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EFFECTS OF CARBON REDUCTION LABELS: EVIDENCE FROM SCANNER DATA

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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 or demand. 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. (*JEL* D12, D83, L15, Q54)

I. INTRODUCTION

Households in the EU are responsible for 25% of total EU greenhouse gas emissions.[1] 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, that is, as the product is grown or manufactured, transported, stored, and used (Figure 1). More than 27,000 goods (or services) in the United Kingdom now carry this label and it is estimated that the label appears on goods worth 3.3 billion pounds in annual sales.[2] The objective of these carbon labels is to move households' behavior toward lower amounts of carbon consumption.[3] 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-à-vis other similar goods that do not have the carbon label. In this study, we investigate the effectiveness of the carbon reduction label using real market data from a major supermarket chain in the United Kingdom. In particular, we examine whether a specific category of carbon-labeled goods—carbon-labeled

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1. 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.

2. From the website of the Carbon Trust at: http://www.carbontrust.com/client-services/footprinting/footprint-certification.

3. For a detailed discussion on carbon labeling and its potential usefulness in reducing carbon dioxide emissions, see Cohen and Vandenbergh (2012) and references cited therein.

ABBREVIATIONS

AIDS: Almost Ideal Demand System
ATT: Average Treatment Effect for the Treated
DID: Difference-in-Difference
GDA: Guide Daily Amount

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detergents—obtain a price premium compared to detergents without the label.

This study contributes to the literature on carbon labeling in two important ways. First, in contrast with previous empirical studies on carbon labels, our data are not limited to a specific location or to a specific store but are based on observed consumer behavior in the whole of the United Kingdom. Second, in our data we observe transaction prices for labeled and unlabeled detergents before and after the labeling started. This feature of our data allows us to utilize standard microeconometric techniques (elaborated below) to tease out the average treatment effect. Our empirical analysis concentrates on the impact 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 stores of other supermarket chains. However, as a robustness check we also estimate simple demand models. In contrast to previous experimental studies on carbon labels (discussed below), in the United Kingdom (and therefore also in our data) the carbon labels used are complicated and include detailed information on the carbon dioxide emissions of the products (i.e., the number of grams of CO_2 emissions). Given this detailed information and the fact that people's buying behavior may be 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 allow 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. Recent work by Seiler (2013) shows the presence of high search costs in the detergent market and hence we would expect search costs to have an effect on the willingness to pay for carbon-labeled detergents in our case as well.

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) regression that takes advantage of the fact that some of the detergents were labeled sometime after our data starts. This method allows us to estimate the average impact of the carbon reduction label on the detergent prices. However, as the impact of the carbon reduction 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 (i.e., if we have heterogeneous treatment effects). To address this question, we use a relatively new technique called the synthetic control method.[4] 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 DID 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, that is, 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.

Our study is one of the first empirical papers to systematically study the effects of a carbon label using real market data in a quasi-experimental setup. Although there is a relatively large theoretical and empirical literature on labeling, there have been very few empirical 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. In recent years, a few experimental studies have investigated the effectiveness of carbon label. Using a simple experiment Michaud, Llerena, and Joly (2013) find a significant price premium for low carbon footprint products. However, the choice setting that the study exploits in the experimental design is very different from a real life purchase choice and therefore the external

4. Another option could be to use the DID setup and estimate separate treatment effects for each labeled product (using interactions or separate subsamples of these products). However, as Conley and Taber (2011) show (see also Donald and Lang 2007), the conventional statistical inference methods are not consistent for DID when there are a small number of treated units and a large number of control units. This is clearly a problem in our setting, as allowing heterogeneous treatment effects would allow us to have only one unit in the treatment group (for each treated product considered) and many products in the control group. In addition, we note that as the synthetic control method does not require the common trend assumption or any additional assumptions about the specific type of parametric functional form used, it is more flexible and robust than the DID setup when studying heterogeneous treatment effects.

validity of the results can be weak.[5] Also, using a conjoint choice experiment (included in a 2008 U.S. survey), Onozaka and Mcfadden (2011) find some evidence to show 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 impact on the sales of the least carbon intensive products and a negative impact on the sales of most carbon intensive products during an 8-week follow-up period. Although their results may capture real market behavior, the study is limited in scope and duration. Moreover, as the experimental design they use is not very rigorous, it is difficult to evaluate the impact of the labels based on their results.[6]

The rest of the article is structured as follows: Section II presents a literature review and our setting which help to delineate the different types of price premium that we could possibly observe in the data; Section III describes the data for the paper and the methods used in the empirical analysis; Section IV gives the results of the empirical analysis, while Section V discusses the results and policy implications; and Section VI concludes.

II. LITERATURE REVIEW AND SETTING

In this section, we review the main theoretical and empirical literature on the effects of labeling. In addition, we outline some factors that may affect the effectiveness of environmental labels and discuss how these factors pertain to our setting.

A. Theoretical Results

The theoretical literature predicts that the introduction of a carbon label should lead to a price premium (in our case a "carbon premium"). The intuition behind this result is the following: 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 leads to a higher price for that good.[7] The label allows firms to either segment the market or differentiate their products. More specifically, a large number of theoretical models mainly use the Mussa and Rosen's (1978) utility function or its variant (Bonroy and Constantatos 2015):[8]

$$U(\theta) = \theta q - p, \tag{1}$$

where θ represents the consumer willingness to pay for the product and it is assumed to be uniformly distributed in [0; 1], while q represents the product quality or environmental friendliness and p the product price.

In the above setup, we can expect the introduction of a label to lead to an increase of the labeled product price independent of market conditions or on the level of competition. We now go through three distinct cases, where a price premium can emerge for labeled products. First, it is well known that the introduction of a label in a competitive market will segment the market into two: the labeled market and the unlabeled market. In the labeled market, demand will increase (consumers have higher willingness to pay for environmentally friendly product) and supply may decrease (generally only few firms can comply with the label requirements) resulting in a higher price for the labeled product (see Bonroy and Constantatos 2015; Mattoo and Singh 1994; Sedjo and Swallow 2002; Zago and Pick 2004). In the unlabeled market, if the number of firms remaining in the market is higher than the number of consumers still willing to buy the unlabeled product, then the price will decrease (otherwise the price can remain constant or increase). Second, a monopoly can also choose to segment their market due to the label. In this case, monopoly could switch to a mass marketing strategy where it provides one product for the whole market or to a segmentation strategy where it produces two different variants of a good: a green and a polluting variant. The segmentation

5. For instance, Michaud et al. (2013) consider only three different product characteristics in the experimental design: a product price, an eco-label, and a carbon footprint with two different levels (high emissions vs. low emissions). The carbon label used in their experiments is much simpler than the labels typically used in the real market.

6. One particular weakness related to the design is that they do not look at the changes in sales of unlabeled products.

7. It is typically assumed that consumers obtain a higher utility from the consumption of green product because of a warm glow effect (Andreoni 1990). They feel better knowing that they have contributed to the environment protection.

8. See the literature review by Bonroy and Constantatos (2015) for details. Two classic variants of this utility function are the consideration of a degenerated distribution or the perception of the product quality q. In the former case, we only have two groups of consumers: one valuing the environment and the other not.

strategy allows the monopoly to exploit more consumer surplus by imposing a higher price for the green (labeled) product. If the fixed costs of producing the green product are not too high then the segmentation is always the most profitable strategy and results in a price increase for the labeled product. In this case, the price of the unlabeled product can decrease or remain the same depending on potential cannibalization (Chen 2001).[9] Third, the introduction of the label allows for vertical product differentiation (Bonroy and Constantatos 2015).[10] In a duopoly, facing price competition and selling homogenous products, the Bertrand paradox will lead to price equaling marginal cost with no profit for either of the two firms. After the introduction of the label, price competition among firms may decrease because of vertical product differentiation with the green product corresponding to the high quality product. In this case, the price of the labeled and the unlabeled product will both increase. However, the price increase of the labeled product will be much higher (more than twice in the most simple case with zero marginal cost) than the price increase of the unlabeled product (for a literature review presenting these different models, see Bonroy and Constantatos 2015 and Mason 2013). It is also worth noting that an environmentally friendly product is typically considered costlier to produce than its polluting equivalent. The labeling cost can be divided in two parts: the first part is a compliance cost as the product should achieve a certain environmental quality in order to get the label; and the second part corresponds to the certification cost coming from the monitoring and testing of the product. A possible increase in cost has to be compensated by an increase in price.

There are also theoretical reasons to expect small or even zero price premiums. If we relax the assumption that the consumers fully (blindly) trust and understand the label then the emergence of a price premium is less likely as we explain in the following three scenarios below. First, consumers may believe that firms can fraudulently label polluting or environmentally unfriendly products, in which case price premiums may fail to emerge. In competitive markets, firms have a high incentive to fraudulently affix a label on their polluting products (see Hamilton and Zilberman 2006). Second, the type of certification matters for the emergence of a premium. Self-labeling may produce smaller price premiums than third party certification as the former is less credible. Finally, consumers may be unsure about the value of the label. They may know it means that the firms have passed the certification standard requirements, but they probably will not know the difficulty of these requirements. In such a case, consumers may use the number of firms using labeling to estimate the difficulty of having the label and thus its value. The price premiums can therefore be decreasing in the number of products which have the label (Harbaugh, Maxwell, and Roussillon 2011).

To conclude, the emergence of price premiums for a labeled product is to be expected in most situations.[11] The situations where the emergence of a premium is unlikely include the case of a competitive market, where one can have fraudulent labels, or when there are a large number of firms using the label. In any case, it should be noted that the results elaborated above depend on a number of specific assumptions that may not be true in reality.

B. Price Premiums in Practice

Empirically, the emergence of a price premium for an environmental label and the magnitude of the premium conditional on its emergence depends on the following three factors:

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 consumers' 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 premium for organic products (see, e.g., Griffith and Nesheim 2013 or Nimon and Beghin 1999). However, organic products are often considered

9. Recently, Houde (2014) has shown using a structural demand model that firms use the certification to price discriminate their products.

10. As mentioned by Bonroy and Constantatos (2015), this idea is very close to the model of vertical product differentiation of Gabszewicz and Thisse (1979) with the labeled product representing the high quality product and the pollutant product representing the low quality product.

11. Note that the existence of a price premium does not mean that the introduction of a label will be welfare enhancing.

as a tastier and healthier alternative to their nonorganic counterparts and therefore they incorporate some private benefit as well as attributes of a public good type. Note that in general taste and nutritional aspects of the good are much more important for consumers than the environmental characteristics of the good (see Bougherara and Combris 2009; Fletcher and Downing 2011; Gadema and Oglethorpe 2011; Griffith and Nesheim 2013).[12]

For the specific case of the carbon label, Michaud et al. (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.[13] In a recent survey, Hartikainen et al. (2014) find positive attitudes toward carbon labels in an online-survey of 1,010 Finnish consumers and report that "90% stated that a carbon footprint would have at least a little impact on their buying decision, but the information became meaningful only when many other purchasing criteria (such as price and taste) were satisfied."

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; Thogersen 2000). Related to this, 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 toward these products. In our case, the carbon reduction label is placed at the back of the detergent, which may affect the salience of the label.

Finally, the manner in which information about environmental quality is communicated to the consumer also appears to matter for the emergence of a price premium. Information about the environmental quality of a good can be of many types. The two most common types of indicators of environmental quality are (1) simple labels of approval (e.g., an eco-label such as the EU flower or the Nordic Swan), and (2) 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 numbers and possibly 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 experimental field data have documented that more information is not always better and that consumers prefer simpler information to more detailed information (see BIO Intelligence Service 2012; Kiesel and Villas-Boas 2013; Teisl, Rubin, and Noblet 2008; Wansink and Chandon 2006; Wansink, Sonka, and Hasler 2004).

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).[14] Previous

12. Other relevant papers include Teisl, Roe, and Hicks (2002) and Houde (2014). Teisl et al. (2002) use the almost ideal demand system (AIDS) model to estimate the impact of the dolphin-safe label. Their results indicate that the dolphin-safe label affected consumer behavior and the market share of canned tuna. However, it is very difficult to compare this paper (or its results) to our setting, because the label was a label of approval and it was adopted in the study period by the three largest tuna companies in the world. Moreover, their paper also deviates methodologically from more recent papers that look at the impact of environmental labels (including our paper). Houde (2014) instead studies the effects of Energy Star certification in the U.S. appliance market. Again, the label studied is quite different in comparison to the carbon label in the United Kingdom, because the Energy Star label is a label of approval and identifies the most energy efficient products in the marketplace. Using a structural demand model, he finds that consumers respond to certification in different ways.

13. Note that the approach used in these studies is quite different from ours, because experimental studies control for salience and understanding of the label as well and they also assume away search costs, all of which are likely to be important in our case.

14. One could be skeptical about whether information about the carbon footprint of a 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.

FIGURE 1
An Example of a Carbon Reduction Label

research suggests that consumers appear to have difficulties in understanding this label. Based on the survey of 428 UK shoppers, Gadema and Oglethorpe (2011) found that "81% either strongly agreed or agreed that understanding carbon footprint information and comparing carbon footprints was difficult and confusing." Indeed, 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 can 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, it is difficult to predict its impact on the market and on prices. However, based on the theoretical and empirical studies on environmental labels, we can outline the following scenarios or predictions:

1. If consumers value the carbon reduction label and interpret it perfectly, we would expect to find a price premium that varies among different labeled products.
2. If consumers have limited ability and use the label as a proxy for environmental quality, we would expect all labeled products (detergents) to obtain the same price premium.[15]
3. If consumers find it too complicated to assess the labels, we would expect to find no premium at all for any labeled product.

III. DATA AND EMPIRICAL APPROACHES

A. Data

For our empirical analysis, we utilize a unique data set based on a noted supermarket chain's scanner data. The data consist 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 United Kingdom. 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.[16] Of these 43 detergents, only five detergents (shown in bold in Table 1) are carbon labeled. All of these labeled detergents belong to the supermarket brand that has many detergents in the unlabeled category as well.[17] These carbon-labeled products have the following carbon footprints: (4) 700 g of CO_2 per wash, (7) 750 g of CO_2 per wash, (17) 850 g of CO_2 per wash, (32) 700 g of CO_2 per wash, and (41) 600 g of CO_2 per wash. The label given on the back of the product package informs customers of 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 (Figure 1). 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.

Our data consist of item-level transactions for detergents for 60,000 customers for a period of 104 weeks. The data consist of prices for these detergents and categorical dummies for a

15. This idea (or scenario) is based on a naive version of Milgrom's unraveling argument: the consumer observes that the firm is disclosing something, and therefore expects or assumes the labeled product to be better quality than the other unlabeled product (see Milgrom and Roberts 1986).

16. We replace wherever appropriate in the product names given in Table 1, the name of the supermarket chain with the phrase "Own Brand."

17. During the sample period, we consider in our analysis the supermarket chain already had six different types of products certified/labeled: toilet paper, kitchen rolls, laundry detergents, chilled and long-life orange juice, light bulbs, and 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, which is why we decided to concentrate on detergents.

TABLE 1
List of Detergent Products

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

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.[18] We

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

TABLE 2
Summary Statistics: Detergent Data

Variable	Mean	Std. Dev.	Min.	Max.	N
Carbon label	0.118	0.323	0	1	4,369
Own brand	0.61	0.488	0	1	4,369
Powder	0.296	0.457	0	1	4,369
Tablet	0.446	0.497	0	1	4,369
Liquid	0.258	0.438	0	1	4,369
Size	1.234	0.604	0.385	3.36	4,369
Price discount	0.078	0.252	0	1	4,369
Marked down	0.002	0.009	0	0.2	4,369
No. of washes	19.44	6.884	10	42	4,369
Two-in-one	0.166	0.372	0	1	4,369
Average price per wash	0.168	0.057	0.044	0.362	4,369

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 span 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 five aforementioned carbon-labeled detergents was available only after week 10 in 2008. This fact is important because it allows us to use a DID estimation approach and to 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.

B. DID 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 DIDs and the synthetic control method.

Our first method, the DID 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, e.g., 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.[19]

Fortunately, the carbon label for detergents came into existence some time after the period from when our data starts. Hence this provides 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 DID setup. As 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 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 that would violate this assumption in the present application. As the supermarket chain in question labeled different kinds of products with different footprints, treatment assignment does not appear to be systematic or favorable to the most potential (or effective) products. Yet, it should be recognized that as only a small number of products were labeled, the treatment effect estimate obtained with the DID method might only be representative for the labeled products as well as for the product category considered in the study.

19. 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).

C. Synthetic Control Method

In the DID specification, we test for the emergence of a price premium in a simple label versus no label setup. The basic DID 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 includes both high and low carbon footprint detergents (varying from 650 g of CO_2 emissions to 800 g 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 DID specification, we use the synthetic control method following the approach outlined by Abadie, Diamond, and Hainmueller (2010).[20] 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

20. Another option would be to use the DID setup and interact the treatment group and period indicators with an indicator for each labeled product. However, this approach has a few weaknesses 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 five 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 reliable as discussed in the introduction.

are the same pretreatment (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.

The synthetic control method generates an artificial or synthetic control unit using a weighted average or a convex combination of the observed control units.[21] 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 five 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).

IV. RESULTS

A. *DID Specifications*

A common criticism of the DID 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 behavior of the carbon-labeled detergents had these carbon-labeled detergents, not actually been carbon labeled. As 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 pretreatment 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 that 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 pretreatment period are very similar for the carbon-labeled and unlabeled detergents.[22] 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.

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

$$\text{(2)} \quad \log(price)_{it} = \beta_0 + \gamma_3 \left(CarbonLabel_i * TreatPeriod_t\right) + \boldsymbol{\beta}'\mathbf{X}_{it} + \delta_i + \sum_t (WeekDummies)_t + \varepsilon_{it}$$

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

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

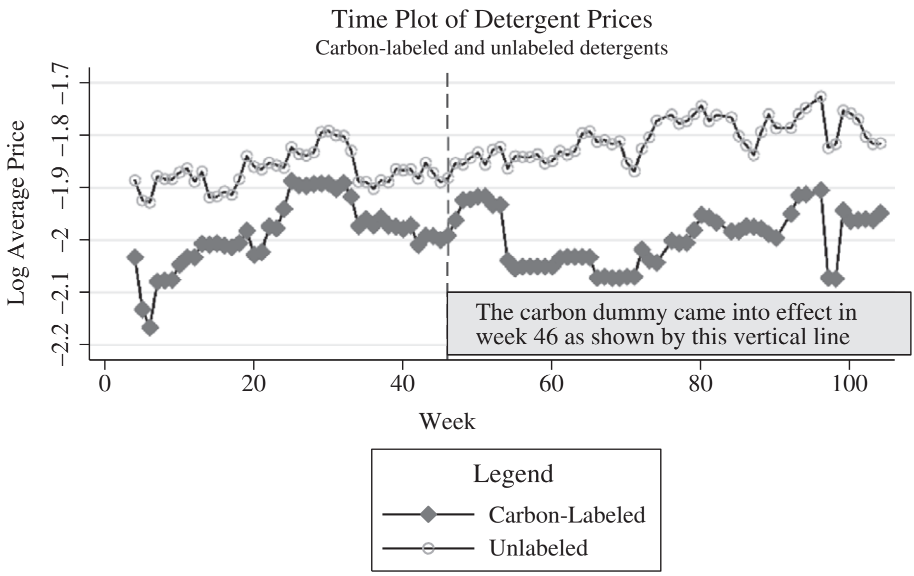
$$TreatPeriod_t = \begin{cases} 1 & \text{if Week >= Week 10 in 2008} \\ 0 & \text{otherwise.} \end{cases}$$

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

21. The idea behind the synthetic control method is that a (convex) combination of control units provides a better counter-factual for the treated unit than any single control unit alone. In our case, labeled detergents form the treatment group while unlabeled detergents form the control group. For K unlabeled detergents, we assign weights $W = (w_1, w_2, \ldots, w_K)$ (with $w_k \geq 0$ and $^{\text{L}}w_k = 1$) to each of these control detergents. The weights are chosen so that the synthetic detergent resembles the actual carbon-labeled detergent as much as possible. We refer the interested reader to Abadie et al. (2010) for additional technical details and to Abadie and Gardeazabal (2003) for an economic application.

22. We also drew the same graph using only the supermarket's own products (labeled and unlabeled detergents). The price trends are very similar for these two groups of products in this case also. For more details, please see Appendix S1.

FIGURE 2
Price Plots of Carbon-Labeled and Unlabeled Detergents



Source: Scanner level data from a noted supermarket chain (collapsed from the transaction level to the week level)

different-sized detergent products comparable.[23] In addition, we use a logarithmic transformation for the dependent variable for the ease of interpretation (coefficients can be interpreted as percentage changes).[24] 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. In some regressions, 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 DID specification given in Equation (2), 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 $(CarbonLabel_i * TreatPeriod_t)$, 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.[25]

The results of the DID regressions are reported in Table 3. We first report the regression results for a simple OLS specification, where product-specific fixed effects are not controlled for in column 1. Column 2 reports the results of the same regression with additional controls. Columns 3 and 4 report the results of regressions which control for product fixed effects and which control for the standard errors involved in the estimation process in different ways. Note that 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 the problems caused by these two issues in the estimation process. Bertrand, Duflo, and Mullainathan (2004) show that conventional standard errors often severely understate the standard deviation of the estimators in the DID framework.

23. We also estimate the main models without using any normalization. The results are very similar and consistent with our results presented later. For more details, please see Appendix S1.

24. Again, the results and conclusions are not sensitive to this choice.

25. We also consider a simple OLS regression (i.e., without product fixed effects), where the DID specification is the conventional specification used in the literature: $log\,(price)_{it} = \beta_0 + \gamma_1 CarbonLabel_i + \gamma_2 TreatPeriod_t + \gamma_3 \left(CarbonLabel_i * TreatPeriod_t\right) + \sum_t (WeekDummies)_t + \varepsilon_{it}$

TABLE 3
Price Regressions

	(1) OLS (clustered SE)	(2) OLS w/ controls (clustered SE)	(3) FE (clustered SE)	(4) FE (bootstrap SE)
CarbonLabel * TreatPeriod	−.065	−.064	−.069	−.069
	(.071)	(.070)	(.068)	(.066)
CarbonLabel	−.133	−.138		
	(.097)	(.099)		
TreatPeriod	.033	.019		
	(.031)	(.031)		
Price Discount		$-.237^{***}$	$-.189^{***}$	$-.189^{***}$
		(.061)	(.022)	(.021)
Marked Down		1.381	$-.695^{*}$	$-.695^{*}$
		(1.222)	(.284)	(.285)
Product Fixed Effects	No	No	Yes	Yes
Week Dummies	Yes	Yes	Yes	Yes
No. of Obvs.	4,369	4,369	4,369	4,369

Notes: 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. 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. 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 pretreatment period. The DID estimator is the coefficient on the interaction term CarbonLabel * TreatPeriod. *t*-Statistics reported under each coefficient in parenthesis. OLS, ordinary least squares regression; FE, fixed effects regression; SE, standard errors.

Significance at $^{+}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

They propose using block-bootstrapped standard errors. So in Table 3 we report the results of the DID regression with product fixed effects using both clustered standard errors (in column 3) and bootstrapped standard errors (in column 4). We note that for all results reported in Table 3, we use heteroskedastic robust standard errors. Also, all reported standard errors are clustered at the product level.[26]

The regression results in Table 4 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 not statistically significant in any of specifications considered. 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.[27]

Based on our earlier discussion (see Section II) 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, because 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.

B. 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 unlabeled detergents. Next, we

26. To address the autocorrelation issue, we also use an alternative approach suggested by Bertrand et al. (2004). We collapse the data to two time periods (before and after the introduction of the labels) and estimate the regression model using the collapsed data. The results were very similar to the results in Table 3. For more details, please see Appendix S1.

27. For robustness, we also rerun regression 2 earlier by limiting our sample only to those detergents that belong to the supermarket chain. We find that the interaction term $CarbonLabel_i$ * $TreatTime_t$ is insignificant in all specifications considered (these are the same specifications that we used in the columns of Table 3) indicating that the impact of the carbon label is insignificant. So our main result is again robust to using this alternative control group. For more details, please see Appendix S1.

TABLE 4
Demand Regressions

	(1) OLS (clustered SE)	(2) OLS w/ controls (clustered SE)	(3) FE (clustered SE)	(4) FE w/ (bootstrap SE)
CarbonLabel * TreatPeriod	.157	.021	.014	.014
	(.197)	(.140)	(.130)	(.123)
CarbonLabel	.034	.091		
	(.387)	(.128)		
TreatPeriod	−.104	.104		
	(.092)	(.109)		
Price Discount		−.075	−.025	−.025
		(.055)	(.044)	(.041)
Marked Down		−1.884	−1.200	−1.200
		(1.402)	(1.134)	(1.197)
Average Price		.067*	−.141*	−.141*
		(.033)	(.064)	(.065)
Sum Expenditure		.003***	.002***	.002***
		(.000)	(.000)	(.000)
Mean Detergent Price		.060	.338*	.659*
		(.106)	(.160)	(.327)
Product Fixed Effects	No	No	Yes	Yes
Week Dummies	Yes	Yes	Yes	Yes
No. of Obvs.	4,369	4,369	4,369	4,369

Notes: 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. 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. 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 pretreatment period. The DID estimator is the coefficient on the interaction term CarbonLabel * TreatPeriod. *t*-Statistics reported under each coefficient in parenthesis. OLS, ordinary least squares regression; FE, fixed effects regression; SE, standard errors.

Significance at $^{+}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

use the synthetic control method to investigate whether one or several of the five carbon-labeled detergents have product-specific price changes that differ from the price changes of similar unlabeled detergents. 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 $\widetilde{\mathbf{X}}$ (note that this vector excludes the treatment dummy and the dummy for the treatment period and their interaction):

$$\widetilde{\mathbf{X}} = \{TabletDummy, LiquidDummy, Twoinone\\ Dummy, PriceDiscountDummy, MarkedDown\\ Dummy, Numberofwashes, OwnBrandDummy\}$$

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).[28]

In odd-numbered Tables 5–13, 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 L as given in the fourth entry in the list of detergents in Table 1) is a carbon-labeled detergent. The synthetic detergent 4 comprises 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 detergent 9 gets a weight of only 0.006 in this convex combination. Note that all weights are non-negative

28. 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, and so on. 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.

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

(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.

We also list the pretreatment characteristics of the actual carbon-labeled detergent along with 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 6–14. 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 well). Therefore, the synthetic detergent provides a reasonable approximation to the pretreatment characteristics of the actual detergent. We also note from the other even-numbered tables (Tables 8–14) that for all carbon-labeled detergents, the synthetic detergent appears to mirror the pretreatment characteristics of the actual detergent accurately.

Next, we plot the actual and counterfactual trajectories of the outcome of interest, namely, 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 five detergents. We show these actual and counterfactual price trajectories for the carbon-labeled products in Figures 3–7.

These graphs show that in the pretreatment period the price trajectories of the counterfactual product (synthetic control) are almost identical for observed price changes for the actual

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

labeled products. The only exception is the second labeled product, but even for this case the price difference between labeled and synthetic product appear to stay constant before and after the treatment.

In agreement with the results of the DIDs 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 five labeled products, which appear to indicate that there is no price premium for any of the carbon-labeled detergents.

V. FURTHER ANALYSIS AND DISCUSSION

A. 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 et al. (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 et al. (2004) show that more information is not always better and their result suggests that people generate better

FIGURE 3
Price Trajectory for Own Brand Non-Bio Liquid Wash 1.5 L

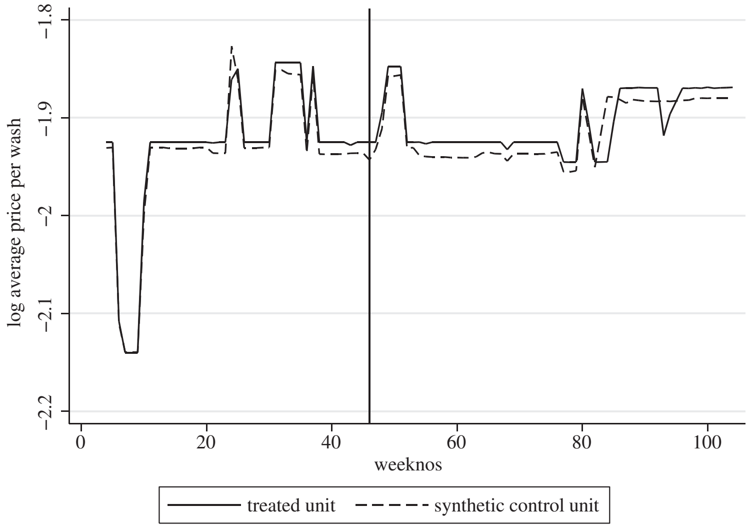
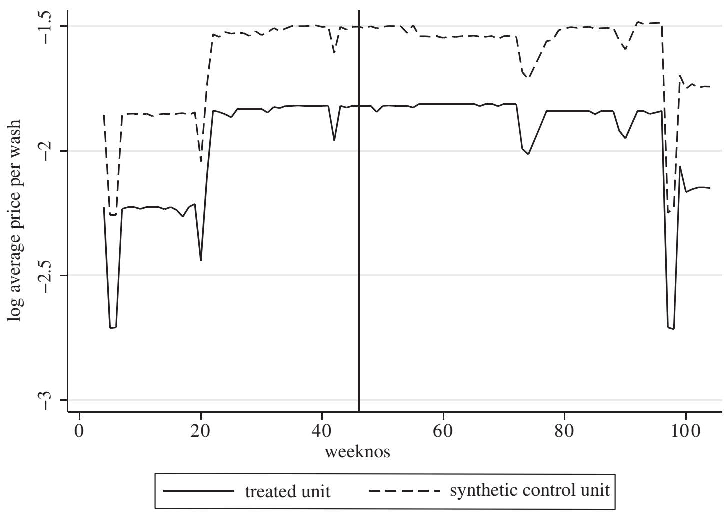


FIGURE 4
Price Trajectory for Own Brand Non-Bio 1.2 kg



inferences from short claims than from long claims on the front label. More recently, Muller and Ruffieux (2011) show 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. Similar results are found in a report published by the European Commission on the design of an environmental index. BIO Intelligence Service (2012) studied consumer preferences for different kinds of label designs using a survey of over 1,500 people in three different European countries. The results suggest that consumers prefer a scale which can be

FIGURE 5
Price Trajectory for Own Brand Non-Bio Tablets 48 Pack 24 Washes/1.8 kg

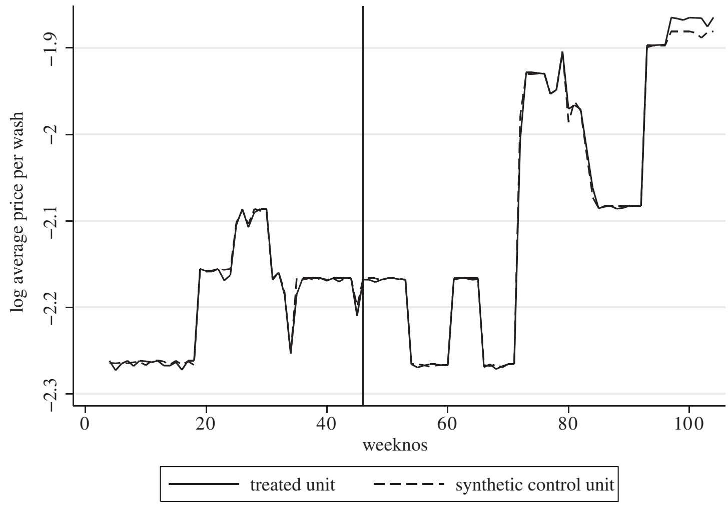
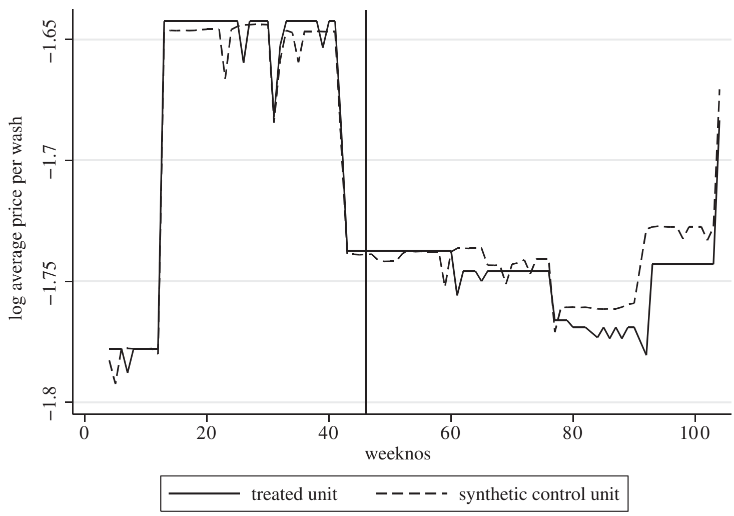


FIGURE 6
Price Trajectory for Own brand Non-Bio Liquid Capsules 20 Wash/1 L



expressed as a color code system, such as a traffic light system.[29] Upham, Dendler, and Bleda (2011) conducted 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 of these different studies support the idea that the carbon reduction label is difficult to understand.

In the context of the carbon reduction label, the aforementioned results would suggest that the label could be more effective if, instead of

29. It is stated in the report 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."

FIGURE 7

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

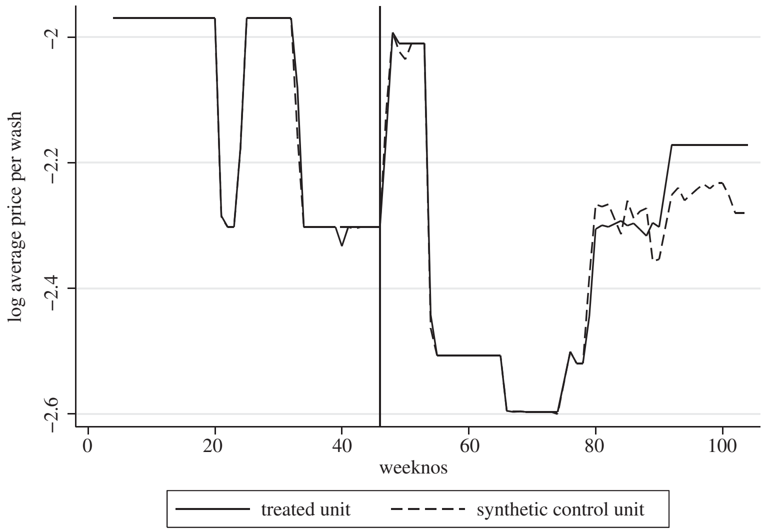


TABLE 13

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

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 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 et al. (2013), who find that a much simpler type of carbon label affects consumers' behavior 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 that 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.

B. *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, as we do not have product-level aggregate sales data for different detergent products but only for our sample of consumers (60,000 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 are less suitable for estimating demand models than price models.

Despite these difficulties, as a robustness check we estimated simple demand models for detergents. For these estimations, we once again used the DID 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 DID demand regressions are presented in Table 4.

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 nonexistent price impacts originate from the consumer side and from consumers' problems in understanding these labels.

C. *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. As the carbon reduction label is a voluntary label, it appears 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.[30] 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

30. Koos (2011) shows that a larger supply of environmental-labeled goods 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.

it commits itself to reducing the CO_2 emissions of its product within 2 years. In comparison, a simple label of approval or a traffic light system can be much more financially demanding for the firm and this high cost may become a barrier for the adoption of these labels.[31] We think that the Carbon Trust Fund aimed to spread the use of the carbon reduction label 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 supermarket chains in the United Kingdom except this particular supermarket chain adopted carbon reduction labels for their products. It appears 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.[32] So why did the other supermarket chains not 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.[33] 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.[34] 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, that is, 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 just to 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 Guide Daily Amount (GDA) 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 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, 100 g 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. Actually, the Carbon Trust has recently introduced two new labels which are simpler and convey less information. These labels are more like labels of approval.[35] We think that 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.

31. 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.

32. See the report on the supermarket chain in the article by Adam Vaughan in the guardian.co.uk, Monday, January 30, 2012, 15.02 GMT.

33. 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.

34. Harbaugh et al. (2011) show that the quality and the number of products having a label may impact the size of the potential price premium.

35. See the following website for more information: http://www.carbontrust.com/client-services/footprinting/footprint-certification/carbon-footprint-label

VI. CONCLUSIONS

We have studied the impact of the carbon reduction label for prices of detergents. We utilized detailed scanner data from a noted UK supermarket chain 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 DID approach, indicate that the carbon reduction label has no impact on prices, that is, 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 to indicate 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 DID regression as well as the synthetic control method appear to outline a consistent story. The evidence appears to be quite strong that there does not exist a price premium for carbon-labeled detergents.

As we discussed in this study, 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 appears to be the case for carbon labels in general according to several surveys. 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. Since our analysis concentrated on detergents, in future research it would be also important to study the effectiveness of carbon label for other products or product categories.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Additional results and graphs