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# Effects of Carbon Reduction Labels: Evidence From Scanner Data<sup>†</sup>

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## Abstract

We investigate the effects of carbon reduction labels using a detailed scanner data set. Using a difference-in-differences estimation strategy, we find that having a carbon label has no impact on detergent prices. We also investigate possible heterogeneous effects of carbon labels using the synthetic control method. We find no evidence to indicate that the prices for the counterfactual detergents without the label would have been any different from the prices of the carbon labeled detergents. We investigate the reasons for these results and conclude that the specific design of the carbon label is responsible for its lack of success.

**Key words:** Environmental labeling, carbon footprint, quasi-experiment, scanner data, synthetic control.

**JEL Classification:** D12, D83, L15, Q54.

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## 1. INTRODUCTION

Households in the EU are responsible for 25% of total EU greenhouse gas emissions.<sup>1</sup> In an effort to reduce household greenhouse gas emissions, the Carbon Trust Fund in the United Kingdom has introduced a new product label called the carbon reduction label for many common household goods. This carbon label shows the approximate number of grams of carbon dioxide that a product generates during its life cycle, i.e., as the product is grown or manufactured, transported, stored and used. More than 27,000 goods in the UK now carry this label and it is estimated that the label appears on goods worth 3.3 billion pounds in annual sales.<sup>2</sup> The objective of these carbon labels are to move households' behaviour towards lower amounts of carbon consumption.<sup>3</sup> To examine if the carbon label is effective one could test if households are willing to pay more for goods that have a carbon label or a lower carbon footprint (less carbon dioxide emissions over the lifetime of the good). If consumers are willing to pay more for carbon labeled (or low carbon footprint) goods, there is an incentive for firms to lower the carbon footprint of their goods, label them accordingly and charge a higher price. So an indirect test of the effectiveness of the carbon reduction label is the emergence of a higher price (or a price premium) for goods that have the carbon label *vis-a-vis* other similar goods that do not have the carbon label. In this paper, we investigate the effectiveness of the carbon reduction label using real market data and in particular test whether there is a price premium for carbon labeled detergents compared to other detergents that do not have this carbon label.

Results from theory suggest that the introduction of an environmental label on a good should lead to a higher price (or a price premium) for the labeled good irrespective of the nature of the competition for the good in the market (Mattoo and Singh [1994], Engel [2004], Sedjo and Swallow [2002], Cason and Gangadharan [2002] and Amacher, Koskela, and Ollikainen [2004]).<sup>4</sup> In contrast to the theoretical results, empirical studies have documented a wide range of values for the price premia associated with goods which have an environmental label – ranging from high values to even zero. Survey results suggest that people appear to value environmental attributes of a good.<sup>5</sup> Empirical studies based on

<sup>1</sup>See the recent report published by the European Environment Agency which can be downloaded from the website: <http://www.eea.europa.eu/publications/end-use-energy-emissions>.

<sup>2</sup>From the web site of the Carbon Trust Fund at: <http://www.carbontrust.com/client-services/footprinting/footprint-certification>.

<sup>3</sup>For a detailed discussion on carbon labeling and its potential usefulness in reducing carbon dioxide emissions see Cohen and Vandenberg [forthcoming] and references cited therein.

<sup>4</sup>For a literature review on how the introduction of a label can lead to a price premium see Bonroy and Constantatos [2013].

<sup>5</sup>Findings from the recent survey literature suggest that growing numbers of consumers claim to be influenced by green issues in their purchasing decisions. For example, according to the Eurobarometer [2009] survey 95% of all Europeans think that environmental protection is important and 65% are willing to pay more for environmentally friendly products. In the UK, Landor's Green Brands survey found that 62% of respondents agreed with the statement, "I make a conscious effort to purchase green products", and 57% of UK respondents agreed with, "I am purchasing

stated preference and experimental data mostly support the survey results and a large number of papers have found consumers' willingness to pay to be higher for goods that have environmentally friendly attributes, including attributes of a pure public good type (see e.g., [Blend and Van Ravenswaay \[1999\]](#), [Carlsson, Frykblom, and Lagerkvist \[2007\]](#) and [Brecard, Hlaimi, Lucas, Perraudou, and Salladarre \[2009\]](#)).

However, several studies based on real market data (either scanner or household level data) have found smaller premiums for goods that have environmental labels ([Teisl, Roe, and Hicks \[2002\]](#) and [Bjorner, Hansen, and Russell \[2004\]](#)). The difference in the results obtained from experimental and stated preference data compared to the results obtained with real market data can be attributed to at least two reasons. The first is the well known hypothetical bias – people are not necessarily willing to pay more for environmentally friendly labeled products but feel obliged to say so when asked. That is, people tend to overestimate their contribution in a hypothetical setting or when no incentive-compatible scheme is used.<sup>6</sup> The second reason is that the emergence of a price premium is conditional on three factors: consumers' willingness to pay for the labeled attribute, consumers' comprehension of the label and consumers' awareness of the label. We discuss these three factors in more detail in Section 2.

Even though there is a relatively large theoretical and empirical literature on labeling, there have only been a few studies investigating the carbon label and its effectiveness. This lacuna may result from the fact that carbon labels were introduced only a few years ago. Although, empirical studies on the carbon label using real market data are almost non-existent, in recent years a few experimental studies have investigated the effectiveness of carbon label. Using simple experiments [Michaud, Llrena, and Joly \[forthcoming\]](#) and [Kohnle \[2013\]](#) have found a significant price premium for low carbon footprint products. However, the choice setting that these studies use in their experimental design is very different from a real life purchase choice and therefore the external validity of the results could be weak.<sup>7</sup> Also, using a conjoint choice experiment (included in a 2008 U.S. survey), [Onozaka and Mcfadden \[2011\]](#) find some evidence that labels which signal carbon-intensity of a product can have a negative impact on the effectiveness of other environmental labels. Finally, [Vanclay \*et al.\* \[2011\]](#) study the effectiveness of a traffic light style carbon label placed on the shelves in one grocery store in Australia. Interestingly, they find the shelf labels to have a small positive

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more green products than I used to". Moreover, in the survey by Consumer Focus in 2007, 54% of the survey respondents said that they were buying more environmentally friendly products than two years before.

<sup>6</sup>Several studies have documented this "hypothetical bias" in the stated preference approach; for a discussion see, for example, [Murphy, Allen, Stevens, and Weatherhead \[2005\]](#) or [List and Gallet \[2001\]](#).

<sup>7</sup>For instance, [Michaud, Llrena, and Joly \[forthcoming\]](#) consider only three different product characteristics in their experimental design: a product price, an eco-label and a carbon footprint with two different levels (high emissions vs. low emissions). Besides having a small number of characteristics the carbon label used in their experiments is much simpler than the labels typically used in the real market which may have an effect on the results.

impact on the sales of the least carbon intensive products and a negative impact on the sales of most carbon intensive products during a 8 week follow-up period. Although their results may capture real market behavior, their study is limited in scope and duration and most importantly it lacks a rigorous experimental design (as explained in their paper).<sup>8</sup>

In this paper we use a detailed scanner data set from a major supermarket chain in the UK to examine if a specific category of carbon labeled goods – carbon labeled detergents – obtain a price premium compared to detergents without the label. In comparison to previous studies on the carbon label cited above, one strength of the data that we use for our analysis is that our data is not limited to a specific location or a specific store but it is based on observed consumer behavior in the whole of the UK. Another advantage that we have is that we can observe transaction prices for labeled and unlabeled detergents before and after the labeling started. This quasi-experimental design allows us to utilize standard micro-econometric techniques (elaborated below) to tease out average treatment effects. Our empirical analysis will mainly concentrate on the impacts of the carbon reduction labels on detergent prices as we do not have either the aggregate sales data for individual products or the data on customers' purchases in the stores of other supermarket chains. However, as a robustness check to our price regressions we also estimate simple demand models. In contrast to the previous experimental studies on the carbon labels cited earlier, in the UK (and therefore also in our data) the carbon labels used are complicated and include detailed information on the carbon dioxide emissions of the products. Given this detailed information (i.e., the number of grams of  $CO_2$  emissions) and the fact that people's buying behavior might be quite different in a market setting than in the laboratory, it is interesting to investigate the impact of the carbon label with real market data. Real market data also allows us to account for the effect of search costs, which are typically (or implicitly) assumed to be zero in the laboratory and in choice experiments. In fact, as the recent work by [Seiler \[2013\]](#) has shown the presence of high search costs in the detergent market, we would expect search costs to have an effect on the willingness to pay for carbon label detergents in our case as well.

In our empirical analysis, we make use of two methods to test for the emergence of a higher price for carbon labeled detergents. The first method is a standard difference-in-differences (DID hereafter) regression that takes advantage of the fact that some of the detergents were carbon labeled sometime after our data starts. This method allows us to estimate the average impact of the carbon reduction label on the detergent prices (i.e. the average treatment effect on the treated). However, since the impact of the carbon reduction label can be different for products with different carbon footprints (i.e. products

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<sup>8</sup>In fact, since they do not at all look at the sale changes of unlabeled products, it is difficult to evaluate the impact of the labels based on their results.

with different carbon labels), it is also important to investigate whether treatment effects vary across labeled products (i.e., if we have heterogeneous treatment effects). To address this question, we use a (relatively new) technique called the synthetic control method.<sup>9</sup> We use this method to estimate the counterfactual price trajectories for each labeled product individually. We then compare the price trajectories of the counterfactual detergents with real carbon labeled detergents. We also estimate simple demand models (in a difference-in-difference setup) to examine the impact of the carbon reduction label on the sales of carbon labeled detergents.

The results we get from the DID regressions show that on average the carbon reduction label has no effect on price, i.e., there is no price premium for detergents that have a carbon label. We do not find any demand impacts for the carbon reduction label either, although we note that the results of the demand models might be sensitive to the sample that we use in estimation. Finally, the results obtained using the synthetic control method indicate that there is no evidence that prices would had been higher/lower for products with low/high level of carbon emissions compared to the corresponding counterfactual products without the label.

The rest of the paper is structured as follows. Section 2 presents a simple theoretical framework that helps delineate the different types of price (or carbon) premia that we could possibly observe in the data. Section 3 describes the data for the paper and the methods used in the empirical analysis. Section 4 gives the results of the empirical analysis, while Section 5 discusses the results and policy implications. Finally, Section 6 concludes.

## 2. SETTING

The theoretical literature predicts that an increase in the environmental quality of a good usually leads to a price premium (in our case a “carbon premium”). The idea behind this result is that a consumer gets higher utility from consuming a more environmentally friendly good which leads to a higher willingness to pay for that good and in turn to a higher price for that good.<sup>10</sup> However, in practice, the emergence of a price premium and the magnitude of this premium conditional on its emergence depends on the following three factors:

<sup>9</sup>Another option would be to use the difference-in-differences (DID) set-up and interact the treatment group and period indicators with indicators of labeled products. However, since the synthetic control method does not require the common trend or any kind of parametric functional form assumptions for its validity, it is more flexible and robust than the DID.

<sup>10</sup>In the theoretical literature an increase in the environmental quality is considered as an increase in quality which permits vertical product differentiation, market segmentation and/or an increase in the willingness to pay for the product. The environmental label on a good allows a firm to signal the increase in environmental quality for the good in question. For details, see e.g. the literature review done by [Bonroy and Constantatos \[2013\]](#) and the references therein.

- (1) Consumers' valuation of the environmental characteristic.
- (2) Consumers' awareness of the label: a consumer needs to look for the label resulting in a search cost.
- (3) Consumers' understanding of the label. This depends on consumer's cognitive ability to process the information on the label.

Regarding consumers' valuation of the environmental characteristic, many studies using the hedonic approach have found considerable price premia for organic products (see for example, [Griffith and Nesheim \[2010\]](#) or [Nimon and Beghin \[1999\]](#)). However, organic products are often considered a tastier and healthier alternative to their non-organic counterparts and therefore they incorporate some private benefit as well as attributes of a public good type. In general it seems that taste and nutritional aspects of the good are much more important for consumers than the environmental characteristics of the good (see [Griffith and Nesheim \[2010\]](#), [Bougherara and Combris \[2009\]](#) and [Fletcher and Downing \[2011\]](#)). For the specific case of the carbon label, [Michaud, Llrena, and Joly \[forthcoming\]](#), [Kohnle \[2013\]](#) and [Vanclay \*et al.\* \[2011\]](#) have found a price premium using an experimental approach suggesting that consumers value products with a low carbon footprint. However, their approach is quite different from ours, because these studies control for salience and understanding of the label or assume away search costs, all of which are likely to be important in our case.

Consumers' difficulty in noticing the label, which is typically more likely to be the case in real markets than in experimental and stated preference settings, appears to be an important factor in the emergence of a price premium ([Rubik and Frankl \[2005\]](#), [Thøgersen \[2000\]](#)). [Noussair, Robin, and Ruffieux \[2004\]](#), show in an experimental framework that consumers may not read the label and thus buy GMO products despite their claimed animosity towards these products. In our case, the carbon reduction label is at the back of the product, which may affect the salience of the label.

Finally, the manner in which information about environmental quality is communicated to the consumer also seems to matter for the emergence of a price premium. Information about the environmental quality of a good can be of many types.<sup>11</sup> The two most common types of indicators of environmental quality are *(i)* simple labels of approval (e.g., an eco-label such as the EU flower or the Nordic Swan), and *(ii)* labels showing detailed information on the product in the same way as nutritional information (e.g., energy cards or the information showing the percentage of material made from recycled materials). An eco-label informs the consumer that the product is complying with a certain standard of environmental quality. For labels which involve detailed environmental information, consumers can observe the exact "amount" of an environmental attribute usually expressed in

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<sup>11</sup>See ISO website for a definition of the different kinds of environmental information.

numbers and a scale to determine whether the product is environmentally friendly or not (rather like the Guideline Daily Amount for nutritional information). Often, these labels are mandatory, which means all the products in the same product category have to be labeled. Several studies using field experimental data have documented that more information is not always better and that consumers prefer simpler information to more detailed information (see Wansink, Sonka, and Hasler [2004], Wansink and Chandon [2006], Teisl, Rubin, and Noblet [2008], Kiesel and Villas-Boas [forthcoming] and BIO Intelligence Service [2012]).

In our case the carbon label is voluntary, which is why only some of the products in a product category have the label. The specific form of the carbon label used on detergents is called the carbon reduction label and it indicates the approximate amount of  $CO_2$  emissions generated by the labeled product or detergent with the sentence: “*We have committed to reduce this carbon footprint*”. In addition, the label indicates the carbon footprint of a labeled product in the same product category (see Figure 1 in the appendix).<sup>12</sup> By reading the carbon reduction label on a single product, the consumer knows the  $CO_2$  emissions generated by the labeled product, but does not know whether this amount of  $CO_2$  emissions is environmentally friendly. In order to understand the label and to find the number of labeled products and their associated  $CO_2$  emissions, the consumer needs to review all the products within the product category. Even if all of this information could be collected by the consumer, he/she does not necessarily have a scale or a reference point to understand this information. Thus, given the particular form of the carbon reduction label, we need to figure out how the consumer processes all of this information. In the rest of this section we develop three different scenarios regarding consumers’ reaction to the label and the possible consequences of their behavior on the willingness to pay for the product and hence on the effect of the label on the product price.<sup>13</sup>

Our set-up is as follows. We assume that there are  $K$  labeled products in a certain category of goods denoted by  $i = 1, \dots, K$ . The emissions of the labeled product  $i$  is given by  $E_i$  and  $E_i = E_1, \dots, E_K$ . There are  $N$  products in the whole category, so the number of unlabeled products is given by  $(N - K)$ .<sup>14</sup>

### *First case scenario*

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<sup>12</sup>One could be skeptical about whether information about the carbon footprint of comparable product affects consumers’ purchases. For the conscientious consumer who reads the detailed information on each labeled product the information about the benchmark product does not add any new information at all, while for the consumer who wants to save time by just looking at the logo for the product the information about the benchmark product is probably written too small to be noticed or they may simply not use this information anyway.

<sup>13</sup>We use a formal or mathematical approach only to facilitate exposition. Our arguments are quite intuitive.

<sup>14</sup>Recall that the consumer needs to review all the products in the product category in order to determine  $K$  and the  $CO_2$  emissions of each of the products.



In this scenario we assume that the maximum level of  $CO_2$  emissions within a product category is common knowledge and we call it  $E_{max}$ . For simplicity, we normalize the different levels of emissions in the closed interval  $[0, 1]$  with 0 denoting no emissions at all and 1 denoting the maximum possible level of emissions (equal to  $E_{max}$ ). Then, the gain in  $CO_2$  emissions from purchasing product  $i$  is represented by  $G_i = 1 - E_i$  with  $G_i = G_1, \dots, G_K$ . Thus the higher the gain, the more environmentally friendly the product. The maximum gain, i.e., the highest possible environmental quality is equal to  $G_{max} = 1 - 0 = 1$  and the minimum gain is  $G_0 = 0$ . Without loss of generality, we can order the gains as follows:  $G_0 = 0 \leq G_1 < G_2 < \dots < G_K$ . Consumer valuation of the environmental gain is given by  $\theta$ .<sup>15</sup> We suppose that in order to appreciate the amount of gain a consumer enjoys by consuming a product  $i$  or  $G_i$ , the consumer needs to know what the position of the product is in relation to the other labeled products. Thus, the consumer needs to construct his/her own scale of environmental gain.<sup>16</sup> We let  $u(G_i)$  to represent the consumer's utility from a gain of  $G_i$  for product  $i$  according to his/her personal scale of environmental gain.

To construct the scale of reference the consumer needs to compare all of the  $K$  labeled products together and thus search for all the  $K$  labeled products from the total set of  $N$  products available in the market. This is clearly costly. The search cost denoted  $C(K, N, a)$  depends on three variables – (i) the consumers' cognitive ability  $a$ , with  $C_a < 0$ , (ii) the number of products to look at or  $N$ , with  $C_N > 0$  and (iii) the number of labeled products with which to compare a product with or  $K$ , with  $C_K > 0$ . Note that the partial derivative for  $K$  is positive, since increasing the number of labeled products will increase the number of products with different carbon footprints. The willingness to pay for the environmental attribute once the product is labeled equals:

$$(1) \quad U(G_i) = \theta u(G_i) - C(K, N, a)$$

Note that the cost of constructing the scale is the same for each labeled product whatever its level of emissions. However, the utility that the consumer derives from the consumption of product  $i$  depends on the gain that she/he derives from the reduction in the  $CO_2$  emissions from product  $i$  or  $G_i$ . Thus:

$$U(G_i) = \theta u(G_i) - C(K, N, a) > U(G_{i-1}) = \theta u(G_{i-1}) - C(K, N, a)$$

As  $G_{i-1} < G_i$ , we can equivalently order the different utility levels as:  $U(G_1) < U(G_2) < \dots < U(G_k)$ . So we should have different levels of willingness to pay (WTP) according to the different levels of  $CO_2$  emissions. If we further assume that the labeled products are otherwise identical, then products with lower carbon footprint level should have higher

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<sup>15</sup>For simplicity, we assume  $\theta$  to be identical for all consumers. However, this is not necessary as long as the ranking of the environmental gain is the same among consumers.

<sup>16</sup>We can also think of the consumer as trying to assess the distribution of the  $CO_2$  emissions.

demand and prices. If consumers behave according to the scenario outlined here, we would expect a price premium for carbon labeled products that depends on the level of the carbon footprint of the product.

This scenario seems to conform to the experimental results obtained by [Michaud, Llrena, and Joly \[forthcoming\]](#). They find evidence of a significant price premium for products (roses) with low carbon emissions. However, we note that in their simple experimental design, the label is much simpler (high vs. low carbon footprint) and the *entire* category of products that they consider in their experiment is labeled. Thus their setting differs considerably from the scenario that we have just described.

We note that as the number of products in a category and as the number of labeled products increase, the difficulty in comparing each one of them increases as well. The increase in utility due to the label can thus be offset by rising search costs on the side of the consumer. In fact, it is possible that for some labeled products the potential gain coming from labeling the product does not exceed the cost of searching for information, leading to no increase in WTP for the product at all.<sup>17</sup> Thus, in this scenario it is also possible that only the most environmentally friendly product will have an increase in price and that other labeled products will not get any premium.

### *Second case scenario*

As it is costly for the consumer to construct her own scale of reference, he/she may instead choose to use the environmental information in a way different from that envisaged in scenario 1 in order to save some effort. The consumer can simply ignore the detailed information (or the actual footprint) and just look at the logo.<sup>18</sup> In fact, many studies have shown that consumers usually prefer simpler information to more detailed information and that they are also more familiar with simple labels.<sup>19</sup> The cost of searching for information will depend on the time spent looking up this information and on the consumers' ability to process this information. If consumers want to decrease the time spent looking for the label, they may not search for all the labeled products within the labeled category but they may just reward

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<sup>17</sup>Indeed, for a product with  $E_{max}$  emissions, its environmental gain is equal to  $G_1 = 0$  whereas the cost of constructing the scale is still the same whatever the product labeled and positive.

<sup>18</sup>We assume that the consumer is not necessarily looking (just) for the label. We are trying to find out what the consumer willingness to pay is for the product if the consumer sees the label. We could just as well take into account the probability that the consumer sees the label in the cost function by including (for instance) the ratio  $K/N$  in our specifications. This will not change our predictions for any scenario.

<sup>19</sup>Regarding the carbon footprint, the study by [Upham, Dendler, and Bleda \[2011\]](#) mentioned earlier also reports individuals' comments on the label like: "It's difficult. I've no idea what 260 g of carbon looks like. I'm sure it's better [than the comparatively higher carbon product] but I have no idea what the impact of 260 g is like. I have no idea." and like: "They should put, as with calories, how much you should do a day or a week". These comments support the idea that the continuous information on the carbon reduction label might be difficult to understand and that the consumer would prefer simpler information.

positively any disclosure regardless of the amount of  $CO_2$  emissions disclosed.<sup>20</sup> In this case, the search cost will be independent of the number of labeled products and on the numbered products in the product category and it will depend only on the consumer’s cognitive ability  $a$ . So the search cost will be just  $C(a)$  in this case.

However, even if consumers are not looking at information on the level of  $CO_2$  emissions regarding  $K$  (the number of comparable products) or  $N$  (the total number of products in a category), they still need to make some kind of assumption on the distribution of the level of  $CO_2$  emissions. We assume that consumers suppose that  $G$  follows a distribution  $f(g)$  between  $[0, 1]$ . We also assume that consumers believe that any unlabeled product which is not disclosing its level of  $CO_2$  emissions has a higher level of emissions than the labeled product with the highest level of carbon emissions. According to the unraveling argument, any product above the worst quality has an incentive to disclose its quality (see for example, the paper by [Milgrom and Roberts \[1986\]](#) in the context of a monopoly and the paper by [Okuno-Fujiwara and Suzumura \[1990\]](#) in the context of an oligopoly). Hence any product that is not disclosing its quality should be of the worst type. Assuming unraveling behavior from the firm, any disclosure will mean that the product is above the worst environmental quality for that product category available in the market. Then consumers may calculate the expected value of the environmental gain associated with the label as:

$$u(G_i) = \int_0^1 gf(g)dg = E[G]$$

So the utility in this case does not depend on the level of the carbon footprint.<sup>21</sup> Moreover, in this case the label could also be interpreted as a simple eco-label, and so the consumer should reward all the labeled products similarly and independently of the carbon footprint that these products are disclosing. Hence consumer’s utility when consumers are only making use of the logo should be:

$$(2) \quad U(G_i) = \dots = U(G_K) = \theta E[G] - C(a)$$

If we assume that this utility is positive (i.e. that  $U(G_i) = \dots = U(G_K) > 0$ ), the consumer would be willing to pay more for the carbon reduction labeled product. Therefore, in this scenario all the labeled products should receive the same price premium independent of the level of  $CO_2$  emissions disclosed.

### *Third case scenario*

<sup>20</sup>[Upham, Dendler, and Bleda \[2011\]](#) report that “...the footprint symbol was often interpreted as signifying a reduction in carbon emissions: people assumed that the label indicated that the company was signaling positive action on climate change, or that this was a lower-carbon variant of a product”.

<sup>21</sup>Note that we postulate that consumers use a distribution to estimate the expected value of the gain, but they may as well use other heuristics to give a value to the environmental gain. This will not change the conclusion of our second scenario as long as the gain associated with labeling is the same for all the labeled products.

In practice, consumers may find it too difficult or time-consuming to understand and read the label and they may prefer to just ignore it. In this last scenario, we assume that the consumer places very little value on the environment and/or has very low ability and thus a very high cost of acquiring environmental information about the product. If consumers do not value the environmental attribute sufficiently highly they will not be able to offset the cost of acquiring information with the environmental gain from the product and so in this case the label will have no impact on price.<sup>22</sup> Formally this situation arises when:

$$(3) \quad \theta E[G] - C(a) \leq 0 \text{ and/or } U(G_K) = \theta u(G_K) - C(K, N, a) \leq 0$$

Therefore in this case it will not be profitable for consumers to invest time searching for environmental information on the product or understanding the label.

We now summarize our predictions from these three different scenarios. These predictions pertain to the effect that the carbon reduction label may have on the prices of labeled detergents.<sup>23</sup>

- (1) If consumers value the carbon reduction label and interpret it perfectly, we would expect to find price premia that vary among different labeled products.
- (2) If consumers have limited ability and use the label as a proxy for environmental quality we expect all labeled products (detergents) to obtain the same price premium.
- (3) If consumers find it too complicated to assess the labels we expect to find no premia at all for any labeled product.

In the next section we use real market data to investigate empirically which of these three possible scenarios holds for our case.

### 3. DATA AND EMPIRICAL APPROACHES

**3.1. Data.** For our empirical analysis we utilize a unique data set based on a noted supermarket chain’s scanner data.<sup>24</sup> The data consists of detailed purchase information on clubcard account holders of the supermarket chain, 60,000 customers in total. This sample is a representative (random) sample for all the clubcard account holders of this supermarket chain in the UK. For these customers we have detailed information on product sales and daily transaction prices of 339 distinct products. Among these products there are 43 detergents,

<sup>22</sup>In a recent study on consumer comprehension of the carbon reduction label, [Fletcher and Downing \[2011\]](#) reported that 43% of respondents found it difficult to understand whether a product is environmentally friendly based on the information on the product packaging and needed to make an effort to look for the environmental information on the packet about it.

<sup>23</sup>Note that we do not consider the supply side of the market as we prefer not to make any assumptions on what type of competition exists in this market. We also assume that the label only affects the WTP of the labeled product and does not change the competition structure in the market.

<sup>24</sup>For reasons of confidentiality we are not able to reveal the name of this supermarket chain.

the names of which are given in Table 1.<sup>25</sup> Of these 43 detergents, only 5 detergents (shown in bold in Table 1) are carbon labeled. All of these labeled detergents belong to the supermarket brand which has many detergents in the unlabeled category as well.<sup>26</sup> These carbon labeled products have the following carbon footprints: (4) 700 grams of  $CO_2$  per wash, (7) 750 grams of  $CO_2$  per wash, (17) 850 grams of  $CO_2$  per wash, (32) 700 grams of  $CO_2$  per wash, (41) 600 grams of  $CO_2$  per wash. The label given on the back of the product package informs customers the amount of  $CO_2$  emissions produced during the product’s life cycle on average and demonstrates a commitment to reduce the detergent’s carbon footprint. In addition, the label gives information on the carbon footprint of a benchmark product and advice on how customers could reduce their carbon footprint even further, for example, by reducing the washing temperature.

[Insert Table 1]

Our data consists of item level transactions for detergents for 60,000 customers for a period of 104 weeks. The data consists of prices for these detergents and categorical dummies for a number of product attributes like the type of detergent, a supermarket brand dummy (i.e., a dummy that indicates if the detergent is of the same brand as the supermarket chain) as well as other product attributes like the size of the detergent. In addition, we also have detailed information on the expenditure on the detergent and whether the detergent was bought on a price discount or whether the price at which the detergent was bought was marked down.<sup>27</sup> We note that it is particularly important to control for promotions in our specification because the effect of promotions is time-varying and typically varies across products. We also note that if we did not have access to transactions data on individual products then it would not be possible to control for promotions.

For tractability, we collapse (or aggregate) the transactions level data to weekly level data. Besides balancing the data, the use of weekly level data allows us to reduce the autocorrelation of price observations considerably. Our data spans from financial week 17 of 2007 to financial week 15 of 2009 (both weeks inclusive). Therefore, we have data for a period of 104 weeks (36 weeks in 2007, 52 weeks in 2008 and 16 weeks in 2009). Note that the carbon reduction label came into effect on week 10 in May 2008, which means that the carbon reduction label on the 5 aforementioned carbon labeled detergents was available only post

<sup>25</sup>We replace wherever appropriate in the product names given in Table 1, the name of the supermarket chain with the phrase “Own Brand”.

<sup>26</sup>During the sample period we consider in our analysis the supermarket chain already had 6 different types of products certified/labeled: toilet paper, kitchen rolls, laundry detergents, chilled and long life orange juice, light bulbs, Jaffa oranges / soft fruit. However, only a small number of products had been labeled in each of these product categories. The number of labeled products was smaller for other product categories than for detergents and so we decided to concentrate on detergents.

<sup>27</sup>Some of these variables are used in our analysis, although we note that in difference-in-difference models time-invariant control variables or characteristics (such as detergent type) become redundant.

week 10 in 2008. This fact is important since it allows us to use a difference-in-differences estimation approach and control for time-invariant unobserved product characteristics both for labeled and unlabeled detergents.

Table 2 reports the summary statistics for the variables used in our analysis.

[Insert Table 2]

**3.2. Difference-in-Differences Regressions.** Our aim is to investigate the effect that the carbon reduction label has on the prices of detergents that have this label. As mentioned earlier, we use two econometric techniques to test if carbon labeled detergents get a higher price than unlabeled detergents – the difference-in-differences and the synthetic control method.

Our first method, the difference-in-differences approach, is an improvement over the traditional hedonic method that is usually used in the extant literature to isolate the effect that an environmental label has on the price of a good. The conventional hedonic approach, using cross-sectional data, isolates the effect that an environmental label has on the price of a good by regressing the price of a good on a number of characteristics of the good including a dummy for whether a good has a label. However, in the cross-sectional setting the hedonic method cannot generally be used to estimate the causal impact of the label (or the environmental quality) but only to obtain the degree of correlation between the label and the price of a product (see for example, [Bajari and Benkard \[2005\]](#)). This is because, typically, there are unobserved factors (product characteristics etc.) that are correlated both with the product label and with product prices making the label an endogenous characteristic.<sup>28</sup>

Fortunately, for us the carbon reduction label for detergents came into existence some time after the period from when our data starts. This provides us with a market level quasi-experimental setting in which we can observe labeled and unlabeled detergents both before and after the carbon reduction labels were introduced and use these labeled and unlabeled products as treatment and control groups in a standard difference-in-differences setup. Since there is no change in any other product characteristics for labeled and unlabeled detergents, we can use this quasi-experimental setup to isolate the treatment effect or consumers' average marginal willingness to pay for the carbon reduction label. Note that we are actually measuring the average treatment effect for the treated (ATT) which in the present setting measures the amount by which the price of detergents with the carbon reduction label have changed relative to what the prices of these detergents would have been without the label. As usual, the DID estimator allows the treatment assignment (i.e. which products are

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<sup>28</sup>For more detailed discussion on endogeneity problems in these kind of hedonic regressions, see for example, [Greenstone and Gayer \[2009\]](#) and [Kuminoff, Parmeter, and Pope \[2010\]](#).

labeled) to correlate with time-invariant product-specific factors. However, consistent estimation of treatment effect rests on the assumption of independence of treatment assignment and unobserved time-variant factors. We are not aware of any reasons which would violate this assumption in the present application. Since the supermarket chain in question labeled different kind of products with different footprints, treatment assignment does not seem to be systematic or favorable to the most potential (or effective) products. We note that as only a small number of products were labeled, the treatment effect estimate obtained with the difference-in-differences method might only be representative for the labeled products.

**3.3. Synthetic Control Method.** In our difference-in-differences specification we test for the emergence of a price premium in a simple label versus no label setup. The basic difference-in-differences specification is not flexible enough to allow for different labels to have different effects on the prices of the carbon labeled detergents. To elucidate: in our data the group of labeled detergent products include both high and low carbon footprint detergents (varying from 650 grams of  $CO_2$  emissions to 800 grams of  $CO_2$  per wash), but our DID specification does not take this detailed information on the numerical value of the carbon footprint into account while estimating the treatment effect.

To allow for carbon reduction labels that have different carbon footprints (i.e., show different numbers for the grams of  $CO_2$  emitted) to have different effects on detergent prices and to lend robustness to our earlier results from the difference-in-differences specification, we use the synthetic control method following the approach outlined in [Abadie, Diamond, and Hainmueller \[2010\]](#).<sup>29</sup> In the synthetic control method we construct, in turn, for each carbon labeled detergent, an artificial or “synthetic” product or detergent which in all other product characteristics is as close as possible to the actual carbon-labeled detergent except that this artificial detergent does not have the carbon reduction label. This method is flexible enough to allow detergents with different (low and high) carbon footprints to have different effects on detergent prices. Another advantage of the synthetic method is that it does not require us to assume that unobserved factors affecting price are fixed over time or that the time trends of prices for labeled and unlabeled detergents are the same pre-treatment (as required by the DID specification). In addition, the synthetic method is fully nonparametric in the sense that no explicit functional form or distributional assumptions are required.

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<sup>29</sup>Another option would be to use the difference-in-differences (DID) setup and interact the treatment group and period indicators with an indicator for each labeled product. However, this approach has a few weakness at least in the context of our application. First, it requires stronger assumptions than the synthetic control method (common trend and functional form assumptions). Second, the problem with this kind of regression in our setting is that we would then have 5 treatments (different labels), but only one product for each treatment. Although this kind of regression can be estimated, statistical inference on the interaction terms is not very reliable.

The synthetic control method generates an artificial or synthetic control unit using a weighted average or a convex combination of the observed control units.<sup>30</sup> We treat the carbon labeled detergent as the treatment group (or treated unit) and the unlabeled detergents as the control group. Our outcome of interest is the logarithmic (normalized) price. Using the synthetic control method we iteratively produce synthetic controls (or construct synthetic products) for each of the 5 carbon labeled detergents. The group of detergents that comprises the control group does not, of course, comprise any of the five carbon labeled detergents. After obtaining the synthetic control as a convex combination of unlabeled detergents, we graphically plot and compare the actual observed price trajectory (over time) of the carbon labeled detergent with the estimated counterfactual price trajectory for the synthetic detergent (this is the price trajectory that would have resulted for the carbon labeled detergent if the detergent had not been carbon labeled).

## 4. RESULTS

**4.1. Difference-in-difference Specifications.** A common criticism of the difference-in-difference approach is the uncertainty whether the control group is able to faithfully reproduce the outcome that would have been observed in the counterfactual situation in the absence of the treatment. In our setting, this requirement translates to whether the detergents which do not have the carbon reduction label are able to mimic the counterfactual behaviour of the carbon labeled detergents had these carbon labeled detergents, not actually been carbon labeled. Since we are looking at the effect of the labeling (treatment) on detergent prices (outcome), what we need to first ensure is that the unlabeled detergents follow the same price trend pre-treatment as the carbon labeled detergents. The usual approach in the literature is to use data from the pre-treatment period(s) to show that the time trends of the treatment (carbon-labeled detergents) and the control (unlabeled detergents) groups are the same for the outcome variable in question. We show such a graph in Figure 2 which plots the time trends for average logarithmic prices (across weeks) for carbon labeled and unlabeled detergents. As shown in Figure 2, the price trends in the pre-treatment period are almost exactly the same for carbon labeled and unlabeled detergents. The graph also suggests that labeling does not have much of an impact on the prices of the carbon labeled detergents (the treatment group) post treatment.

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<sup>30</sup>The idea behind the synthetic control method is that a (convex) combination of control units provides a better counterfactual for the treated unit than any single control unit alone. In our case labeled detergents form the treatment group while non-labeled detergents form the control group. For  $K$  non-labeled detergents we assign weights  $W = (w_1, w_2, \dots, w_K)$  (with  $w_k \geq 0$  and  $\sum w_k = 1$ ) to each of these control detergents. The weights are chosen so that the synthetic detergent resembles the actual carbon labeled detergent as far as possible. We refer the interested reader to [Abadie, Diamond, and Hainmueller \[2010\]](#) for additional technical details and to [Abadie and Gardeazabal \[2003\]](#) for an economic application.



[Insert Fig. 2]

We now present the results of the difference-in-difference regressions that we use to investigate the effects of carbon labeling on the transaction prices for carbon-labeled detergents. Our difference-in-difference specification is the following:

$$(4) \quad \log(\text{price})_{it} = \beta_0 + \gamma_3(\text{CarbonLabel}_i * \text{TreatPeriod}_t) + \beta' \mathbf{X}_{it} + \delta_i + \sum_t (\text{WeekDummies})_t + \epsilon_{it}$$

where  $\text{CarbonLabel}_i$  and  $\text{TreatPeriod}_t$  are defined as follows:

$$\text{CarbonLabel}_i = \begin{cases} 1 & \text{if detergent is carbon labeled product} \\ 0 & \text{otherwise.} \end{cases}$$

$$\text{TreatPeriod}_t = \begin{cases} 1 & \text{if Week} \geq \text{Week 10 in 2008} \\ 0 & \text{otherwise.} \end{cases}$$

Note that we use the logarithm of normalized price as the dependent variable. Normalization is done by dividing the (money) price of the detergent with the number of washes the detergent has on average. This normalization gives us the price per wash which makes different sized detergent products comparable. In addition, we use a logarithmic transformation for the dependent variable for the ease of interpretation (coefficients can be interpreted as percentage changes). The week dummies  $\sum_t (\text{WeekDummies})_t$  in the specification above control for any possible exogenous time trends (expected mean change) in the log price of detergents during the sample period that affects all detergent products. The vector  $\mathbf{X}_{it}$  consists of the following control variables  $\mathbf{X}_{it} = \{\text{Price Discount Dummy}_{it}, \text{Marked Down Dummy}_{it}\}$ . Note that in the difference-in-difference specification given in equation 5 above, we include product fixed effects (for product  $i$ ) denoted in the above specification as  $\delta_i$ . The coefficient of interest is  $\gamma_3$ , the coefficient of the interaction term  $(\text{CarbonLabel}_i * \text{TreatTime}_t)$ , which shows the differential impact of carbon labeling on the price of the carbon labeled detergents using the corresponding changes for *all other* unlabeled detergent products as control.<sup>31</sup>

[Insert Table 3]

The results of the difference-in-difference regressions are reported in Table 3. We first report the regression results for a simpler specification, where product-specific fixed effects are not controlled for (in column 1)<sup>32</sup> and then report other specifications in all of which product

<sup>31</sup>We also consider a simple OLS regression (i.e., without product fixed effects), where the difference-in-differences specification used is the conventional specification used in the literature :  $\log(\text{price})_{it} = \beta_0 + \gamma_1 \text{CarbonLabel}_i + \gamma_2 \text{TreatPeriod}_t + \gamma_3 (\text{CarbonLabel}_i * \text{TreatPeriod}_t) + \sum_t (\text{WeekDummies})_t + \epsilon_{it}$

<sup>32</sup>See the footnote above.

fixed effects are controlled for and in which we also control for the nature of the standard errors involved in the estimation process in different ways (in columns 4 and 5). Note that as the prices of individual products are quite heavily autocorrelated over time and also correlated within product category (including time dummies mitigates but does not totally remove the autocorrelation), it is important to address these issues in the statistical inference. [Bertrand, Duflo, and Mullainathan \[2004\]](#) show that conventional standard errors often severely understate the standard deviation of the estimators in a DID framework. They propose using block-bootstrapped standard errors. To account for these issues, we report in [Table 3](#) the results of the difference-in-difference regression for the following three specifications *i*) product fixed effects with heteroscedastic robust standard errors (in column 3) and *ii*) product fixed effects with clustered standard errors at the product level (in column 4) and finally *iii*) product fixed effects with bootstrapped standard errors at the product level (in column 5).

The regression results in [Table 3](#) show that the coefficient of  $\gamma_3$  (the coefficient of the interaction term  $CarbonLabel_i * TreatTime_t$ ) is negative and nearly zero in all the four different specifications considered. The coefficient is statistically significant in the first specification, but it is not significant even at the 10% level for all other specifications (where the “correct” standard errors are used). In addition, when we use the bootstrapped standard errors the results are highly insignificant. Given the small magnitude of the coefficient in all cases, we can conclude that there is no perceptible difference in the prices between carbon labeled and unlabeled products after the carbon reduction label came into effect. In other words, our results show that the labeling does not affect the prices of carbon-labeled detergents relative to unlabeled detergents.

Based on our earlier discussion (see [Section 2](#)) we think that the small magnitude of the coefficient and the insignificant treatment effects (for most specifications) is not surprising. However, it is important to emphasize that zero *average* impact does not conclusively show (at least for now) that the carbon reduction labels do not have any impact on prices, since it does not rule out the possibility that some of the labels may have had a positive effect on price and some of the labels may have had a negative effect on price. Therefore we need to investigate how the labels may have affected the prices of individual detergents.

**4.2. Synthetic Control Approach.** The regressions results in the previous section suggest that on average there is little to no change in the price of carbon-labeled detergents compared to non-labeled detergents. Next, we use the synthetic control method to investigate whether one or several of the 5 carbon labeled detergents has product-specific price changes that differ from the price changes of similar unlabeled detergents. For this first, as mentioned earlier, we construct the synthetic control for each carbon labeled detergent. To this end we use the

following set of variables as given by the vector  $\tilde{\mathbf{X}}$  below (note that this vector excludes the treatment dummy and the dummy for the treatment period and their interaction):

$$\tilde{\mathbf{X}} = \{ \textit{Tablet Dummy}, \textit{Liquid Dummy}, \textit{Two in one Dummy}, \\ \textit{Price Discount Dummy}, \textit{Marked Down Dummy}, \textit{Number of washes}, \\ \textit{OwnBrand Dummy} \}$$

These variables are the criteria that we use to create convex combinations of unlabeled detergents from the control group for each carbon labeled detergent (in turn).<sup>33</sup>

In odd-numbered Tables 5 to 13 we show the weights that each detergent in the control group (not carbon labeled) has in the synthetic approximation of the actual treatment detergent (carbon labeled). To illustrate, detergent no.4 (Own Brand Non-Bio Liquid Wash 1.5 Ltr as given in the fourth entry in the list of detergents in Table 1) is a carbon labeled detergent. The synthetic detergent 4 comprises of a convex combination of other control or unlabeled detergents with weights given in Table 5. Detergent 3 gets a high weight of 0.973 in this convex combination whereas the detergent 9 gets a weight of only 0.006 in this convex combination. Note that all weights are non-negative (most of the weights being zero) and sum to one. Also note that none of the other carbon labeled detergents (nos. 7, 17, 32 and 41) are in the control group that make up the synthetic detergent. Thus, the synthetic control method constructs the counterfactual using only the most similar control units.

[Insert Table 5]

[Insert Table 7]

[Insert Table 9]

[Insert Table 11]

[Insert Table 13]

We also list the pretreatment characteristics of the actual carbon labeled detergent along with that of its synthetic counterpart for each carbon labeled detergent (i.e., for detergent nos. 4, 7, 17, 32 and 41) and show these in even-numbered Tables 6 to 14. So, for example, from Table 6 for detergent 4 we find that while the actual detergent has 17 washes, the synthetic detergent has 17.03 washes (and a similar interpretation holds for other characteristics as

<sup>33</sup>For the synthetic control method we have had to drop a few detergents for which we did not have data for all 104 weeks. For example, for detergent number 2 we did not have data from week 98, for detergent 12 we did not have data from weeks 24 to 47, etc. So we had to drop detergent numbers 2, 12, 33, 35 and 38 from the data set used in the analysis. We also had to drop data for some periods (weeks) for which we had data missing on the outcome of interest (log of the average price per wash). For example in week 1 we have data for only 37 detergents and similarly for week 2 we also have data only on 37 detergents. So we had to drop week numbers 1, 2, 3, 75, 83, 91 and 95.

well). Therefore, the synthetic detergent provides a reasonable approximation to the pre-treatment characteristics of the actual detergent. We also note from the other tables (Table 10 to Table 14) that for all carbon labeled detergents, the synthetic detergent seems to mirror the pre-treatment characteristics of the actual detergent accurately.

[Insert Table 6]

[Insert Table 8]

[Insert Table 10]

[Insert Table 12]

[Insert Table 14]

Next, we plot the actual and counterfactual trajectories of the outcome of interest, *viz.*, the logarithmic price of the actual carbon labeled detergent and the synthetic detergent which shows what would have happened if the carbon-labeled detergent had not been labeled. We repeat the exercise for all 5 detergents. We show these actual and counterfactual price trajectories for the carbon labeled products in Figures 3 to 7.

[Insert Fig 3]

[Insert Fig 4]

[Insert Fig 5]

[Insert Fig 6]

[Insert Fig 7]

These graphs show that in the pre-treatment period the price trajectories of the counterfactual product (synthetic control) are almost identical for observed price changes for the actual labeled products. The only exception is the second labeled product, but even for this case the price difference between labeled and synthetic product seem to stay constant before and after the treatment.

In agreement with the results of the difference-in-differences approach, the price trajectories of the actual detergent and its synthetic control move together very closely both pre- and post-treatment (i.e., after the carbon label actually came into effect on the 10th week of 2008 as shown by a vertical dotted line). This result suggests that the carbon footprint on the detergent products did not have any effect on the prices of these products.

Importantly, this is the case for all 5 labeled products, which seem to indicate that there is no price premium for any of the carbon labeled detergents.

## 5. DISCUSSION

**5.1. Price Impacts.** We think that the most plausible explanation for our results is that customers find it difficult to notice, understand and compare carbon footprints of different detergents and therefore do not reward carbon labeled or less carbon intensive products with a price premium. Our explanation is consistent with the finding of [Teisl, Rubin, and Noblet \[2008\]](#), who show that price premiums are more difficult to find for labels which have detailed information as this information is cognitively more difficult for the consumer to process. Similarly, [Wansink, Sonka, and Hasler \[2004\]](#) show that more information is not always better and their result suggests that people generate better inferences from short claims than from long claims on the front-label. More recently [Muller and Ruffieux \[2011\]](#) have shown how the design of the label may affect consumer behavior. In a laboratory experiment with 364 subjects they find that consumer responses to nutritional logos vary among different logos and on average consumer response is better for those logos that simplify the message most. In addition, they find that for all 7 logos the label is effective when subjects compare products with labels/logos to products without these labels/logos. Similar results are found in a report published by the European Commission on the design of an environmental index. [BIO Intelligence Service \[2012\]](#) studies consumer preferences for different kinds of label designs using a survey of over 1500 people in three different European countries. They show that consumers prefer a scale which can be expressed as a color code system, such as traffic light system.<sup>34</sup> [Upham, Dendler, and Bleda \[2011\]](#) conduct interviews on a sample of people asking them specific questions about their understanding of the carbon footprint and found that people misunderstood or had cognitive difficulties in processing the information on the label. The results from all these different studies seem to support the idea that the carbon reduction label is difficult to understand. Moreover, as the carbon reduction label is printed at the back of the products, the label can be hard for consumers to notice. Related to this point, [Noussair, Robin, and Ruffieux \[2004\]](#) have found that consumers do not always notice labels, but once they do notice they (might) change their behavior.

In the context of the carbon reduction label, the aforementioned results would suggest that the label could be more effective if it was more salient, and if instead of simply indicating the level of  $CO_2$  emissions in grams it would (instead) signal which detergents have a high carbon footprint and which detergents have a low carbon footprint. This would make it

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<sup>34</sup>They state that: “Labels that present the performance of a product on a comparative scale, such as star, letters or numbers, or a color code system are vastly preferred and are more easily understood and motivating than those that present technical information only.”

more likely for the consumer to be aware of the carbon reduction label and also to have a scale in order to understand this information (and not just the absolute value). These conclusions are also consistent with the experimental findings of [Michaud, Llrena, and Joly \[forthcoming\]](#) and [Kohnle \[2013\]](#), who find that a much simpler type of carbon label affects consumers' behaviour in experimental conditions.

Of course, it is possible that there are reasons other than cognitive difficulties in understanding the carbon reduction label that might explain our results. First, we note the specific time frame of our study is exceptional as the recorded purchases took place during the credit crunch. The economic crisis may have tempered pro-environmental behavior from the consumers as well as their budget for green product purchases. Second, it is also possible that the product category could affect the efficacy of labeling in the sense that carbon labeling could be more effective for products with higher budget shares or because detergents are like an "inventory" good for which promotions and discounts play a key role. Third, and maybe most importantly, it is possible that consumers have actually responded to carbon labeling, but their response is not reflected in price but in the quantity purchased. We find the last explanation quite plausible and therefore we consider it in detail in the next subsection.

**5.2. Demand Effects.** So far we have focused exclusively on looking at the price impacts of the carbon reduction label. It is possible that the carbon reduction label could have had an impact on the demand of carbon labeled products that is not reflected in the price. Hence, it is interesting to look at the direct demand effects of the labeling. Unfortunately, since we do not have product-level aggregate sales data for different detergent products but only for our sample of consumers (60000 clubcard account holders) it might be challenging to uncover demand functions for the carbon labeled products using our data. Note that the demand estimation is also complicated by the fact that we do not observe people's purchases in the stores of other supermarket chains. This implies that we do not, for example, observe whether there may have been systematic changes in market shares of certain products or in the buying behavior of customers. Because of these reasons our data is less suitable for estimating demand models than price models.

Despite these difficulties, as a robustness check we estimate simple demand models for detergents. For these estimations we once again used the difference-in-difference approach, but now our dependent variable is the (logarithm of) the expenditure share of individual detergent products. As regressors we use the same explanatory variables that we used in the price models. Following standard demand models we included own price, the average price of substitutes (or detergents) and aggregate spending on detergents as additional regressors. Note that we need to control for these variables, because the treatment indicator is not

necessarily uncorrelated with these variables. However, our results are not sensitive to the exclusion of these variables.

The regression results for the difference-in-difference demand regressions are presented in the appendix. In the demand models that include fixed effects, the coefficient estimates of price and expenditure variables are statistically significant and have the expected signs (i.e. own price has a negative effect and substitute price and expenditure have positive effects on the quantity purchased). The treatment effect of the label on demand is positive in all models, but is far from significant (when correct standard errors are used). Moreover, numerically the estimate is small which indicates that the demand impact on carbon labeled detergents is negligible. However, it is worth emphasizing that these estimation results can be sensitive to our specific sample, which is not necessarily a representative sample for all the customers of the supermarket chain (but only for the clubcard account holders). This is not an issue in price regressions, because price effects should be representative for all the customers and not just for clubcard account holders (at least when discounts are controlled for). This is why the results of the demand estimation may be less reliable or robust than the results we obtain on detergent prices. In any case, we think that it is safe to say that these results strengthen our conclusion that non-existent price impacts originate from the consumer side and from consumers' problems in understanding these labels.

**5.3. Design of Carbon Reduction Labels.** It is important to understand why the Carbon Trust Fund adopted the carbon reduction label and the rationale behind the particular design of this label. We briefly discuss below some of the reasons why this might be so.

We believe that to reduce the carbon footprint of products, the Carbon Trust Fund intended to design a label which supposedly would have wide accessibility. Since the carbon reduction label is a voluntary label, it seems that the idea was that if the label was easily accessible (and thus more attractive to firms) then it was more likely that it would be adopted by many firms and used on a number of different products.<sup>35</sup> In its current form the carbon reduction label allows a firm to use the carbon reduction label to certify all its products whatever their level of  $CO_2$  emissions. Thus, any firm can have the label as long as it commits itself to reducing the  $CO_2$  emissions of its product within two years. In comparison, a simple label of approval or a traffic light system can be much more financially demanding for the firm and this may become a barrier for the adoption of these labels.<sup>36</sup> We think that the Carbon Trust Fund aimed to spread the use of the carbon reduction label

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<sup>35</sup>Koos [2011] shows that a larger supply of environmental-labeled good within the market increases the likelihood of purchasing these goods. Indeed, the availability of these labeled products in the supermarket is a necessary condition for the purchase of the labeled good. Moreover, his results indicate that the larger the share of major retailers using the label, the more likely the labeled product is bought.

<sup>36</sup>With a simple label of approval a firm might have to make improvements or investments in its production process to raise the environmental quality of its products above the level imposed by the label and this could be costly. With

so that even if the actual reduction in emissions for any product is small (as compared to, say, a easier to understand traffic light label system) the cumulative reduction in emissions achieved from all products (adopting this label) taken together would mean a sufficient overall reduction in the total level of carbon emissions.

However, we note that none of the other major super market chains in the UK except this particular super market chain have adopted Carbon Reduction Labels for their products. It seems that this general lack of adoption of the label and its (consequent) lack of proliferation has affected its efficacy. In fact the supermarket chain in question has recently gone on record complaining about how other supermarket chains have not followed its example of implementing carbon reduction labels and it is thinking of even giving up on the carbon reduction label.<sup>37</sup> So why did not the other supermarket chains adopt this label? Although the labeling process is very easy, it is still costly to implement the label. Given this cost we believe that firms would be willing to adopt the label only if they expect to obtain a price premium and/or an increase in demand for the labeled products to make it worthwhile for them to apply for the label and use it.<sup>38</sup> As previously argued a simple label of approval or a traffic light labeling system in the front package is more likely to be noticed and is therefore more likely to generate a price premium for the labeled products. We believe that ambiguity as to whether a price premium would actually emerge for labeled products has prevented other firms from adopting the label.<sup>39</sup> The supermarket chain in question may have committed itself too soon in adopting the label and so it is now keen to roll back the label.

Another reason why the Carbon Trust Fund might have adopted the carbon reduction label in its current form, i.e., as a label which discloses the exact level of  $CO_2$  emissions generated by a product (instead of having a simple label of approval or adopting a traffic light system) could be to just educate consumers. If consumers observe the exact number of grams of  $CO_2$  emissions from a product they may become aware about the impact of their carbon consumption on the level of  $CO_2$  emissions released. This is similar to, say, a GDA (guide daily amount) scale which is used to educate consumers about the nutritional characteristic of a product. Moreover, observing the  $CO_2$  emissions for each product allows the consumer to compare not only products within the same category but also products across

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a traffic light label a firm's products could end up being classified as environmentally unfriendly and therefore the firm could be reluctant to apply for such a label.

<sup>37</sup>See the report on the supermarket chain in the article by Adam Vaughan in the guardian.co.uk, Monday 30 January 2012 15.02 GMT.

<sup>38</sup>Firms endure some certification costs related to the monitoring and assessment of the  $CO_2$  emissions disclosed as well as packaging costs. For instance the noted supermarket chain claims "a minimum of several months' work" to calculate the carbon footprint of a product.

<sup>39</sup>Harbaugh, Maxwell, and Roussillon [2011] show that the quality and the number of products having a label may impact the size of the potential price premium.



categories. We note though that it would probably take quite a long time before consumers become accustomed to evaluating information about carbon emissions in the products they consume in this way. This is especially hard since comparison across product categories is complicated. For example, 100g of  $CO_2$  emissions could be the signal of a green product in the detergent category but could signal a brown product for apples. The value of the level of  $CO_2$  emissions cannot be understood only by itself but needs to be compared along a range of other values. Therefore, we think that the use of a scale or a traffic light could complement the disclosing of the exact amount of  $CO_2$  emissions. Ideally, a short front package logo could complement more detailed information at the back and could be easier to notice and understand. Decreasing the cognitive cost of label comprehension could increase the likelihood of its purchase and lead to the emergence of a price premium while at the same time achieving consumer education.

## 6. CONCLUSIONS

We have studied the impact of the carbon reduction label for prices of detergents. We utilized detailed scanner data from a noted super market chain in UK recording consumers' transaction prices before and after the introduction of the carbon reduction labels to evaluate the effects of the labeling. Our regression results, based on a difference-in-difference approach, indicate that the carbon reduction label has no impact on prices, i.e., on average there is no premium for detergents that have a carbon reduction label compared with detergents that do not have a carbon reduction label. We also did not find any demand impact for the carbon reduction label, although the results of simple demand models need to be interpreted with caution. We also used the synthetic control method to allow for the effect of the carbon reduction label to be different for products with different carbon footprints. We did not find any evidence that prices would have been different for individual labeled products with low/high levels of carbon footprint than for the counterfactual synthetic products without the label. Therefore, the results from the difference-in-difference regression as well as the synthetic control method seem to outline a consistent story. The evidence seems to be quite strong that there does not exist a price premium for carbon labeled detergents.

As we discussed in our paper, our results may appear somewhat surprising since one would expect that the presence of an environmental label should lead to an increase in price when consumers value the environmental attribute. This seems to be the case for carbon labels in general according to several surveys (see for example, the [Eurobarometer \[2009\]](#) survey). However, we believe that the specific design of this carbon label is responsible for its lack of success. The specific form of the label used includes detailed information on

carbon emissions and it is difficult for consumers to process this information. It is therefore important to investigate the effectiveness of simpler carbon labels in the future.

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<p><b>working with the Carbon Trust</b></p>  <p><b>850g</b> <b>CO2</b> <b>per wash</b></p>	<p>The carbon footprint of this product is <b>850g</b> per wash and we have committed to reduce this</p>
	<p>By comparison the carbon footprint of non-biological washing liquid is <b>600g</b> per wash</p>
	<p>Help to reduce this footprint. Washing at <b>30°C</b> rather than <b>40°C</b> saves <b>160g CO2</b> per wash</p>

FIGURE 1. An example of a carbon reduction label

TABLE 1. List of Detergent Products

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(1) Fairy Liquitabs Non-Bio 11Wash 385G
(2) Fairy Non Bio Liquid Wash 1.37Ltr
(3) Own Brand Bio Liquid Wash 1.5 Ltr
(4) <b>Own Brand Non-Bio Liquid Wash 1.5 Ltr</b> (Carbon Labeled)
(5) Persil Powder Non-Bio 28 Wash/2.38Kg
(6) Own Brand Powder Bio 800G
(7) <b>Own brand Non Bio 1.2Kg</b> (Carbon Labeled)
(8) Own Brand Powder Colour 800G
(9) Own Brand Value Bio Conc Liquid Wash 1 Litre
(10) Fairy Powder Non-Bio 10 Wash/800G
(11) Persil Powder Non-Bio 10 Wash/850G
(12) Own Brand Non-Bio Tablets 24 Pk 12 Washes/900G
(13) Persil Tablets Non-Bio 24Pack 12Wash/912G
(14) Own Brand Powder Non-Bio 30 Wash/2.4Kg
(15) Own Brand Colour Liquid Capsules 10 Wash/500Ml
(16) Own Brand Bio Tablets 48 Pk 24 Washes/1.8 Kg
(17) <b>Own Brand Non-Bio Tablets 48 Pk 24 Washes/ 1.8Kg</b> (Carbon Labeled)
(18) Own Brand Colour Tablets 48 Pk 24 Washes/1.8 Kg
(19) Persil Non-Bio Capsules 20 Pk 10 Wash
(20) Fairy Non-Bio Tablets 56 Pk 28 Wash/1.848Kg
(21) Persil Non-Bio Capsules 40 Pk 20 Wash
(22) Own Brand 2In1 Freshtablets 48 Pk 24 Washes/1.8 Kg
(23) Persil Bio Liquigel 1.5 Ltr
(24) Persil Non-Bio Liquigel1.5 Ltr
(25) Fairy Liquitabs Non-Bio 22Wash/770G
(26) Persil Tablets Non-Bio 48Pack 24Wsh 1.74Kg
(27) Own Brand Powder 2In1 Lavender 800G
(28) Own Brand Lav 2In1 Liqd Wash 1.5 Ltr
(29) Own Brand 2In1 Lav Tablets 48 Pk 24 Washes/1.8Kg
(30) Persil Non-Bio Small & Mighty 730Ml
(31) Surf Tropical Small & Mighty 730Ml
(32) <b>Own brand Non-Bio Liquid Capsules 20 Wash/1Ltr</b> (Carbon Labeled)
(33) Own Brand Bio Liquid Capsules 20 Wash/1Ltr
(34) Own Brand Colour Liquid Capsules 20 Wash/1Ltr
(35) Own Brand 2 In 1 Lavliquid Capsules 20 Wash/1Ltr
(36) Own Brand 2In1 Oceantablets 48 Pk 24 Wash/1.8Kg
(37) Surf Sunshine Small & Mighty 730Ml
(38) Persil Non-Bio Small & Mighty 1.47Ltr
(39) Own Brand Super Conc Colour Liqd 700Ml/20Wsh
(40) Own Brand Super Conc Bio Liquid 700Ml/20Wsh
(41) <b>Own Brand Super Conc Non-Bio Liqd Wash 700Ml/ 20Wsh</b> (Carbon Labeled)
(42) Own Brand Super Conc2In1 Lav Liqd 730Ml/20Wsh
(43) Own Brand Powder Non-Bio 42 Wash/3.36Kg

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TABLE 2. Summary Statistics : Detergent Data

Variable	Mean	Std. Dev.	Min.	Max.	N
CarbonLabel	0.118	0.323	0	1	4369
Own brand	0.61	0.488	0	1	4369
Powder	0.296	0.457	0	1	4369
Tablet	0.446	0.497	0	1	4369
Liquid	0.258	0.438	0	1	4369
Size	1.234	0.604	0.385	3.36	4369
Price Discount	0.078	0.252	0	1	4369
Marked Down	0.002	0.009	0	0.2	4369
No. of Washes	19.44	6.884	10	42	4369
Two-in-One	0.166	0.372	0	1	4369
Average Price per wash	0.168	0.057	0.044	0.362	4369

TABLE 3. Price Regressions.<sup>abcd</sup>

	(1)	(2)	(3)	(4)	(5)
	OLS w/o controls	OLS w/ controls	FE	FE w/ cluster. se	FE w/ bootstrap. se
CarbonLabel * TreatPeriod	-.065** (.024)	-.064** (.023)	-.069 (.068)	-.069 (.068)	-.069 (.066)
CarbonLabel	-.133*** (.017)	-.138*** (.017)			
TreatPeriod	.033 (.079)	.019 (.079)			
Price Discount		-.237*** (.019)	-.189*** (.022)	-.189*** (.022)	-.189*** (.021)
Marked Down		1.381* (.666)	-.695* (.284)	-.695* (.284)	-.695* (.285)
Product Fixed Effects	NO	NO	YES	YES	YES
Week Dummies	YES	YES	YES	YES	YES
No. of Obsv.	4369	4369	4369	4369	4369

<sup>a</sup> Dependent variable is the logarithm of normalized price. Normalization is done by dividing the (money) price of the detergent with the number of washes the detergent has on average.

<sup>b</sup> Independent variables are given in the rows. Price Discount is a dummy for detergents that are offered on a price discount. Marked Down is a dummy for detergents that are marked down.

<sup>c</sup> CarbonLabel is a dummy variable which is 1 for detergents that are carbon labeled and 0 for detergents that are not carbon labeled. TreatPeriod is a dummy which is 1 for the post treatment period or the period after May 2008, the date at which the carbon label came into effect, and 0 for periods before this date or the pre-treatment period. The difference-in-differences estimator is the coefficient on the interaction term CarbonLabel \* TreatPeriod.

<sup>d</sup> **Note** : *t*-statistics reported under each coefficient in parenthesis. Significance at :<sup>+</sup>  $p < 0.10$ , \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ . All standard errors reported are robust except column(5). Standard errors are clustered at the product level for the last two columns.

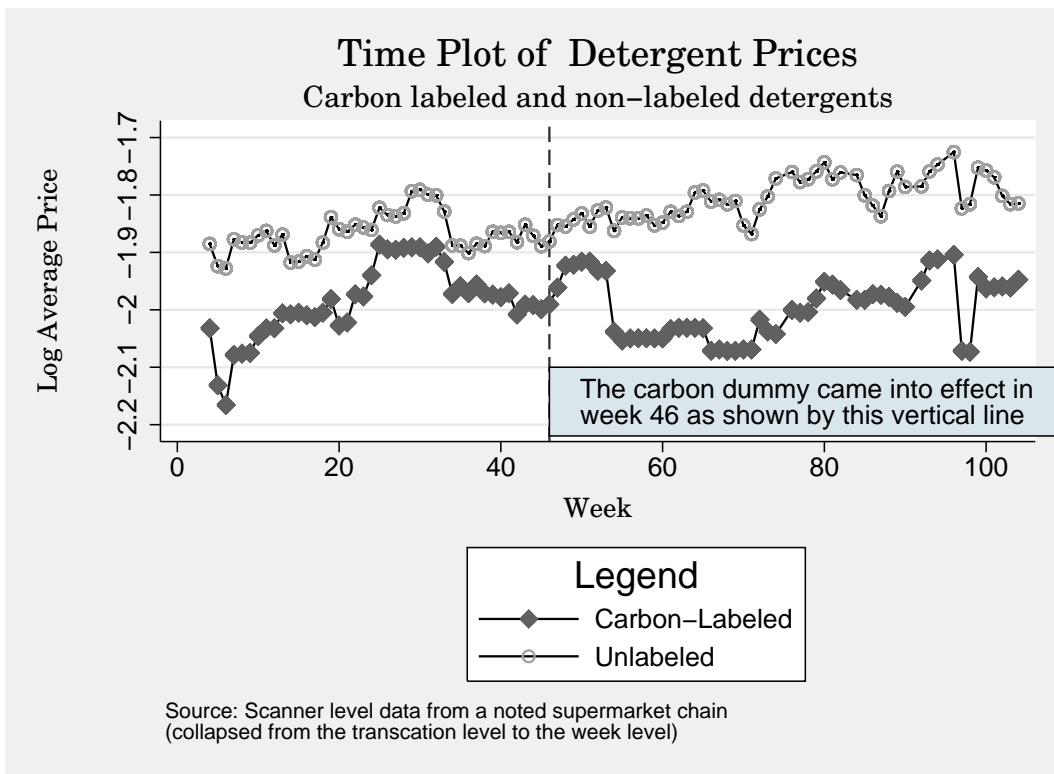


FIGURE 2. Price plots of carbon-labeled and unlabeled detergents

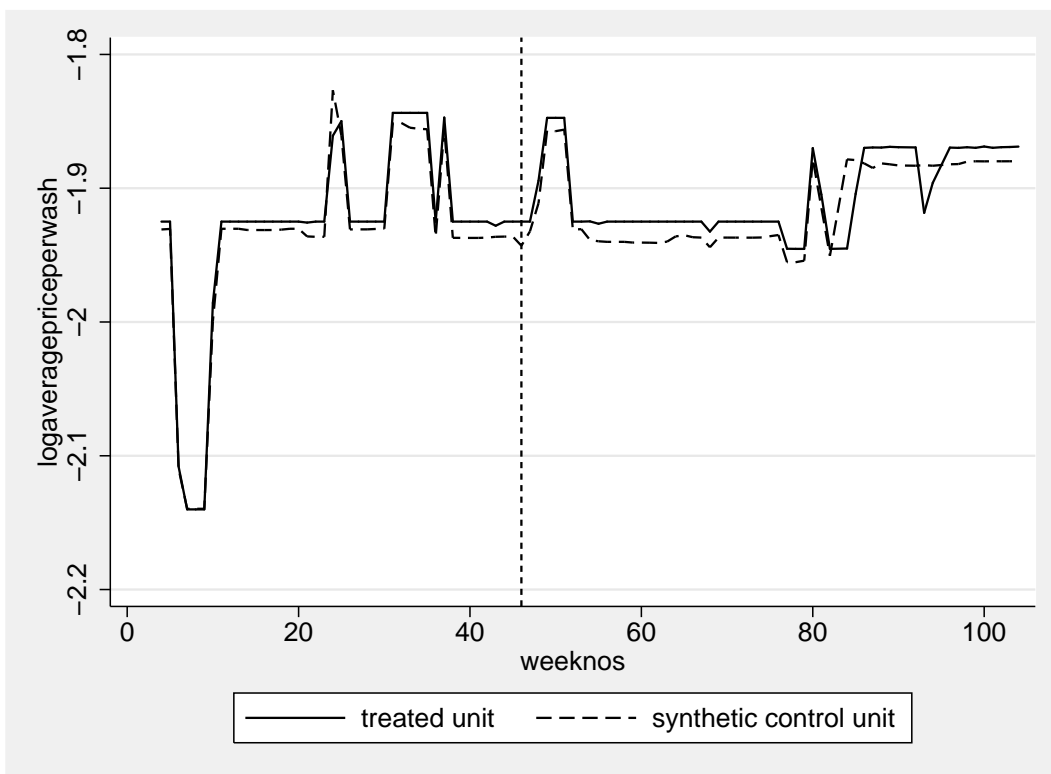


FIGURE 3. Price trajectory for Own Brand Non-Bio Liquid Wash 1.5 Ltr.

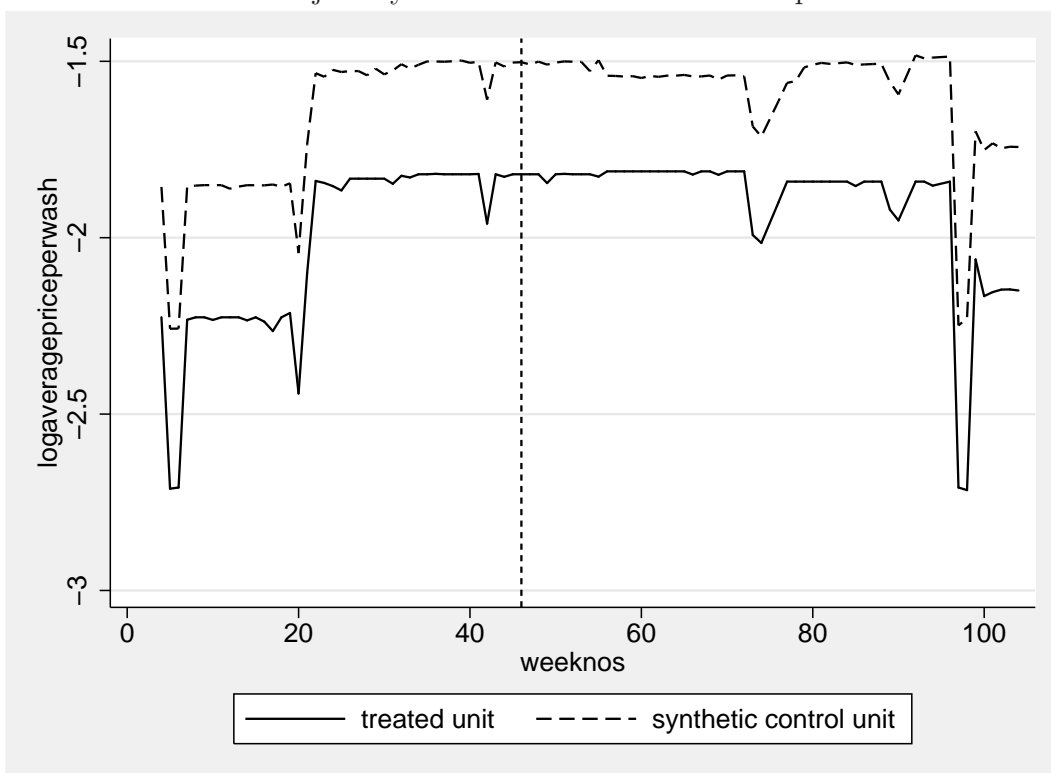


FIGURE 4. Price trajectory for Own Brand Non-Bio 1.2Kg

TABLE 4. Demand Regressions.<sup>abcd</sup>

	(1)	(2)	(3)	(4)	(5)
	OLS w/o controls	OLS w/ controls	FE	FE w/ cluster. se	FE w/ bootstrap. se
CarbonLabel * TreatPeriod	.157 (.197)	.021 (.037)	.014 (.130)	.014 (.130)	.014 (.123)
CarbonLabel	.034 (.387)	.091** (.030)			
TreatPeriod	-.104 (.092)	.104 (.111)			
Price Discount		-.075+ (.044)	-.025 (.044)	-.025 (.044)	-.025 (.041)
Marked Down		-1.884 (1.331)	-1.200 (1.134)	-1.200 (1.134)	-1.200 (1.197)
Average Price		.067*** (.008)	-.141* (.064)	-.141* (.064)	-.141* (.065)
Sum Expenditure		.003*** (.000)	.002*** (.000)	.002*** (.000)	.002*** (.000)
Mean Detergent Price		.060 (.138)	.338* (.160)	.338* (.160)	.659* (.327)
Product Fixed Effects	NO	NO	YES	YES	YES
Week Dummies	YES	YES	YES	YES	YES
No. of Obsv.	4369	4369	4369	4369	4369

<sup>a</sup> Dependent variable is the logarithm of the ratio of spending on detergents for a week over the total spending on all products for a week .

<sup>b</sup> Independent variables are given in the rows. Price Discount is a dummy for detergents that are offered on a price discount. Marked Down is a dummy for detergents that are marked down. Average price denotes the own price of the detergent (averaged by week). Mean Detergent price denotes the average price of substitutes. Sum Expenditure denotes the aggregate spending on detergents in that week.

<sup>c</sup> CarbonLabel is a dummy variable which is 1 for detergents that are carbon labeled and 0 for detergents that are not carbon labeled. TreatPeriod is a dummy which is 1 for the post treatment period or the period after May 2008, the date at which the carbon label came into effect and 0 for periods before this date or the pre treatment period. The difference-in-differences estimator is the coefficient on the interaction term CarbonLabel \* TreatPeriod.

<sup>d</sup> **Note** : *t*-statistics reported under each coefficient in parenthesis. Significance at :<sup>+</sup>  $p < 0.10$  \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ . All standard errors reported are robust except column(5). Standard errors are clustered at the product level for the last two columns.

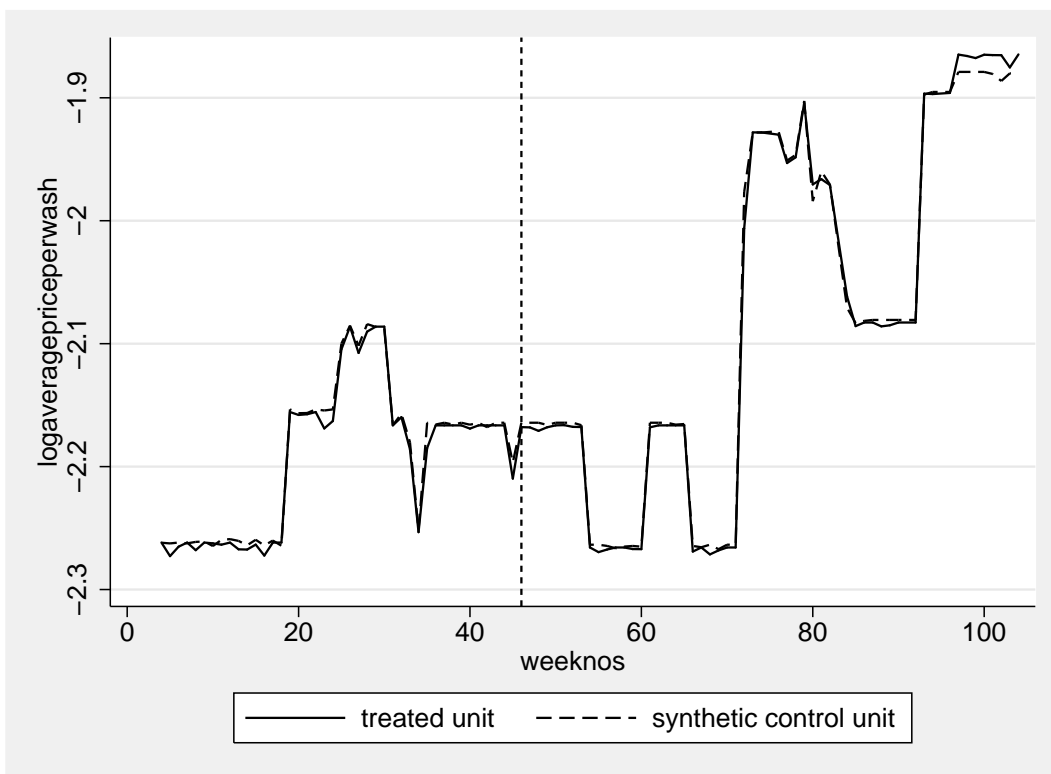


FIGURE 5. Price trajectory for Own Brand Non-Bio Tablets 48 Pack 24 Washes/ 1.8Kg

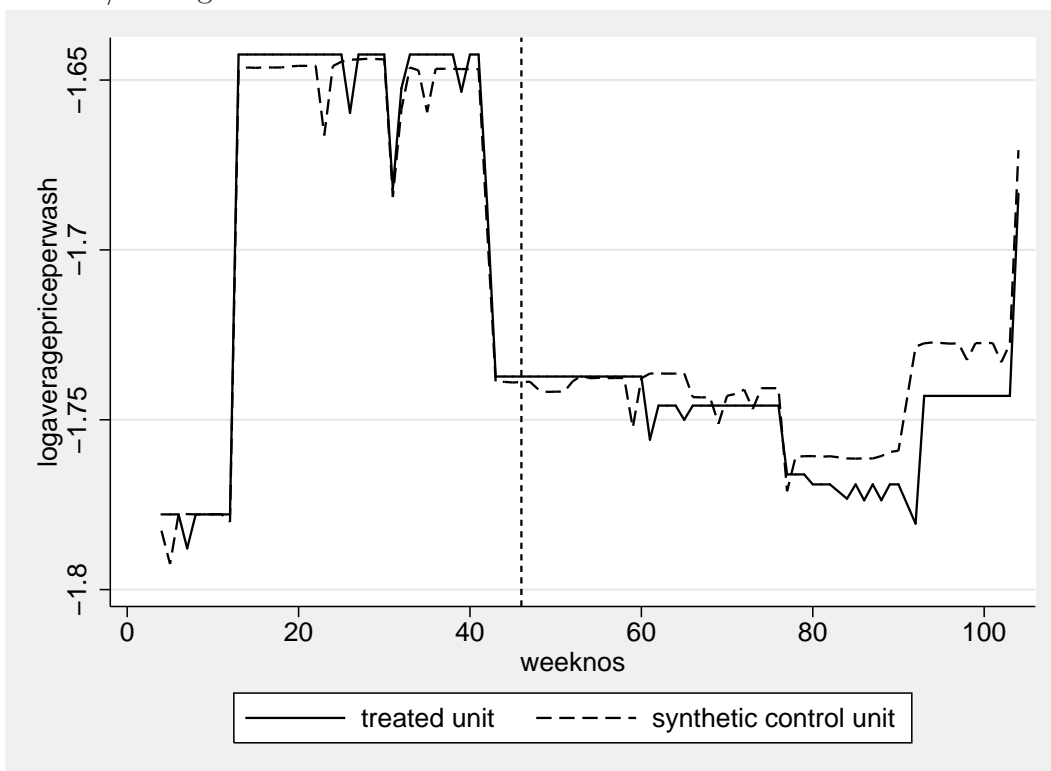


FIGURE 6. Price trajectory for Own brand Non-Bio Liquid Capsules 20 Wash/1Ltr.

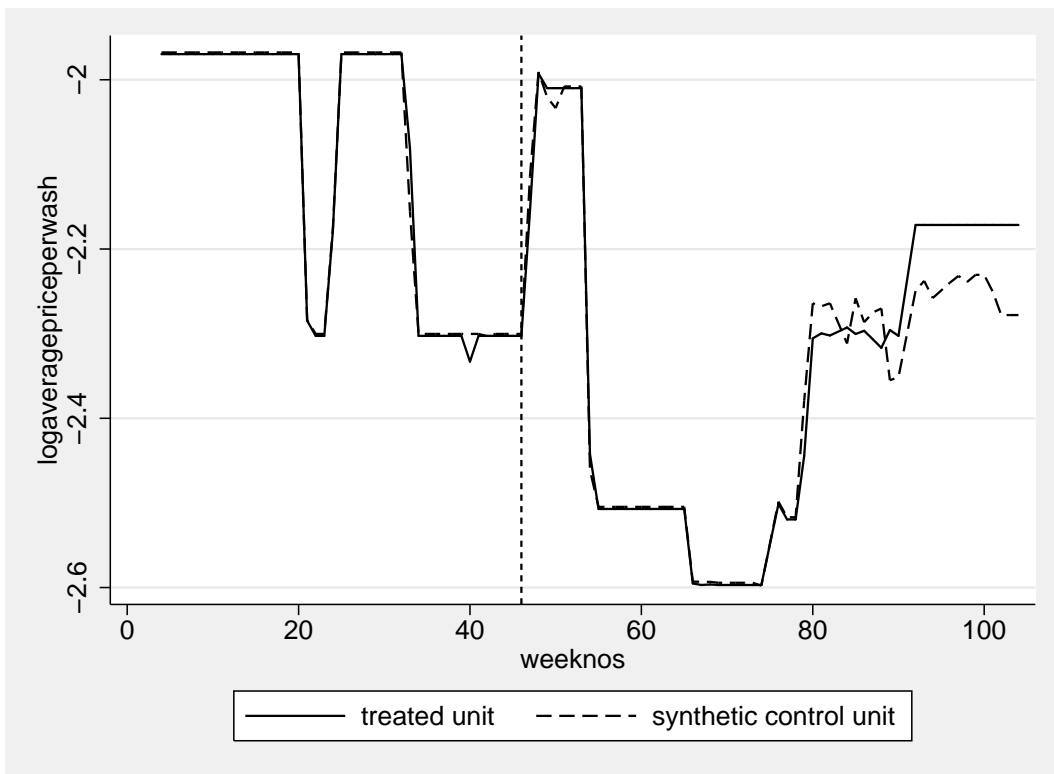


FIGURE 7. Price trajectory for Own Brand Super Conc. Non-Bio Liquid Wash 700ML/ 20Washes

TABLE 5. Detergent weights in synthetic unit for detergent no. 4

Treatment Detergent no. 4			
Control Detergent no.	Weight	Control Detergent no.	Weight
1	0	23	0.002
3	0.973	24	0
5	0	25	0
6	0	26	0
8	0	27	0
9	0.006	28	0
10	0	29	0
11	0	30	0
13	0	31	0
14	0	34	0
15	0	36	0
16	0	37	0
18	0	39	0
19	0	40	0.018
20	0	42	0
21	0	43	0
22	0		

TABLE 6. Log(price) predictor means for detergent no. 4

Log(price) predictor means		
Treatment Detergent no. 4		
Variables	Real	Synthetic
Number of washes		17 17.031
Two in one dummy		0 0
Own brand dummy		1 0.997
Powder dummy		0 0
Liquid dummy		1 0.999
Tablet dummy		0 0
Discount (average)	0.0333569	0.0329327
Mark down (average)	0.0003054	0.0000147



TABLE 7. Detergent weights in synthetic unit for detergent no. 7

Treatment Detergent no.7			
Control Detergent no.	Weight	Control Detergent no.	Weight
1	0	23	0
3	0	24	0
5	0	25	0
6	0.662	26	0
8	0.182	27	0
9	0	28	0
10	0	29	0
11	0	30	0
13	0	31	0
14	0	34	0
15	0	36	0
16	0	37	0
18	0	39	0
19	0	40	0
20	0	42	0
21	0	43	0.156
22	0		

TABLE 8. Log(price) predictor means for detergent no. 7

Log(price) predictor means			
Treatment Detergent no. 7			
Variables	Real	Synthetic	
Number of washes		15	14.992
Two in one dummy		0	0
Own brand dummy		1	1
Powder dummy		1	1
Liquid dummy		0	0
Tablet dummy		0	0
Discount (average)		0	0
Mark down (average)	0.0061858	0.006187	

TABLE 9. Detergent weights in synthetic unit for detergent no. 17

Treatment Detergent no.17				
Control Detergent no.	Weight	Control Detergent no.	Weight	
1	0	23	0	
3	0	24	0	
5	0	25	0	
6	0	26	0	
8	0	27	0	
9	0	28	0	
10	0	29	0	
11	0	30	0	
13	0	31	0	
14	0	34	0	
15	0	36	0	
16	0.458	37	0	
18	0.541	39	0	
19	0	40	0	
20	0	42	0	
21	0	43	0	
22	0			

TABLE 10. Log(price) predictor means for detergent no. 17

Log(price) predictor means			
Treatment Detergent no. 17			
Variables	Real	Synthetic	
Number of washes		24	23.976
Two in one dummy		0	0
Supermarket store dummy		1	0.999
Powder dummy		0	0
Liquid dummy		0	0
Tablet dummy		1	0.999
Discount (average)		0	0
Mark down (average)		0.0035762	0.0035729

TABLE 11. Detergent weights in synthetic unit for detergent no. 32

Treatment Detergent no.32				
Control Detergent no.	Weight	Control Detergent no.	Weight	
1	0	23	0	
3	0	24	0	
5	0	25	0	
6	0	26	0	
8	0	27	0	
9	0	28	0	
10	0	29	0.005	
11	0	30	0	
13	0	31	0	
14	0	34	0.971	
15	0.014	36	0	
16	0	37	0	
18	0	39	0	
19	0	40	0	
20	0.01	42	0	
21	0	43	0	
22	0			

TABLE 12. Log(price) predictor means for detergent no. 32

Log(price) predictor means			
Treatment Detergent no. 32			
Variables	Real	Synthetic	
Number of washes		20	19.96
Two in one dummy		0	0.005
Own brand dummy		1	0.99
Powder dummy		0	0
Liquid dummy		0	0
Tablet dummy		1	1
Discount (average)		0	0.0004813
Mark down (average)		0.001897	0.002492

TABLE 13. Detergent weights in synthetic unit for detergent no. 41

Treatment Detergent no.41				
Control Detergent no.	Weight	Control Detergent no.	Weight	
1	0	23	0	
3	0	24	0	
5	0	25	0	
6	0	26	0	
8	0	27	0	
9	0	28	0	
10	0	29	0	
11	0	30	0	
13	0	31	0	
14	0	34	0	
15	0	36	0	
16	0	37	0	
18	0	39	0.449	
19	0	40	0.55	
20	0	42	0	
21	0	43	0	
22	0			

TABLE 14. Log(price) predictor means for detergent no. 41

Log(price) predictor means			
Treatment Detergent no. 41			
Variables	Real	Synthetic	
Number of washes		20	19.98
Two in one dummy		0	0
Own brand dummy		1	0.999
Powder dummy		0	0
Liquid dummy		1	0.999
Tablet dummy		0	0
Discount (average)		0	0
Mark down (average)		0.0005066	0.0005059