Price Impacts of Carbon Reduction Labels: Evidence From Scanner Data †

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Abstract

We investigate the effects of the introduction of carbon reduction labels on the prices of detergents using a detailed scanner level data set which records consumers' transaction prices before and after the introduction of the carbon labels. In contrast to other empirical studies looking at the impact of environmental labels using scanner or household data, we utilize a quasi-experimental setting to address our research question. We use a standard difference-in-difference estimation strategy to investigate the average effect of the carbon label on detergent prices. We find that having a carbon label has no impact on detergent prices on average, i.e., there is no "carbon premium". To examine if there are product-specific price premia for detergents with different levels of carbon emissions (i.e., with different carbon footprints), we utilize a more flexible approach known as the synthetic control method. We do not find evidence that the prices for the counterfactual synthetic detergents without the label would have been any different than the prices for the actual carbon labeled detergents.

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 green house gas emissions (see the recent report published by the European Environment Agency[1]). In an effort to reduce household green house gas emissions, the Carbon Trust fund in the United Kingdom has introduced a new product label called the carbon 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.[2] Given the importance of the objective of the carbon label – moving households' behaviour towards lower amounts of carbon consumption – it is important to examine from an academic as well as from a policy perspective if this objective is satisfied.[3] One way to examine if the carbon label is effective is to see 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 a test of the effectiveness of the carbon label is the emergence of a higher price (or a price premium) for goods that have the carbon label *vis-a-vis* other similar similar goods that do not have the carbon label. In this paper, we investigate the effectiveness of the carbon label using real market data and, in particular, test whether there is a price premium for carbon labeled detergents.

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], Kotchen [2006],Cason and Gangadharan [2002] and Amacher, Koskela, and Ollikainen [2004]).[4] However, for the price premium to emerge consumers must be willing to pay more for an environmentally friendly product and consumers must also understand what the label means. In contrast to the theoretical results which generally predict a price premium for goods with an environmental label, 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

[1]This report can be downloaded from the web site: http://www.eea.europa.eu/publications/end-use-energy-emissions.
[2]From the web site of the Carbon Trust Fund at: http://www.carbontrust.com/client-services/footprinting/footprint-certification.
[3]For detailed discussion on carbon labeling and its potential usefulness in reducing carbon dioxide emissions see Cohen and Vandenbergh [forthcoming] and references therein.
[4]Hamilton and Zilberman [2006] show that some restrictions such as enforcement and monitoring of the label are needed for the successful implementation of the label, especially in a competitive market.

that people appear to value environmental attributes of a good.[5] Empirical studies based on stated preference and experimental data support these survey results and a large number of papers find 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 the Eurobarometer [2009] survey).

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]). This is especially the case with environmental characteristics of a pure public good type such as the EU Flower or the Nordic Swan (see for example, Bjorner, Hansen, and Russell [2004] and Brecard, Hlaimi, Lucas, Perraudeau, and Salladarre [2009]).[6] The difference in the results obtained from experimental and stated preference data versus the 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.[7] The second reason is consumers' difficulty in noticing the label or understanding it properly, which is typically more likely to be the case in real markets than in experimental and stated preference settings (e.g. Rubik and Frankl [2005], Thogersen [2000] and Noussair, Robin, and Ruffieux [2004]). It is important to note here that the manner in which information about environmental quality is communicated to the consumer also seems to matter for the emergence of a price premium. Several studies using field experimental data have documented that more information is not always better and that an accurate (and hence more detailed) label may not be the best way to drive consumers towards the optimal choice (see Wansink, Sonka, and Hasler [2004], Wansink and Chandon [2006], Teisl, Rubin, and Noblet [2008] and Kiesel and Villas-Boas [forthcoming]).

Despite the 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 the carbon label was introduced only a few years ago and is

[5]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 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 responsible products than two years before.

[6]Many studies with real market data have also found that taste and nutritional aspects of the good are much more important for consumers than the environmental characteristics of the good (Griffith and Nesheim [2010], Bougherara and Combris [2009]and Fletcher and Downing [2011]).

[7]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].

used only in a few countries. Although empirical studies on 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 a simple experiment Michaud, Llrena, and Joly [forthcoming] find a significant price premium for low carbon footprint roses. However, the choice setting that they use in their experimental design is very different from a real life purchase choice and therefore the external validity of their results could be weak.[8] 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, Shortiss, Aulsebrook, Gillespie, Howell, Johanni, Maher, Mitchell, Stewart, and Yates [2011] studied the effectiveness of traffic light style carbon label placed on shelves in one grocery store in Australia. They found the shelf labels to have a small positive 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).[9]

In this paper we use 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 similar 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 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 some simple demand models. In contrast to previous experimental studies on the carbon labels cited earlier, in the UK (and therefore also in our data) the carbon labels used 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

[8] 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.

[9] 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.

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 [forthcoming] has shown the presence of high search costs in the detergent market may have an effect on the willingness to pay for carbon label detergents.

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 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). However, since the impact of the carbon label can be different for products with different carbon footprints (i.e. products with different carbon labels), it is also important to investigate whether treatment effects vary across labeled products. To address this question, we use a (relatively new) technique called the synthetic control method.[10] We use this method to estimate counterfactual price trajectories for each labeled products individually. We then compare the price trajectories of the counterfactual detergents with real carbon labeled detergents. We also estimate very simple demand models (in a difference-in-difference setup) to see the impact of the carbon label on the sales of carbon labeled detergents.

The results we get from the DID regressions show that on average the carbon 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 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 as 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 to delineate the different types of price (or carbon) premia that we could 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.

[10] Other option would be to use difference-in-differences (DID) regression and interact the treatment group and period indicators with the indicators of labeled products. However, since the synthetic control method does not require common trend or any kind of parametric functional form assumptions, it is more flexible and robust than DID.

2. Setting

The empirical and theoretical literature finds that an increase in the environmental quality of a good usually leads to a price premium (in our case a "carbon premium").[11] The idea behind this result is that consumer gets higher utility from consuming a more environmentally friendly good which leads in turn to a higher willingness to pay for that good and finally to a higher price for that good.[12] 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:

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

Information about the environmental quality of a good can be of many types.[13] 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), *(ii)* labels showing detailed information on the product (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 more detailed environmental information, consumers can observe the exact "amount" of an environmental attribute usually expressed in numbers. However, the numbers on the good indicating the environmental quality of the good are usually of little use to the consumer. These numbers need to be compared either with a range of other numbers that (similarly) indicate the environmental quality for other goods or with a benchmark value for the environmental attribute in question. Indeed, it is probably presumptuous to think that the consumer could evaluate the carbon-friendliness of a good without knowing the amount of carbon emissions that other similar products generate.[14] So most of the time consumers

[11] Studies using the hedonic approach has found considerable price premium for organic products; see e.g. Griffith and Nesheim [2010] or Nimon and Beghin [1999]. For the specific case of the carbon label, Michaud, Llrena, and Joly [forthcoming] and Vanclay, Shortiss, Aulsebrook, Gillespie, Howell, Johanni, Maher, Mitchell, Stewart, and Yates [2011] find a price premium using an experimental approach.

[12] In the theoretical literature an increase in the environmental quality is considered as an increase in quality which permits vertical product differentiation 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.

[13] See ISO website for a definition of the different kinds of environmental information.

[14] Upham, Dendler, and Bleda [2011] study consumer understanding of the carbon footprint by interviewing a sample of consumers. They report the following individual comments from this interview: "I've seen these on things, but you just, I mean how much is, when you see stuff like 12 kg and 55 kg, how much is that, what does that actually mean? I can't quantify it in any way."

need a scale to understand the detailed environmental information especially when the label is voluntary.

In our case the carbon label indicates the exact amount of CO_2 emissions generated by the labeled product with the sentence: "*We have committed to reduce this carbon footprint*". In addition, the label indicates the carbon footprint of a benchmark product in the same product category.[15] By reading the carbon label, the consumer may know: the number of labeled products in the specific product category and the CO_2 emissions emitted by each of these labeled products. The consumer also needs to review all the products within the product category in order to determine the actual number of labeled products and their associated CO_2 emissions. However, 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.[16] Thus, given the particular form of the carbon label, the problem is 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 the effect of the label on the product price.

The number of products in a certain category of goods that are labeled are denoted by the letter k. E_i with $i = 1, .., k$ represents the CO_2 emissions of a labeled product. The total number of products in the whole category is denoted by n, so the number of unlabeled products is given by $(n - k)$.[17]

First case scenario

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 $G_i = 1 - E_i$ where $i = 1, .., k$ denotes a labeled product. 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

[15] One could be sceptical 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 be bothered to use this information anyway.

[16] The carbon label does not give any precise reference point for the consumer to assess whether or not the amount of CO_2 emissions indicated on the label is actually environmentally friendly (or "green") or environmentally unfriendly (or "brown"). In addition, no information is given on the carbon footprint of the unlabeled products.

[17] Recall that the consumer need to review all the products in the product category in order to determine k and the CO_2 emissions of each of the products.

gains as follows: $G_0 = 0 \leq G_1 < G_2 < \ldots < G_k$. Consumer valuation of the environmental gain is given by θ.[18] 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.[19] We use $u(G_i)$ 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 the k labeled products together and thus search for all the k labeled from the total set of n products available in the market. This clearly is costly. The search cost which we denote by $C(k, n, a)$ depends on three variables – *(i)* the difficulty that the consumer has in understanding the label or 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 $C_k > 0$. The willingness to pay for the environmental attribute once the product is labeled equals:

$$U(G_i) = \theta u(G_i) - C(k, n, a) \tag{1}$$

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 consumption of product i will depend on the gain that she 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: $U(G_1) < U(G_2) < \ldots < U(G_k)$. 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 the products with lower carbon footprint level should have higher demand and prices. If consumers behave according to the scenario outlined here, we would expect a price premium for carbon labeled products that depend on the level of carbon footprint.

This scenario tends to be supported by the experimental results from Michaud, Llrena, and Joly [forthcoming], since they find evidence for 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

[18] For simplicity we assume θ 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.

[19] We can also think that the consumer may try to assess the distribution of the CO_2 emissions.

of products that they consider in their experiment is labeled. Thus their setting differs considerably from the scenario that we have just considered.

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 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.[20] 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 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. In fact, many studies have shown that consumers usually prefer simpler information to more detailed information and they are also more familiar with simple labels.[21] Indeed, of the 25 eco-labels for carbon emissions listed at the web site www.ecolabelling.org, about 4/5 provide a simple label of approval without any detailed information about the product's carbon footprint. 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 positively any disclosure regardless of the amount of CO_2 emissions disclosed.[22] 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.

[20] 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.

[21] Regarding the carbon label and 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: "I don't understand why they can't do a traffic light system if they've got the numbers. Surely it's not that hard,if you've got the numbers surely you know where it fits on a scale?" and also 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 label might be difficult to understand and that the consumer would prefer simpler information.

[22] 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".

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. In this scenario, we assume that they simply suppose that G is uniformly distributed 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 not disclosing its quality should be of the worst type. Assuming unraveling behavior from the firm, any disclosure will mean that the product is probably above the average level of 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:

$$u(G_i) = \int_{E[G]}^{1} qdq = (1 - E[G]^2) = 3/4$$

So the utility in this case does not depend on the level of the carbon footprint.[23] 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 they are disclosing. Hence consumer willingness to pay when they are only making use of the logo should be:

$$U(G_i) = ... = U(G_k) = \theta(3/4) - C(a) \tag{2}$$

If we assume that this utility is positive (i.e. that $U(G_i) = ... = U(G_k) > 0$), the consumer would be willing to pay more for the carbon 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

In practice, consumers may find it too difficult or time-consuming to understand and read the label and they may prefer to just ignore the label. 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 for acquiring environmental information about the product. More precisely, if the consumers do not value the environmental attribute sufficiently highly they will not be able to offset the environmental gain from the product with the cost of acquiring information

[23] Note that we assume, for simplicity, that G is distributed uniformly between 0 and 1 which gives a pdf function equal to 1 and $E[G] = 1/2$. However, similar conclusions could be obtained using weaker assumptions. In fact, it would be enough to assume that consumer get some fixed utility from consuming carbon labeled products.

and so in this case the label will have no impact on price.[24] Formally this situation arises when:

$$\theta(3/4) - C(a) \leq 0 \text{ and/or } U(G_k) = \theta u(G_k) - C(k, n, a) \leq 0 \tag{3}$$

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 on the effect of the carbon label on the prices of labeled detergents:[25]

(1) If the consumers value the carbon label and interpret it perfectly, we would expect to find price premiums that vary among different labeled products.
(2) If the consumers have limited ability and use the label as a proxy for environmental quality we expect all the labeled products to obtain the same price premium.
(3) If the 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.[26] 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, the names of which are given in Table 1.[27] Of these 43 detergents, only 5 detergents (shown in bold in Table 1) are carbon labeled.[28] These carbon labeled products have the following

[24] In a recent study on consumer comprehension of the carbon label, Fletcher and Downing [2011] report that 43% of respondents found it difficult to understand whether a product is environmentally-friendly based on the information on product packaging and need to make an effort to look for information on pack about it.
[25] 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.
[26] For reasons of confidentiality we are not able to reveal the name of this supermarket chain.
[27] We replace wherever appropriate in the product names given in Table 1, the name of the supermarket chain with the phrase "Own Brand".
[28] During the sample period we consider 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 for 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.

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 how much CO_2 emissions are 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 carbon footprint of a benchmark product and advice on how customers could reduce the carbon footprint even further, for example, by reducing the washing temperature.

[Insert Table 1]

Our working data consists of item level transactions for detergents for all the 60,000 customers (clubcard account holders) 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., if the detergent is the same brand as the supermarket chain) as well as other product attributes like size. In addition, we also have detailed information on the expenditure on the detergent and whether the detergent was bought on a price discount or price was marked down.[29] 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. Note also that if we did not have access to transactions data on individual products it would not be possible to control for these promotions making our results biased.

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 original data spans from financial week 17 of 2007 to financial week 15 of 2009 (both weeks inclusive). Therefore, we have data over a period of 104 weeks (36 weeks in 2007, 52 weeks in 2008 and 16 weeks in 2009). Note that the carbon label came into effect on week 10 in May 2008, which means that the carbon label on the 5 aforementioned carbon labeled detergents was available only post week 10 in 2008. This 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]

[29] Some of these variables are used in our analysis, although we note that in the difference-in-difference models, time-invariant control variables or characteristics (such as detergent type) become redundant.

3.2. **Difference-in-Differences Regressions.** Our aim is to investigate the effect that the carbon 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-difference method and the synthetic control method.

Our first method, the difference-in-differences approach, is an improvement over the traditional hedonic method 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.[30] 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 correlation between the label and the price of a product (see for example, Bajari and Benkard [2005] and Wallander [2008]). 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.[31]

Fortunately for us the carbon label for detergents came into existence some time after the period when our data starts. This provides us with a market level quasi-experimental setting in which we can observe both labeled and unlabeled products before and after the carbon 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 other product characteristics for labeled and unlabeled detergents, we can use this quasi-experimental setup to isolate consumers' average marginal willingness to pay for the carbon 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 label have changed relative to what the prices of these detergents would have been without the label.[32]

[30] Rosen [1974] first proposed and used the hedonic approach to estimate implicit prices of characteristics or consumers' marginal willingness to pay for characteristics of a product. Although Rosen concentrated on perfect competition, later work by Bajari and Benkard [2005] showed that the hedonic model could be used without assuming perfect competition or making other supply side assumptions.

[31] 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].

[32] The estimation of treatment effects rests on the assumption of independence of treatment assignment and potential outcomes. We are not aware of any reasons which would violate this assumption in the present application. Since the supermarket chain in question labeled very different kind of products with different footprints, treatment assignment does not seem to be systematic or favorable to the most potential (or effective) 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 specification does not take this detailed information on the numerical value of the carbon footprint into account while estimating the treatment effect in the difference-in-difference framework.

To allow for carbon 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, we use the synthetic control method following the approach outlined in Abadie, Diamond, and Hainmueller [2010].[33] 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 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. In addition, the synthetic method is fully nonparametric in the sense that no explicit functional form or distributional assumptions are required.

The synthetic control method generates an artificial or synthetic control unit using a weighted average or a convex combination of the observed control units.[34] We treat the carbon labeled detergent as the treatment (or treated unit) and the unlabeled detergents as

[33]Another option would be to use the difference-in-differences (DID) setup and interact the treatment group and period indicators with an indicator of 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.

[34]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 non-labeled detergents form the control group. For J non-labeled detergents we assign weights $W = (w_1, w_2, \ldots, w_J)$ (with $w_j \geq 0$ and $\sum w_j = 1$) to each of these control detergents. The weights are chosen so that the synthetic detergent most closely resembles the actual carbon labeled detergent. Let X_1 denote a $(K \times 1)$ vector of K pre-treatment variables (or detergent characteristics) in the treatment unit and let $\mathbf{X_0}$ denote a $(K \times J)$ matrix which contains the values of the same variables for the J possible control units. Let V be a diagonal matrix with nonnegative components reflecting the relative importance of the different predictors for the outcome. The vector of weights W^* is then chosen to minimize: $(X_1 - \mathbf{X_0}W)' V (X_1 - \mathbf{X_0}W)$. The matrix V is chosen such that the price path for the treatment unit during the pre treatment period is best reproduced by the resulting synthetic control detergent. 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.

the control group as in the difference-in-differences approach. The outcome of interest is the logarithmic (normalized) price. The synthetic control method iteratively produces synthetic controls (or constructs 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 and 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 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 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 to show that the time trends of the treatment (carbon-labeled detergents) and the control (unlabeled detergents) groups are the same for the dependent variable in question. We show such a graph in Figure 1 which plots the time trends for average logarithmic prices (across weeks) for carbon labeled and unlabeled detergents. As shown in figure 1, the price trends for the pre-treatment period are not exactly the same for carbon labeled and unlabeled products, but the difference seems to be very small. The graph suggests that labeling does not have much of an impact on the prices of the carbon labeled detergents (the treatment group).[35]

[Insert Fig. 1]

We 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.

[35] If the trends between treatment and control groups are not parallel in the pre-treatment period then this might cause the standard difference-in-differences estimates to be biased. However, as we see from figure 1, for our case the pre-treatment trends are similar for treatment and control groups. So in our case we can use the standard difference-in-differences framework. We use the more flexible synthetic control method mainly for robustness and also to control for the issues that may be created because of the specific nature of the carbon label (the fact that the carbon label shows us the grams of CO_2 emitted).

Our difference-in-difference specification is the following:

$$log(price)_{it} = \beta_0 + \gamma_3(CarbonLabel_i * TreatPeriod_t) + \beta^{'}\mathbf{X}_{it} + \delta_i + \sum_t (WeekDummies)_t + \epsilon_{it}$$

where $CarbonLabel_i$ and $TreatPeriod_t$ are defined as follows:

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

$$TreatPeriod_t = \begin{cases} 1 & \text{if Week >=Week 10 in 2008} \\ 0 & \text{otherwise.} \end{cases}$$

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 $\sum_t (WeekDummies)_t$ 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 $\mathbf{X}_{it} = \{Price\ Discount\ Dummy_{it}, Marked\ Down\ Dummy_{it}\}$ Note that in the difference-in-difference specification given in equation 4 above, we include product fixed effects (for product i)denoted in the above specification as δ_i. The coefficient of interest is γ_3, the coefficient of the interaction term $(CarbonLabel_i * TreatTime_t)$, 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.[36]

[Insert Table 3]

The results of the difference-in-difference regressions are reported in Table 3. We first report the regression results for the simpler specification, where product-specific fixed effects are not controlled for (in column 1)[37] and then for other specifications in all of which product fixed effects are controlled for and in which we control for the nature of the standard errors involved in the estimation process in different ways (in columns 2, 3 and 4). Note that as the prices of individual products are quite heavily autocorrelated over time and within product category (including time dummies mitigates but does not totally remove the autocorrelation), it is

[36] The specification 4 above is not the conventional difference-in-differences specification usually used in the literature. 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 : $log(price)_{it} = \beta_0 + \gamma_1 CarbonLabel_i + \gamma_2 TreatPeriod_t + \gamma_3(CarbonLabel_i * TreatPeriod_t) + \beta^{'}\mathbf{X}_{it} + \delta_i + \sum_t (WeekDummies)_t + \epsilon_{it}$

[37] See the footnote above.

important to take autocorrelation into account in the statistical inference. Also, Bertrand, Duflo, and Mullainathan [2004] have shown that conventional standard errors often severely understate the standard deviation of the estimators. They propose using block-bootstrapped standard errors. Therefore, we report in Table 3 the results of the difference-in-difference regression for the following three specifications *i*) product fixed effects included with heteroscedastic robust standard errors (in column 2) and *ii*) product fixed effects included with clustered standard errors at the product level to allow for any residual time series correlations within individual product (in column 3) and finally *iii*) product fixed effects with bootstrapped standard errors at the product level (in column 4).

The regression results in Table 3 show that the coefficient of γ_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, 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 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 insignificant statistical insignificancy of the treatment effect is not surprising. However, it is important to emphasize that zero *average* impact does not conclusively show (at least for now) that the carbon 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 of price and some labels may have had a negative effect on price. This is the reason why it is important to investigate how the labels may have affected the prices of individual labeled products.

4.2. **Synthetic Control Approach.** The regressions results in the previous section suggest that 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. 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):

$$\begin{aligned}\tilde{\mathbf{X}} \;=\; & \{Tablet\ Dummy, Liquid\ Dummy, Twoforone\ Offer\ Dummy,\\ & Price\ Discount\ Dummy, Marked\ Down\ Dummy, Number\ of\ washes,\\ & OwnBrand\ Dummy\}\end{aligned}$$

These variables are the criteria used to create convex combinations of unlabeled detergents from the control group for each carbon labeled detergent (in turn).

Odd-numbered Tables 5 to 13 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 the 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. 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 2 to 6.

[Insert Fig 2]

[Insert Fig 3]

[Insert Fig 4]

[Insert Fig 5]

[Insert Fig 6]

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 the treatment period.

In agreement with the results of the difference-in-differences approach, the price trajectories of the actual detergent and its synthetic control also move together very closely post-treatment, i.e., after the carbon label actually came into effect (the 10th. week of 2008 is shown as 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 products 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 costlier or more difficult for the consumer to process. Similarly, Wansink, Sonka, and Hasler [2004] show that more information is not always better and their result suggest that people generate more positive 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 the consumer behavior. In a laboratory experiment with 364 subjects, they find that consumer responses to nutritional logos vary among different logos and on average it is more effective for those logos that simplify the message most. In addition, they find that for all 7 logos the label is effective when the subjects compare products with labels/logos to products without these labels/logos. Finally, as the carbon label is at the back of the product, the label can be harder to notice. Related to this, e.g. Noussair, Robin, and Ruffieux [2004] have found that consumers do not always notice the label, but once they do notice they (might) change their behavior.

In the context of the carbon label, these results would suggest that the label would be more effective if it could be more salient, and instead of simply indicating the CO_2 emissions in grams would instead signal which detergents have a high carbon footprint and which detergents have a low carbon footprint. This makes it necessary for the consumer to be aware of the carbon label and to have a scale in order to understand the information and not just the absolute value. These explanations are also consistent with the experimental findings of Michaud, Llrena, and Joly [forthcoming], who find a much simpler type of carbon label to generate a price premium in experimental conditions.

Of course, it is possible that there are reasons other than cognitive difficulties in understanding the carbon label(s) which might partly explain our results. First, we note the specific economic 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 the labeling in the sense that carbon labeling could be more effective for products with higher budget shares. Third, and maybe most importantly, it is possible that consumers could have actually responded to

carbon labeling, but their response is not reflected in price but in quantity purchased. Since we find the last explanation most important alternative explanation, we will evaluate and discuss it in detail in the next sub-section.

5.2. **Demand Effects.** We have so far focussed exclusively on looking at the price impacts of the carbon label. It is possible that the carbon label could have had an impact on demand of carbon labeled products that is not reflected in price. So 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 is 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 have been systematic changes in market shares of certain products or in buying behavior of the customers. Because of these reasons our data is less suitable for demand estimation than the home-scanner data used in several previous empirical studies utilizing scanner data.

Despite these difficulties, as a robustness check we estimate some simple demand models for detergents. For these demand estimations we once again use the difference-in-difference approach, but now our dependent variable is the expenditure share of individual detergent products (or its logarithm). As regressors we use the same explanatory variables that we used in the price models. In addition, following standard demand models we included own price, the average price of substitutes (or detergents) and aggregate spending on detergents as additional regressors.

The regression results for the difference-in-difference demand regressions are presented in the appendix. In the different demand models presented, the coefficient estimates of price and expenditure variables are statistically significant and have the expected signs (i.e. own price has negative and substitute price and expenditure positive effects on quantity purchased). The variable of interest, the coefficient on the interaction term which gives the average treatment effect of the label on demand is positive in all models, but is far from significant in all specifications. Moreover, numerically the estimate is very small which indicates that the demand impact on carbon labeled detergents is very small. However, it should be emphasized that these estimation results may be sensitive to our specific sample, which is not necessarily a representative sample for all the customers of the supermarket chain. In addition, even though we are able to control for product-specific time-invariant factors in these regressions, endogeneity might be still an issue in the demand models due to measurement errors in (time-varying) substitute prices and aggregate spending. 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. **Some comments on the form of the Carbon label.** Our results indicate that the carbon label does not have any impact either on the market price or on the demand of carbon labeled detergents. So why did the super market change adopt this label? One explanation can be that the implementation of the label is not a risky strategy as the implementation cost for a firm that chooses to adopt this label is generally low. In contrast, a traffic light label system or simple label of approval would be more expensive for a firm seeking to label its products with such type of a label.[38] However, we note that other major super market chains in the UK have not yet adopted this type of carbon labels for their products. It seems that this general lack of adoption of the label and the consequent lack of proliferation of the label 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 now even thinking of giving up the carbon label.[39].

So why didn't the other supermarket chains adopt the label? Although the labeling process is inexpensive, it still costs a firm money 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 or an increase in demand for the labeled products to make it worthwhile for them to apply for the label and use it.[40] As previously argued a simple label of approval or a traffic light system in the front package is more likely to be noticed and more likely to generate a price premium for labeled products. We believe that the ambiguity that a price premium would actually emerge for labeled products has prevented other firms from adopting the label.[41] The supermarket chain in question may have committed itself too soon to adopt the label and so it is now keen to roll back the label.

Apart from whatever motives the supermarket chain may have in adopting the label, it is also important to understand the aims of the Carbon Trust Fund in adopting the carbon

[38] 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 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.

[39] 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.

[40] 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.

[41] 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.

label. To reduce the carbon footprint of products, the Carbon Trust Fund designed a label which is widely accessible. It seems that the idea was that if a label can be easily accessed and used on a number of products then it is more likely that it will be adopted by many firms.[42] In its current form the carbon label allows a firm to use the 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. We think that the Carbon Trust Fund aimed to proliferate the use of the carbon label so that even if the actual reduction in emissions for any product would be small (as compared to, say, a easier to understand traffic light label system) the cumulative reduction in emissions achieved from all products taken together would mean a sufficient overall reduction in the total level of carbon emissions.

Another reason why the Carbon Trust Fund could have adopted the carbon label in its current form, i.e., as a label that 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 categories. We note though that it would probably take quite a lot of time before consumers become accustomed to evaluating information about carbon emissions in the products they consume in this way. This is especially harder for consumers since the 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 a brown product for apples. The value of the CO_2 cannot be understood only by itself and 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 a more detailed information at the back and be easier to notice and understand. Decreasing the cognitive cost of the label comprehension should increase the likelihood of its purchase and of the price premium emergence while achieving consumer education.

[42] Koos [2011] shows that 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, their results indicate that the larger the share of major retailers using the label, the more likely the labeled product is bought.

6. Conclusions

We have studied the impact of the carbon reduction label for prices of detergents. We utilized detailed scanner level data from a noted super market chain in UK recording consumers' transaction prices before and after the introduction of the carbon labels to evaluate the effects of the labeling. Our regression results, based on a difference-in-difference approach, indicate that the carbon label has had no impact on prices, i.e., on average there is no premium for detergents that have a carbon label compared with detergents that do not have a carbon label. We also did not find any demand impacts for the carbon 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 carbon labels 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 level 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 the carbon label 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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TABLE 1. List of Detergent Products

(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) **Own Brand Non-Bio Liquid Wash 1.5 Ltr** (Carbon Labeled)
(5) Persil Powder Non-Bio 28 Wash/2.38Kg
(6) Own Brand Powder Bio 800G
(7) **Own brand Non Bio 1.2Kg** (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) **Own Brand Non-Bio Tablets 48 Pk 24 Washes/ 1.8Kg** (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) **Own brand Non-Bio Liquid Capsules 20 Wash/1Ltr** (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) **Own Brand Super Conc Non-Bio Liqd Wash** 700Ml/ 20Wsh (Carbon Labeled)
(42) Own Brand Super Conc2In1 Lav Liqd 730Ml/20Wsh
(43) Own Brand Powder Non-Bio 42 Wash/3.36Kg

TABLE 2. Summary Statistics : Detergent Data

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Carbon-Label	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-for-One Offer	0.166	0.372	0	1	4369
Average Price per wash	0.168	0.057	0.044	0.362	4369

TABLE 3. **Price Regressions**.[a b c d]

	(1) OLS	(2) FE	(3) FE w/ cluster. se	(4) FE w/ bootstrap. se
Carbon-Label ∗ Treat-Period	–.06**	–.07	–.07	–.07
	(.02)	(.07)	(.07)	(.07)
Carbon-Label	–.14***			
	(.02)			
Treat-Period	.02			
	(.08)			
Price Discount	–.24***	–.19***	–.19***	–.19***
	(.02)	(.02)	(.02)	(.02)
Marked Down	1.38*	–.69*	–.69*	–.69*
	(.67)	(.28)	(.28)	(.28)
Fixed Effects	NO	YES	YES	YES
Week Dummies	YES	YES	YES	YES
No. of Obvs.	4369	4369	4369	4369

[a] 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.

[b] 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.

[c] Carbon-Label is a dummy variable which is 1 for detergents that are carbon labeled and 0 for detergents that are not carbon labeled.Treat-Period 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 Carbon-Label ∗ Treat-Period.

[d] **Note** : t-statistics reported under each coefficient in parenthesis. Significance at $:^{+}$ $p < 0.10$ * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are clustered at the (3-digit) industry level.

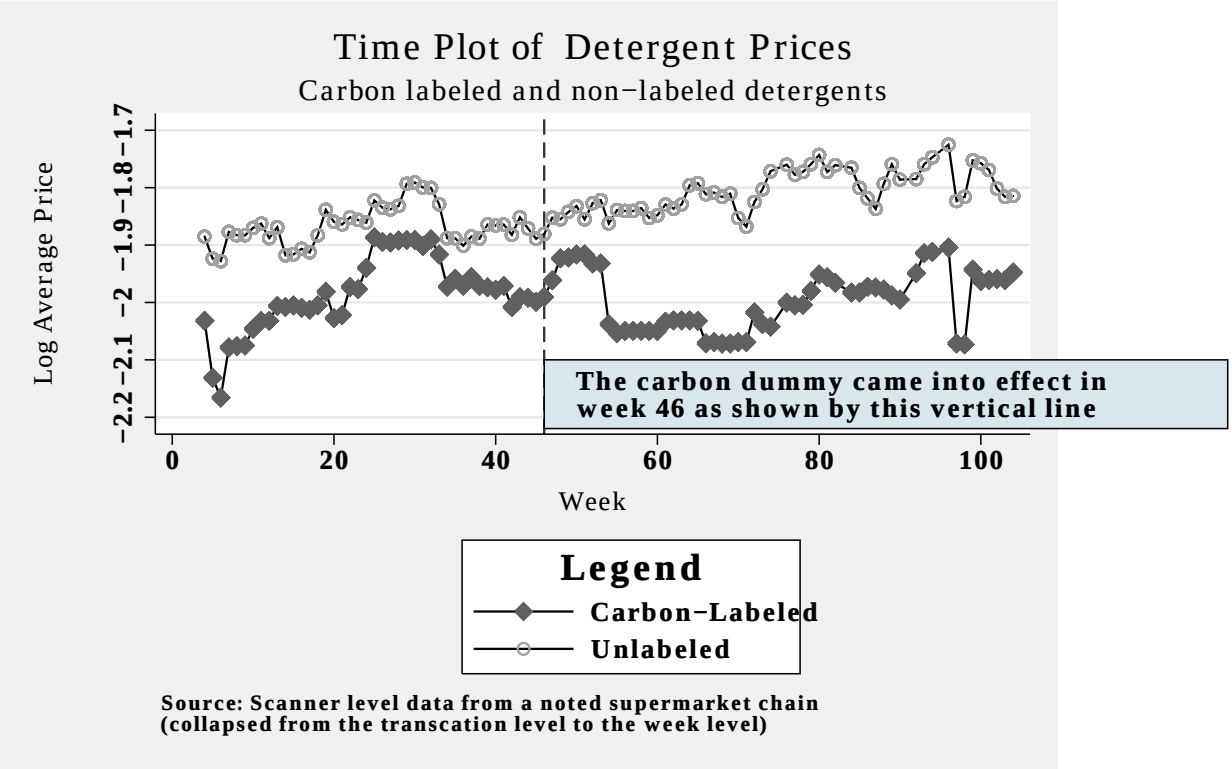

FIGURE 1. Price plots of carbon-labeled and unlabeled detergents

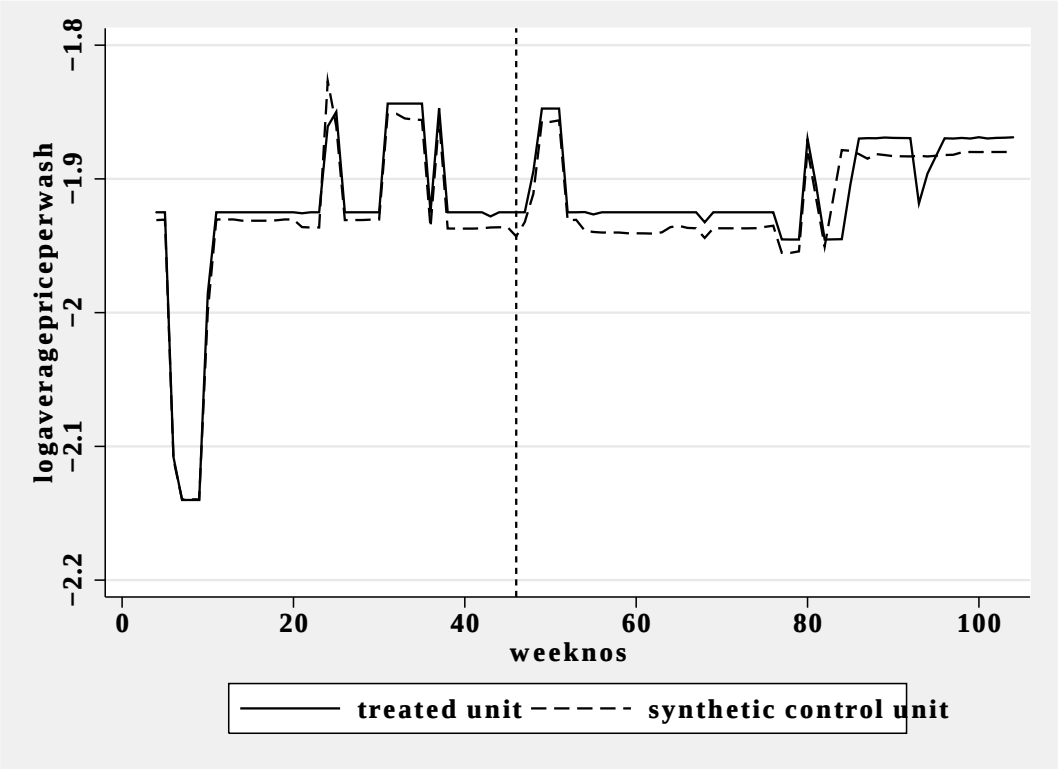

FIGURE 2. Price trajectory for Own Brand Non-Bio Liquid Wash 1.5 Ltr.

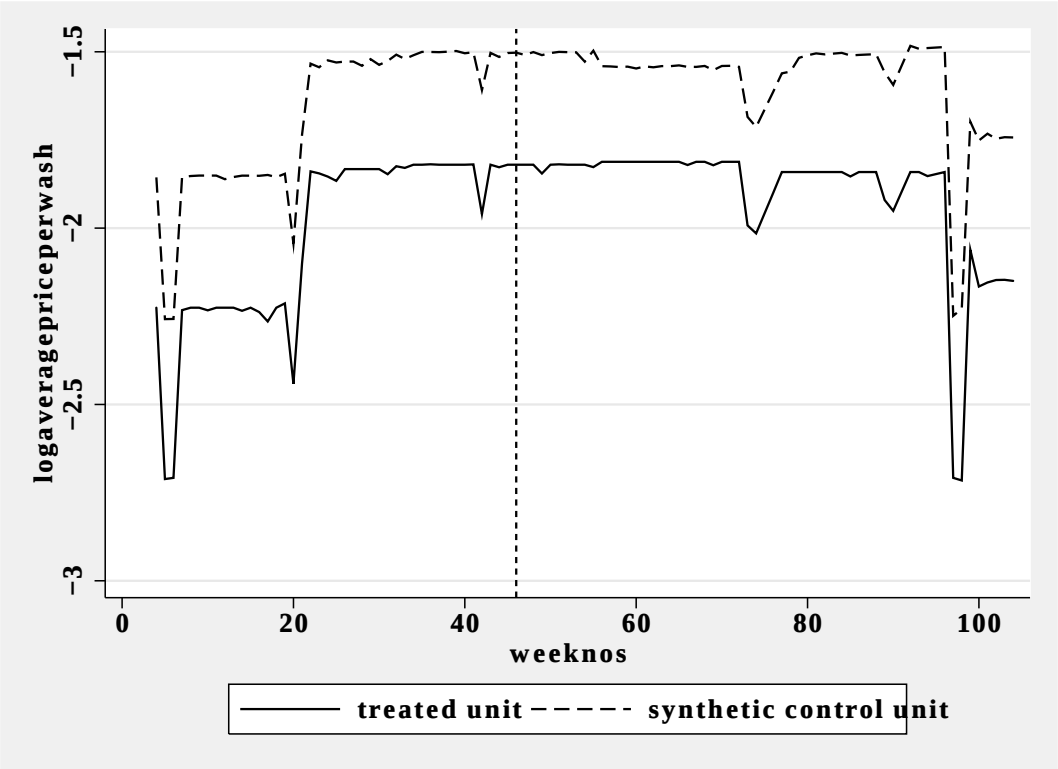

FIGURE 3. Price trajectory for Own Brand Non-Bio 1.2Kg

TABLE 4. **Demand Regressions**.[a b c d]

	(1) OLS	(2) FE	(3) FE w/ cluster. se	(4) FE w/ bootstrap. se
Carbon-Label ∗ Treat-Period	.02	.01	.01	.01
	(.04)	(.13)	(.13)	(.16)
Carbon-Label	.09**			
	(.03)			
Treat-Period	.10			
	(.11)			
Price Discount	–.08+	–.02	–.02	–.02
	(.04)	(.04)	(.04)	(.04)
Marked Down	–1.88	–1.20	–1.20	–1.20
	(1.33)	(1.13)	(1.13)	(.90)
Average Price	.07***	–.14*	–.14*	–.14*
	(.01)	(.06)	(.06)	(.06)
Sum Expenditure	.00***	.00***	.00***	.00***
	(.00)	(.00)	(.00)	(.00)
Mean Detergent Price	.06	.34*	.34*	.66+
	(.14)	(.16)	(.16)	(.38)
Product Fixed Effects	NO	YES	YES	YES
Week Fixed Effects	YES	YES	YES	YES
No. of Obvs.	4369	4369	4369	4369

[a] 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 .

[b] 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.

[c] Carbon-Label is a dummy variable which is 1 for detergents that are carbon labeled and 0 for detergents that are not carbon labeled.. Treat-Period 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 Carbon-Label ∗ Treat-Period.

[d] **Note** : t-statistics reported under each coefficient in parenthesis. Significance at $:^{+}$ $p < 0.10$ * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are clustered at the (3-digit) industry level.

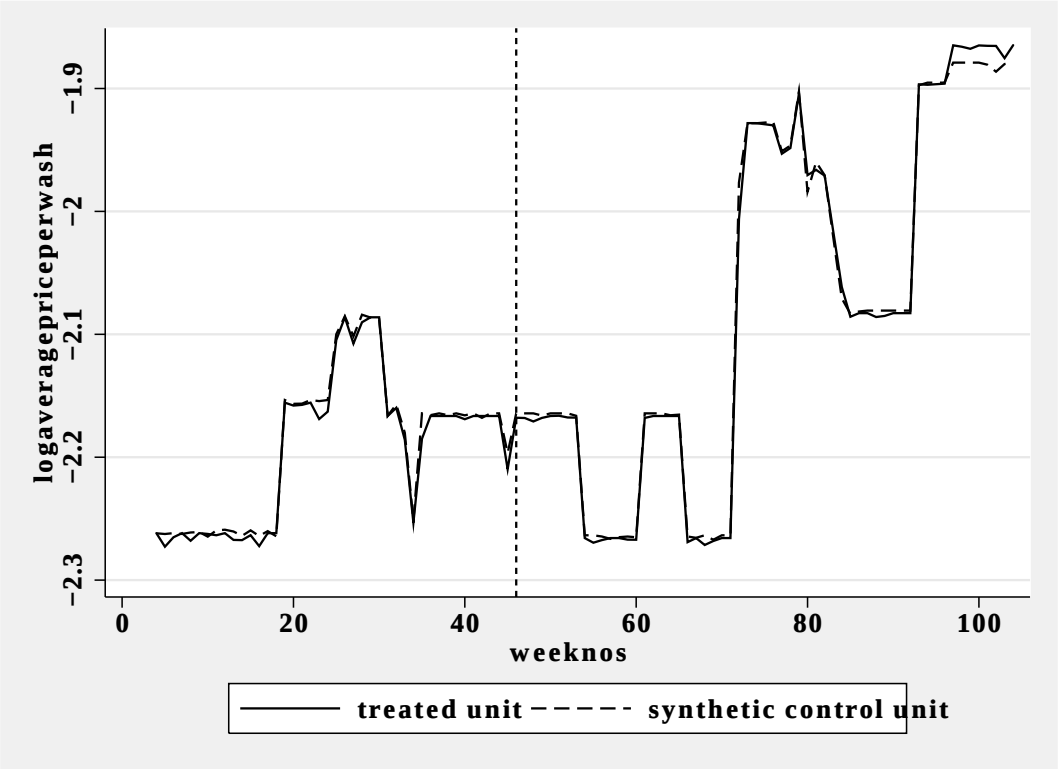

FIGURE 4. Price trajectory for Own Brand Non-Bio Tablets 48 Pack 24 Washes/ 1.8Kg

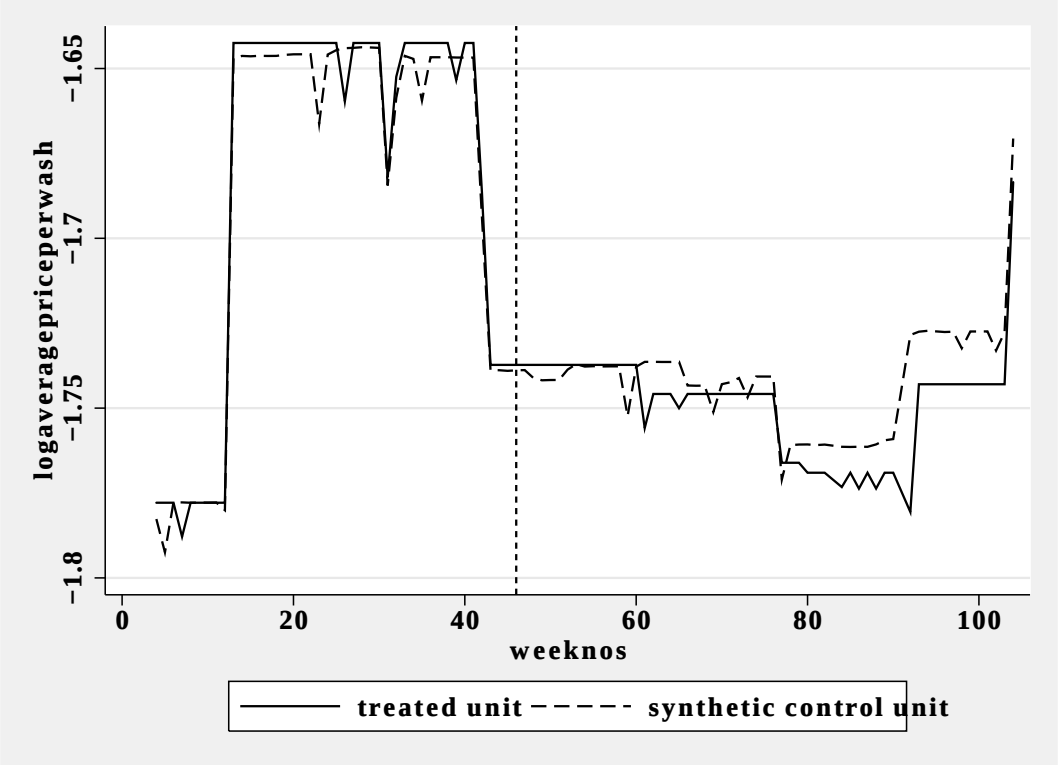

FIGURE 5. Price trajectory for Own brand Non-Bio Liquid Capsules 20 Wash/1Ltr.

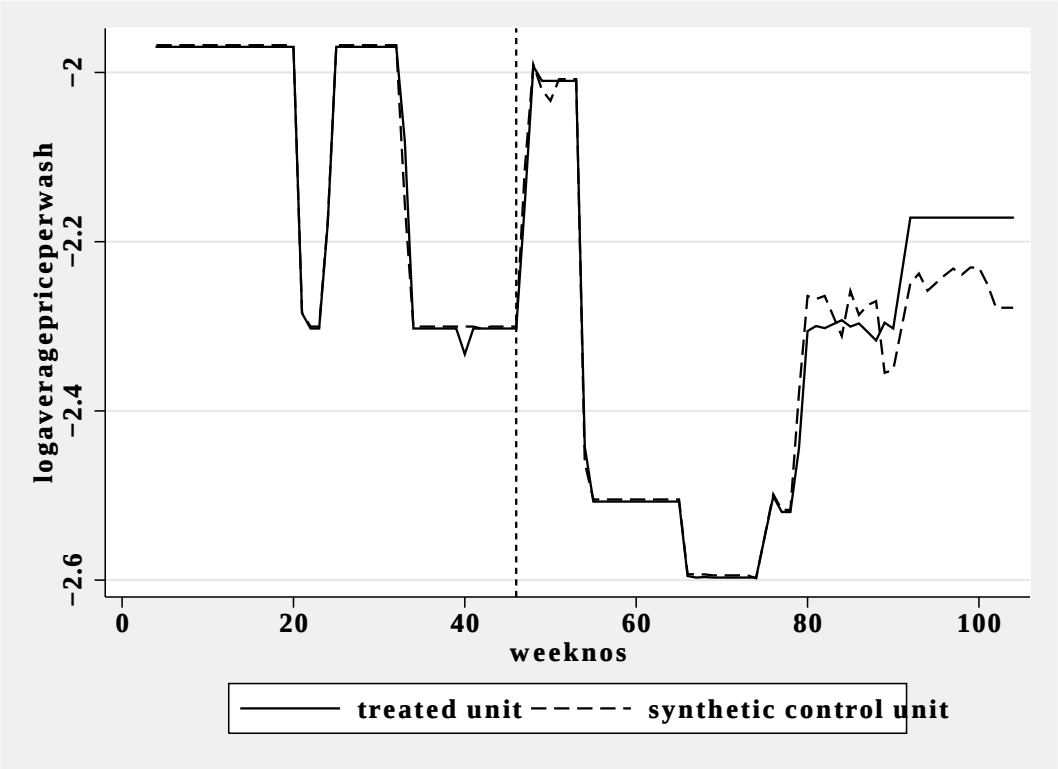

FIGURE 6. Price trajectory for Own Brand Super Conc. Non-Bio Liquid Wash 700Ml/ 20Washes

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 for one offer	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 for one offer	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 for one offer	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 for one offer	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 for one offer	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