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Impacts of Mandatory GE Food Labeling: A Quasi-Natural Experiment

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Abstract

In July 2016, Vermont became the first U.S. state to require mandatory labeling of foods containing genetically engineered (GE) ingredients. The introduction of the Vermont law serves as a quasi-natural experiment on the economic effects of mandatory GE labeling. We investigate the market response in the U.S. sugar market. Almost all beet sugar is GE, while cane sugar is GE-free. Prior to 2016, cane and beet sugar were regarded as homogenous. However, in mid-2016, refined cane sugar began selling at a premium over refined beet sugar. We find the mandatory labeling initiative generated about a 13% price discount for beet sugar and a premium of about 1% for cane. Food manufacturers' concerns over mandatory labeling caused them to switch inputs. This resulted in a redistribution of welfare in the U.S. sugar industry.

Key Words

GMO labeling, Vermont Act 120, National Bioengineered Food Disclosure Standard, sugar market

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> *"Many food companies have decided to label their products as non-GMO. And because practically all sugar beets in the U.S. are genetically modified, those food products are now using sugar derived from sugar cane . . ."* Dan Charles, National Public Radio (May 12, 2016)

Legislation is not made in a vacuum. Markets evolve even as policy debate transpires, and markets anticipate policy changes. Once a policy outcome becomes sufficiently likely, producers adjust to minimize costs and maximize benefits. But these adjustments can be costly to reverse even if the policy outcome never comes to pass or is later quashed. Segmentation of the U.S. sugar market in response to mandatory labeling legislation for food containing genetically engineered (GE) ingredients is one such example of this phenomenon.[1]

In May 2014, Vermont became the first (and only) state to pass mandatory labeling rules for GE foods sold for consumption at home.[2] The law (Act 120) took effect on July 1, 2016, but was nullified by federal legislation later that month. Penalties and requirements under the Vermont law were harsh. Consumers could sue for violations of the labeling requirements "without needing to demonstrate any specific damage occurred as a result of the alleged violation" (Bovay and Alston, 2018). Manufacturers of improperly labeled products sold in Vermont would be fined $1,000 per day, per product.

About two weeks after the Vermont law took effect, U.S. Congress responded with the National Bioengineered Food Disclosure Standard (NBFDS), which pre-empts state-level labeling initiatives and imposes federal disclosure requirements for some GE-containing foods but allows that the disclosure need not be explicit on the product label (Charles, 2016).[3] On May 4, 2018, the USDA released a set of proposed requirements under the NBFDS, including a statement on the consequences for non-compliance and mechanisms for enforcement (FR, 2018). These rules have not been finalized and are currently subject to public comment.

In spite of the widespread use of food labels worldwide (Carter and Gruère, 2003*a*; Gruère, Carter and Farzin, 2009; Kiesel, McCluskey and Villas-Boas, 2011; Van Eenennaam et al., 2014; Vigani and Olper, 2013), empirical evidence of market impact is scant. Existing research focuses entirely at the retail level. Kiesel, McCluskey and Villas-Boas (2011) review literature that uses market-level and natural experiments to examine the effects of nutritional label requirements on consumer behavior. Teisl, Bockstael and Levy (2001) employ an experiment to study the welfare effects of the provision of nutrition information on supermarket shelves to highlight whether the food product was low or reduced in fat, cholesterol, sodium, and calories. Berning, Chouinard and McCluskey (2010) and Kiesel and Villas-Boas (2013) conduct field experiments to examine the effects of nutrition labels on the sales of microwave popcorn. Some research has also used scanner data to evaluate consumers' purchasing decisions in the context of GE labeling rules (Chang, 2006; Marks, Kalaitzandonakes and Vickner, 2004). Gruère (2006) incorporates the behavior of food manufacturers by comparing the fraction of food products labeled with information regarding the use of GE inputs in Canada (where GE labeling is voluntary) and France (where GE labeling is mandatory).

We analyze the effects of GE food labeling laws and associated product reformulation on the relative prices of GE and non-GE food ingredients. Our analysis focuses on the U.S. refined sugar market, an interesting case for several reasons. Most importantly, sugar is a key ingredient in many processed food products; thus, understanding the effects of labeling laws on the sugar market has broad relevance across a wide range of consumer products. Sugar also has two distinct GE and non-GE production methods. In the United States, sugar is produced from both sugarcane and sugarbeets. Sugarcane stalks are milled to produce raw sugar. Raw cane sugar is then sent to a refining facility to be transformed into refined sugar. Sugbarbeets, in contrast, have no raw stage; they are processed from beet to refined sugar in one continuous process. The U.S. market share for beet (cane) sugar is approximately 58% (42%). Almost all U.S. sugarbeet production is GE, while cane sugar is GE-free. However, sugar derived from beets is chemically identical to sugar derived from cane (Klein, Altenbuchner and Mattes, 1998).

Finally, regulations in the U.S. sugar market create a relatively clean setting in which to identify the impacts of labeling requirements. U.S. cane and beet growers receive annual marketing allotments (i.e., production quotas) and all imports are subject to tariff-rate quotas or volumetric restrictions. Imported sugar accounts for about 25% of the U.S. supply, and all imports are cane sugar.

[Figure 1 about here.]

Since early 2016, refined cane sugar has traded at an unusual price premium of up to 7.9¢ per lb. (27%) over refined beet sugar. Figure 1 shows refined cane and beet prices from January 2008 to December 2017. Prices historically moved in a close one-to-one relationship. From January 2008 to December 2015, the maximum difference between cane and beet prices was just 2¢ per lb.

We ask two questions related to the relationship between GE labeling laws and market segmentation in the U.S. sugar industry. The first question is one of attribution—can the divergence in U.S. cane and beet prices be attributed to input reformulation in response to the Vermont labeling initiative? A structural break analysis reveals that the breakdown in the relationship between cane and beet prices occurred in the May–July 2016 period. July 2016 is the month Vermont's mandatory labeling law took effect. Historical price relationships before and after July 2016 reveal that the locus of the break was at the refiner level and the shock was confined to the U.S. market. It seems clear that food manufacturers responded to the Vermont legislation by changing their input mix.

The second question is one of impact—if labeling requirements caused the price divergence, what would refined sugar prices have been in the absence of such legislation? Using a standard regime-switching regression model, we find that the Vermont law induced a break in the price relationship between U.S. and world sugar prices. This price premium has persisted under the NBFDS. Relative to what prices would have been in the absence of legislation—GE labeling requirements generated an average premium for cane sugar of approximately 1% and a discount for beet sugar of around 13%. In the 12-month period immediately following the July 2016 legislation, mandatory GE labeling requirements generated a $40 million windfall for U.S. cane refiners and cost U.S. beet processors approximately $400 million.

Economics of GE Food Labeling Laws & Input Mix

Economists have studied the drivers and international differences in GE labeling requirements (Carter and Gruère, 2003*a*; Gruère, Carter and Farzin, 2009; McCluskey, Wesseler and Winfree, 2018; Vigani and Olper, 2013) and the impact of mandatory labels on consumer and producer behavior. From the consumer perspective, mandatory GE labels function both as a sorting mechanism for consumers (Crespi and Marette, 2003; Fulton and Giannakas, 2004) and as a signal about the relative safety of GE foods (Artuso, 2003; Lusk and Rozan, 2008). The consumer impacts and potential price differences between GE and non-GE ingredients also affect manufacturers' input and supply decisions (Carter and Gruère, 2003*b*).

Firm-level Decision

The introduction of the Vermont law forced manufacturers to make a binary choice: (1) maintain current product formulation and label or (2) switch to non-GE inputs to avoid labeling. The profit-maximizing strategy is a function of the share of consumers willing to buy GE-labeled foods, the cost of switching from GE- to non-GE inputs, and the cost of compliance with the labeling policy (Carter and Gruère, 2003*b*). Consumers may interpret a mandatory label as a warning that GE foods pose a food safety threat or are of poor quality. If so, some consumers previously unwilling to pay a premium for non-GE may pay to avoid GE as a result of the policy. Moreover, for most food products reformulation towards non-GE inputs is unlikely to have a substantial effect on the final food price. GE ingredients are typically used in highly processed products and represent a small share of the food dollar (Cowan, 2010). These factors push the food manufacturer to convert to non-GE inputs to avoid labeling.

A similar choice exists for retailers (Kalaitzandonakes and Bijman, 2003). For example, supermarkets like Trader Joe's, Whole Foods, and many others seek to differentiate themselves by offering foods perceived by consumers as higher quality. If consumers perceive foods containing GE products as lower quality due to a label, retailers may choose not to offer them (Carter et al., 2012; Van Eenennaam et al., 2014).

The reformulation decision was not exclusive to suppliers selling into Vermont. One can easily imagine the following circumstances: a food manufacturer labels food in compliance with one state's law, but a retailer (perhaps accidentally) sells the product in Vermont where the label is non-compliant with local law. The food manufacturer would be liable and subject to penalties under the Vermont law. Furthermore, economies of scale may incentivize the food manufacturer to use only one input. Most food manufacturers supply several states out of a single production facility. So, even if a small share of the market requires labeling, the product requirement may change the entire supply chain. The history of litigation over labeling rules suggests the cost of adhering to mandatory labeling could be high.[4]

The passage of the NBFDS is not an emancipation for food manufacturers (or retailers) who already reformulated in light of the Vermont law. On one hand, the NBFDS is not (in the strict sense) a mandatory labeling policy. The limited disclosure requirements may reduce the incentive to reformulate (Bovay and Alston, 2018). On the other hand, the decision to convert from GE- to non-GE ingredients is not the dual of the decision to convert back. Once the decision to convert to non-GE ingredients is made, it is somewhat irreversible. If GE products are perceived as being of lower quality than their non-GE counterparts (regardless of whether this perception is influenced by labeling legislation), the decision to reformulate away from GE ingredients and towards non-GE ingredients sends a message of quality upgrading to consumers—a source of differentiation from competitors. For a manufacturer who has already reformulated to non-GE inputs, the decision to convert back to GE ingredients sends a message of quality downgrading. The move would open the manufacturer to loss of market share. The switch back to GE ingredients would not necessarily lead to a significant cost saving for many food products. The relative silence in the economics literature on quality downgrading is telling on this point. Additionally, manufacturers considering a move back to GE ingredients may face substantial political backlash by pressure groups opposed to GE technology. The uncertainty with respect to the specific requirements of the NBFDS reinforce these points for risk-averse manufacturers.

Market-level Outcomes

To see how markets have responded to potential mandatory labeling, we turn to the sugar industry. In late 2015 and early 2016, many food manufacturers, including Campbell Soup, ConAgra, General Mills, Hershey, Kellogg's, and others, announced they would switch to sourcing sugar from cane rather than beets (Perez, 2016). Several explicitly cited the Vermont legislation and the absence of a federal labeling bill as the primary driver behind this decision (Clayton, 2016; Meersman, 2015). Following these announcements, the close historical relationship between refined cane and beet prices began to deteriorate (figure 1).

This breakdown in the price relationship is consistent with the theoretical effects of mandatory labeling laws on input markets. Figure 2 presents a simple conceptual model of the U.S. sugar market. Segments S_{Beet} and S_{Cane} in panels (a) and (b) of figure 2, respectively, represent the supply schedules for refined beet and cane sugar produced domestically. Marketing allotments under the U.S. sugar program make supply highly inelastic at a certain quantity for both products.

[Figure 2 about here.]

Prior to the promulgation of a mandatory labeling law, cane and beet sugar were treated as a homogenous commodity. Thus, the total supply of domestically produced refined sugar in the U.S. (S_{Sugar}) in panel (c) was the horizontal sum of S_{Beet} and S_{Cane}. Schedule D_{Sugar} also shown in panel (c) depicts the residual demand for refined sugar (net of TRQ and Mexican imports) by U.S. food manufacturers and other sugar users. Equilibrium occurs where market demand for sugar equals market supply, shown by the intersection of schedules S_{Sugar} and D_{Sugar} in panel (c). In this equilibrium, Q_{Sugar} units of sugar were sold, Q_{Beet} of which were derived from beets and Q_{Cane} of which were derived from cane (where Q_{Beet} +

$Q_{Cane} = Q_{Sugar}$). All sugar was sold at price P_f.

Enactment of a mandatory labeling law segmented the demand schedule for refined sugar. A portion of the market, including food manufacturers who reformulate towards non-GE, was now willing to pay a premium to purchase sugar derived from cane. Demand for GE-free cane sugar is depicted as schedule $D_{GE-free}$ in panel (b). Those who do not reformulate or are unwilling to pay a premium for cane will continue to source from beet (depicted as schedule D_{Beet} in panel (a)).

Under a mandatory labeling policy, equilibrium occurs when the demand for GE-free sugar is equal to the supply of cane sugar and the demand for sugar users unwilling to pay a premium aligns with the supply of beet sugar. In figure 2, this equilibrium is represented by the intersection of schedules $D_{GE-free}$ and S_{Cane} in panel (b) and the intersection of schedules D_{Beet} and S_{Beet} in panel (a).

The law drives a wedge between the price of non-GE and GE inputs. Processors of non-GE inputs receive a premium for their products, while processors of GE inputs receive lower prices. The premium to cane refiners is $P_{Cane} - P_f$ and the discount to beet processors is $P_f - P_{Beet}$. The policy results in transfers of economic welfare away from beet processors and towards cane refiners. The total windfall to cane refiners is $(P_{Cane} - P_f)Q_{Cane}$. The total loss to beet processors is $(P_f - P_{Beet})Q_{Beet}$. The introduction of GE labeling requirements also results in a deadweight loss equal to the sum of triangle k in panel (a) and triangle j in panel (b).

Methodology & Preliminary Analysis

In this section, we examine whether the theoretical and anecdotal evidence regarding the relationship between GE labeling laws and U.S. sugar prices is supported by empirics. We first use a structural break test to determine whether the timing of the break in cane relative to beet prices is consistent with the legislative and policy timeline. We then use a regime-switching regression model to measure the historical relationship between U.S. and world refined sugar prices prior to the observed break. Finally, we compare pre- and post-structural-break prices for refined sugar to measure the effects of the labeling legislation. Model robustness and sensitivity are considered in Section 5.

Our data includes monthly observations of U.S. raw and refined cane sugar, refined beet sugar, and world raw and refined sugar prices from January 2011 to December 2017. The U.S. raw cane price is the Intercontinental Exchange (ICE) Sugar No. 16 nearby futures contract.[5] The world raw price is the nearby price for the ICE No. 11 contract.[6] There is no futures market for refined sugar in the United States. We use the average monthly spot price for refined cane sugar and the average monthly spot price for refined beet sugar published by the *Milling & Baking Magazine*.[7] The world refined price is the nearby price for the ICE No. 5 London Daily futures contract for white (i.e., refined) sugar free-on-board in Europe.[8] Deliveries under the London No. 5 contract can be either refined beet or cane sugar.

The start date is purposefully chosen as January 2011 to limit the analysis to the relevant market environment. The volume of Mexican sugar exports to the U.S. increased substantially in FY2011 and has remained high since then (USITC, 2015). This change in export volumes likely affected the relationship between U.S. and world prices, on which our regression analysis hinges.

Table 1 presents Augmented Dicky-Fuller (ADF) test statistics for monthly U.S. and world sugar prices from Jan-2011 to Dec-2017 (Dickey and Fuller, 1979). The third column reports the corresponding MacKinnon approximate p-value. As shown in table 1, we fail to reject the null hypothesis of non-stationarity for all price series. In other words, U.S. and world sugar prices follow a random walk.

[Table 1 about here.]

Under U.S. sugar policy, all sugar imports are subject to volumetric restrictions and all U.S. production is subject to marketing quotas. In this setting, it is unlikely that shocks to the world market would be fully passed through to the U.S. market (and vice versa). A preliminary question is whether U.S. and world sugar prices move together in this policy environment. To formally test whether U.S. prices and world prices are cointegrated, we construct a vector-error correction model (Engle and Granger, 1987). To verify that refined cane and beet sugar prices were cointegrated prior to the introduction of the mandatory labeling law, we measure the cointegrating relationship between Jan. 2011–Dec. 2015. We remove later periods because they are potentially affected by the mandatory labeling requirements. The analysis indicates a statistically significant long-run cointegration relationship between all three price series (results are reported in table 2). Prior to the imposition of GE labeling laws, U.S. cane and beet refined sugar prices were cointegrated with each other and each series was cointegrated with world refined prices at the 99% level of confidence.

[Table 2 about here.]

Structural Break Analysis

An important step in our analysis is to determine when the breakdown in the cointegrating relationship between monthly U.S. refined cane and beet prices occurred. We estimate the following equation over the entire sample period:

$$P_t^c = \alpha + \beta P_t^b + e_t \tag{1}$$

Variable P_t^c represents the U.S. price for refined cane sugar at time t and P_t^b is the corresponding U.S. price for refined beet sugar. We consider Supremum Wald and Likelihood Ratio (L.R.) tests for a structural break at an unknown break date using a symmetric, 15% sample trim (Andrews, 1993; Kim and Siegmund, 1989; Quandt, 1960). We conduct the analysis with variables specified in both levels and natural logarithmic form.

[Table 3 about here.]

Table 3 reports the results of the structural break tests. All tests reject the hypothesis of no structural break with 99.99% confidence. The Wald tests identify July 2016—the month the Vermont GE Labeling Law took effect and the NBFDS was enacted—as the most likely date when the structural break occurred. The Likelihood Ratio tests identify the break date two months earlier, in May 2016.

Figure 4 plots Wald and L.R. statistics for each candidate break date for the specification in logs. The two tests are generally consistent. July 2016 is the most likely date for the break in the Wald specification and the second-most-likely date in the L.R. specification. Similarly, May 2016 is the most likely date for the break in the L.R. specification and the second-most-likely in the Wald specification. Interestingly, the figure shows a substantial increase in the both the Wald and L.R. statistic for May 2014—the month the Vermont Labeling Law was passed.

[Figure 3 about here.]

These findings strongly support the conclusion that the break in sugar prices was the result of the GE labeling initiatives. Food manufacturers faced with the pending Vermont legislation (and other state laws on the horizon) initially waited to convert to GE-free ingredients in hopes that Federal legislation would invalidate mandatory labeling rules. When the Vermont law became imminent, food intermediaries reformulated away from GE ingredients (beet sugar) towards non-GE ingredients (cane sugar), resulting in a price premium for cane and a discount for beet.

There is still the possibility that the timing of the GE labeling legislation and the price divergence could have been coincidental. For example, the breakdown in the cane-to-beet cointegrating relationship could have been caused by non-U.S.-centric factors or issues unique to the U.S. but occurring elsewhere along the sugar supply chain. To conclusively attribute the cane-to-beet price break to mandatory labeling requirements, one must consider these alternative explanations. For clarity and brevity, we focus on the July 2016 candidate break in the analysis that follows. We have conducted a corresponding analysis for the May 2016 candidate break. Because the difference involves only two data points from a much larger sample, point estimates between the two breakpoints are virtually identical for all analyses that we have conducted. All findings and discussion that follow are robust to the use of the May 2016 break date.

Table 4 reports the correlation between U.S. and world sugar prices (again in natural logarithmic form) prior to and after July 2016. As shown in Column 1, the U.S. refined cane price and the U.S. refined beet price had a correlation of 1.00 prior to July 2016. In other words, a shock to the cane price was fully transmitted to the beet price, and vice versa. The prices were perfectly co-integrated. However, following the July 2016 break, the correlation between the two price series fell to 0.57, indicating a breakdown in the relationship.

[Table 4 about here.]

Within the U.S. market, the July 2016 break appears to have been isolated to refined sugar. Turning to row 2 of table 4, the correlation between the U.S. refined cane price and the U.S. raw cane price fell from 0.96 to -0.12 following the break. The correlation between U.S. refined beet and U.S. raw cane went from being highly positive (0.95) to highly negative (-0.74). These pre- and post-July 2016 correlations for refined-to-raw sugar have important implications for the distributional impacts of the policy. As noted in the Introduction, sugarcane is first processed into raw sugar and then sent to refiners for further processing into refined sugar. In contrast, sugar produced from sugarbeets does not have a "raw" stage; processing is a single, continuous process from beet to refined sugar. The fact that the price impact does not appear to have been transmitted to the raw stage of cane production suggests that—over the period of analysis— any benefits of the policy were most captured by cane refiners. The world market did not experience a divergence in the relationship between raw (cane) sugar prices and the price for refined sugar (which may be filled with either cane or beet sugar) in July 2016. As shown in the final two columns of table 4, the correlation between world raw and refined sugar prices was 0.99 before July 2016 and 0.98 afterward. The locus of the shock is the U.S. refined sugar market.

Price Impact

We now turn to the question of impact—what would U.S. refined sugar prices have been in the absence of GE labeling legislation? We treat the introduction of Vermont's GE labeling law as a quasi-natural experiment making use of two findings from the previous section to identify impact: First, U.S. sugar prices were highly correlated with world sugar prices prior to the law taking effect (rows 3 and 4 of table 4). Second, world prices were unaffected by the Vermont law (columns 7 and 8 of table 4). Taken together these factors suggest that world sugar prices constitute an almost-ideal control against which to assess the effects of the Vermont law.

One method by which to identify the treatment effects of a mandatory labeling law would be an experimental design. Kiesel and Villas-Boas (2013), for example, use a difference-in-difference (DD) model to identify the effects of mandatory nutrition labeling on consumer behavior. However, such an approach requires strict assumptions. One of these assumptions, known as the parallel trends assumption, requires that—in the absence of treatment—the average outcomes for the treated and control groups would have followed parallel trends over time (Abadie, 2005). The time-series properties of our data and the restrictive U.S. policy environment suggest that our setting fails to meet this assumption.[9]

Rather than a pure experimental approach, we construct a standard regime-switching model to compare the historically observed relationship between U.S. and world refined sugar prices prior to the introduction of the Vermont GE Labeling Law with the observed relationship on and after July 2016. In contrast to the DD design, the regime-switching model only requires that U.S. and world prices were correlated prior to July 2016 and that world prices were unaffected by U.S. labeling requirements. We assess the impact of GE food labeling legislation by comparing the price series for U.S. refined cane and beet sugar implied by the pre- and post-legislation coefficient estimates. We estimate the following regime-switching model:

$$P_t = \alpha + \delta\lambda_t + (1 - \lambda_t)\beta w_t + \gamma\lambda_t w_t + \epsilon_t \tag{2}$$

from Jan-2011 to Dec-2017, where P is, alternatively, the U.S. refined cane sugar price and the U.S. refined beet sugar price. Subscript t denotes time. Variable w represents the ICE No. 5 white sugar price (i.e., the world refined sugar price). All prices are monthly and are specified in natural logarithmic form. Variable λ is an indicator variable equal to unity in periods on and after July 2016, and equal to zero otherwise. Parameters $\alpha, \delta, \beta, \gamma, \epsilon$ are estimated. Alternative models and specifications are considered in Section 5.

Results from the regime-switching regression model for beet and cane prices, respectively, are shown in columns (1) and (2) of table 5. Comparing results across columns, we see that the coefficient on the pre-labeling-law world price is identical for U.S. beet and cane prices (0.84) and statistically significant at 99% confidence. This result is as expected: prior to the introduction of the law, U.S. cane and beet prices tracked closely with each other and with world prices. The results in table 5 lend credence to our decision not to use a DD estimation approach. Even prior to July 2016, U.S. and world prices did not follow a parallel trend. Wald tests reject the restriction that $\beta = 1$ for both the cane and beet equations.

[Table 5 about here.]

In both equations, the Vermont law appears to have had two effects on U.S.-world price relationships. First, it drove a wedge between U.S. and world prices (shown by variable "GE Law"), and, second, it reduced the U.S.-world price-cointegrating relationship (shown by variable "Post-Law*World Ref. Price"). Each result is independently significant at the 99% level.

These effects are also jointly statistically significant. Table 6 reports the results of several post-estimation Wald tests. For both the cane series and the beet series, we reject the joint hypothesis that there was no price wedge and that the U.S.-world cointegrating relationship was unchanged following the introduction of the law (i.e., $\delta = 0, \gamma = \beta$). Similarly, for each equation, we reject with 99% confidence the hypothesis that the U.S.-world cointegrating relationship was the same prior to and following the introduction of the Vermont Law (i.e., $\delta = \beta$).

[Table 6 about here.]

These findings are entirely consistent with the theoretical effects of mandatory GE labeling. First, the law induces a price premium (or discount) for non-GE (GE) products relative to what the price would have been in the absence of the legislation. Second, GE and non-GE products are no longer interchangeable in regions that are *de facto* subjects to labeling requirements. Thus, such laws reduce integration with external markets that continue to treat the GE and non-GE products as homogenous.

The total impact of the Vermont labeling law on U.S. refined sugar prices is the aggregate effect from the two forces discussed above. We estimate this impact for the 12-month period immediately following the structural break using the pre- and post-structural-break coefficient estimates from table 5. The counterfactual estimate (CF) for what U.S. refined sugar prices would have been had the Vermont Law not taken effect is calculated as $CF_t = \hat{\alpha} + \hat{\beta} * w_t$. Post-regime beet and cane prices are calculated as $\hat{P}_t = \hat{\alpha} + \hat{\delta} + \hat{\gamma} * w_t$.[10]

[Figure 4 about here.]

Constructed CF and Post-law-regime prices series are shown in logs in figure 4 and summarized in levels in table 7. Our estimation suggests that, in the absence of GE labeling legislation, the average U.S. refined sugar price would have been approximately 35.38¢ per lb. Over the same period, we derive an "actual" post-regime average price of 35.03¢ per lb. for cane sugar and 30.54¢ per lb. for beet sugar. A comparison of counterfactual and post-regime prices suggests that the legislation reduced beet prices by approximately 12.8% over the period and raised cane prices by 1.0%.

[Table 7 about here.]

Implications for Producer Welfare

We now turn to a discussion of the implications for producer welfare. To evaluate the revenue impacts of mandatory labeling initiatives on U.S. cane refiners and beet processors (shown in Figure 2 as $(P_{Cane} - P_f)Q_{Cane}$ and $(P_f - P_{Beet})Q_{Beet}$, respectively), we calculate gross receipts as the product of observed domestic deliveries and actual versus counterfactual prices.[11]

Note that this welfare measure may misstate welfare impacts if sugar processors responded to changes in sugar prices by adjusting marketings. For example, one could imagine that, in light of falling domestic beet prices, U.S. beet processors may have responded by shifting away from the domestic market towards markets abroad, increased storage volumes, or deliveries for non-human consumption (e.g., ethanol refineries). Aspects of the U.S. sugar program makes such adjustments extremely unlikely. The USDA administers marketing allotments (i.e., production quotas) to U.S. processors and other import restrictions for international suppliers. These supply constraints drive U.S. prices above world prices, and—even in light of falling prices—the domestic market is much more attractive than the export market. Moreover, marketing allotments reduce the incentive to store excess sugar because sugar stored today must compete with future production to meet quota restrictions.

[Figure 5 about here.]

Figure 5 compares monthly domestic deliveries from July 2016–June 2017 (the 12-month period after the structural break) with the domestic deliveries for the same months in the previous year. As one would expect given the supply constraints under the U.S. sugar program, there appears to be no appreciable difference in domestic cane deliveries in the 2016/17 period relative to the 2015/16 period (in Panel (b) of figure 5). On the other hand, beet deliveries in Panel (a) of figure 5 appear to have expanded in the 2016/17 period relative to 2015/16. The increase in domestic deliveries is due—at least in part—to favorable weather conditions and higher-than-expected yields (ERS, 2017). However, if (counter to expectations) some portion of the expansion in beet deliveries is the result of the breakdown in the co-integrating price relationship, implications are twofold.

First, the use of observed domestic deliveries to calculate gross receipts represents a *lower bound* for the estimated costs of GE labeling laws on U.S. beet processors. Second, and perhaps more importantly, the extent to which the cane-to-beet price wedge is permanent is an open question. If U.S. beet processors, faced with falling beet prices, chose to increase deliveries as opposed to increasing temporary storage, it may imply that beet processors regard the price wedge as permanent.

Post-Vermont regime and counterfactual monthly gross receipts for U.S. cane and beet processors are reported in table 8. Over the 12-month period after the Vermont GE labeling law took effect, mandatory labeling requirements have cost U.S. beet processors approximately $435 million. Yet the premium created for non-GE food ingredients has not resulted in a symmetric windfall. The U.S. cane sector gained only about $40 million as a result of the law. Note also the finding in Section 3.1 that the raw-to-refined price relationship broke down after July 2016. This suggests that the $40 million likely was received by cane refiners, and was not passed on to growers in the form of higher cane prices.

[Table 8 about here.]

The substantial imbalance between the losses to beet processors and the gains to cane refiners is only partically connected to the deadweight loss of GE labeling requirements. Losses to beet processors are in part offset by a gain to food manufacturers purchasing beet sugar. Likewise, the gain to cane refiners is offset in part by a loss to food manufacturers purchasing cane sugar. Lower costs to GE products may also be passed through to consumers in the form of lower food prices. The magnitude of these offsets—and in turn the deadweight loss—is dependent on the elasticities of demand in each market.

Robustness and Sensitivity

In this section, we use alternative specifications to examine the robustness of our model. We consider the inclusion of alternative and additional controls, the possible existence of confounding factors, and the implications of our time-series data. The percentage impact of Vermont labeling requirements on U.S. refined sugar prices implied by these alternative specifications ranges from 1% to 13% for cane and -10% to -16% for beet.

Columns (1) and (2) of table 9 present the results from re-estimating the regime-switching model shown in equation 2 using the world raw price as the control variable rather than the world refined price. Consistent with the findings in table 5, the Vermont law drives a wedge between U.S. and world prices and reduces the level of integration between the two markets. These results imply a price impact that is nearly identical to that discussed above for both cane and beet prices. This is not surprising because world raw and refined sugar prices are almost perfectly correlated over the sample period (table 4).

[Table 9 about here.]

Next, we consider confounding factors. Beginning in January 2011, Mexican sugar exports to the U.S. increased substantially. This surge in imports gave rise to antidumping and countervailing duty (ADCVD) proceedings, which, in December 2015, culminated in volumetric and price restrictions on Mexican sugar exports to the United States (USITC, 2015). Carter, Saitone and Schaefer (2017) find that these restrictions impacted the U.S.-world price relationship. We control for this by including an indicator variable in the regime-switching model equal to unity for all time periods after December 2015 (and zero otherwise). The world price is again the world refined price. Estimation results for this specification are reported in Columns (3) and (4) of table 9. Coefficient estimates imply the Vermont law reduced beet prices by 16% and increased cane prices by 13%.

Another potential estimation issue relates to the time-series properties of our data. Spurious correlation caused by non-stationarity in our data could lead to incorrect inference.

The risk of spurious correlation is low in this setting because of the commodity nature of sugar—market prices move together. However, for the sake of robustness, we correct for non-stationarity via first-difference estimation.

[Table 10 about here.]

Results from re-estimating equation 2 in first differences are reported in Columns (1) and (2) of table 10, respectively, for beet and cane prices. First-differencing substantially reduces the precision of our estimates, but findings are unchanged in substance. Turning first to Column (1), the GE law drives a 2% (positive) wedge between U.S. beet and world refined prices. Coefficients on first-differenced world prices are insignificant. The point estimate falls from 0.015 to 0.003. Combining the two effects implies a 10% reduction in U.S. refined beet prices as a result of the Vermont Law. Cane results in Column (2) show a 1.7% increase in Cane prices as a result of the Labeling Law. Coefficients on world refined prices are significant at 99% both before and after the imposition of the law, but the post-law coefficient is not significantly different from the pre-law coefficient. In Columns (3) and (4), we add the indicator variable that controls for the imposition of the U.S.-Mexico ADCVD suspension agreements. Results are similar to those in Columns (1) and (2) and imply a 9.8% reduction in beet prices and a small ($\approx$ 1%) increase in cane prices as a result of the law.

Conclusion

In the United States, a push for mandatory labeling of GE foods began in Oregon, California, and Washington and rippled through at least one-half of all U.S. states. In many ways, Vermont Act 120, which passed in May 2014 and took effect in July 2016, was the culmination of those efforts. The law required that (with a few exemptions) foods containing GE ingredients sold for home consumption be labeled. The law also established harsh penalties for food manufacturers found to be in violation of labeling requirements. Congress responded soon after the Vermont law took effect with the successful promulgation of the National Bioengineered Food Disclosure Standard (NBFDS). The NBFDS nullifies all state-level attempts to establish mandatory labeling rules and, instead, imposes disclosure requirements at the federal level. Many aspects of the NBFDS are currently subject to public comment and remain to be finalized.

In the period surrounding the implementation of Vermont Act 120, commodity markets responded. In this research, we investigate the response in the U.S. sugar market. In mid-2016, refined cane sugar began selling at a substantial premium over refined beet sugar. Our analysis supports the explanation that the divergence in U.S. prices for refined cane and beet sugar was the result of Vermont's mandatory GE labeling. The divergence occurred on or around July 2016—the month the Vermont Act took effect.

Counterfactual price estimates generated by a regression model suggest that GE food labeling initiatives generated a small premium for cane sugar and a price discount for beet sugar of approximately 13% relative to what prices would have been in the absence of such legislation. An open question is whether the new cane-to-beet price wedge is permanent or, alternatively, whether prices will converge again once the U.S. Food and Drug Administration (FDA) has offered final guidance on NBFDS compliance. Increased domestic deliveries by U.S. beet processors in the face of falling beet prices suggests that growers believe the price wedge may be permanent. Implications extend beyond the U.S. sugar industry to other ingredients containing GE.

We stress that our estimates are only a *partial* measure of the welfare effects of the Vermont law. Our results should also be regarded as short-run estimates of the producer welfare impacts. We do not consider downstream or long-run implications of the legislation. In the future, producers may lobby for changes to quota allotments or other aspects of U.S. sugar policy to mitigate the impacts of labeling policies. New technologies, such as the GE sugarcane varieties currently being testing in Brazil (Mano, 2017), may also alter future returns to GE versus non-GE foods in the U.S. and abroad.

Finally, to understand the full effects of the legislation one would need to formally incorporate the consumer benefits (or costs) of the policy. However, we believe the consumer-level effects are likely to be small—at least in the short run–in the current context. We cite two primary reasons for this belief: First, because sugar prices represent a small share of the final food dollar for processed foods, a change in the relative prices of GE and non-GE ingredients, is unlikely to have a substantial effect on food prices. Second, the results documented here are unlikely to result in substantial information to the consumer. At the retail level, the regime change is not one from the absence of labels to the presence of labels. Prior to the implementation of the Vermont law, products featuring GE-free and organic labels were readily available.

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Notes

[1] GE technology is defined here as in Van Eenennaam et al. (2014):

> "Genetic engineering (GE) can be defined as the manipulation of an organism's genes by introducing, eliminating, or rearranging specific genes using the methods of modern molecular biology, particularly those techniques referred to as recombinant deoxyribonucleic acid (rDNA) techniques."

[2] Exempted from labeling requirements were alcohol, food served in restaurants, ready-to-eat foods, foods derived from animals raised with GE feed, and foods manufactured with GE processing aids, such as enzymes (Bovay and Alston, 2018).

[3] Food manufacturers can use a text statement, a symbol, or the words "scan here for more food information" accompanied by a QR code that can be read by a smartphone. Small manufacturers may print a website URL or phone number that customers can call for more information (FR, 2018).

[4] For example, in 1986, California passed Proposition 65—a referendum requiring businesses to provide a warning about chemicals contained in their products. Similar to Vermont's labeling law, Proposition 65 contains a provision allowing private citizens to file lawsuits against businesses alleging violations of warning requirements. Between 2000 and 2016, businesses paid over $280 million to settle Proposition 65 cases initiated by private citizens (OAG, 2016).

[5] Monthly prices obtained from table 4 of the ERS *Sugar and Sweeteners Yearbook*. "Nearby" refers to the contract with the closest settlement date. The ICE No. 16 contract specifies that 112,000 pounds of raw cane sugar be physically delivered to one of five U.S. refinery ports: New York, Baltimore, Galveston, New Orleans, or Savannah. Delivery months are January, March, May, July, September, and November.

[6] Monthly prices obtained from table 3b of the ERS *Sugar and Sweeteners Yearbook*. The No. 11 contract specifies delivery of 112,000 pounds of raw cane sugar in delivery months March, May, July, and October. Delivery on the No. 11 contract occurs at a port in the country of origin free-on-board on the receiver's vessel. Delivery can originate in about 30 different countries, including Australia, Brazil, Costa Rica, and South Africa.

[7] Monthly prices obtained from table 5 and 5a of the ERS *Sugar and Sweeteners Yearbook*. Prices are the simple average of the lower end of the range of quotations from *Milling & Baking News* for days in each month.

[8] Monthly prices obtained from table 2 of the ERS *Sugar and Sweeteners Yearbook*.

[9] We note that the synthetic control method does not require the parallel trend assumption. Instead, it uses a comparator constructed as a weighted average of all available control units (Abadie, Diamond and

Hainmueller, 2010). The weights are chosen to ensure that, prior to the intervention, levels of covariates and outcomes are similar over time to those of the treated unit. This method is unnecessary here because we rely on a single—but well-chosen—control: the world sugar price.

[10] Note that we have actual observations for "post-regime" beet and cane prices. We use our predicted estimates instead of actual prices to isolate the impact of Vermont law. A variety of demand and supply factors not related to the Vermont law can impact U.S. and world prices in any given month. By focusing on the average relationship over time, we eliminate (or at least substantially reduce) the biases created by these extraneous factors.

[11] Data on domestic cane and beet deliveries by U.S. processors are obtained from table 19 of the ERS *Sugar and Sweeteners Yearbook*.

Figure 1: U.S. refined sugarcane and sugarbeet prices

Note: U.S. refined beet and cane prices are obtained from table 5 and 5a of the ERS *Sugar & Sweeteners Report*. Table 5 is available online at https://www.ers.usda.gov/data-products/sugar-and-sweeteners-yearbook-tables.aspx; table 5a is not online, but is available from ERS upon request. Underlying data are the simple average of the lower end of the range of quotations from *Milling & Baking News* for days in each month.

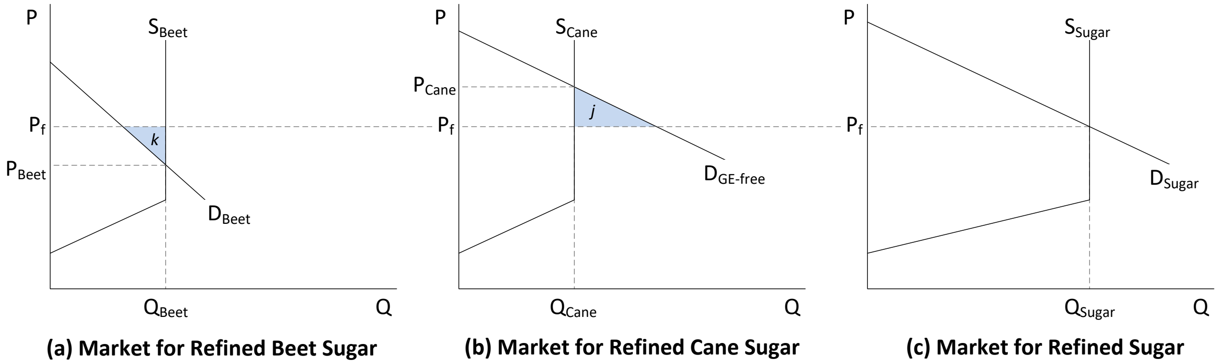

Figure 2: Impact of GE food labeling laws on U.S. sugar market

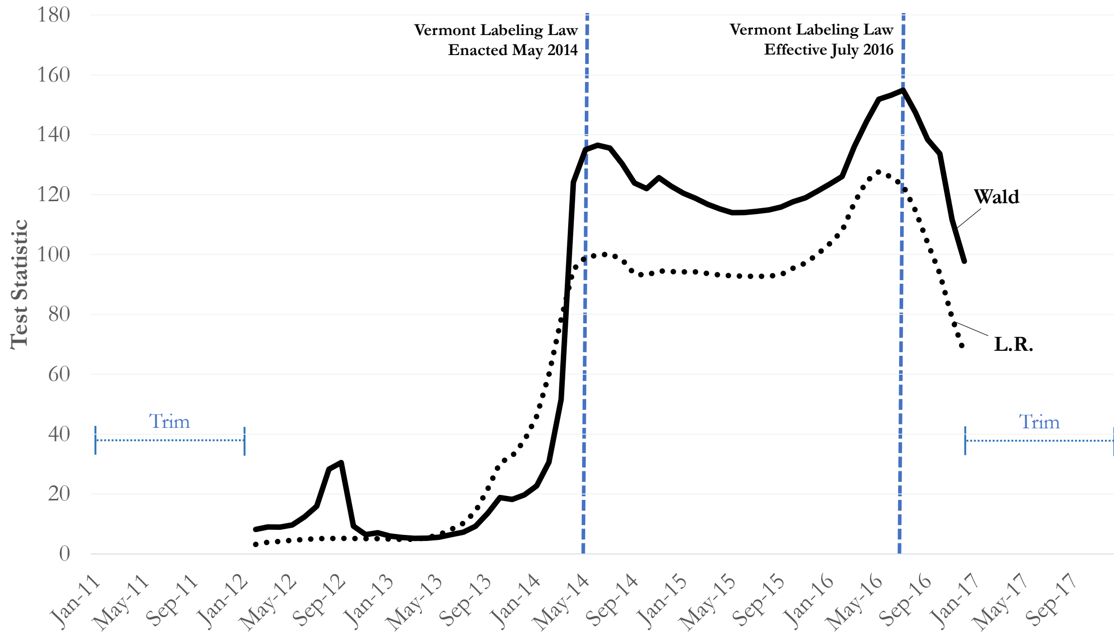

Figure 3: Tests for break in U.S. beet-cane price relationship

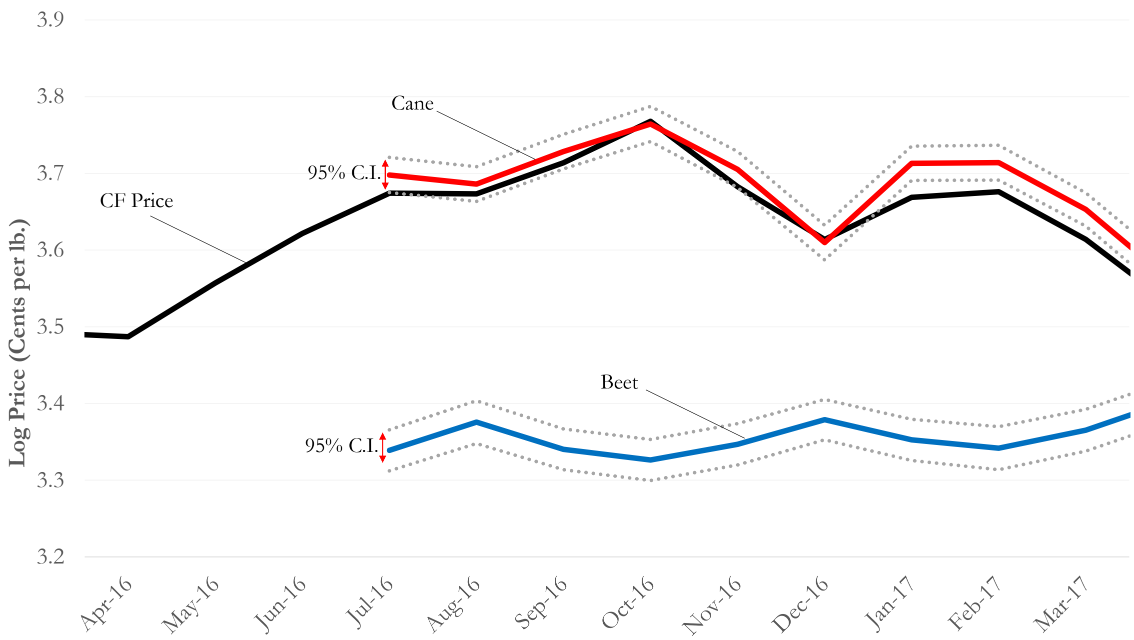

Figure 4: Counterfactual price forecast

Note: Confidence intervals for GE-law-regime price series are constructed using the Bayesian Bootstrap method with 1,000 draws from the posterior distribution for each parameter estimate from Columns (1) and (2) of table 5.

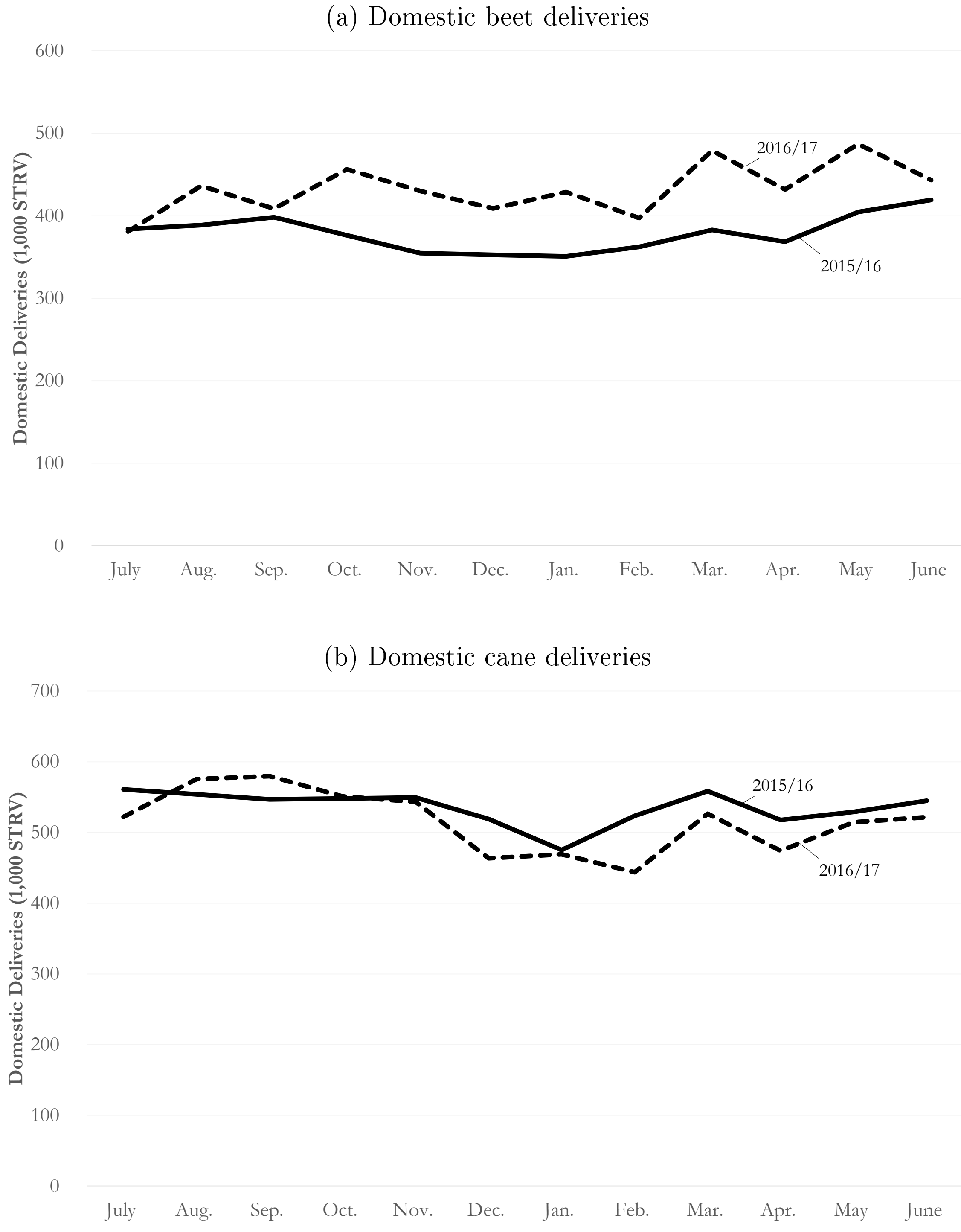

Figure 5: Domestic cane and beet deliveries

Note: Domestic cane and beet deliveries obtained from ERS *Sugar and Sweeteners Yearbook* table 19.

Table 1: Augmented Dickey-Fuller Tests for Stationarity

Log Price Series	Obs.	Test-Statistic	P-Value	Conclusion
U.S. Refined (Cane)	83	-1.775	0.39	*Fail to reject non-stationarity*
U.S. Refined (Beet)	83	-1.883	0.34	*Fail to reject non-stationarity*
World Refined	83	-1.90	0.33	*Fail to reject non-stationarity*
World Raw (Cane)	83	-2.31	0.29	*Fail to reject non-stationarity*

Note: All prices are monthly averages and are specified in natural logarithmic form.

Table 2: VECM Cointegration Results (Jan 2011–Dec 2015)

Series	Obs.	χ^2	P-value	Conclusion
Cane; Beet	58	2688.647	0.00	Cointegrated
Cane; World	58	6.872	0.01	Cointegrated
Beet; World	58	6.769	0.01	Cointegrated

Note: All prices are monthly averages and are specified in natural logarithmic form.

Table 3: Structural Break Test

Specification	Estimated Break	Sup. Wald	P-Value	Obs.
Wald Levels	Jul-2016	142.97	0.0000	84
Wald Logs	Jul-2016	154.91	0.0000	84
L.R. Levels	May-2016	119.34	0.0000	84
L.R. Logs	May-2016	127.66	0.0000	84

Note: Trimmed sample runs from Feb. 2012–Dec. 2016 (15% trim)

Table 4: Price Correlation Matrix Pre- and Post-July 2016

	U.S. Ref. Cane		U.S. Ref. Beet		US Raw Cane		World Raw Cane	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
U.S. Ref. Beet	1.00	0.57						
U.S. Raw Cane	0.96	-0.12	0.95	-0.74				
World Raw Cane	0.75	-0.65	0.72	-0.83	0.72	0.71		
World Refined	0.74	-0.61	0.71	-0.91	0.71	0.76	0.99	0.98

Note: All prices in natural logarithmic form.

Table 5: U.S.-World Sugar Price Relationships, Pre- and Post-Vermont GE Labeling Law

VARIABLES	(1) Log U.S. Ref. Beet Price	(2) Log U.S. Ref. Cane Price
Constant (α)	0.96***	1.01***
	(0.28)	(0.26)
GE Law (δ)	3.63***	3.00***
	(0.31)	(0.28)
Pre-Law*World Ref. Price (β)	0.84***	0.84***
	(0.09)	(0.08)
Post-Law*World Ref. Price (γ)	-0.39***	-0.15***
	(0.04)	(0.04)
Observations	84	84
R-squared	0.56	0.55

Note: Robust standard errors in parentheses; ***p<0.01, ** p<0.05, * p<0.1

Table 6: Post-Estimation Wald Tests

	U.S. Ref. Beet Price		U.S. Ref. Cane Price	
Null Hypothesis	Wald Statistic	P-Value	Wald Statistic	P-Value
δ=0	134.43	0.000	113.65	0.000
γ=β	137.02	0.000	68.23	0.000
δ=0, γ=β	155.33	0.000	121.35	0.000

Table 7: Impact of GE food Labeling Laws on U.S. Sugar Prices

Refined Price Series	Average Price: Jul-16–Dec-17 *(¢ per lb.)*	Impact of Labeling Laws *(% Change)*
U.S. Cane	35.38	1.0
	(3.49)	
U.S. Beet	30.54	-21.7
	(1.26)	
Counterfactual	35.03	
	(3.49)	

Note: Standard deviation in parentheses.

Table 8: U.S. Sugar Industry Gross Receipts (GE-Law vs. No Law Scenario)

		Gross Receipts, July '16–June '17		
	Deliveries	GE Law	No Law	**Difference**
	(1,000 STRV)	*(Million Dollars)*		
Beet	5,188	$2,961.56	$3,396.97	**-$435.40**
Cane	6,187	$4,091.25	$4,050.77	**$40.48**

Note: Gross receipts are obtained by multiplying GE-Law & No-Law prices by domestic deliveries (1.07 raw-to-refined conversion rate).

Table 9: Robustness: Alternative Controls and Confounding Factors

VARIABLES	(1) Log U.S. Ref. Beet Price	(2) Log U.S. Ref. Cane Price	(3) Log U.S. Ref. Beet Price	(4) Log U.S. Ref. Cane Price
GE Law	2.890***	2.453***	4.286***	3.691***
	(0.288)	(0.247)	(0.410)	(0.362)
Pre-Law*World Price	0.733***	0.723***	1.101***	1.107***
	(0.082)	(0.076)	(0.137)	(0.122)
Post-Law*World Price	-0.335***	-0.148***	-0.388***	-0.148***
	(0.052)	(0.034)	(0.044)	(0.037)
ADCVD			0.196**	0.207***
			(0.078)	(0.068)
Constant	1.473***	1.526***	0.113	0.114
	(0.243)	(0.228)	(0.449)	(0.399)
Observations	84	84	84	84
R-squared	0.572	0.565	0.613	0.624

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 10: Robustness: First-Difference Estimation

VARIABLES	(1) Log U.S. Beet Price	(2) Log U.S. Cane Price	(3) Log U.S. Beet Price	(4) Log U.S. Cane Price
GE Law	0.020***	0.017***	0.022***	0.017***
	(0.006)	(0.006)	(0.005)	(0.008)
Pre-Law*World Price	0.015	0.146***	0.019	0.147**
	(0.047)	(0.049)	(0.005)	(0.058)
Post-Law*World Price	0.003	0.141***	0.007	0.143**
	(0.47)	(0.049)	(0.052)	(0.056)
ADCVD			-0.002	-0.001
			(0.008)	(0.008)
Constant	-0.009*	-0.007	-0.009	-0.007
	(0.005)	(0.005)	(0.007)	(0.007)
Observations	83	83	83	83
R-squared	0.06	0.08	0.06	0.08

Note: Robust standard errors in parentheses; ***p<0.01, ** p<0.05, * p<0.1