CCA and EU ETS sites. However:

- in Analysis Sample 1, meters that are part of a Climate Change Agreement (CCA) organisation with 'member only' CRC exemptions (applying to only parts of their business) are included in the CRC sample, provided that the meters are not located at a CCA site; while
- in Analysis Sample 2 all meters belonging to an organisation with any CCA exemption are excluded from the CRC sample.

We tend to find smaller impact estimates for Sample 2 than for Sample 1. We provide evidence which suggest that this is because meters belonging to CCA organisations tend to have higher consumption and the effect of CRC is stronger for meters with higher consumption.

Finally, both at the meter and building level, we divided the sample into five groups based on their consumption, in order to understand heterogeneity in the response to CRC across these groups. The impact is measured separately for each quintile.

The main findings of the econometric analysis can be summarised in the following table, where one, two or three stars respectively denote statistical significance at the 10%, 5% and 1% level. Three stars indicate that the result is more robust. The quintiles column lists the consumption bands that display significant impacts at least at the 5%. Cells marked 'not available' (n/a) indicate specifications that we have not considered in this report.

Data aggregation level	Analysis Sample	Electricity consumption decrease	Quintiles in which effect is statistically significant at least at the 5%
Meter level	Sample 1	5.1% ***	All 5
	Sample 2	3.7% ***	n/a
Building level	Sample 1	6.0% ***	Top 2
	Sample 2	3.1%	None
Postcode level	Sample 1	6.2% ***	n/a
	Sample 2	4.4% ***	n/a
Establishment level	Sample 1	5.5% ***	n/a
	Sample 2	4.5% ***	n/a
Organisation level	Sample 1	8.1% ***	n/a
	Sample 2	6.6% *	n/a

Table 1: Decrease in electricity consumption attributed to the CRC (2010-2012)

Notes: (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level.

This shows that depending on which sample is used the CRC is shown to reduce electricity use between 3.7% and 5.1% at the meter level for the period 2010-2012. We have used the meter-level estimates as the basis for our overall estimate of CRC impact on electricity consumption, as they are not affected by the matching errors and loss of unmatched sample which affect higher levels of aggregation.

In addition, we use data on gas consumption available for a sub-sample of organisations. Although the data is incomplete and should be considered as experimental, as described in section 2.2.3, we find that:

- Analysis of gas meter data at building level does not show statistically significant impacts overall. Analysis by consumption band shows that there is a significant 30% reduction in the top consumption percentile band (80-100%) for both sample groups. This is consistent with larger users of gas being more ready to replace boilers or change their processes to reduce consumption. However the coverage of NEED is restricted by matching constraints so this result needs to be interpreted with caution. Further research could explore how far the large effect observed for the top quintile of CRC gas meters, compared to information declarer meters, is attributable to CRC or other factors.
- Analysis of carbon emissions at building level, from combined electricity and gas consumption data, shows a significant impact across both sample groups (between 6-8%). This is significant for the top four consumption bands in Sample 1, but is only significant in the middle three consumption bands for Sample 2. Again, the caveat regarding the representativeness of the gas data applies here too.

Further analysis of electricity data has been undertaken at postcode, establishment and organisation level, to research possible effects of the CRC on employment, turnover and energy efficiency. As we cannot directly measure energy efficiency, we looked instead at its inverse: energy intensity. We could not model full energy intensity because of the difficulty in matching gas data reliably across the sample within the timescale of the study, so we used electricity intensity measured in two ways (electricity consumption relative to either employment or turnover) as a proxy for energy intensity. The findings of the analysis of electricity in relation to employment are summarised in Table 2 below:

Data aggregation level	Analysis Sample	Employment decrease	Electricity Intensity decrease (electricity over employment)
Postcode level	Sample 1	n/a	4.8% ***
	Sample 2	n/a	3.1% ***
Establishment level	Sample 1	3.0% ***	2.5% **
	Sample 2	3.2%***	1.3%
Organisation level	Sample 1	0.6%	7.6% *
	Sample 2	-1.3%	8.0% *

Table 2: Decrease in employment and electricity consumption intensity attributed to the CRC[1]

As shown in Table 2, we found a negative effect on employment at establishment level only. However, we do not view this as a robust finding because this result was not replicated across the other specifications.

Table 2 also shows that the electricity intensity (relative to employment) of CRC organisations decreased relative to information declarers, with results being statistically significant in all but one of the specifications shown here. The other analyses conducted in this section were to investigate any impact on electricity intensity in relation to turnover. This could only be analysed at organisation level, the only level for which turnover data is available. This impact was not statistically significant, and therefore these results are not shown in Table 2 but are described further in section 3.5.

In conclusion, there is broad and robust evidence that the CRC has had an impact on electricity consumption – and also carbon emissions – of at least 3-5% between 2010 and 2012. The CRC also appears to have had some impact in reducing electricity intensity (defined here as electricity consumption per unit of employment).

[1] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level; (n/a) indicates results not available for that level of aggregation.

1. Introduction

This is the first econometric evaluation of the CRC Energy Efficiency Scheme (CRC), a major initiative by the UK government to reduce greenhouse gas (GHG) emissions and energy consumption in sectors that are not already covered by policies such as the European Union Emission Trading System (EU ETS) and Climate Change Agreements (CCAs).

After preliminary consultation during 2006 and 2007, enabling legislation for the CRC scheme was passed in late 2008, as part of the Climate Change Act 2008. Qualification for the CRC was based on electricity usage, with over 13,000 organisations required to report their electricity consumption in 2008. CRC regulations were passed in 2010 and the CRC scheme was first implemented in April 2010 among organisations with half hourly electricity meters, targeted at those organisations with total annual electricity consumption exceeding 6,000 MWh in the base year of 2008.

The original CRC scheme involved a levy on emissions and revenue recycling to the participating organisations on the basis of their performance. In October 2010 the Government simplified the scheme and removed the recycling element. In the 2012 Autumn Statement, the Government removed the PLT and the Chancellor stated that "the Government will review the effectiveness of the CRC in 2016 [...] the tax element of the CRC introduced at Spending Review 2010 will be a high priority for removal when the public finances allow."

The purpose of this study is to estimate the average causal impact of the scheme on energy consumption and assess other outcomes in participating organisations. The main approach will be to compare growth rates of energy consumption in participating organisations with suitable control groups over the introduction period.

We draw control organisations from the group of so called ‘information declarers’: organisations that had a least one half-hourly meter in 2008 and who had submitted their electricity consumption for 2008 but were below the eventual threshold of 6,000 MWh.

Information declarers were chosen as the control group because they are close in scale to CRC participants but have not been required to comply with the scheme. However, it is possible that information declarers responded to the CRC despite not actually being included in the scheme for several reasons:

i. The requirement to declare information might have raised the awareness of energy consumption within the organisation.

ii. In the early stages of consultation on the CRC, around 2007, it was not clear exactly what the cut-off threshold for participation would be. Some information declarers might have reduced consumption in anticipation of being captured by the scheme, or have taken action to avoid being captured by the eventual threshold.

iii. Similarly, information declarers could have reduced consumption in order to avoid being included in the CRC scheme in later years. This would have been particularly relevant in

2012, since April 2012 to March 2013 was the qualifying year for inclusion in the second phase of the CRC starting in 2014.

All these mechanisms aspects could lead to a reduction in energy consumption and emissions in information declarers as a result of the CRC. There is evidence from other workstreams, presented in the synthesis report, that some information declarers have been influenced by the CRC in these ways. This implies that our estimates of CRC impact using information declarers as the control group are likely to represent a lower bound of the overall impact of CRC.

We also explored using 'non-treated' organisations as a control group; i.e. organisations that did not have a half-hourly electricity meter and were therefore not included in the information declaration exercise. We found that meters belonging to 'non-treated' organisations tended to have much lower electricity consumption per meter per year than both CRC and information declarer organisations. This means they are less comparable to CRC organisations therefore a less suitable control group. Using them as a second control group was in any case not possible within the timescale for this study.

2. Approach

2.1. Methodology

We derive the main CRC impact estimates from a difference-in-differences strategy which we replicate across different datasets at various aggregation levels (meter point, building, postcode, establishment, and organisation) and outcome variables. We compare the average difference in an outcome such as electricity consumption relative to a base year in CRC-participating units (e.g. meter points) with similar non-participating units.

We find similar non-participating control group units through several steps. We first start with the whole population of information declarers, which are likely to be more similar to CRC organisations than organisations without half-hourly electricity meters. Secondly, we match CRC and control group organisations on the basis of various matching variables, which vary by aggregation level.[2] These include industrial sector, building type, energy intensity and so on. As the matching variables vary across the different analysis datasets, we discuss them in detail in the results section. As a basic specification, we used electricity consumption levels in 2008 as a matching variable because of the policy coverage being defined using these levels. However, our main criterion for assessing the quality of the matching procedure is to look at pre-treatment trends; i.e. we examine whether treatment and control organisations – on average – moved in similar directions before the start of the policy. If this is the case we can be more confident that any divergence in trends found after the policy introduction is due to causal policy factors rather than other factors.

We implement our matching approach by discretising all matching variables (unless they are already discrete such as industrial sector); e.g. when matching on energy consumption in a base year, we divide the sample into energy consumption bands. We then fit regressions of the form:

$$E_{it} - E_{i2008} = \beta_{tCRC} \times CRC_i + \beta_t + \sum_M \beta_{Mt} \times M_i + \epsilon_{it}$$

where E_{it} is an outcome in aggregation unit i (i.e. meter point, organisation etc.) at time t; e.g. (log) electricity consumption.

CRC_i is an indicator variable equal to 1 if an organisation is covered by Phase 1 of the CRC, and 0 if it is not.

β_t is a set of time fixed-effects

β_{tCRC} is a set of time fixed-effects specific to CRC participants; i.e. the parameters β_{tCRC} tell us the average difference-in-differences between CRC and information declarer (InfoDec) organisations for a given year. If the control group and matching criteria are adequately defined, this provides an estimate of the causal impact of the CRC policy (see Annex B).

[2] One of the main reasons of using all these different aggregation levels is that they allow wider or different sets of variables to be used for the analysis including the matching of treatment and control units.

M indexes various sets of discrete matching variables and M_i is an indicator equal to 1 if a unit i falls into a particular category; e.g. M could represent a certain pre-policy implementation band of energy consumption or a certain sector. Note that we interact these matching categories with a full set of time fixed-effects. This allows for full flexibility as regards to time-specific shocks within all matching categories. As a consequence we identify any CRC effects solely from differences between CRC and InfoDec units within these categories. This approach deals satisfactorily with extreme values: they do not contribute to the identification as all identification comes from difference within bands of matched variables. So if a treated unit is very extreme and there is no non-treated unit in the same extreme band, this unit would not contribute to the estimated policy impact.

In the equation above and all results below we use 2008 as the base year. We experimented with other base years, however, 2008 has a number of advantages:

- The CRC was proposed in the 2008 Climate Change Act in late 2008. Hence 2008 is the closest year to the start of the policy that is plausibly not affected by potential pre-policy effects.
- Using a year as close as possible to the start of the policy minimises the loss of organisations where data further back in time is not available because of incomplete data gathering or because of organisation entry.
- Qualification for the CRC policy was based on 2008 electricity consumption and so 2008 is also a desirable year for various matching of control and treatment groups. Using the same years for matching and comparison purposes reduces the risk of further sample loss because of missing variables.

As well as presenting the annualised effects graphically, we also report the average pre- and post-treatment difference between CRC and InfoDec organisations. To report pre- and post-treatment differences, we fit the following restricted version of Equation 1:

$$E_{it} - E_{i2008} = \beta_{Pre,CRC}\mathrm{I}\{t < 2010\} \times CRC_i + \beta_{Post,CRC}\mathrm{I}\{t \geq 2010\} \times CRC_i + \beta_t + \sum_M \beta_{Mt} \times M_i + \epsilon_{it}$$

which contains the same variables as equation (1) except for $I\{t < 2010\}$, a dummy that takes the value 1 if the observation measures consumption in a year before 2010 and the value 0 otherwise. Conversely, $I\{t \geq 2010\}$ is equal to 0 if $t < 2010$ and 1 otherwise.

A few caveats should be noted in relation to the pre- and post-treatment periods. Firstly, the pre-treatment period covers the calendar years 2006-2009 inclusive, while the post-treatment period covers the calendar years 2010-2012. The meter data is available for calendar year periods, which provides an approximate match to the financial years used by the CRC policy. Secondly, the specification in equation 2 would not allow for so called 'pre-treatment effects'; i.e. responses to CRC before the actual start of the policy in 2010. However, the year-by-year specification in equation 1 would allow for such effects in 2009, which is the only pre-treatment year after the policy was confirmed. As we never found any effects in 2009, using specification 1, we decided that specification 2 is an appropriate model simplification.

This ‘discretised’ methodology allows us to compute a large number of different specifications with very limited time. Any matching methods that rely on non-discretised matching approaches – while not difficult to implement in principle – typically require vastly more time to compute.

The main alternative to this “control group” approach would be to establish any CRC effect by looking at a trend break in outcome variables such as electricity consumption for CRC participant organisations. However, this would be based on the assertion that the growth in electricity consumption would have been unchanged over the introduction of the CRC in the absence of the policy. While this is always a strong assumption it seems particularly implausible in the present setting where the policy introduction falls within the deepest recession in a generation (between 2008 and 2012). We have therefore chosen to pursue the control group approach.

Using Regression Discontinuity Design (RDD) was also considered. However it cannot be easily implemented as it requires aggregating meter data to organisational level, and ensuring that the level of organisation is equivalent to that used for policy inclusion. This was not possible in practice. Besides, there were not a sufficiently large number of organisations around the 6,000 MWh threshold to support RDD.

2.2. Data sources

2.2.1. Overview

For this project we draw on a number of different data sources, which are discussed in this section in turn. Our main dataset is derived from annual electricity meter point readings, which are collated in a Meter dataset maintained by DECC.

While this dataset provides information on the electricity consumption of the full population of CRC participants and information declarers[3], it does not provide anything else apart from the location of the meter and the name of the associated organisation. In particular it does not provide any information on variables such as the sector of the organisation or other economic variables such as output and employment.

To expand the range of available variables we combine this data with the following additional datasets:

- NEED: a building level dataset provided by DECC
- The Business Structure Database (BSD) provided by the ONS

These datasets are at different aggregation levels from the Meter dataset. In particular in the case of NEED, the database provides data only on a subset of the underlying population, which could raise issues if this subset is somehow not representative.

Also, there is no direct mapping available that links electricity meters to the business data available in the BSD. Hence we have to rely on merging based on postcode and/or company names. This somewhat fuzzy merging process means that we lose some observations or introduce measurement error in the case of mismatches.

Hence basic trade-offs arise as to what kind of dataset to analyse: on the one hand we can work with fewer variables covering a larger part of the underlying observations, or on the other

[3] Indeed the database contains information on all non-domestic consumers of electricity in the UK.

hand we can focus on a wider set of variables at the cost of narrowing the size of the sample, as well risking the introduction of a measurement error.

We proceed below by undertaking analysis within 5 different analysis datasets which provide different trade-offs in terms of number of variables vs. size of sample. The datasets are at different aggregation levels and combine different sets of variables, but the analysis undertaken with each dataset is similar. The pros and cons of the different datasets are summarised in the table below.

Short name	Short Description	Key advantages	Caveats
Electricity Meter Level	Full meter database	• Using complete population	• Narrow set of available variables
Building Level	Aggregating the meter data at the building level and merging with NEED	• Matching on building type possible • Gas consumption data	• Only a sub-sample of the CRC organisations can be used.
Postcode Level	Aggregation at the postcode level. Allows easy merging of nearly the full sample of Meter data with ONS business register data.	• Approximate match with Business Structure Database (BSD) data for nearly the whole population • Matching on industrial sectors possible	• Potential merging error when several organisations share the same postcode
Establishment Level	More precise merging with the ONS data at the level of an establishment = Postcode X Organisation	• Precise match with BSD data	• Reduced sample size
Organisation Level	Combining meter and BSD data at the organisation level	• Can use BSD turnover measure.	• Reduced sample size

Table 3: Descriptions of different datasets used in the analysis

It turns out that our key results are remarkably robust across these different datasets.

Within every analysis dataset we also draw several Analysis Samples. These deal with the issue of policy overlap. A subset of the organisations that are in principle eligible for CRC are already subject to either the EU ETS and/or are part of a Climate Change Agreement.

If this is the case several exemption rules from the CRC may apply:

- Both the ETS and CCA operate at the installation level, which is typically below the organisation level. Any installation that is part of either of those schemes is exempt from the CRC.
- In addition, any other energy consumption by a CCA organisation can be exempt if the share of consumption from the CCA regulated installation is large enough (more than 25% of the organisation's consumption).
- Even if this does not apply at the level of the entire organisation, an organisation can receive an exemption for an entire subsidiary if the unit includes a CCA facility and the 25% rule applies at the level of the subsidiary (see bullet point above). These are referred to as 'member only' (or partial) exemptions.

The DECC Meter Level Dataset records these exemptions, however only at the level of the CRC participating organisation. This is not an issue for organisations that receive an organisation-wide exemption. However, in the case of organisations that receive 'member only' exemptions, applying to some parts of the business, we only know that the organisation has received a partial exemption. We do not know exactly which meters are covered by the exemption and which meters are subject to CRC.

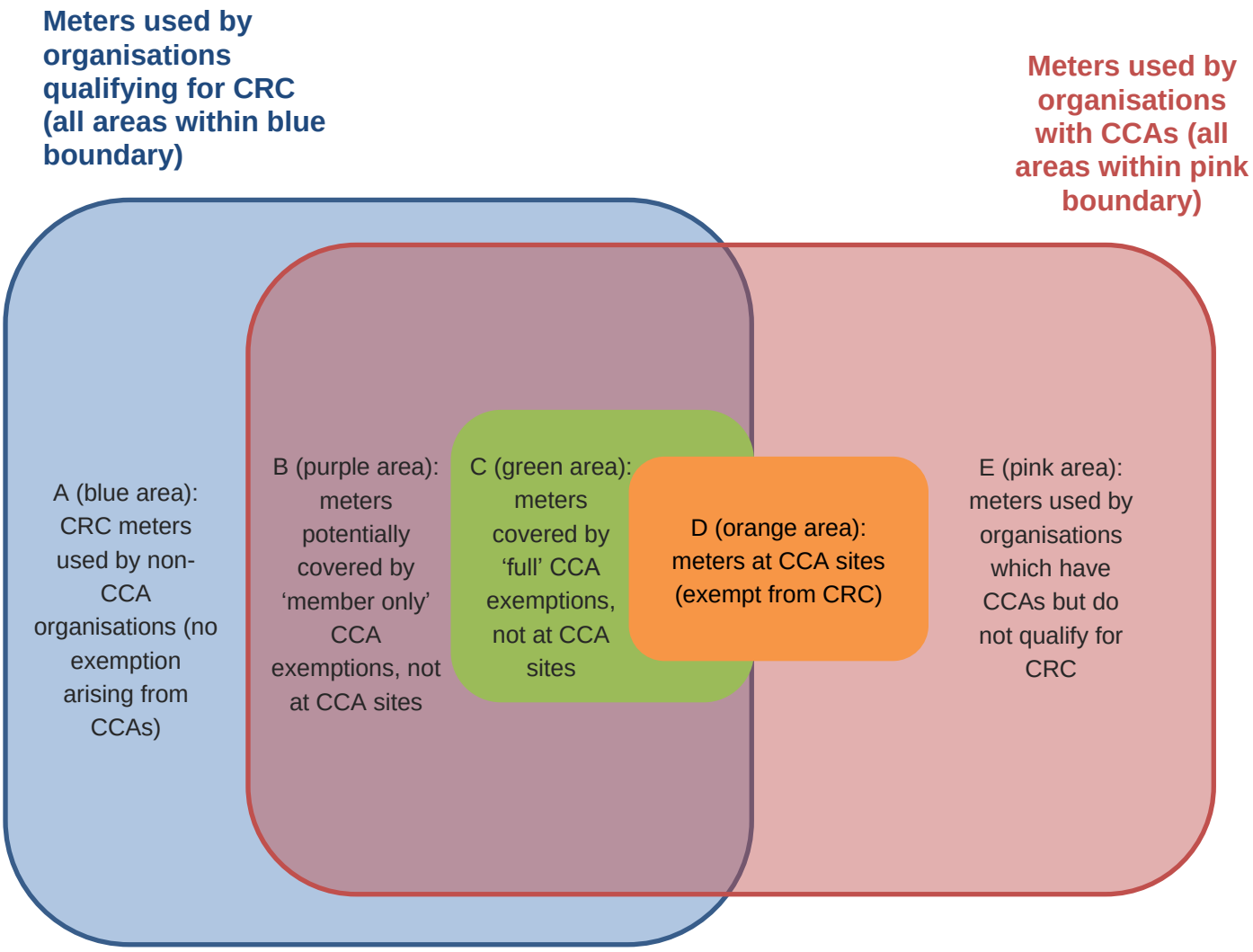
To deal with this we defined two different *Analysis Samples*, which are best understood by reference to Figure 1 below. Both samples include all meter points that are in organisations without CRC exemptions. This corresponds to area A in Figure 1.

- In addition **Analysis Sample 1** includes the meter points of organisations with 'member only' (partial) CCA exemptions that are not at CCA locations; i.e. it includes area B as well as area A. It still excludes areas C, D and E. The idea is that because 'member only' exemptions are granted to organisational units that are associated with a CCA it is plausible that such units (along with their meter points) are geographically close to a CCA installation. Hence meter points that are at the same postcode as a CCA are probably exempt from CRC whereas other meter points in the same organisation are probably not exempt. Of course we can easily imagine cases where this is not necessarily true; e.g. a subsidiary might extend over several locations, so that meters that are not at CCA locations might also be exempt (Error 1). Equally, sometimes organisations have very separate business units combined at the same location so that it might be the case that despite being at the same postcode as the CCA facility of an organisation, a meter might nevertheless be subject to CRC (Error 2). While it would of course be desirable to fully rule out such errors, it is important to realise that they are likely to make our estimates more conservative. Note that in the case of Error 1 we would assign some meters as subject to CRC even though they are not. Hence, if we still find that – on average – there is a CRC effect the true CRC would actually be larger than our estimate. In the case of Error 2 we would simply drop the organisation out of our sample thereby making it smaller, which again leads to lower statistical significance.

- Analysis Sample 2 does not include any additional meter points but simply excludes all meters for organisations with any form of exemption arising from CCAs (including 'member only' (partial) CCA exemptions). It corresponds to area A only in Figure 1. In our results below we find smaller impact estimates with this sample. This makes it tempting to think of Analysis Sample 2 as a more conservative estimate. However, we think that there are two issues to consider here: by dropping meter points associated with CCA exemptions we tend to drop the larger meter points in our sample. Below we show that the impact of CRC tends to be larger for this subset of meter points. Consequently, when dropping these, the average impact for the resulting sample using Analysis Sample 2 becomes smaller. But a second issue however is that our estimate of this smaller impact will be more precise because we dropped all observations that might be subject to measurement error (i.e. meters that were not directly influenced by CRC because of partial CCA exemptions).

Hence, we could think of Analysis Sample 1 as the more 'conservative' sample in that the resulting estimate is biased somewhat towards 0 (being subject to measurement error) relative to the true (although larger) average impact.

Meters located at locations with EU ETS postcodes are excluded from both Analysis Sample 1 and Analysis Sample 2. Exclusion of EU ETS meters is simpler because there is no equivalent of the 25% threshold rule for CCA exemptions.



Sample 1 = area A (blue) + area B (purple)

Sample 2 = area A (blue) only

Figure 1: Definition of analysis samples[4]

[4] Area B (coloured in purple) includes non-CCA-site meters for all parts of organisations with 'member only' CCA exemptions from CRC, because we do not know which meters are covered by the 'member only' exemptions and which are not. Meters in Area B are therefore 'potentially covered' by 'member only' exemptions: they will include some meters on which CRC is paid and some which are exempt from CRC payments.

These **Analysis Samples** are defined at the meter point level **Analysis Dataset**. However we adapt this definition to all other Analysis Datasets accordingly; e.g. at the building level we include a building in analysis sample 1 if all the meter points in the building are part of Analysis Sample 1 at the meter point level. In the following paragraphs we discuss each Analysis Dataset in more detail separately.

2.2.2. DECC meter data

Using information provided by the energy companies about their customers DECC has assembled a dataset with annual electricity consumption at the meter point level. We are using a subset of this dataset, which was created by DECC statisticians by selecting meter points associated with organisations that were selected to be part of the CRC scheme or belonging to the group of so called 'information declarers'. This includes all organisations with at least one settled half-hourly meter.

Row 1 of Table 4 shows basic descriptive statistics for these meters, irrespective of their CRC status. In total we are dealing with just over 100,000 meters of which the majority (78%) are in organisations that meet the 6,000 MWh threshold (CRC eligible meters). In 2008 they were jointly responsible for nearly 128 TWh of electricity consumption. When restricting to Analysis Sample 1 we drop about 10% of meters, which represent nearly 30% of electricity consumption. This is not surprising as both CCA and EU ETS are targeting the most energy intensive sectors. The average electricity usage in meters associated with such organisations, which are excluded from Analysis Samples 1 and 2, is much higher than usage in the rest of the population. Row 5 of Table 4 shows this for EU ETS related meters. Rows 7 to 10 report separate statistics for the different types of exemption types from CRC related to participation in CCAs: meters belonging to organisations with 'General' and 'Group' exemptions are excluded from both Analysis Samples 1 and 2, as are meters at CCA locations which belong to organisations with 'member only' exemptions. Analysis Sample 1 differs from Analysis Sample 2 in that meters belonging to organisations with 'member only' exemptions are included in the Analysis Sample 1 CRC sample, provided that they are not at CCA locations.

Meters in organisations that meet the CRC threshold criterion (shown in row 6) use more energy than the population average, which is in line with expectations. Meters at non-CCA locations belonging to organisations with 'member only' CCA exemptions (which are included in Analysis Sample 1) have slightly higher mean electricity consumption than those with no CCA exemptions (as in Analysis Sample 2), but median consumption is similar.

		Electricity consumption in 2008 (GWh)					
Sample		Mean	Median	95th percentile	Sum	Meters	CRC meters
All data		1.19	0.33	4.36	127,937	107,395	84,683
Meeting CRC criteria		1.34	0.32	5.17	113,374	84,683	84,683
Analysis Sample 1		0.92	0.32	3.42	88,725	96,104	74,848
Analysis Sample 2		0.88	0.32	3.28	77,719	88,389	67,133
Meters with missing postcode		1.17	0.34	4.80	7,317	6,255	4,922
ETS meters		9.48	2.07	43.53	10,179	1,074	951
CCA exemptions	General	4.77	1.65	18.53	2,295	481	479
	Group	6.61	2.34	22.67	18,539	2,803	2,761
	Member only at non CCA locations	1.51	0.31	5.21	12,723	8,442	8,338
	Member only at CCA locations	6.22	2.03	25.52	8,151	1,311	1,293
	None	1.00	0.30	3.89	72,487	72,365	71,811

Table 4: Descriptive statistics for electricity meter data[5]

The main concern from an evaluation point of view is the comparability of meter points in the treatment (CRC) and control groups (InfoDec). Table 5 examines this by showing descriptive statistics for these two groups separately once we restrict the overall population to either of our main analysis samples. Because CRC participation is based on a size threshold in terms of electricity consumption it is not surprising that the mean consumption is higher among CRC meters.

However, it is worth noting that the size threshold applies at the level of the organisation, whereas we are using meter level data. Hence, it is theoretically possible that, where two organisations operate an energy consuming facility of exactly the same type and scale, it would be included in the CRC for one organisation (which operates two or more such facilities) but not for the other (which operates only one such facility and falls below the CRC threshold). Indeed from Table 5 we can see that median meter in either group (CRC and InfoDec) is virtually the same (0.36 compared to 0.30 GWh per meter in 2008). It is only at the very top (e.g. the 95th percentile) that CRC organisations consume more.

[5] This table presents the mean electricity consumption per meter for each sample together with the median and 95th percentile for electricity consumption per meter. The sum is the total electricity consumption across all meters in the sample.

Analysis Sample 1 excludes meter points with missing postcode, meter points with postcodes that appear in the ETS registry as well meter points that are exempt from the CRC because of CCA participation. However, meters of organisations that receive a 'member only' exemption are only excluded if the meter is located at a postcode that is listed in DECC's published list of sites with CCA certificates.

Analysis Sample 2: this is similar to Analysis Sample 1, but it excludes all CRC meters of organisations that are in receipt of any CCA exemption. This will exclude some CRC meters. CCA exemption categories are defined at the organisation level; i.e. we have information that an organisation has an exemption but we do not know exactly which meters the exemption is referring to.

Sample		Electricity consumption in 2008 (GWh) Mean	Median	95th percentile	Sum	Meters
Analysis Sample 1	InfoDec	0.64	0.36	2.24	13,530	21,256
	CRC	1.00	0.30	3.86	75,195	74,848
Analysis Sample 2	InfoDec	0.64	0.36	2.24	13,530	21,256
	CRC	0.96	0.30	3.75	64,188	67,133

Table 5: Comparing treatment and control group for electricity meter sample

Figure 2 shows the normalised distribution of meter points by scale of electricity consumption, for both information declarers and CRC participants. These distributions have been truncated at the 95 percentile (i.e. omitting the highest 5% of meters in each case). The graphs show that the distribution of electricity consumption by meter point is similar for CRC and InfoDec meters, in both Analysis Sample 1 and Analysis Sample 2, up to the 95th percentile. The figure also suggests that CRC meters tend to be slightly smaller than InfoDec meters for most of the distribution, since the red line is below the blue line except for very low consumption meters. Hence finding control group meters comparable in size to treatment group meters should not be an issue. This shows there is common support on consumption levels.

(a) Analysis Sample 1 **(b) Analysis Sample 2**

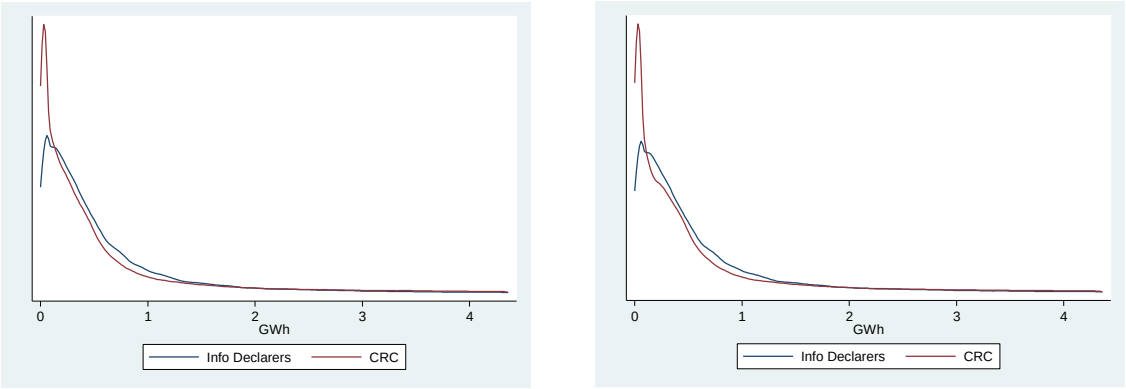


Figure 2: Comparing and control group for electricity meter sample[6]

2.2.3. Building level data

DECC maintains a dataset aggregated to the building level data. Unlike the meter data, which contains the population of meters, the matched NEED data contains only a sample of all buildings in the UK. This is due to the complexity of address matching of non-domestic

[6] The figures show kernel density plots of the distribution of meter point level electricity consumption in 2008 across policy treatment status for Analysis Sample 1 and Analysis Sample 2 respectively. The figures are truncated at the 95th percentile for better readability.

buildings, in comparison to the domestic sector. Non-domestic buildings tend to have more complicated addresses as well as being occupied by more than one organisation (see DECC[7]). The data is therefore still incomplete and should be considered as experimental. However, one of the characteristics available in the database is the electricity meter points associated with a particular building. This makes it easy to combine it with the meter data.

As shown in Table 6, 26% of the meters can be assigned to a building included in the NEED data, representing 26.6% of the electricity consumption in 2008. The descriptive statistics on the electricity consumption in 2008 are for the whole sample of meters of that row, including both CRC and Information Declarers, except for the 3rd row which shows only those meters which can be matched in NEED and also meet CRC criteria. Meters matched to NEED display a slightly higher consumption throughout the distribution than the non-NEED data: presumably this is a consequence of NEED being somewhat biased towards larger organisations. If considering CRC meters more specifically, 25.2% are matched to NEED. When focussing on Analysis Samples 1 and 2, these proportions are nearly identical with respectively 26.6% and 26.2% of meters included in the Building level data. As in the meter dataset, meters in these samples display lower mean energy consumption, driven by some of the highest GWh values meters not being part of the samples (because of the exclusion of meters belonging to organisations which have full exemptions from CCAs and EU ETS).

	Electricity consumption in 2008 (GWh)					
Sample	Mean	Median	95th percentile	Sum	Meters	CRC meters
All non-NEED data	1.18	0.30	0.76	93,955	79,437	63,374
All NEED data	1.22	0.40	0.88	33,982	27,958	21,309
CRC meters in 'All NEED data' sample	1.38	0.40	0.91	29,419	21,309	21,309
Building level Analysis Sample 1	0.89	0.38	0.79	22,717	25,614	19,216
Building level Analysis Sample 2	0.87	0.40	0.80	20,187	23,184	16,786

Table 6: Descriptive statistics for electricity meter data included in NEED[8]

Table 7 reports the mean electricity consumption per meter within each Analysis Sample. As for Table 5 above, it is higher for CRC meters than InfoDec meters (0.96 compared to 0.68 GWh per meter in 2008 for Analysis Sample 1): again, this is driven by some high-consumption meters as the median values are very similar. Note however that the distribution of consumption for Analysis Samples 1 and 2 are very similar when we only look at datapoints that can be matched to the NEED dataset. This was not the case in the Meter level data shown in Table 5 above, in which it appeared that Analysis Sample 1 included more high consumption CRC meters than Analysis Sample 2. This disparity between the Building and Meter level data stems from the NEED database that might for example not include higher consumption sites that have more 'complicated' addresses.

[7] See "The non-domestic National Energy Efficiency Data-Framework (ND-NEED)", https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/314725/non_domestic_need_framework.pdf (DECC, 2014).

[8] Descriptive statistics in columns 1 to 4 are for the whole sample described by the 'Sample' column. The number of meters in that sample is stated in the 'Meters' column. The number of these meters that are part of the CRC are stated in the 'CRC Meters' column.

Sample		Electricity consumption in 2008 (GWh) Mean	Median	95th percentile	Sum	Meters
Analysis Sample 1	InfoDec	0.68	0.41	0.82	4,363	6,398
	CRC	0.96	0.37	0.78	18,354	19,216
Analysis Sample 2	InfoDec	0.68	0.41	0.82	4,363	6,398
	CRC	0.94	0.39	0.79	15,824	16,786

Table 7: Comparing treatment and control group for electricity meters in the building level dataset

The meter data is aggregated at the building level using the UPRN (Unique Property Reference Number). A building is considered as participating in the CRC if at least 50% of its electricity consumption in 2008 is accounted for by meters that are themselves part of the CRC, according to the criteria set for each sample. We drop from the sample buildings that have a positive but less than 50% share of CRC covered electricity, which for Analysis Sample 1 represents close to 20% of the total meter consumption (see footnote 6). Also, when aggregating the two Analysis Samples, buildings are only included if all meters in the building are part of the given sample.

As a result of this aggregation, Table 8 shows that 18,922 buildings constitute Analysis Sample 1 at the Building level, with 14,351 of them part of the CRC. Analysis Sample 2 has as expected slightly fewer CRC buildings, but it is interesting to note that their electricity consumption distribution is very similar to that of Analysis Sample 1.

No records of gas meters are held by the Environment Agency. Therefore, one of the benefits of exploiting the NEED dataset is that for 7,997 buildings (42%) in the case of Analysis Sample 1 (and 44% in the case of Analysis Sample 2), a positive consumption of gas is reported. This allows us in the next section to analyse the effect of the CRC on gas consumption too.

Sample			Energy consumption in 2008 (GWh) Mean	Median	95th percentile	Sum	Buildings
Analysis Sample 1	InfoDec	Elect.	0.74	0.43	0.88	3,400	4,571
		Gas	1.04	0.41	1.09	2,220	2,135
	CRC	Elect.	1.01	0.37	0.78	14,539	14,351
		Gas	1.00	0.33	0.98	5,881	5,862
Analysis Sample 2	InfoDec	Elect.	0.74	0.43	0.88	3,376	4,567
		Gas	1.04	0.41	1.09	2,217	2,133
	CRC	Elect.	1.01	0.39	0.80	12,511	12,346
		Gas	0.93	0.34	0.98	4,937	5,328

Table 8: Comparing treatment and control group for buildings

As reported for the full dataset of meters, Figure 3 shows the normalised distribution by scale of electricity consumption, for meter points included in the Building level dataset. The distributions have been truncated at the 95th percentile (i.e. the highest 5% of meters have been omitted). As in Figure 2, the distribution is similar for CRC and InfoDec meters, in both Analysis Sample 1 and Analysis Sample 2, up to the 95th percentile. This shows common support in terms of energy consumption.

In addition to information on gas consumption, the NEED data brings information about the building's type, allowing the analysis in section 3.2 to differentiate the effect of CRC between these categories. Figures 4 and 5 show respectively for Analysis Samples 1 and 2 the number of buildings of each type included in the Building level datasets. In both cases there is a dominance of 'Shop and premises' category, which also includes warehouses. A large proportion of these are part of the CRC. The figures exclude buildings of 'Unknown' type.

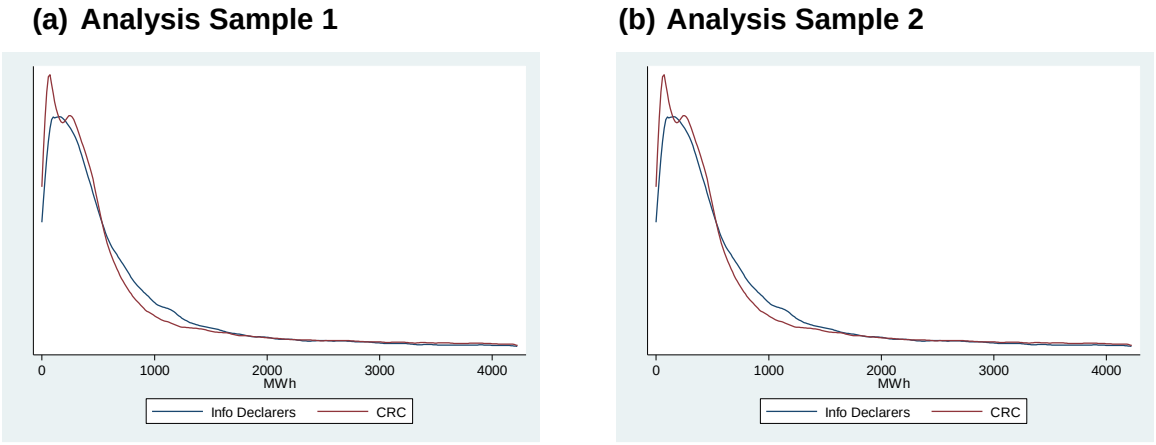


Figure 3: Treatment and control group for electricity meter sample – building dataset

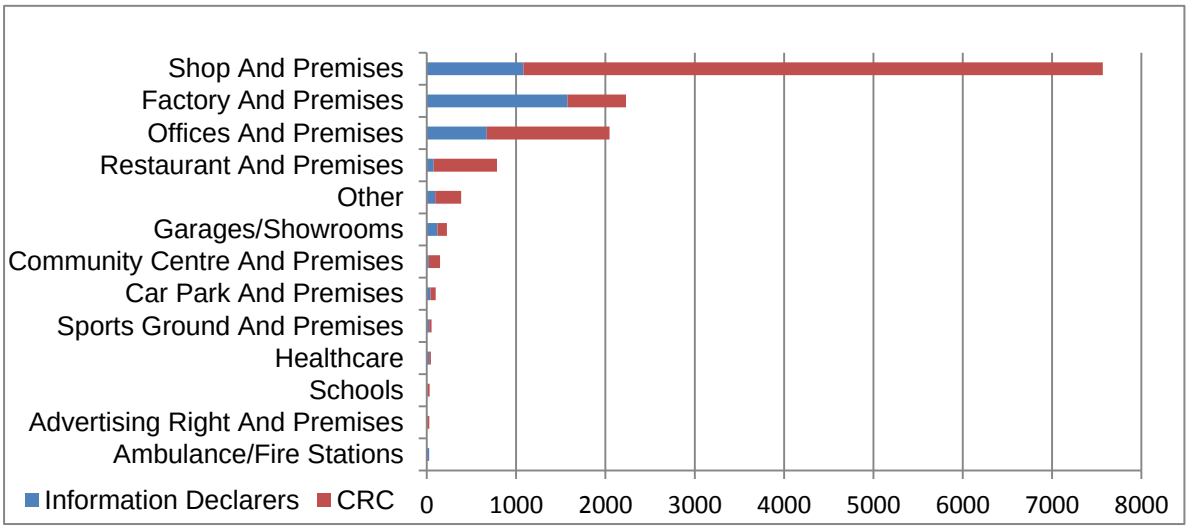


Figure 4: Number of buildings in Analysis Sample 1, per building type in 2008 building level dataset

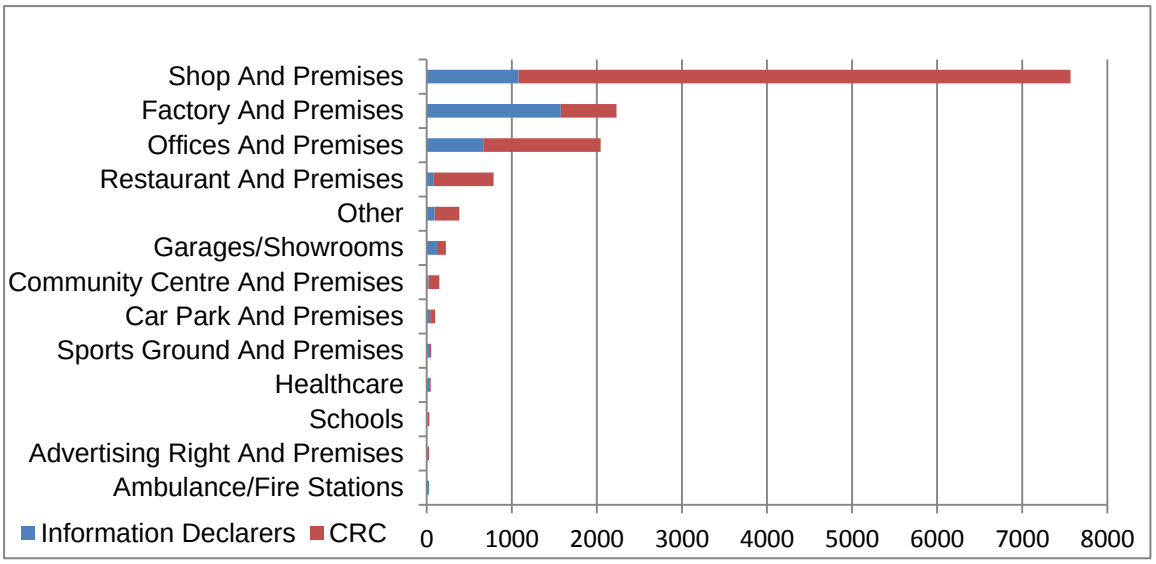


Figure 5: Number of buildings in Analysis Sample 2, per building type in 2008 building level dataset

2.2.4. Postcode level data

In addition to data on energy use we are interested in other economic data, which we incorporate by using the ONS Business Structure database (BSD). The BSD provides historic information from the UK government's Inter Departmental Business Register (IDBR). Unfortunately, the Meter dataset maintained by DECC and described in section 2.2.2 does not record any identifiers that would allow an immediate link to the IDBR.

Thus as a first step, to examine the robustness of our results, we combine the Meter and BSD datasets using postcode information only. This means that we are able to merge all meters with postcode information, which is virtually the complete population. The drawback is that in some cases there are multiple organisations at the same postcode which implies that we potentially have some measurement error. This would primarily be a concern if not all the organisations at the same postcode shared the same CRC status. Nevertheless, we mitigate this possibility by excluding postcodes where we have evidence that not all meters at the postcode share the same CRC status. This will add some bias as smaller buildings are likely to be more affected by this than larger ones, so the matched sample may have some bias towards larger buildings. In addition, to construct the equivalent of Analysis Samples 1 and 2 at the meter level we only include postcodes where all meters are included in Analysis Samples 1 and 2 at the organisation level.

Table 9 reports descriptive statistics on the resulting samples. Despite the additional restrictions we account for nearly 70% of the energy consumption in both Analysis Samples 1 and 2. The mean and average consumption are slightly larger in the resulting sample (shown in Table 9) than in the original meter level dataset (shown in Table 4). This is most likely a consequence of the aggregation of meters rather than bias in this sample.

	Electricity consumption in 2008 (GWh)					
Sample	Mean	Median	95th percentile	Sum	Postcodes	CRC postcodes
All data	1.62	0.40	5.84	111,772	69,002	55,892
With meter meeting CRC criteria	1.82	0.38	7.03	101,609	55,891	55,892
Analysis Sample 1	1.17	0.37	4.19	61,399	52,328	41,248
Analysis Sample 2	1.13	0.38	4.08	53,001	46,896	35,816

Table 9: Descriptive statistics for electricity meter data at the postcode level[9]

2.2.5. Establishment level data

By establishment we mean all facilities of a given organisation at the same location (defined by postcode). Note that establishments are below the organisational level and that a CRC organisation could be composed of several establishments. Compared to the postcode level database discussed above, we are able to distinguish between multiple active organisations at the same postcode, by using the company name made available in the Meter data as an additional matching criterion. Because of spelling variations and mistakes this can be challenging. An additional problem arises because the UK Data Service Secure Lab (UKDS) through which the BSD data is accessed removes company names for confidentiality.

To work around this we have relied on several steps. Firstly, on the basis of company names we combined, outside the UKDS Lab, meter points with Company's House Company Register Number (CRNs). The UKDS provides a look-up from CRNs to the company number system used by the IDBR. We rely on this to combine the Meter data with the BSD and to disambiguate in cases where several organisations share a particular postcode. If we fail to disambiguate (because we do not get a CRN match at any stage) we do not include the organisational units at this particular postcode.

This means that the resulting dataset will only cover a sample of the underlying population. This is not necessarily a problem as long as the resulting sample is representative.

As Table 10 shows this reduces our sample considerably both in terms of the meters included but also in terms of the electricity consumption covered. Both Analysis Samples 1 and 2 now only cover about 25% of the energy consumption of the Analysis Samples 1 and 2 at the meter point level and just under 40% of the postcode level dataset. However, comparing mean, median and 95th percentile of the resulting distribution looks very close to the postcode level dataset, which gives confidence that it is a representative sub-sample (i.e. comparing rows 3 and 4 between Tables 9 and 10).

[9] To obtain Analysis Samples 1 and 2 we restrict the sample to postcodes where all meters at a given postcode are included in Analysis Samples 1 and 2 at the meter point level. Moreover, we only include postcodes where all meters have a uniform treatment status.

	Electricity consumption in 2008 (GWh)					
Sample	Mean	Median	95th percentile	Sum	Establish-ments	CRC Establish-ments
All data	1.84	0.50	6.37	37,421	20,344	14,469
CRC establishment	2.24	0.51	8.20	32,445	14,469	14,469
Analysis Sample 1	1.21	0.47	4.41	22,836	18,928	13,082
Analysis Sample 2	1.15	0.47	4.31	20,676	18,057	12,211

Table 10: Descriptive statistics for electricity at the establishment level[10]

In Table 11 we also report descriptive statistics on electricity intensity measured as electricity consumption over employment. The purpose of reporting this here is primarily to inform other workstreams in the CRC evaluation, by checking the descriptive statistics of the samples and control groups used in quantitative research. While the means differ between some of the CRC and information declarer comparison groups, the medians are broadly similar. This data is analysed further in the final synthesis report for the evaluation.

[10] To obtain Analysis Samples 1 and 2 at the establishment level we only include establishments where all meter points are included in Analysis Samples 1 and 2 at the meter point level.

		Electricity intensity in 2008 (GWh per employee)				
Sample / Type of organisation		Mean	Median	95th Percentile	Establish-ments	CRC Establish-ments
All data		0.09	0.01	0.25	20,302	14,469
CRC establishment		0.11	0.01	0.30	14,469	14,469
Analysis Sample 1		0.07	0.01	0.25	18,894	13,082
Analysis Sample 2		0.07	0.01	0.24	18,024	12,211
Not interviewed in quantitative research	Private Sector CRC above 75th percentile	0.08	0.01	0.21	6,998	6,998
	Private Sector CRC 50 to 75th percentile	0.06	0.01	0.17	1,181	1,181
	Private Sector CRC 25th to 50th percentile	0.04	0.01	0.12	789	789
	Private Sector CRC 0 to 25th percentile	0.05	0.01	0.18	409	409
	Private sector InfoDec above 3GWh in 2008	0.07	0.01	0.19	1,079	
	Public sector CRC above 50 percentile	0.15	0.01	0.57	742	742
	Public sector CRC below 50 percentile	0.11	0.00	0.47	167	167
	Public Sector InfoDec above 2GWh in 2008	0.18	0.01	1.33	55	
	CRC with exemptions	0.25	0.05	0.58	2,364	2,364
Interviewed in quantitative research	Private Sector CRC above 75th percentile	0.16	0.01	0.57	1,434	1,434
	Private Sector CRC 50 to 75th percentile	0.03	0.01	0.13	340	340
	Private Sector CRC 25th to 50th percentile	0.06	0.01	0.25	259	259
	Private Sector CRC 0 to 25th percentile	0.05	0.01	0.20	113	113
	Private sector InfoDec above 3GWh in 2008	0.07	0.02	0.18	227	
	Public sector CRC above 50 percentile	0.06	0.01	0.25	136	136
	Public sector CRC below 50 percentile	0.10	0.01	0.51	33	33
	Public Sector InfoDec above 2GWh in 2008	0.17	0.01	1.33	29	
	CRC with exemptions	1.25	0.06	2.14	164	164

Table 11: Descriptive statistics for electricity intensity at the establishment level

2.2.6. Organisation level data

Turnover information is available in the BSD only at the organisation not the local unit or establishment level. Hence, in order to analyse effects of the CRC on energy intensity in terms of turnover, we need to work at this level. Employment is also available at the organisation level, allowing us to further confirm our findings from the postcode and establishment level data on energy efficiency/intensity.

As far as the energy data is concerned this involves simply aggregating the establishment level data to the organisation level. However, there is a potential complication to this aggregation in that we might not have been able to merge all establishments of a given organisation with the BSD. In order to be conservative, we consequently only include organisations in the organisation level dataset if we have been able to merge all establishments within an organisation. This is a crucial element of the organisation-level analysis, as we want to be able to compare the aggregated electricity consumption to the correct level of employment or turnover and can therefore only do so if we have included all parts of the organisation that have contributed to the turnover or total employment measure.

This aggregation leads to a database of 3,450 organisations as shown in Table 12, of which 626 are part of the CRC. An organisation is considered as part of the CRC if 50% of its electricity consumption is made at sites that are regulated by the CRC.[11] As can be seen from the second row, these are organisations that have a much higher energy consumption than average, at every point of the distribution. In order to obtain samples that are comparable to Analysis Samples 1 and 2, we aggregate the establishment level samples to the organisation level using the same criteria: an organisation is only included in the organisation level Analysis Sample 1/2 if we have been able to merge all of its establishments from Analysis Sample 1/2 to the BSD. Due to this requirement, which is necessary to ensure representativeness of the organisation-level data, the difference between the resulting Analysis Sample 1 and 2 is very minor. The two Analysis Samples include smaller electricity consumers than the whole sample which is likely to be due to the most energy intensive organisations being part of CCAs or EU ETS and therefore being exempt from CRC.

	Electricity consumption in 2008 (GWh)					
Sample	**Mean**	**Median**	**95th percentile**	**Sum**	**Firms**	**CRC Firms**
All data	2.31	0.67	8.12	7,982	3,450	626
With meter meeting CRC criteria	8.38	3.78	27.61	5,244	626	626
Analysis Sample 1	1.36	0.60	1.34	4,339	3,186	377
Analysis Sample 2	1.36	0.60	1.34	4,310	3,173	367

Table 12: Descriptive statistics for electricity at the organisation level

In the resulting organisation level Analysis Sample 1, we compare CRC and information declarer organisations in terms of their aggregate electricity consumption, employment and turnover. Table 13 shows that CRC organisations are larger in terms of all three variables and across the distribution. This is also true of course for Analysis Sample 2, as shown in Table 14.

[11] We also experimented with different rules at this point. Specifically we looked at firstly keeping all buildings and setting the CRC indicator at the building level to 1 if at least one meter in the building is covered by CRC and secondly at keeping only buildings where all meters have the same status. The basic pattern of results emerges in either case. However, in the first case some of the effects are a bit smaller and less significant, which is in line with expectations. If not all meters are covered then the treatment effect measured at the building level should be smaller.

Variable		Mean	Median	95th percentile	Sum	Firms
Electricity consumption in 2008 (GWh)	InfoDec	0.97	0.54	3.37	2,714	2,809
	CRC	4.31	1.57	15.80	1,625	377
Employment in 2008	InfoDec	79.41	48.50	255.00	222,988	2,808
	CRC	261.86	130.00	973.00	98,721	377
Turnover (in Thousands GBP) in 2008	InfoDec	11.77	4.12	35.00	33,052	2,808
	CRC	297.70	12.87	305.02	112,232	377

Table 13: Comparing treatment and control group for organisation level Analysis Sample 1

Variable		Mean	Median	95th percentile	Sum	Firms
Electricity consumption in 2008 (GWh)	InfoDec	0.97	0.54	3.37	2,714	2,808
	CRC	4.44	1.66	16.26	1,301	293
Employment in 2008	InfoDec	79	49	255	222,982	2,807
	CRC	254	130	1,013	74,522	293
Turnover (in Thousands GBP) in 2008	InfoDec	11.77	4.12	35.00	33,048	2,807
	CRC	344.16	11.94	330.04	100,838	293

Table 14: Comparing treatment and control group for organisation level Analysis Sample 2

In the results below, we will see that using organisation-level data brings a useful dimension to our analysis.

3. Results

3.1. Meter point level

3.1.1. Results for sample as a whole

Figure 6 and Table 15 show our main results for the meter level dataset. We consider several different sets of explanatory variables[12] to illustrate the robustness of our results. Throughout our analysis, to ensure efficiency, we choose the smallest set of matching variables that allows the alignment of pre-treatment trends between the treatment and control group.

We first consider results where we match treatment and control organisations on the basis of 5 energy consumption bands defined on the basis of quintiles of the 2008 distribution of electricity consumption. These are reported in Panels a) and c) of Figure 6 and columns 1 and 3 of Table 15 for Analysis Samples 1 and 2 respectively. The graphs show how after 2009 a significant gap emerges between treatment (CRC) and control (InfoDec) meters.

In Table 15, the coefficient for the 'dummy for CRC meter in years before the introduction of the policy' is the coefficient for 'difference-in-differences' between CRC and InfoDec observations prior to the CRC. If pre-treatment trends were similar between these two groups, we would not expect a significant value for this coefficient: we would expect this co-efficient to be close to zero. 'Dummy for CRC meter in years after the introduction of the policy' is the coefficient for 'difference-in-differences' between CRC and InfoDec observations after introduction of the CRC. If the CRC had the impact of reducing emissions from CRC meters, compared to InfoDec meters, we would expect this to be negative and statistically significant, as is the case here. We see that when averaging across the three post treatment years (2010, 2011 and 2012) the gap corresponds to between 0.056 and 0.071 log point. This can approximately be interpreted as the percentage difference between the two groups[13]; i.e. CRC meters have on average a reduction in emissions over the introduction of CRC that is 5.6 to 7.1% lower than any reduction that occurred in InfoDec meters within the 5 electricity consumption bands.

While this is encouraging, note that in those results our criterion of similar pre-treatment trends is not met. For both samples, the regression table shows pre-treatment coefficients that are significantly different from zero. In panels a) and c) of Figure 6 it is also easy to see there is a divergence between the two series in 2007. In order to control for these pre-treatment trends and compare meters that appear similar before the introduction of the CRC, we experimented with a number of approaches to address this. Firstly, we tried to increase the number of size bands, however the gap remained. We then included average growth rates before 2009 as explicit matching variables.[14] Indeed it was only after including 25 bands defined by splitting the

[12] As described in section 2.1, this implies that we explore different criteria for matching treatment and control groups.

[13] This interpretation will be used throughout this report.

[14] We do not include 2009 in the calculation of these trends to avoid including CRC 'announcement' effects, occurring after the Climate Change Act 2008 (which set up enabling powers for the CRC in November 2008) but prior to CRC implementation. This could have created an 'endogeneity problem' by including CRC influence in our independent explanatory variables. Note that this would not address if firms had already have been influenced by the CRC before 2009 by the CRC which is a remote possibility as the content of the Climate Change Act was

distribution of average pre-2009 growth rates into 4 percentile bands that the pre-treated differences fully disappeared.[15] [16] These are the results that are reported in columns 2 and 5 of the Table and panels b) and d) of the Figure. Hence, while point estimates drop somewhat they are still highly significant and of comparable order of magnitude ranging between 3.7 and 5.1% in the two samples.

As a further robustness check we report in columns 3 and 6 of Table 15 results where we double the number of consumption level bands (i.e. we include bands defined by 10 percentiles rather than quintiles). This has virtually no effect on the resulting point estimates.

Note that throughout this report, matching variables may vary with their availability within datasets at different aggregation levels (e.g. we can only match on sector in those datasets where we have sector variables from the ONS). Including more matching variables was necessary in some specifications necessary to achieve balancing in terms of pre-treatment trends.[17]

obviously discussed before 2007. In un-reported results we therefore also experimented with specifications where matching was entirely based on pre 2007 data. However, this lead to similar results, hence we conclude that this is not a major concern.

[15] We have kept similar matching variables in all specifications using meter level data, NEED data and postcode level data.

[16] This is not just a statistical fix in order to get rid of the pre-treatment gap. Rather, this is about finding a grouping of observational units so that within those groupings treatment and control groups show broadly similar growth trends before the introduction of the policy. Consequently, if subsequent to the policy within those same groupings growth trends diverge strongly, it is more suggestive of a causal policy impact.

[17] For example, different matching variables were used in analysis at establishment and organisational levels, which involved analysis of employment and turnover data.

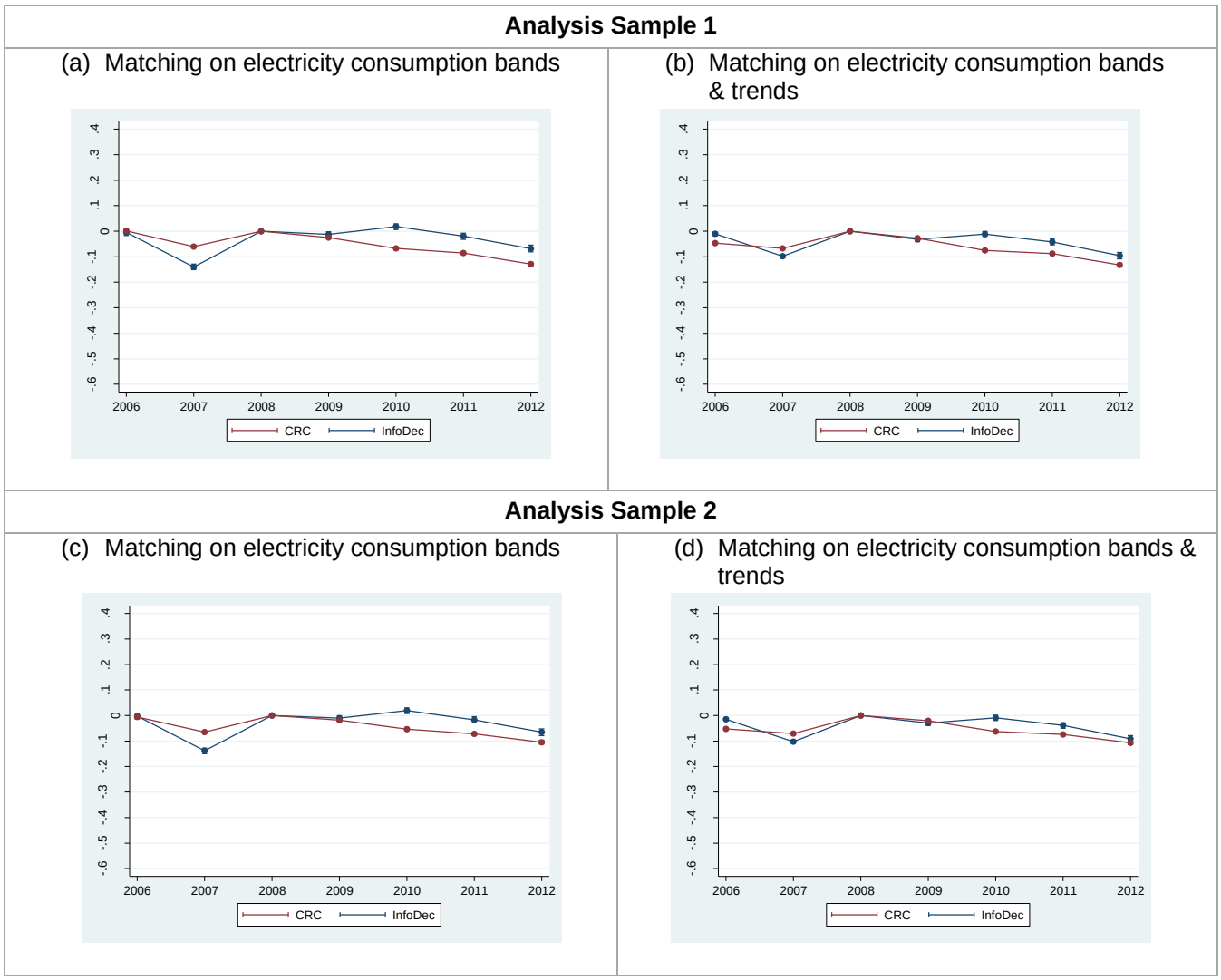


Figure 6: Difference-in-Differences (DiD) results for electricity meter points by year – whole sample[18]

In some of our specifications, including some reported in the following sections, it would appear that any gap between CRC and InfoDec meters declines over time, particularly in 2012. There are four possible explanations:

i. This is a statistical fluke, attributable to one year's data (2012).

ii. Because certain aspects of the CRC policy package were dropped (in particular revenue recycling), the policy had less impact over time.

[18] These figures display, for Analysis Sample 1 (panels (a) and (b) and Analysis Sample 2 (panels (c) and (d)) and for two different matching sets of variables, the average log changes of meter point electricity consumption (relative to 2008) separately for CRC organisations and InfoDec organisations between 2006 and 2012. The vertical bars, although sometimes so small they appear as points, represent the 95% confidence interval. It is not straightforward to establish a one to one relationship between columns of regression Table 15 and the panels of the figures. This is why the tables include descriptions of the specifications. This applies to all results in the report. All time-series results for meter level analysis are based on matching on 20 percentile electricity bands and 4 percentile electricity growth bands.

iii. CRC triggered only a speeding up of energy consumption saving measures so that InfoDec organisations eventually caught up.

iv. The reference year for CRC phase 2 ran from 1st April 2012 to end March 2013, covering most of the 2012 financial year. InfoDec organisations near the threshold had a strong incentive to reduce their electricity consumption in this year to avoid being part of CRC in phase 2.

It was beyond the scope of this paper to distinguish between these different explanations. However, it is something to keep an eye on in future research.

	OLS regression					
Dependent Variable	(log) Change in Electricity consumption relative to 2008					
Sample	Analysis Sample 1			Analysis Sample 2		
	matching on the **2008 electricity consumption in 20 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**	matching on the **2008 electricity consumption in 10 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**	matching on the **2008 electricity consumption in 10 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**
Explanatory variables						
Dummy for CRC meter in years before the introduction of the policy	0.024***	0.001	-0.001	0.021***	0.001	-0.000
	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
Dummy for CRC meter in years after the introduction of the policy	-0.071***	-0.049***	-0.051***	-0.056***	-0.035***	-0.037***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Number of Meters	96104	96104	96104	88389	88389	88389
Number of Observations	641404	641404	641404	589725	589725	589725
R-squared	3.5%	25.1%	26.0%	3.4%	25.5%	26.4%

Table 15: DiD results for electricity meter points by period – whole sample[19]

[19] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

3.1.2. Results by electricity consumption band

In this section we examine whether the overall CRC effect found earlier varies by size (in terms of electricity consumption in the base-year of 2008). For simplicity we rely on the 5 20-percentile electricity consumption bands used as the first set of matching variables in our results above and report separate results for each band (because of time constraints on the analysis, we are reporting Analysis Sample 1 only).

Table 16 reports descriptive statistics separately for the five consumption bands. Table 17 reports regressions results. These are also represented in Figure 7. We see statistically significant differences between CRC and information declarer groups within all five consumptions bands. Point estimates are not uniform, however. The largest effect emerges in the 0 to 20-percentile band with a CRC post treatment effect of 11%. However, note from Table 16 (row 1) that this consumption band is responsible for less than 1% of electricity consumption. Effects are lower in the middle consumption bands: around 3% for bands 2 to 4. Interestingly the effect increases again to 5% for the top band.

This u-shaped pattern is consistent with the following two explanations. On the one hand, the higher a facility's energy consumption, the more salient and important for the bottom line is an optimal response to energy pricing. Hence the same price effect triggers a stronger response. On the other hand for very small energy consumers, the auxiliary polices surrounding CRC might for the first time have triggered concern for energy by management at which point 'low hanging fruit' measures were implemented. Such measures would have been exploited in more energy intensive facilities long before the introduction of the CRC.

		Electricity consumption in 2008 (GWh)						
Sample	Percentile Band	Mean	Median	95th Pecentile	Sum	Share of sum	Meters	Share of Meters
Analysis Sample 1	20	0.03	0.02	0.07	512	0.58%	19,815	20.62%
	40	0.15	0.15	0.22	2,944	3.32%	19,839	20.64%
	60	0.34	0.33	0.44	6,621	7.46%	19,737	20.54%
	80	0.67	0.64	0.98	13,151	14.82%	19,494	20.28%
	100	3.80	2.07	10.87	65,497	73.82%	17,219	17.92%
CRC in Analysis Sample 1	20	0.03	0.02	0.07	408	0.64%	16,913	22.60%
	40	0.15	0.14	0.22	1,864	2.90%	15,267	20.40%
	60	0.34	0.33	0.44	4,489	6.99%	14,789	19.76%
	80	0.67	0.63	0.97	8,606	13.41%	14,167	18.93%
	100	4.08	2.22	11.76	48,821	76.06%	13,712	18.32%

Table 16: Descriptive statistics across electricity consumption bands – Analysis Sample 1

	OLS regression				
	matching on average **pre-2009 electricity consumption growth (4 percentile bands)**				
Dependent Variable	**(log) Change in Electricity consumption relative to 2008**				
Percentile Band	**0-20**	**20-40**	**40-60**	**60-80**	**80-100**
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	0.005	0.003	-0.003	0.004	0.003
	(0.012)	(0.004)	(0.003)	(0.003)	(0.004)
Dummy for CRC meter in years after the introduction of the policy	-0.113***	-0.034***	-0.029***	-0.036***	-0.050***
	(0.028)	(0.011)	(0.008)	(0.008)	(0.010)
Meters	19815	19839	19737	19494	17219
Observations	123063	132576	133921	133510	118334
R-squared	31.9%	25.2%	23.8%	20.3%	20.0%

Table 17: Regressions results by electricity consumption band – Analysis Sample 1[20]

[20] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors. Each column reports the results of the regression for a given quintile's sample. The percentile band row indicates which quintile the column refers to. The matching is based on consumption growth only, because of the analysis being undertaken by consumption band.

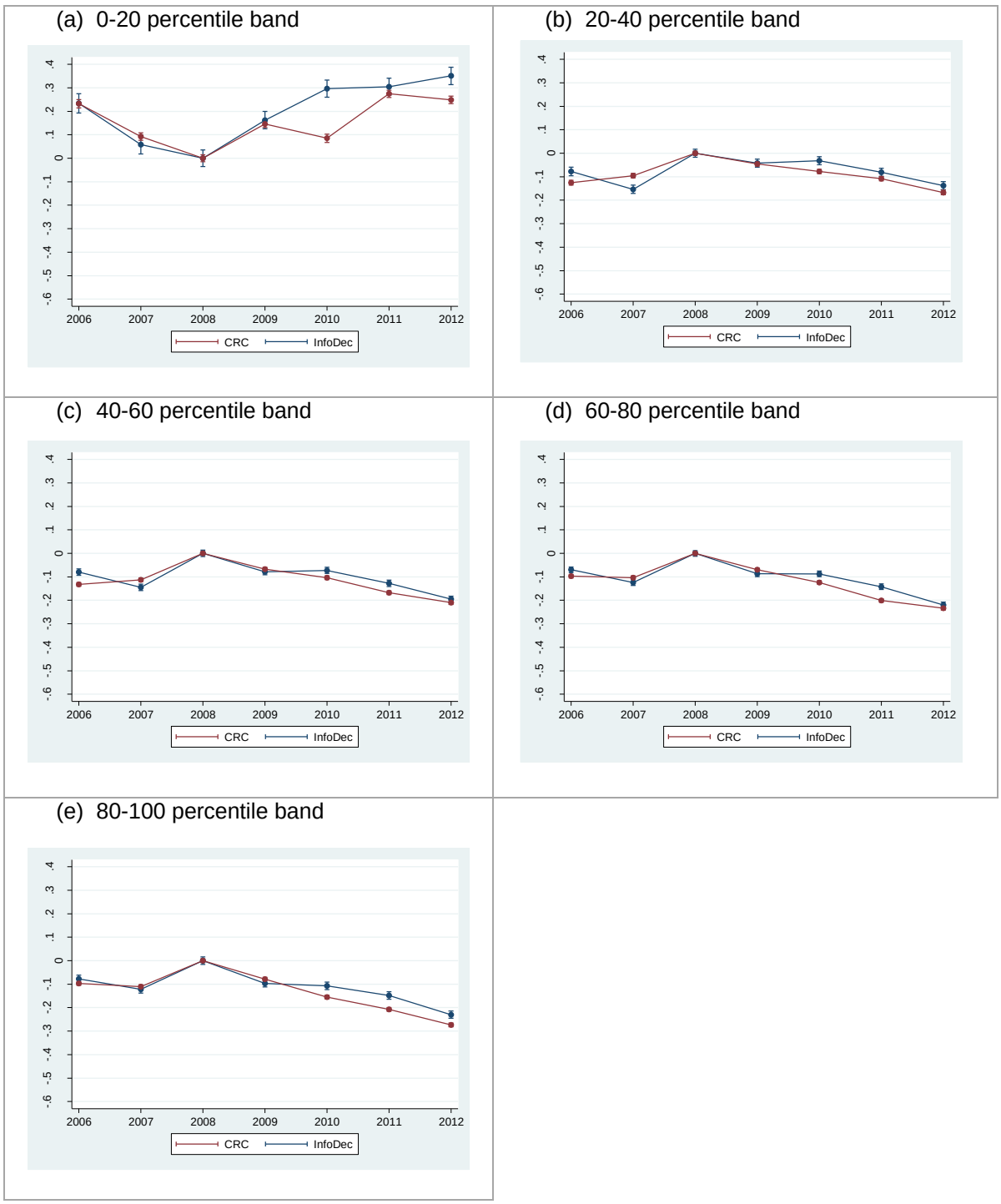


Figure 7: Results by electricity consumption band – Analysis Sample 1[21]

[21] See notes to Figure 6. Each panel corresponds to a quintile in terms of electricity consumption in 2008. All time-series results at meter level are based on matching on 20 percentile electricity bands and 4 percentile electricity growth bands.

3.2. Building level (NEED)

In this section we report CRC impact results on the basis of the approximately 25,000 meter points that we match to the NEED dataset.[22] The results on electricity consumption are based on the aggregation of meter consumption at the building level, whilst the results on gas are based on the data available through NEED.

3.2.1. Electricity

The regression results for electricity in the case of Analysis Samples 1 and 2 are presented in Figure 8 and Table 18. As in the results at the Meter level described in the previous subsection, two sets of matching variables are implemented. First, we use five energy consumption bands (defined on the basis of quintiles of the 2008 electricity consumption distribution) to match treatment and control organisations. Columns 1 and 3 of Table 18 and panels a) and c) of Figure 8 show that this matching results in an estimated significant impact of CRC in the range of -7.8% and -4.7%. But such matching results in balance problems during the pre-treatment period, as can be seen by the significant and positive coefficients for the pre-CRC dummy.

As in section 3.1, we add matching variables to ensure the meters we compare did not differ before the introduction of the CRC. We thereby increase the robustness of our results and meet the requirement that matched pre-treatment and treatment groups should have similar trends in the pre-treatment period. As for the meter level analysis presented in section 3.1, we match on 25 bands with a 4 percentile point width of the average electricity consumption growth before 2009. Panels b) and d) of Figure 8 and columns 2 and 4 of Table 18 show that this successfully controls for pre-treatment trends with the estimates of any pre-CRC effect now economically and statistically insignificant. With Analysis Sample 1, the point estimates of the CRC impact is slightly reduced to 6% but it remains significant at the 1% level. For Analysis Sample 2, the impact of the CRC is insignificant in this case. We show below that this could be due to the types of buildings and meter points that drop out between Analysis Sample 1 and Analysis Sample 2. Analysis Sample 2 includes fewer factories than Analysis Sample 1, yet these are buildings where the CRC impact is likely to be strong because of their higher electricity consumption (as seen in the analysis of CRC impact by meter consumption band in section 3.1.2).

[22] For details on the dataset see Section 2.2.3.

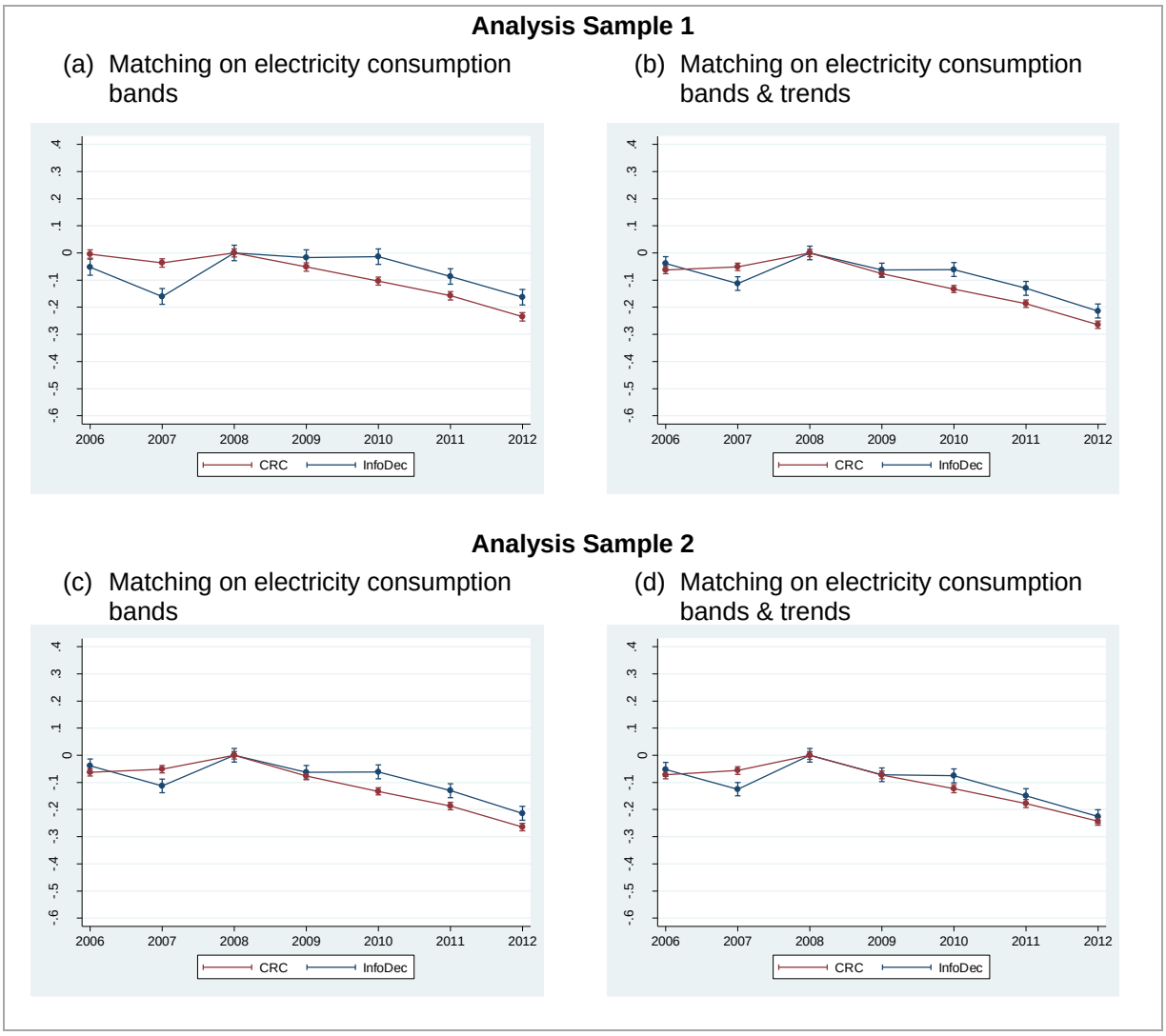


Figure 8: DiD results for building level electricity data by year[23]

[23] See notes to Figure 6. All time-series results at building level are based on matching on 20 percentile electricity bands and 4 percentile electricity growth bands.

	OLS regression			
Dependent Variable	(log) Change in Electricity consumption relative to 2008			
Sample	Analysis Sample 1		Analysis Sample 2	
	matching on the **2008 electricity consumption in 20 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**
Explanatory variables				
Dummy for CRC meter in years before the introduction of the policy	0.045***	0.009	0.049***	0.018
	(0.014)	(0.010)	(0.015)	(0.011)
Dummy for CRC meter in years after the introduction of the policy	-0.078***	-0.060***	-0.047**	-0.031
	(0.021)	(0.021)	(0.023)	(0.022)
Controlling for building type	yes	yes	yes	yes
Buildings	13330	12960	11865	11524
Observations	89987	88084	80164	78501
R-squared	2.9%	20.9%	2.8%	21.8%

Table 18: DiD regression results for building level electricity[24]

3.2.2. Results by electricity consumption bands

As derived at the Meter level, we examine in this section 'difference-in-differences' between CRC and information declarers with Building level data across a range of electricity consumption bands, based on consumption per building. Table 19 shows that the distribution of buildings across the five electricity consumption bands results in mostly similar distributions when comparing Analysis Samples 1 and 2. One notable difference is that the top percentile band contains slightly lower consumption buildings in Analysis Sample 2 than in Analysis Sample 1, both for CRC and InfoDec buildings. However, both samples display the same skewness with the top 20% of buildings accounting for more than 70% of total energy consumption.

The results are presented in Table 20 for Analysis Sample 1, which considers as CRC meters those meters belonging to organisations with 'member only' CCA exemptions (covering some parts of their business) provided they are not at CCA sites. In all specifications the matching is

[24] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

based on both the building's 2008 electricity consumption as well as its growth pre-2009. Differences between the CRC and information declarer groups are statistically significant in the second, fourth and top consumption bands. It is more significant and slightly stronger in the 80-100% percentile band, at -8.8%, which is above the average -6% for the whole sample. This is also illustrated in Figure 9, where it is apparent that panels (d) and (e) exhibit the strongest effect. Whilst it only represents one year and data point, the gap between the CRC and InfoDec buildings seems to become narrower in the final year.

		Electricity consumption in 2008 (GWh)						
Sample	Percentile Band	Mean	Median	95th percentile	Sum	Share of sum	Buildings	Share of Buildings
Analysis Sample 1	20	0.05	0.05	0.12	200	1.12%	3,779	20%
	40	0.20	0.20	0.28	769	4.30%	3,779	20%
	60	0.39	0.38	0.48	1,456	8.13%	3,779	20%
	80	0.70	0.67	0.98	2,645	14.78%	3,779	20%
	100	3.40	2.08	9.28	12,830	71.67%	3,779	20%
CRC in Analysis Sample 1	20	0.06	0.06	0.12	161	1.10%	2,615	18.63%
	40	0.20	0.20	0.28	605	4.13%	2,974	21.19%
	60	0.39	0.38	0.48	1,110	7.57%	2,876	20.49%
	80	0.69	0.67	0.97	1,878	12.81%	2,705	19.27%
	100	3.81	2.34	11.10	10,912	74.40%	2,867	20.42%
Analysis Sample 2	20	0.05	0.05	0.12	177	1.12%	3,378	20%
	40	0.22	0.22	0.29	728	4.59%	3,377	20%
	60	0.40	0.40	0.50	1,353	8.54%	3,378	20%
	80	0.71	0.69	0.98	2,404	15.16%	3,377	20%
	100	3.31	2.05	8.83	11,190	70.59%	3,377	20%
CRC in Analysis Sample 2	20	0.06	0.06	0.12	136	1.08%	2,281	18.84%
	40	0.22	0.22	0.29	538	4.26%	2,491	20.58%
	60	0.40	0.40	0.50	1,016	8.06%	2,531	20.91%
	80	0.71	0.68	0.98	1,645	13.04%	2,329	19.24%
	100	3.75	2.32	10.78	9,281	73.56%	2,474	20.44%

Table 19: Descriptive statistics across electricity consumption bands – building level

	OLS regression				
	matching on average **pre-2009 electricity consumption growth in 4 percentile bands**				
Dependent Variable	**(log) Change in Electricity consumption relative to 2008**				
Percentile Band	**0-20**	**20-40**	**40-60**	**60-80**	**80-100**
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	0.016	0.001	-0.004	0.008	-0.012
	(0.037)	(0.013)	(0.011)	(0.010)	(0.007)
Dummy for CRC meter in years after the introduction of the policy	-0.045	-0.077*	-0.045	-0.073**	-0.088***
	(0.077)	(0.041)	(0.032)	(0.033)	(0.029)
Controlling for building type	yes	yes	yes	yes	yes
Buildings	2392	2695	2539	2514	2806
Observations	15957	18175	17283	17235	19434
R-squared	36.2%	26.3%	23.4%	22.8%	21.7%

Table 20: Regressions results by electricity consumption band – building Analysis Sample 1[25]

[25] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

The matching is based on consumption growth only, because of the analysis being undertaken by consumption band

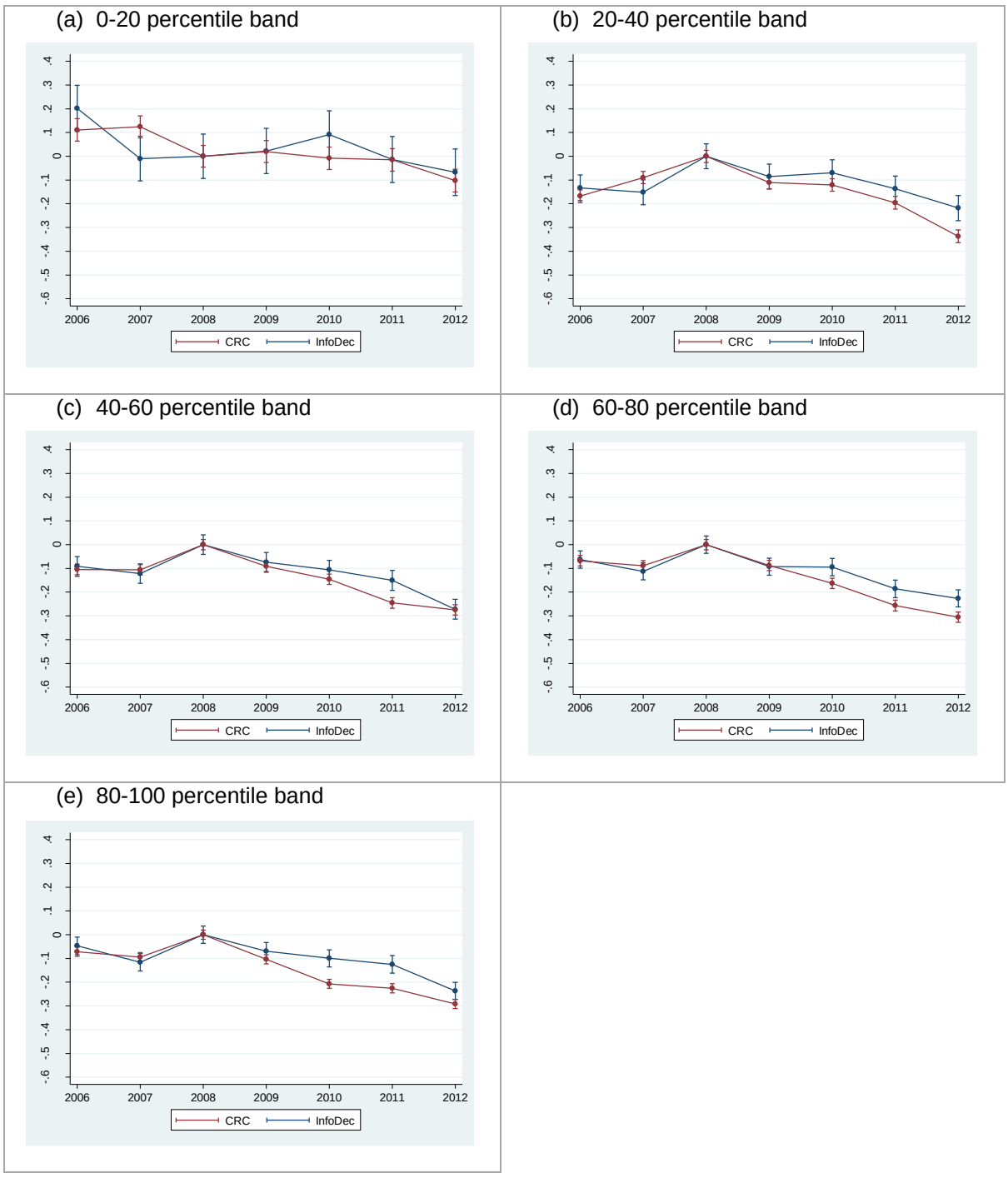


Figure 9: Results by electricity consumption band – building Analysis Sample 1[26]

The results of similar specifications for Analysis Sample 2 are reported in Table 21. The impact of the CRC is only significant for the 60-80% percentile band, and only at the 10% level. This is in line with the absence of any significant effect for the whole sample described earlier in Table 18. It is also consistent with the observation that buildings in the top percentile in terms of size are smaller in Analysis Sample 2 than in Analysis Sample 1, whilst these seem to be the most influenced by CRC in the results for Analysis Sample 1 reported in Table 20.

[26] See notes to Figure 6. All time-series results at building level are based on matching on 20 percentile electricity bands and 4 percentile electricity growth bands.

	OLS regression				
	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**				
Dependent Variable	**(log) Change in Electricity consumption relative to 2008**				
Percentile Band	**0-20**	**20-40**	**40-60**	**60-80**	**80-100**
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	0.013	0.004	0.016	0.011	-0.011
	(0.038)	(0.013)	(0.010)	(0.011)	(0.008)
Dummy for CRC meter in years after the introduction of the policy	-0.023	-0.055	-0.011	-0.063*	-0.039
	(0.077)	(0.040)	(0.034)	(0.034)	(0.030)
Controlling for building type	yes	yes	yes	yes	yes
Buildings	2240	2393	2212	2204	2475
Observations	14973	16229	15052	15096	17151
R-squared	37.2%	27.3%	22.9%	24.2%	23.7%

Table 21: Regressions results by electricity consumption band – building Analysis Sample 2[27]

An additional benefit of using the building level dataset is that the NEED data includes a categorisation into building types, as described in section 2.2.3 above. For some building types, the sample sizes are small as can be seen in Table 22: the sixth column that gives the total number of buildings of that type in Analysis Sample 1. This could affect the findings and the statistical significance of the derived effects.

	Electricity consumption in 2008 (GWh)								
Building type	**Mean**	**Median**	**95th perc.**	**Sum**	**Share of Electricity**	**Build.**	**CRC Build.**	**Coefficient on pre-treatment**	**Coefficient on post-treatment**
Community Centre	0.98	0.33	2.53	97	0.72%	148	125	-0.064	-0.187
Factory And Premises	0.68	0.50	1.95	102	0.76%	2231	654	0.010	-0.145***
Garages/Showrooms	1.56	0.52	5.80	3486	26.17%	225	106	0.063	0.020
Healthcare	0.40	0.34	0.99	90	0.67%	46	19	-0.012	0.206
Offices And Premises	0.30	0.11	0.98	14	0.10%	2045	1374	0.017	-0.062*
Restaurant And Premises	0.40	0.38	0.72	317	2.38%	786	710	-0.055*	0.048
Schools	0.21	0.08	0.98	7	0.05%	32	23	-0.029***	0.067***
Shop And Premises	0.76	0.29	3.57	5722	42.96%	7569	6488	0.022	0.026
Sports Ground And Premises	0.44	0.26	1.23	23	0.18%	53	26	-0.007	-0.159

Table 22: Electricity consumption in 2008 and results by building type – Analysis Sample 1[28]

[27] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

[28] The table reports descriptive statistics as well as regressions results across different building types. (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis

We run the same regression as in column 2 of Table 18 for each sub-sample of buildings in a given category. The last column of Table 22 reports the coefficient for post-CRC and its statistical significance, showing that the most significant and large negative effect of the CRC on electricity consumption is observed in factories, with a -14.5% impact. The insignificant impact of CRC on shops and premises, in the light of a strong impact for the 'trade' sector in section 3.3 below, is surprising. It is possible that it is a consequence of partial matches within the NEED dataset; this should be investigated in more detail in further research. The impact in office buildings is smaller and only significant at the 10% level. Whilst there is a positive and significant effect for schools, it should not be taken into account as there is also a pre-treatment trend and the number of observations is low.

Table 23 reports the results for Analysis Sample 2. The most striking difference compared to the results for Analysis Sample 1 is that the impact estimate for Factory and Premises is no longer significant. The point estimate is also substantially smaller although still negative. This points again to a degree of heterogeneity in the impacts: the CRC effect is stronger in larger facilities that are typically associated with organisations owning CCA facilities. Note that going from Analysis Sample 1 to 2 we lose about one third of the observations.

	Electricity consumption in 2008 (GWh)								
Building type	Mean	Median	95th perc.	Sum	Share of Electricity	Build.	CRC Build.	Coefficient on pre-treatment	Coefficient on post-treatment
Community Centre	0.68	0.48	1.95	98	0.73%	144	120	-0.059	-0.191
Factory And Premises	1.35	0.50	4.90	2,716	20.39%	2009	430	0.041	-0.079
Garages/Showrooms	0.41	0.35	0.99	83	0.62%	202	85	0.015	-0.001
Healthcare	0.29	0.11	0.59	12	0.09%	43	17	-0.123	0.093
Offices And Premises	1.49	0.54	5.66	2,884	21.66%	1931	1260	0.016	-0.053
Restaurant And Premises	0.40	0.38	0.72	315	2.36%	781	706	-0.050*	0.051
Schools	0.21	0.08	0.98	7	0.05%	32	23	-0.029***	0.067***
Shop And Premises	0.78	0.31	3.67	5,026	37.74%	6473	5452	0.019	0.022

Table 23: Electricity consumption in 2008 and results by building type – Analysis Sample 2[29]

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report standard errors. Buildings of unknown type were excluded, as were 127 records that were advertising sites and car parks. 'Shops and premises' also include warehouses. 'Restaurants and premises' include buildings of the 'Public House/club' category. The descriptive statistics reported in the first five columns are for all buildings of the type described for that row. 'Build.' reports the number of buildings in each category, of which a certain number (reported in column 'CRC Build.') are considered as CRC treated as more than 50% of their electricity use in 2008 is measured by meters that are subject to the CRC in Analysis Sample 1. This is explained in footnote 6.

[29] See notes to Table 22.

3.2.3. Gas

As described in section 2.2.3, positive gas consumption is reported for about 40% of the buildings. By using the carbon content of electricity and gas, the total carbon emissions per building can be approximated.[30] Although the limited matching of gas meter data imply that the following results are tentative, we take a similar approach as in section 3.2.1 (Electricity) to derive the impact of the CRC on gas consumption and total carbon emissions for each Analysis Sample.

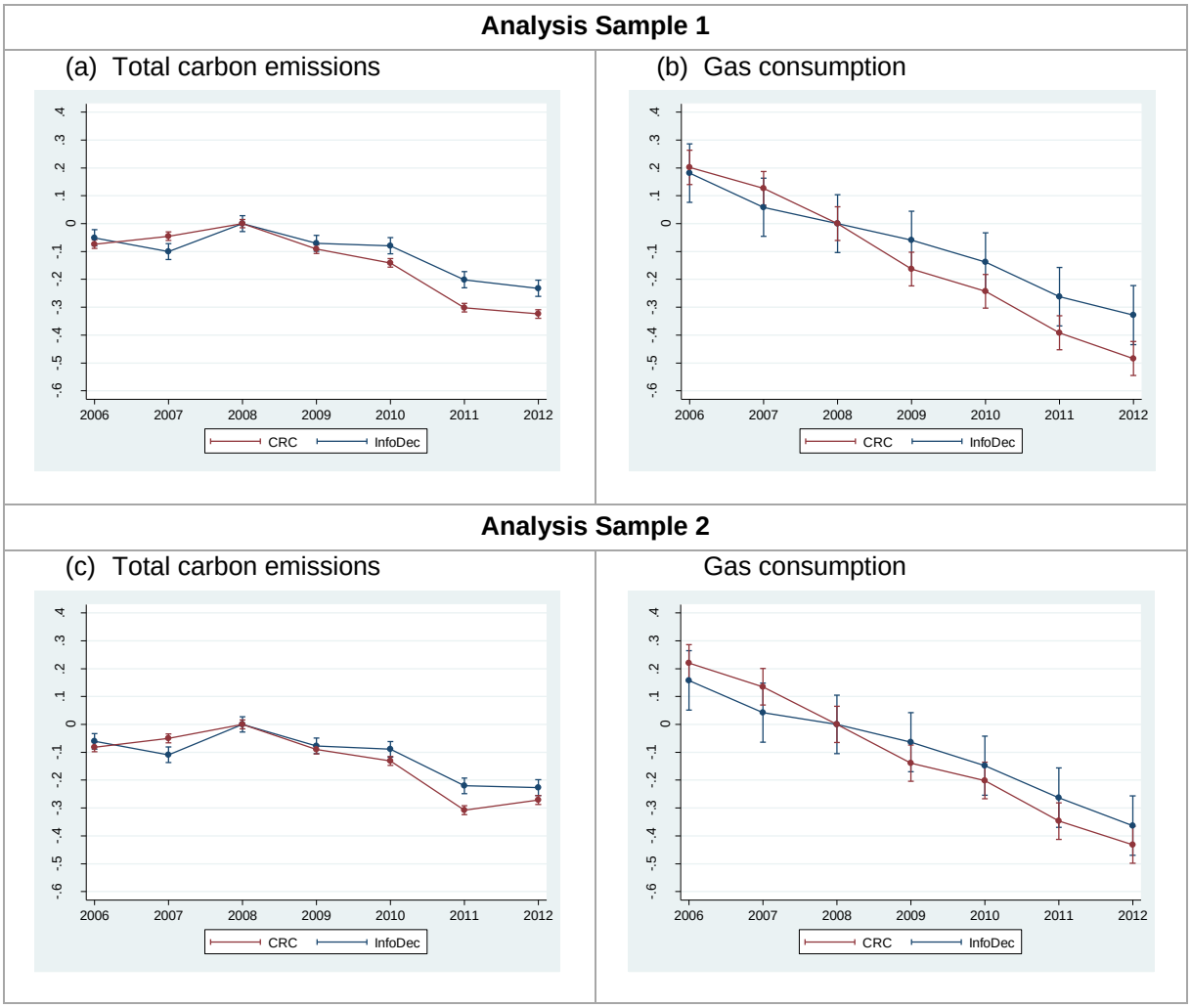

Figure 10: DiD results including gas meter data by year – building level[31]

Figure 10 and Table 24 report the regression results for gas and total carbon emissions in the case of Analysis Samples 1 and 2, in a similar way to the results presented in Figure 8 and Table 18 for electricity at building level. In this case, four sets of matching variables are implemented, so as to use the same matching variables for both outcome variables of interest, and in order to control for pre-treatment trends and satisfy the assumption of parallel pre-treatment trends in the treatment and control groups. We use five gas and five carbon

[30] Although we are not taking into account any other fuel consumption that might be occurring from that building or site, total carbon emissions are measured in kg of CO2 as 0.541 x electricity consumption in kwh plus 0.1836 x gas consumption in kwh. These are the conversion factors that CRC participants were required to use during phase 1.

[31] See notes to Figure 6. All time-series results presented here are based on matching on 20 percentile gas and carbon emissions bands and 4 percentile gas and carbon growth bands.

consumption/emission bands (defined on the basis of quintiles of the 2008 gas consumption or carbon emissions distribution) to match treatment and control organisations on. Secondly, we use 25 bands with a 4 percentile point width of the average gas consumption growth and average carbon emissions growth before 2009. This matching successfully controls for pre-treatment trends as shown by the coefficients for pre-CRC in Table 24 being insignificant. The CRC impact on total carbon emissions is estimated to be a 8.4% (5.8%) decrease in total carbon emissions using sample Analysis Sample 1 (Analysis Sample 2), which is significant at the 1% level. But the CRC impact on gas consumption is insignificant, with a low R^2 in all regressions when gas consumption is the dependent variable.

		OLS regression			
		matching on the **2008 gas consumption and total carbon emissions in 20 percentile bands** as well as the average **pre-2009 gas consumption and total carbon emissions growth in 4 percentile bands**			
Dependent Variable		**(log) Change in consumption relative to 2008**			
		Total carbon	**Gas**	**Total carbon**	**Gas**
Sample		**Analysis Sample 1**		**Analysis Sample 2**	
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy		0.004	-0.005	0.009	0.026
		(0.008)	(0.047)	(0.009)	(0.052)
Dummy for CRC meter in years after the introduction of the policy		-0.084***	-0.130	-0.058***	-0.068
		(0.021)	(0.086)	(0.022)	(0.094)
Controlling for building type		yes	yes	yes	yes
Buildings		12946	5262	11524	4801
Observations		88925	36364	79254	33169
R-squared		17.5%	5.4%	18.9%	5.4%

Table 24: DiD regression results for total carbon and gas – building level[32]

3.2.4. Results by gas consumption and total carbon emissions bands

As previously done for electricity in section 3.2.2, we here compute separately for each quintile of total carbon emissions and gas consumption levels the 'difference-in-differences' between CRC and information declarers with Building level data. Tables 25 and 26 give the descriptive statistics across emissions/consumption bands. We see that as in the case of electricity, the distribution is strongly skewed, with the top quintile of buildings accounting for between 69% and 74% of gas consumption or total carbon emissions. Unsurprisingly, this is true for both Analysis Samples 1 and 2.

[32] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors. Total carbon emissions are approximated in kg of CO_2 as 0.541 x electricity consumption in kWh plus 0.1836 x gas consumption in kWh. Consumption of gas reported as equal to zero are set to missing.

We then run the same regression analysis as in section 3.2.2, matching on both pre-treatment levels and growth rates for total carbon emissions and gas. Table 27 examines 'difference-in-differences' of total carbon emissions between CRC and InfoDec across a range of total emissions bands, based on gas and electricity consumption per building for Analysis Sample 1. These results show that differences in carbon emissions between the CRC and InfoDec groups are statistically significant across all consumption bands except in the 0-20% percentile band. In all four top quintiles, they are statistically significant at the 1% level and the strongest effect of 12% is found for the 20%-40% band. These two sets of results are illustrated in Figure 11.

		Total carbon emissions in 2008 (tons of carbon)						
Sample	Percentile Band	Mean	Median	95th percentile	Sum	Share of sum	Buildings	Share of Buildings
Analysis Sample 1	20	0.03	0.03	0.07	130	1.16%	3,779	20%
	40	0.12	0.12	0.17	467	4.19%	3,779	20%
	60	0.24	0.24	0.30	901	8.06%	3,779	20%
	80	0.46	0.44	0.65	1,735	15.54%	3,779	20%
	100	2.10	1.32	5.92	7,935	71.05%	3,779	20%
CRC in Analysis Sample 1	20	0.04	0.04	0.07	101	1.12%	2,659	18.94%
	40	0.12	0.12	0.17	366	4.07%	2,976	21.20%
	60	0.24	0.24	0.31	691	7.68%	2,894	20.62%
	80	0.46	0.43	0.65	1,204	13.36%	2,642	18.82%
	100	2.32	1.44	6.74	6,644	73.77%	2,866	20.42%
Analysis Sample 2	20	0.03	0.03	0.08	118	1.19%	3,378	20%
	40	0.13	0.13	0.18	450	4.55%	3,377	20%
	60	0.25	0.25	0.32	844	8.54%	3,378	20%
	80	0.47	0.45	0.66	1,592	16.10%	3,377	20%
	100	2.04	1.30	5.74	6,883	69.62%	3,377	20%
CRC in Analysis Sample 2	20	0.04	0.04	0.08	86	1.11%	2,293	18.94%
	40	0.13	0.13	0.18	333	4.31%	2,509	20.73%
	60	0.25	0.25	0.32	634	8.20%	2,537	20.96%
	80	0.47	0.45	0.66	1,066	13.80%	2,282	18.85%
	100	2.26	1.42	6.52	5,607	72.58%	2,485	20.53%

Table 25: Descriptive statistics across carbon emissions bands – building level

Sample	Percentile Band	Gas consumption in 2008 (GWh) Mean	Median	95th percentile	Sum	Share of sum	Buildings	Share of Buildings
Analysis Sample 1	20	0.03	0.02	0.07	44	0.54%	1,582	19.81%
	40	0.14	0.14	0.22	233	2.88%	1,604	20.09%
	60	0.36	0.34	0.50	570	7.06%	1,601	20.05%
	80	0.83	0.82	1.18	1,334	16.51%	1,601	20.05%
	100	3.70	2.09	10.76	5,899	73.01%	1,596	19.99%
CRC in Analysis Sample 1	20	0.03	0.02	0.07	32	0.55%	1,175	20.40%
	40	0.15	0.14	0.22	171	2.93%	1,172	20.34%
	60	0.36	0.34	0.50	403	6.90%	1,133	19.67%
	80	0.84	0.82	1.19	971	16.61%	1,160	20.14%
	100	3.81	2.03	11.57	4,266	73.01%	1,121	19.46%
Analysis Sample 2	20	0.03	0.03	0.07	48	0.67%	1,479	19.86%
	40	0.15	0.15	0.23	229	3.21%	1,495	20.07%
	60	0.37	0.36	0.52	549	7.69%	1,493	20.05%
	80	0.84	0.82	1.18	1,255	17.60%	1,493	20.05%
	100	3.40	2.08	9.39	5,053	70.83%	1,488	19.98%
CRC in Analysis Sample 2	20	0.03	0.03	0.07	34	0.70%	1,066	20.32%
	40	0.15	0.15	0.23	164	3.35%	1,065	20.30%
	60	0.37	0.35	0.52	380	7.76%	1,037	19.77%
	80	0.84	0.83	1.18	899	18.35%	1,065	20.30%
	100	3.38	2.00	9.33	3,420	69.83%	1,013	19.31%

Table 26: Descriptive statistics across gas consumption bands – building level

	OLS regression				
	matching on the **2008 gas consumption and total carbon emissions in 20 percentile bands** as well as the average **pre-2009 gas consumption and total carbon emissions growth in 4 percentile bands**				
Dependent Variable	**(log) Change in total carbon emissions relative to 2008**				
Percentile Band	**0-20**	**20-40**	**40-60**	**60-80**	**80-100**
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	0.011	0.007	0.010	0.016	-0.008
	(0.024)	(0.011)	(0.009)	(0.014)	(0.010)
Dummy for CRC meter in years after the introduction of the policy	0.034	-0.120***	-0.084***	-0.097***	-0.084***
	(0.073)	(0.040)	(0.030)	(0.036)	(0.030)
Controlling for building type	yes	yes	yes	yes	yes
Buildings	2491	2739	2653	2425	2638
Observations	16807	18699	18249	16809	18361
R-squared	31.2%	18.0%	19.1%	18.6%	18.9%

Table 27: Regressions results by carbon emissions band – building level Analysis Sample 1[33]

[33] See notes to Table 24.

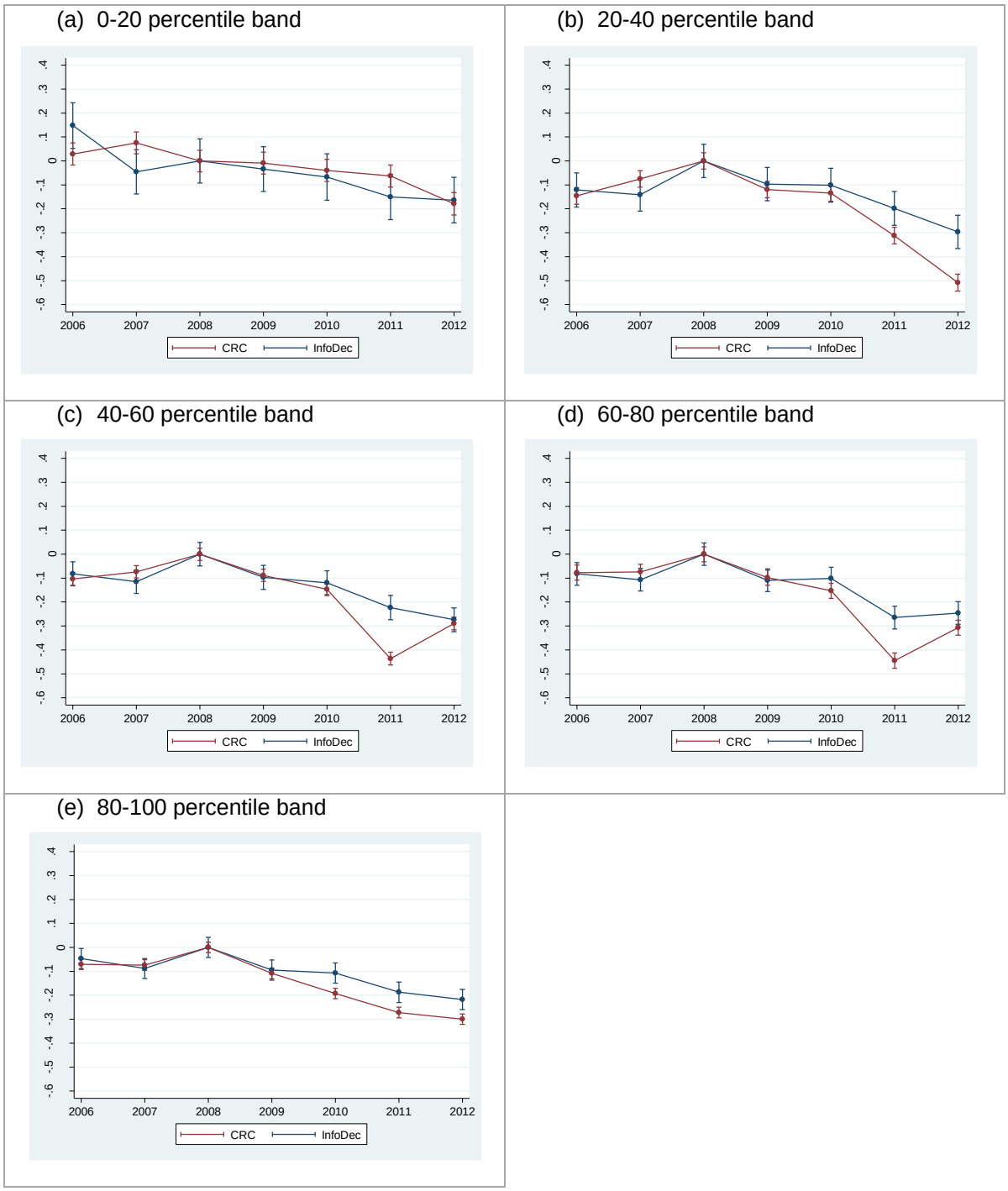

Figure 11: Results by total carbon emissions band – building level Analysis Sample 1[34]

In the case of Analysis Sample 2, shown in Table 28, the impact estimates are slightly less significant and the effects on total carbon emissions are not found to be statistically significant for the top and lowest carbon emissions band. The absence of effects for the largest emitters is logically consistent with the effects found for electricity consumption, which were tentatively explained above by the lower representation of large buildings in Analysis Sample 2.

[34] See notes to Figure 6. All time-series results presented here are based on matching on 20 percentile gas and carbon emissions bands and 4 percentile gas and carbon growth bands.

	OLS regression
	matching on the **2008 gas consumption and total carbon emissions in 20 percentile bands** as well as the average **pre-2009 gas consumption and total carbon emissions growth in 4 percentile bands**
Dependent Variable	**(log) Change in total carbon emissions relative to 2008**

Percentile Band	**0-20**	**20-40**	**40-60**	**60-80**	**80-100**
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	0.001	0.009	0.014	0.019	-0.012
	(0.023)	(0.012)	(0.009)	(0.015)	(0.010)
Dummy for CRC meter in years after the introduction of the policy	0.058	-0.092**	-0.075**	-0.104**	-0.040
	(0.068)	(0.038)	(0.031)	(0.040)	(0.032)
Controlling for building type	yes	yes	yes	yes	yes
Buildings	2356	2398	2349	2100	2321
Observations	15926	16450	16163	14551	16164
R-squared	32.6%	22.1%	20.5%	19.6%	20.0%

Table 28: Regressions results by carbon emissions band – building level Analysis Sample 2[35]

Although no significant effect of CRC on gas consumption was found in aggregate at the building level, as reported in section 3.2.3, we estimate its effect on the change in gas consumption relative to 2008 for each gas consumption band described above. As reported in columns 5 of Table 29 for Analysis Sample 1 and Table 30 for Analysis Sample 2, a very large effect of respectively -29.9% and -31.1% is found for the top quintile, i.e. buildings situated in the 80%-100% quintile of gas consumption. In addition, it is significant at the 1% level. Figure 12 illustrates these effects for Analysis Sample 1. Given the work-in-progress on the NEED data, and in particular on its gas measurements described above, these results should be considered as tentative, but certainly worth more exploration. Further research could explore how far the large effect observed for the top quintile of CRC gas meters, compared to information declarer meters, is attributable to CRC or other factors.

[35] See notes to Table 24.

	OLS regression				
	matching on the **2008 gas consumption and total carbon emissions in 20 percentile bands** as well as the average **pre-2009 gas consumption and total carbon emissions growth in 4 percentile bands**				
Dependent Variable	**(log) Change in total gas consumption relative to 2008**				
Percentile Band	**0-20**	**20-40**	**40-60**	**60-80**	**80-100**
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	0.045	0.058	-0.130***	0.003	-0.043
	(0.165)	(0.063)	(0.045)	(0.035)	(0.037)
Dummy for CRC meter in years after the introduction of the policy	0.009	0.032	-0.080	-0.172	-0.299***
	(0.290)	(0.142)	(0.144)	(0.117)	(0.104)
Controlling for building type	yes	yes	yes	yes	yes
Buildings	1339	1238	1027	942	716
Observations	9137	8580	7130	6542	4975
R-squared	11.0%	10.4%	11.0%	10.9%	14.6%

Table 29: Regressions results by gas consumption band – building level Analysis Sample 1[36]

	OLS regression				
	matching on the **2008 gas consumption and total carbon emissions in 20 percentile bands** as well as the average **pre-2009 gas consumption and total carbon emissions growth in 4 percentile bands**				
Dependent Variable	**(log) Change in total gas consumption relative to 2008**				
Percentile Band	**0-20**	**20-40**	**40-60**	**60-80**	**80-100**
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	0.062	0.087	-0.111**	-0.001	-0.058
	(0.161)	(0.074)	(0.045)	(0.039)	(0.049)
Dummy for CRC meter in years after the introduction of the policy	0.050	0.110	0.078	-0.062	-0.311**
	(0.289)	(0.166)	(0.139)	(0.112)	(0.145)
Controlling for building type	yes	yes	yes	yes	yes
Buildings	1249	1140	923	862	627
Observations	8507	7903	6413	5988	4358
R-squared	11.0%	10.5%	11.6%	12.0%	14.4%

Table 30: Regressions results by gas consumption band – building level Analysis Sample 2[37]

[36] See notes to Table 24.

[37] See notes to Table 24.

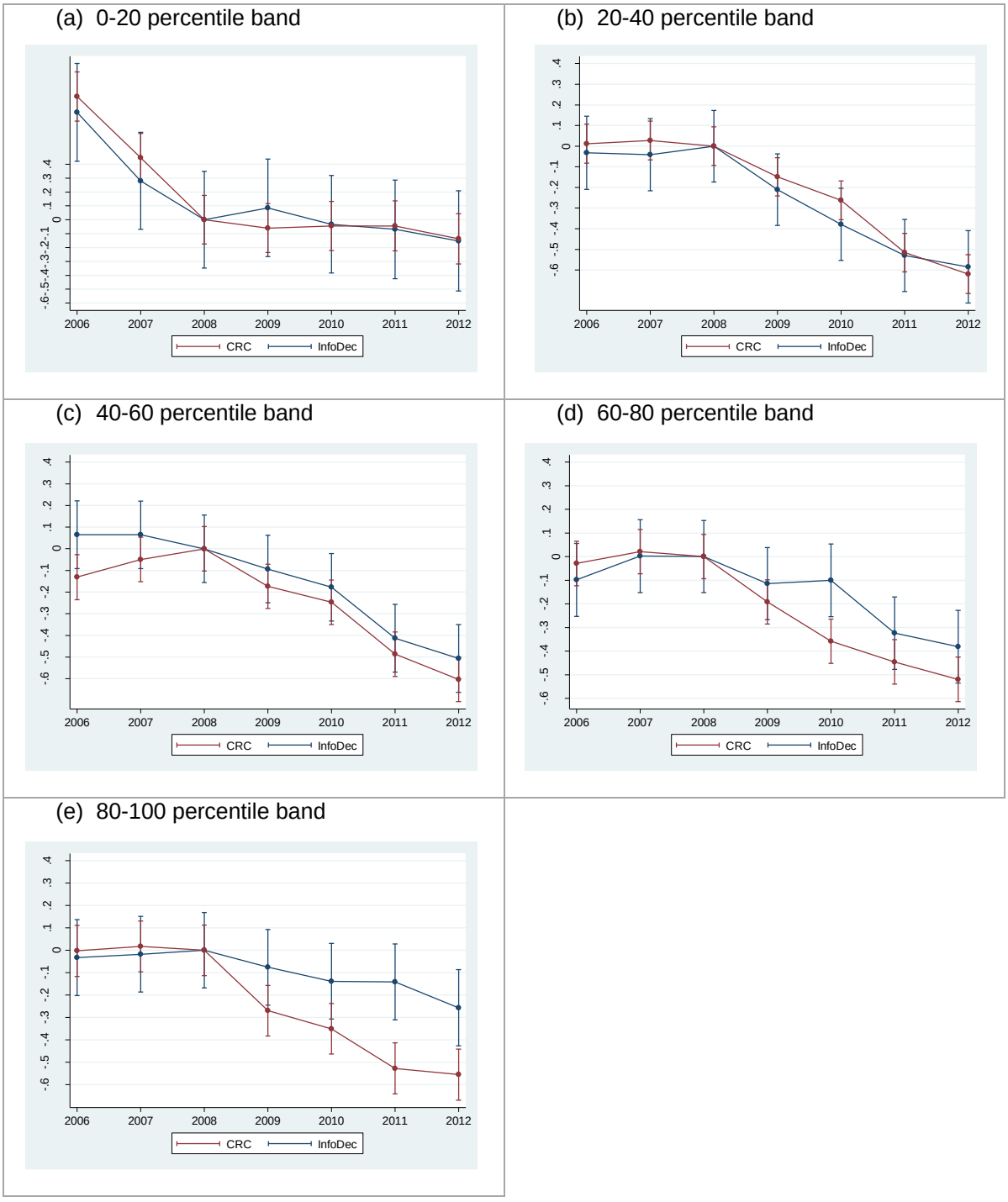

Figure 12: Results by gas consumption band – building Analysis Sample 1[38]

[38] See notes to Figure 6. All time-series results presented here are based on matching on 20 percentile gas and carbon emissions bands and 4 percentile gas and carbon growth bands.

3.3. Postcode level

This section reports our results at the postcode level. As discussed above, the purpose of aggregating to the postcode level is to merge the meter level data with additional variables from the BSD. Consequently, in this section we can report results using electricity intensity (measured as electricity over employment) as well as employment as outcome variables. Moreover, the BSD allows us to breakdown the results by sector.

Figure 13 contains the usual time series plots for our main postcode level result. Tables 31 and 32 report the regression results for electricity and electricity intensity. The time series for electricity look very similar to our earlier results at the meter point and building level. The post treatment point estimates are of similar order of magnitude to the results presented above. Indeed with CRC effects of 6 to 7% for Analysis Sample 1 they are a bit larger than at the meter point level (See columns 1 and 2 of Table 31). Again it is necessary to include pre-treatment trend bands as controls to ensure comparable pre-treatment behaviour of treated and control groups (columns 2 and 4 of Table 29). We also find signficant effects on electricity intensity in Table 32 although they are somewhat smaller with a point estimate of just under 5% for Analysis Sample 1. This is due a small decrease in employment which is, however, too small to be significant.[39]

[39] We did not include a regression table for this last result but it is available on request from the authors.

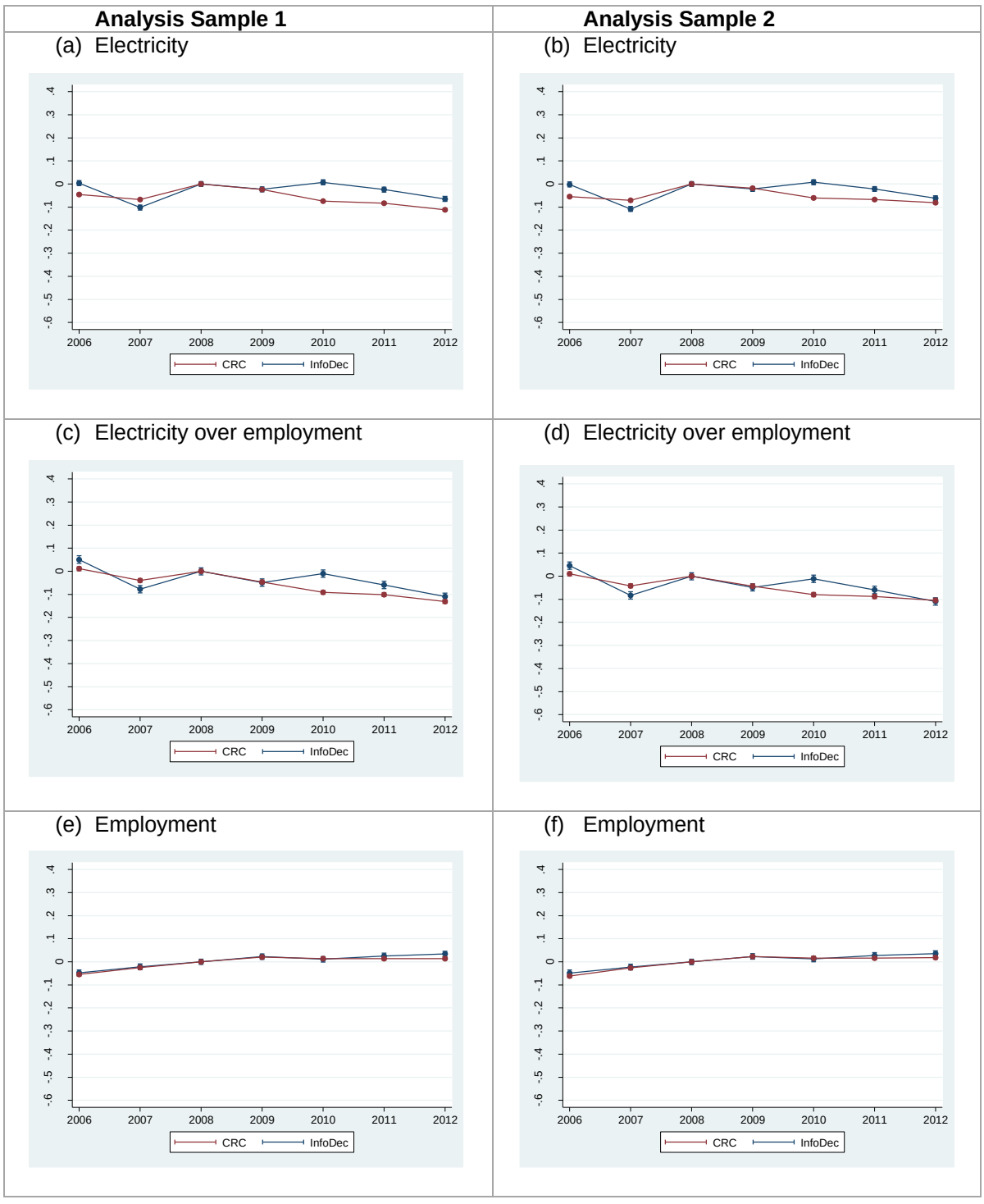

Figure 13: Results at postcode level[40]

[40] See notes to Figure 6. All time-series results at postcode level are based on matching on 20 percentile electricity bands and 4 percentile electricity growth bands.

	OLS regression			
Dependent Variable	(log) Change in Electricity consumption relative to 2008			
Sample	Analysis Sample 1		Analysis Sample 2	
	matching on the **2008 electricity consumption in 20 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**
Explanatory variables				
Dummy for CRC meter in years before the introduction of the policy	0.014***	-0.004	0.011***	-0.002
	(0.003)	(0.002)	(0.004)	(0.002)
Dummy for CRC meter in years after the introduction of the policy	-0.072***	-0.062***	-0.053***	-0.044***
	(0.007)	(0.007)	(0.007)	(0.007)
Number of Postcodes	56287	56287	50557	50557
Number of Observations	351019	351019	314581	314581
R-squared	3.3%	22.6%	3.2%	23.0%

Table 31: Regression results at the postcode level – Electricity Consumption[41]

[41] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

	OLS regression			
Dependent Variable	(log) Change in Electricity consumption over employment relative to 2008			
Sample	Analysis Sample 1		Analysis Sample 2	
	matching on the **2008 electricity consumption in 20 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 4 percentile bands**
Explanatory variables				
Dummy for CRC meter in years before the introduction of the policy	0.020***	0.001	0.018***	0.003
	(0.005)	(0.004)	(0.005)	(0.004)
Dummy for CRC meter in years after the introduction of the policy	-0.046***	-0.048***	-0.030***	-0.031***
	(0.010)	(0.010)	(0.010)	(0.010)
Number of Postcodes	52309	52309	46877	46877
Number of Observations	340996	340996	305319	305319
R-squared	2.0%	12.0%	1.9%	11.9%

Table 32: Regression results at the postcode level – Electricity intensity[42]

Table 33 reports separate results by sector. Note that we report both descriptive statistics and regression coefficients (in the last 2 columns) in one table for simplicity. There is considerable heterogeneity in terms of the post treatment effect. In the majority of sectors there is no significant effect. However, it is re-assuring that there are strong and significant effects in the three sectors that account for the bulk (more than half) of electricity consumption: Trade, Business Services and Hospitality with effects on the order of 7 to 10%.

[42] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

	Electricity consumption in 2008 (GWh)								
Sector	Mean	Median	95th Per-centile	Sum	Share of Elec-tricity	Post-codes	CRC Post-codes	Coefficient on pre-treatment	Coefficient on post-treatment
Agriculture	0.48	0.05	2.08	1,460	2.38%	3057	2490	-0.033***	-0.173***
BusinessServices	1.47	0.40	5.34	13,250	21.58%	9027	6673	0.003	-0.063***
Chemicals	3.10	1.19	13.12	581	0.95%	187	87	-0.007	0.002
Construction	0.93	0.20	2.86	2,258	3.68%	2428	1959	-0.017	-0.096**
Education	0.65	0.45	1.69	1,926	3.14%	2972	2486	0.001	0.008
Electrical	2.04	0.63	7.32	990	1.61%	485	215	-0.017	-0.032
Finance	2.57	0.60	11.85	1,881	3.06%	732	595	-0.010	-0.060
Fishing	0.31	0.05	1.93	24	0.04%	78	61	-0.034	0.002
Food	2.07	0.90	8.15	539	0.88%	260	90	-0.020	-0.166**
Health	0.98	0.28	4.54	3,023	4.92%	3093	2348	-0.005	-0.046**
Hospitality	1.09	0.42	3.73	6,251	10.18%	5752	4816	-0.004	-0.072***
ManufacturingNEQ	2.61	0.96	12.49	219	0.36%	84	58	0.051*	0.112
Metals	1.52	0.51	5.21	1,228	2.00%	806	311	-0.041	-0.163***
Minerals	1.63	0.50	6.99	377	0.61%	231	153	0.025	-0.123
Mining	4.91	0.73	6.65	1,026	1.67%	209	177	0.020	-0.096
OtherPersonalServices	1.15	0.42	3.85	2,839	4.62%	2467	1875	-0.003	-0.077***
Paper	2.50	0.86	5.57	170	0.28%	68	24	-0.027	0.000
Plastic	1.39	0.50	5.39	263	0.43%	189	78	-0.090	-0.242*
PublicAdmin	1.13	0.47	3.75	1,342	2.19%	1187	1011	-0.007	-0.085**
Publishing	2.29	0.39	4.96	808	1.32%	353	212	-0.001	-0.123
Recycling	1.55	0.34	10.48	92	0.15%	59	36	0.021	0.245
Textiles	0.98	0.51	3.78	182	0.30%	185	61	-0.009	-0.052
Trade	0.96	0.36	3.84	14,926	24.31%	15583	13191	-0.007	-0.068***
TransportEquipment	1.97	0.76	7.37	405	0.66%	205	103	0.041*	0.079
TransportCommunicatic	1.89	0.45	5.85	3,764	6.13%	1996	1706	0.003	-0.035
Utilities	2.44	0.76	7.37	1,124	1.83%	461	331	0.023	0.068

Table 33: Results by sector – Analysis Sample 1[43]

3.4. Establishment level

In Figure 14 and Tables 34 and 35 we report our main results at the establishment level: that is the activities of an organisation at a particular location (postcode). As with the postcode results we can combine the electricity data with organisation level data from the ONS to look at a wider range of variables. While reducing the potential for measurement error by exploiting both postcode and organisation name information to merge the datasets, this comes at the price of working with a smaller sample of the underlying data. However, results are very much in line with earlier findings. Again, Analysis Sample 2 leads to somewhat lower estimates but even then the lowest estimate is 3.6% for the post treatment effect (column 1, Table 35). Note that in order to achieve balanced pre-treatment trends between treatment and control, we have included a wider range of matching variables. We now also include bands constructed on the basis of levels and trends in electricity consumption and trends in electricity intensity (columns 1, 3 and 5 of the regression tables as well as for the results shown in the Figure). Alternatively we can achieve a balance by matching on sector as well as electricity consumption (columns 2, 4 and 6).

[43] The table reports descriptive statistics as well as regressions results across different sectors of the economy. (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level.

Similar to the postcode level analysis, we find significant impacts for electricity intensity although only for Analysis Sample 1. The results show a CRC impact on employment at this level of aggregation, but we do not view this as a robust result because it is not replicated at other levels of aggregation.

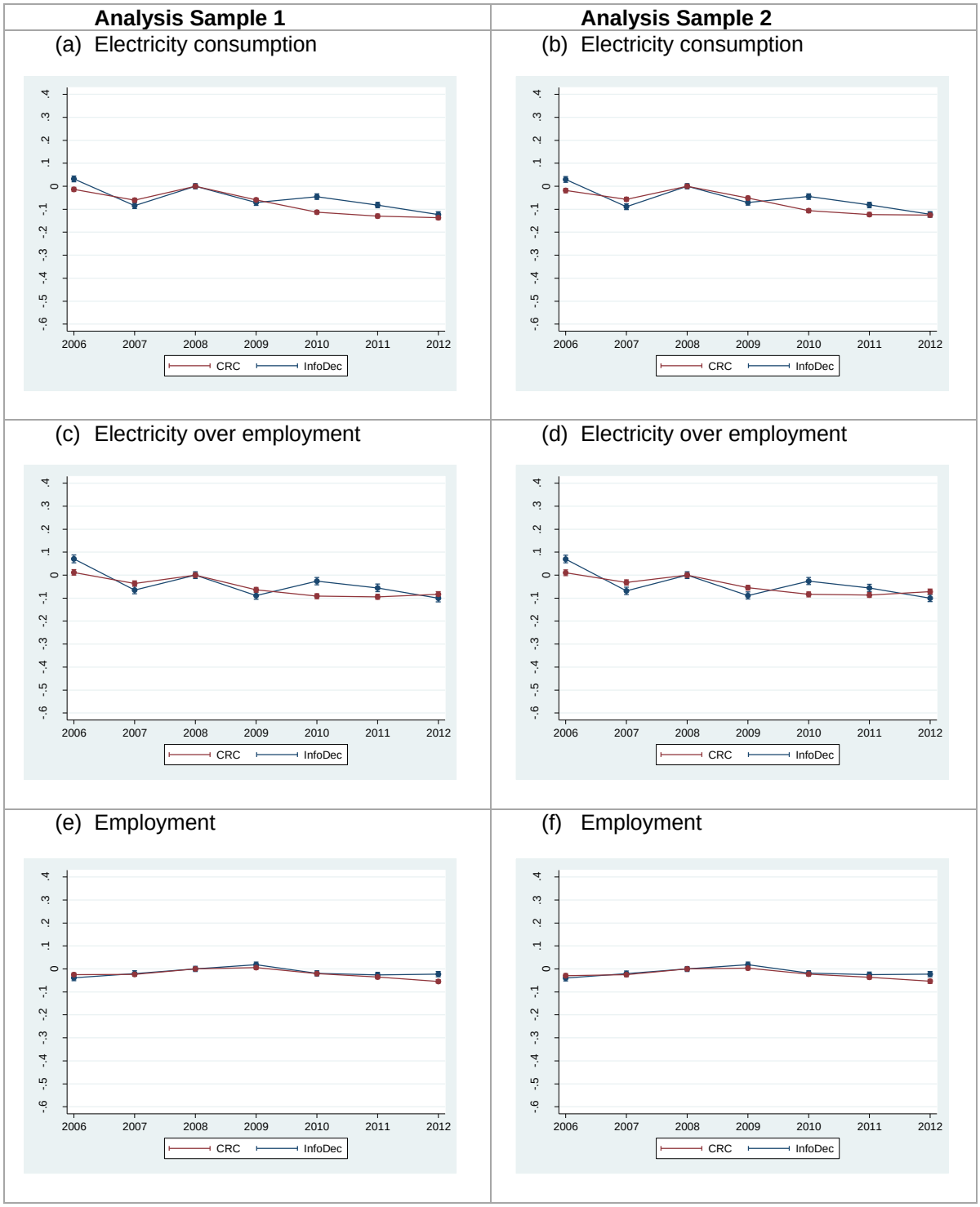

Figure 14: Results at the establishment level[44]

[44] See notes to Figure 6. Matching on the 2008 electricity consumption in 20 percentile bands and the average pre-2009 electricity consumption growth in 10 percentile bands; i.e. the same specification that underlies columns 1, 3 and 5 of Table 34 and Table 35.

	OLS regression					
Dependent Variable	**(log) Change in Electricity consumption**		**(log) Employment**		**(log) Change in Electricity over Employment**	
	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 10 percentile bands** and the average **pre-2009 electricity over employment growth in 10 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and on **two-digit sectors**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 10 percentile bands** and the average **pre-2009 electricity over employment growth in 10 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and on **two-digit sectors**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 10 percentile bands** and the average **pre-2009 electricity over employment growth in 10 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and on **two-digit sectors**
Explanatory variables						
Dummy for CRC meter in years before the introduction of the policy	-0.001	-0.007	-0.002	-0.004	0.000	-0.003
	(0.004)	(0.005)	(0.004)	(0.006)	(0.005)	(0.008)
Dummy for CRC meter in years after the introduction of the policy	-0.044***	-0.055***	-0.014*	-0.030***	-0.030***	-0.025**
	(0.008)	(0.010)	(0.008)	(0.009)	(0.010)	(0.012)
Number of Establishments	18643	18641	18643	18641	18643	18641
Number of Observations	116637	116627	116637	116627	116637	116627
R-squared	14.7%	13.8%	14.7%	2.0%	16.8%	7.2%

Table 34: Regressions results at the establishment level – Analysis Sample 1[45]

[45] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

	OLS regression					
Dependent Variable	(log) Change in Electricity consumption		(log) Employment		(log) Change in Electricity over Employment	
	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 10 percentile bands** and the average **pre-2009 electricity over employment growth in 10 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and on **two-digit sectors**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 10 percentile bands** and the average **pre-2009 electricity over employment growth in 10 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and on **two-digit sectors**	matching on the **2008 electricity consumption in 20 percentile bands** and the average **pre-2009 electricity consumption growth in 10 percentile bands** and the average **pre-2009 electricity over employment growth in 10 percentile bands**	matching on the **2008 electricity consumption in 20 percentile bands** and on **two-digit sectors**
Explanatory variables						
Dummy for CRC meter in years before the introduction of the policy	0.003 (0.004)	-0.003 (0.005)	-0.003 (0.004)	-0.009* (0.006)	0.006 (0.005)	0.007 (0.008)
Dummy for CRC meter in years after the introduction of the policy	-0.036*** (0.008)	-0.045*** (0.010)	-0.016* (0.008)	-0.032*** (0.010)	-0.021** (0.011)	-0.013 (0.013)
Number of Establishments	17781	17781	17781	17781	17781	17781
Number of Observations	111293	111283	111293	111283	111293	111283
R-squared	14.9%	14.0%	14.9%	2.1%	17.0%	7.2%

Table 35: Regressions results at the establishment level – Analysis Sample 2[46]

Table 36 contains results (along with descriptive statistics) by industrial sectors. A similar picture emerges as for the postcode level; i.e. results are highly heterogeneous across sectors. However, there are also some notable differences. Looking again at the largest sectors (in terms of electricity consumption), Business Services is (notably) no longer significant. However, note that in this sample this sector – while still comparatively large - takes a much smaller share of total consumption across the whole sample. This is presumably because Business Services contains many smaller organisations and because of the name matching procedure required to

[46] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

generate establishment-level data, we require they are more likely to be lost in the merging process.

	Electricity consumption in 2008 (GWh)								
Sector	Mean	Median	95th Percentile	Sum	Share of Electricity	Estab.	CRC Estab.	Coefficient on pre-treatment	Coefficient on post-treatment
Agriculture	0.46	0.08	2.05	212	0.93%	461	319	-0.035	-0.062
BusinessServices	1.46	0.52	6.08	1,826	8.03%	1254	724	0.016	-0.016
Chemicals	2.63	0.90	10.86	625	2.75%	238	79	-0.070*	-0.314***
Construction	0.89	0.31	2.20	265	1.17%	297	192	-0.004	-0.138
Eduation	0.85	0.44	3.00	658	2.89%	774	569	0.003	0.037
Electrical	1.64	0.67	6.36	894	3.93%	545	151	-0.034*	-0.034
Finance	2.30	0.53	11.39	955	4.20%	415	352	0.027	0.076
Fishing	0.59	0.46	2.03	9	0.04%	16	10	0.830	1.885
Food	1.95	1.05	5.41	640	2.82%	328	55	-0.015	-0.103*
Health	0.54	0.31	1.70	315	1.38%	588	428	0.055*	-0.001
Hospitality	0.75	0.44	2.38	1,810	7.96%	2416	1994	-0.008	-0.103***
ManufacturingNEQ	3.61	2.16	12.94	224	0.99%	62	36	0.058	0.279
Metals	1.52	0.53	4.20	999	4.39%	659	124	0.011	-0.129**
Minerals	2.41	0.70	6.82	530	2.33%	220	125	0.022	-0.090
Mining	2.65	0.77	6.00	522	2.30%	197	150	0.012	-0.067
OtherPersonalServices	1.18	0.54	3.63	1,343	5.91%	1143	760	0.011	-0.058**
Paper	1.67	0.75	6.37	160	0.70%	96	30	-0.150	-0.286
Plastic	1.47	0.78	5.32	485	2.13%	329	48	0.020	-0.132
PublicAdmin	0.88	0.44	3.22	138	0.61%	156	142	-0.006	0.120
Publishing	1.23	0.62	4.96	307	1.35%	250	65	-0.079	-0.273***
Recycling	1.43	0.52	4.45	104	0.46%	73	41	-0.035	-0.234
Textiles	1.09	0.57	4.19	162	0.71%	149	24	-0.108**	-0.106
Trade	1.03	0.44	4.21	5,622	24.73%	5441	4522	0.002	-0.078***
TransportEquipment	2.03	0.90	8.26	449	1.98%	221	85	0.039	-0.052
TransportCommunication	1.41	0.52	4.95	2,367	10.41%	1677	1510	0.008	-0.034
Utilities	1.96	0.88	7.71	970	4.27%	496	357	0.056	0.114

Table 36: Results by sector at the establishment level – Analysis Sample 1[47]

3.5. Organisation level

Finally, this section presents analysis for electricity meters aggregated to the level of the organisation, as defined in ONS databases. This is not necessarily the same definition of organisations as used for CRC registrations.

The results presented for Analysis Sample 1 in Table 37 and Figure 15 suggest a positive impact of the CRC in reducing electricity consumption by 8.1% and energy intensity in terms of employment (as defined by electricity consumption over employment) by 7.6% although the latter is only significant at the 10% level. Furthermore, they do not show a significant impact of CRC in reducing employment nor the energy intensity in terms of turnover although the point estimate of this effect is negative.[48]

[47] The table reports descriptive statistics as well as regressions results across different sectors of the economy. (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors. 'Estab.' stands for 'Establishment'.

[48] Panel (e) of Figure 15 seems to suggest that the difference between treated and non-treated was reduced in 2012.

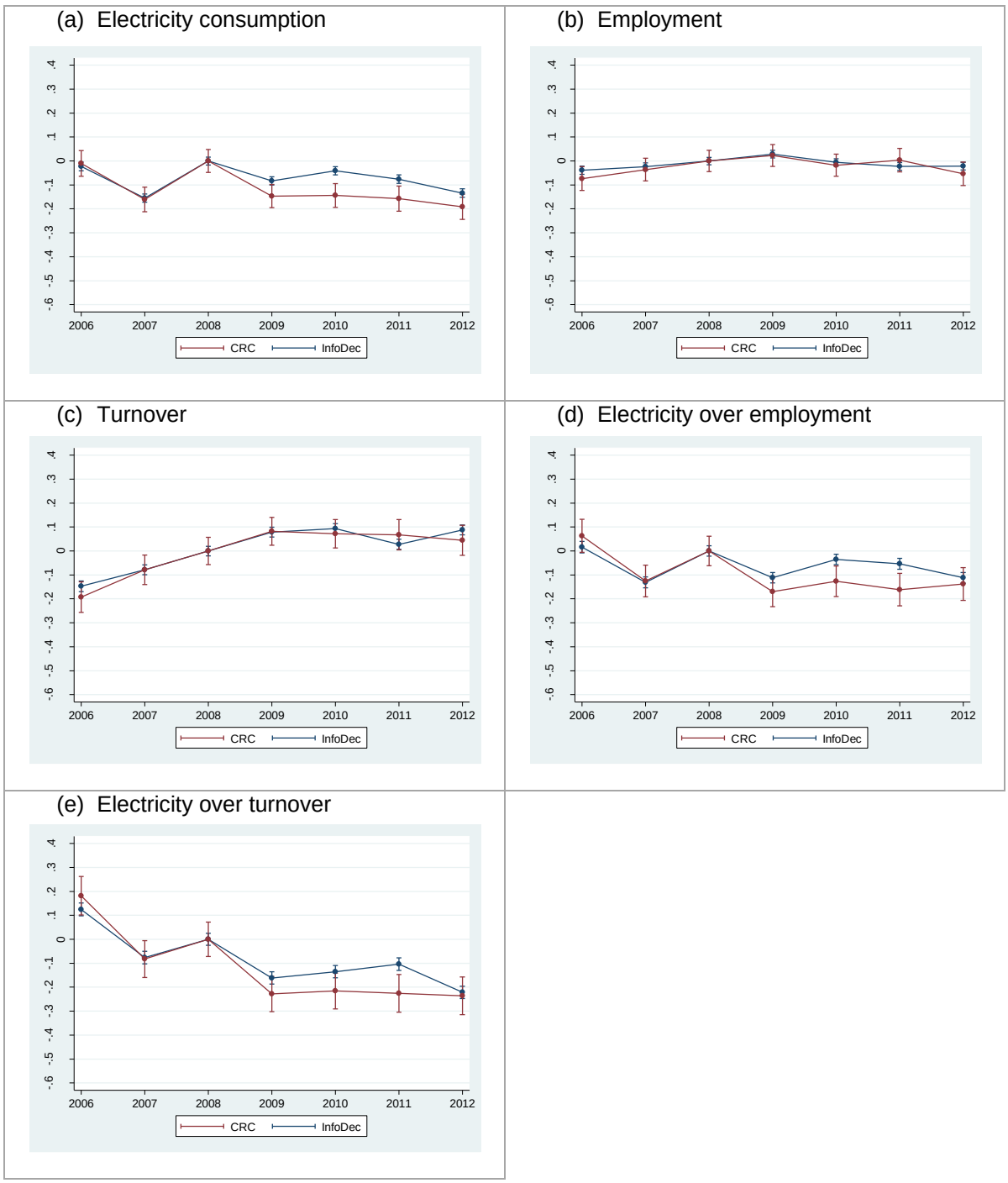

Figure 15: Results at the organisation level – Analysis Sample 1[49]

[49] See notes to Figure 6. Results are derived using 5 bands of 20 percentile electricity consumption, electricity over employment, turnover over employment and electricity growth bands.

	OLS regression				
	matching on the 2008 electricity consumption, the 2008 Electricity over employment, the 2008 turnover over employment and the average pre-2009 electricity consumption growth, all in 20 percentile bands				
Dependent Variable	(log) Change relative to 2008				
	Electricity	Employment	Electricity over employment	Turnover	Electricity over turnover
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	-0.021	-0.017	-0.005	-0.012	-0.009
	(0.016)	(0.019)	(0.026)	(0.030)	(0.034)
Dummy for CRC meter in years after the introduction of the policy	-0.081***	-0.006	-0.076*	-0.009	-0.072
	(0.030)	(0.036)	(0.041)	(0.040)	(0.045)
Number of firms	3427	3427	3427	3427	3427
Observations	20032	20032	20032	20032	20032
R-squared	16.8%	7.2%	11.1%	6.8%	11.0%

Table 37: DiD results for organisation level electricity and employment – Analysis Sample 1[50]

	OLS regression				
	matching on the 2008 electricity consumption, the 2008 Electricity over employment, the 2008 turnover over employment and the average pre-2009 electricity consumption growth, all in 20 percentile bands				
Dependent Variable	(log) Change relative to 2008				
	Electricity	Employment	Electricity over employment	Turnover	Electricity over turnover
Explanatory variables					
Dummy for CRC meter in years before the introduction of the policy	-0.009	-0.021	0.012	-0.017	0.007
	(0.018)	(0.022)	(0.030)	(0.033)	(0.038)
Dummy for CRC meter in years after the introduction of the policy	-0.066*	0.013	-0.080*	0.016	-0.083
	(0.036)	(0.042)	(0.048)	(0.048)	(0.054)
Number of firms	3,322	3,322	3,322	3,322	3,322
Observations	19,511	19,511	19,511	19,511	19,511
R-squared	16.7%	7.1%	11.0%	6.9%	10.9%

Table 38: DiD results for organisation level electricity and employment – Analysis Sample 2[51]

[50] : (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

[51] (*) indicates that the result is significant at the 10% level, (**) at the 5% level and (***) at the 1% level. Figures in parenthesis report standard errors.

Analysis Sample 2 results are shown in Figure 16 and Table 37. These show a slightly less significant CRC impact on electricity use (6.6%, significant at 10%) and a similar impact on electricity intensity (8%, significant at 10%), with no significant impact on employment.

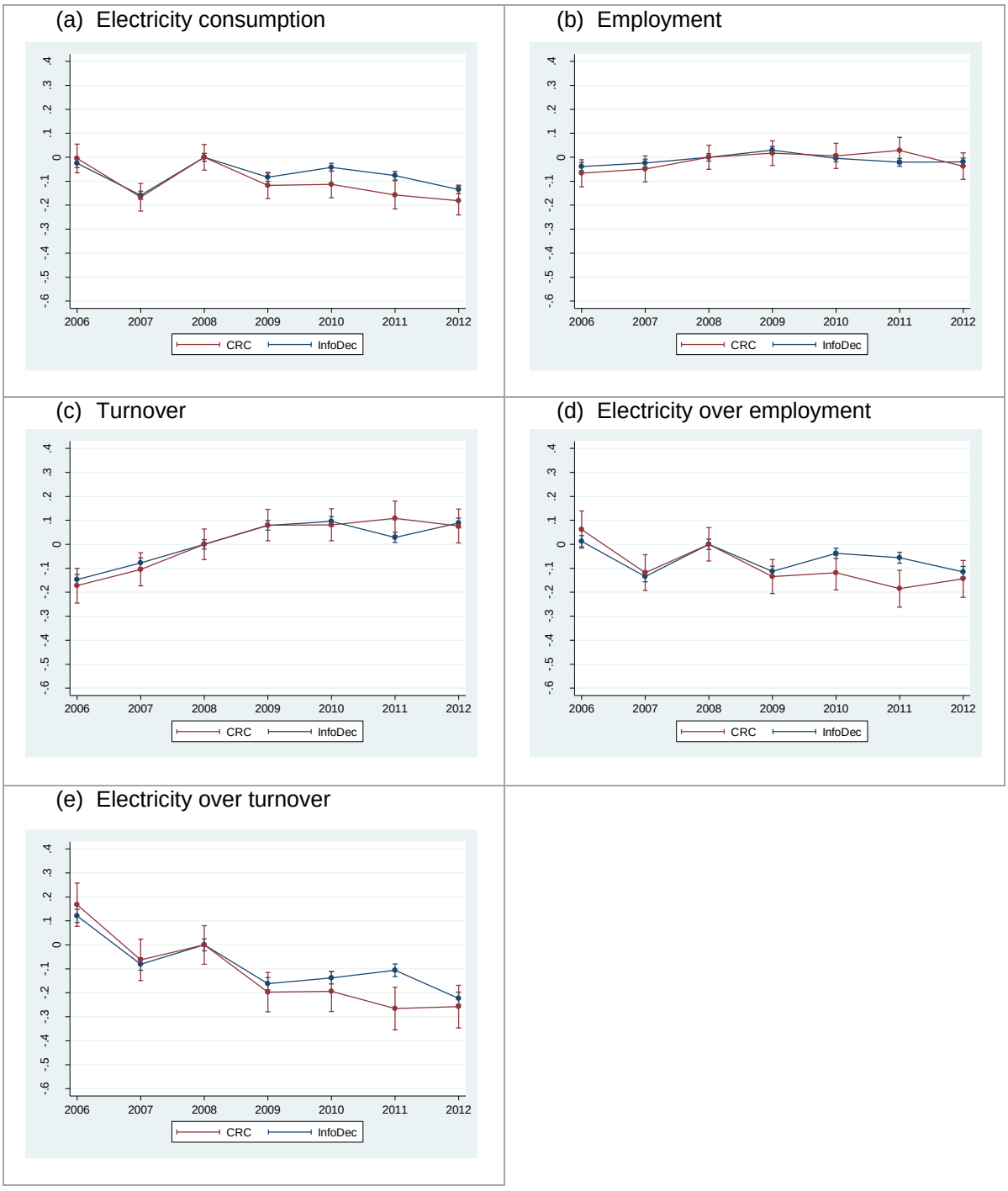

Figure 16: Results at the organisation level – Analysis Sample 2[52]

[52] See notes to Figure 6. Results are derived using 5 bands of 20 percentile electricity consumption, electricity over employment, electricity over turnover and electricity growth bands.

4. Conclusions

This is the first comprehensive econometric evaluation of the CRC Energy Efficiency Scheme. To analyse different outcome variables and introduce additional control variables we conducted the analysis at several different aggregation levels combining different kinds of datasets. At all aggregation levels we find a clear and statistically significant impact of the CRC scheme on electricity consumption, with a reduction of 3-5% compared to the control group (information declarers). There is also some evidence of an impact on gas consumption, although the limited quality of the data matching imply that these are tentative results. While the impact is statistically weaker for gas than for electricity, the point estimates suggest an even larger reduction of more than 10%. Care must be taken in interpreting gas results owing to the limited sample that could be matched in the NEED data, but there appears to be a statistically significant impact for the largest quintile of gas meters (an estimated 30% annual reduction for CRC participants relative to information declarers). Combining gas and electricity consumption, there is evidence that the average effect on implied CO_2 emissions is statistically strong with an impact of between 6-8%.

There is also evidence that CRC led to an improvement in energy efficiency (a reduction in energy intensity), as measured by the proxy of electricity intensity relative to employment. However, the effect is less statistically significant than for electricity consumption and carbon emissions.

In some of our results there is evidence that the CRC effect declines somewhat over time. There are a range of possible explanations for this, including:

- random statistical variation, or
- a reflection of the policy weakening over time, or
- because the main CRC impact is dynamic (i.e. participants adopting measures earlier that would still have been adopted later), or
- avoidance behaviour by the control group (i.e. information declarers trying to avoid being part of CRC in Phase 2).

This is discussed further in the synthesis report, in combination with evidence from the other workstreams.

Annex A: Quality Assurance

The regression results and the analysis presented here have been generated and reviewed by Ralf Martin, Assistant Professor at Imperial College Business School and Mirabelle Muuls, Lecturer in the Grantham Institute at Imperial College London. Ralf led the team and is one of the leading experts on economic studies using the kind of micro data used in this study. As part of his previous research work he developed the raw business level data held by the ONS to make it suitable for micro-level research. This work forms the back-bone of the business data that is now being made available to the research community as a whole through the UKDS. Mirabelle has conducted similar work with Belgian data in the past.

The results were periodically challenged and scrutinised by a project steering group which included representation from DECC, other government departments, the Environment Agency and academics concerned with non-domestic energy efficiency. The final version of the paper was also externally peer reviewed and in response to these comments, further changes have been included in this version.

Annex B: Interpretation of regression coefficients in the CRC study

This annex explains how the regression coefficients can be used as estimates of the annual change in energy consumption for CRC organisations relative to the control group (information declarers).

The 'Difference-in-differences' model

Our analysis is based on a regression model of the form

$$\ln E_{it} = \beta CRC_{it} + \alpha_i + \epsilon_{it}$$

where CRC is an indicator equal 1 for meters, facilities or firms in the CRC. We identify this model by running regressions in differences relative to a base period t=2008. This is because there is concern that CRC participation is correlated with un-observed but non-time varying factors α_i driving the level of energy consumption. Differencing removes these factors thereby leading to an unbiased estimate of β.

$$\ln E_{it} - \ln E_{i2008} = \beta(CRC_{it} - CRC_{i2008}) + \epsilon_{it} - \epsilon_{i2008}$$

But how can we interpret β exactly?

What is the meaning of β?

β represents the difference in log energy consumption between a firm that is covered by the CRC vs a firm that is not.

$$\ln E_{it}^{CRC} - \ln E_{it}^{nonCRC} = \beta$$

To explain this step a bit more (in simplified terms): for CRC firms, the CRC indicator is 1 during the CRC period but 0 in 2008, so:

$$\ln E_{it}^{CRC} - \ln E_{i2008} = \beta + \epsilon_{it} - \epsilon_{i2008}$$

And for information declarers, the CRC indicator is 0 throughout the time period so:

$$\ln E_{it}^{nonCRC} - \ln E_{i2008} = \epsilon_{it} - \epsilon_{i2008}$$

Taking the difference between these two equations, across all the CRC and information declarers, we get:

$$\ln E_{it}^{CRC} - \ln E_{it}^{nonCRC} = \beta$$

Estimating the percentage annual reduction to the CRC

Suppose we denote by g the percentage reduction of energy consumption due to CRC in a given year, relative to information declarers i.e.

$$E_{it}^{CRC} = (1-g)E_{it}^{nonCRC}$$

Then we can write

$$\beta = \ln E_{it}^{CRC} - \ln E_{it}^{nonCRC} = \ln\left[(1-g)E_{it}^{nonCRC}\right] - \ln E_{it}^{nonCRC} = \ln[1-g] \approx -g$$

The last approximation (that ln[1-g] is approximately equal to g) holds for values of g that are not too large (smaller than 0.1 say; note that ln(0.9)=-0.10536). This is a good approximation for almost all of the values of β observed in the CRC study.

So we can use the value of β, the regression coefficient, as an approximation of the percentage annual reduction in CRC energy consumption, relative to information declarers, over the period for which the CRC indicator was set at 1 (i.e. 2010-2012).

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