Relaxing CAFE: Foreign Direct Investment, NAFTA, and Domestic Product Standards*

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Abstract

This paper studies the effects of domestic product standards on the offshoring behavior of automotive firms. In particular, we examine an important non-tariff barrier to trade within US fuel economy policy - the Corporate Average Fuel Economy (CAFE) “Two-Fleet Rule”. By leveraging the removal of the two-fleet rule upon implementation of NAFTA, and exploiting a policy discontinuity based on vehicle characteristics, we present evidence that the costs of offshoring were reduced to a larger degree for varieties that were subject to US fuel economy rules. Specifically, we estimate that prices fell between 5-10% for varieties subject to the CAFE Two-Fleet rule relative to varieties that were exempt from the rule. These effects are persistent, not present for manufacturers that did not offshore prior to NAFTA, and are robust to variety-specific trends. These effects also reconcile the post-NAFTA differences in implied compliance costs between cars and trucks for our treatment manufacturer (Chrysler). Overall, the results highlight the potential costs of regional enforcement of otherwise location-neutral product standards, which may act as a barrier to natural patterns of efficient specialization.

Key Words: Intra-industry trade, offshoring, trade liberalization, corporate average fuel economy, product standards, national treatment

JEL Classifications: F12, F14, F23

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1 Introduction

The last few decades have seen a dramatic (and often contentious) push to include non-trade policy objectives under the umbrella of the World Trade Organization (WTO). These policies, which include intellectual property, environmental, and labor standards, in some cases are already permissible so long as they are imposed on a non-discriminatory basis across exporters, and that domestic producers are subject to the same standard.¹ In this paper we demonstrate that such apparently location-neutral policies can nevertheless distort the location of production and limit gains to trade. We do so by examining Corporate Average Fuel Economy (CAFE) standards in the US, which requires firms to meet a fleet-wide average fuel efficiency standard each year, but treats the domestic and foreign production of multinational automakers as if being from two different firms. This forces firms to allocate their portfolio of production in ways that are not strictly cost minimizing. We identify this production distortion utilizing a natural experiment owing to changes in the CAFE program due to NAFTA.

How can location-neutral policies cause economic distortions? Although designed to reflect a sense of “fairness” in imposing policies across different regions, unless the standard itself is orthogonal to natural sources of comparative and competitive advantage, one can expect an efficiency reducing distortion to arise under otherwise location-neutral policies. This is particularly important for multi-national firms with capacity in both developing and developed locations, who are forced to balance production in ways which are not optimally matched to traditional factors such as wage differences. The light-duty truck industry is a classic example of this, and the focus of the paper. Unconstrained production across the US-Mexico border reflects the role of comparative advantage within automotive multinationals, with significantly more labor intensive plants in Mexico producing specific varieties distinct from those produced domestically.² Hence, when policies that focus on vehicle attributes, such as CAFE, are imposed separately (but equally) across locations, production must be adjusted to earn regulatory compliance. Using a database built from vehicle registrations, we document that the location-specific constraints of the CAFE program imposed a production distortion, with this distortion raising prices 5-10% for regulated varieties relative to unregulated varieties.

¹Most WTO disputes in this area have involved extraction of resources (US-Shrimp) or more direct issues of human health (EU-Asbestos). However, these exemptions from standard trade practice could in theory apply to a wide variety of manufactured goods. For a comprehensive discussion of Article XX, see the WTO Committee on Trade and Environment, secretariat article 203, at <http://docsonline.wto.org/imrd/directdoc.asp?DDFDocuments/t/wt/cte/w203.doc>.

²Specifically, our earlier work in McCalman and Spearot (2013) finds that varieties produced in Mexico were lower scale, less-complex, older in design vintage, and in some cases had lower quality as embodied in carrying-capacity.

The purpose of the CAFE program is to improve the fuel efficiency of vehicles sold in the US and it does this by requiring that vehicles sold by a manufacturer meet a minimum sales-weighted average fuel economy in each year. The CAFE standard naturally varies by broad class of vehicle, with different standards applied to cars and light-duty trucks. As noted above a second restriction is that the CAFE standard must also be met separately for domestic and imported production within a manufacturer – the “Two-Fleet Rule”. This distinction is especially relevant for US automakers who have production facilities in the US, but have also offshored to Mexico. Prior to NAFTA, US firms had to meet the standard separately for their US and Mexican production. However, after NAFTA vehicles produced in Mexico were treated as domestic production.³ If US automakers were indeed constrained by the two fleet rule then its removal should alter the portfolio of vehicles produced in Mexico after NAFTA. For the market segment we consider, light duty trucks, Dodge was the only producer that offshored to Mexico both before and after NAFTA and is consequently our natural point of focus.

To identify the effects of this regulatory change, we exploit the constraints imposed by the two-fleet rule prior to NAFTA, and two loopholes by which firms could avoid CAFE fines within the light-truck segment. Pre-NAFTA, the two-fleet rule was a particularly important constraint for trucks since there are many trucks on either side of the CAFE standard, and thus balancing of production is required for regulatory compliance within each location. However, balancing production across borders will likely mitigate the gains from trade since the US and Mexico are very different production markets. For example, consider a US firm that makes three vehicles: a big truck (below CAFE standard), a small truck (above CAFE standard) and a CAFE-exempt truck (explained more below). Suppose that CAFE is binding (as it is for domestic firms), so the firm’s US production portfolio is just compliant. If they wanted to offshore, they would be unable to move just their small truck to Mexico because their import fleet would be compliant, but their domestic would not. Vice-versa if they tried to offshore their big truck. They could export a balanced portfolio of production, but that likely fails to take advantage of returns to scale in production since big and small trucks require different plants for production, and more importantly, the gains from producing a particular of type of truck in Mexico. Consequently, the regulatory constraint via the two-fleet rule appears to restrict offshoring opportunities.

³For all other trucks produced globally, the policy was eliminated in 1996. As stated by NHTSA, “Beginning in 1980, light trucks were administratively subjected to a similar two-fleet rule. However, given changes in market conditions (the “captive import” sector of the fleet had become insignificant), NHTSA eliminated the two-fleet rule for light trucks beginning with MY 1996.” See <http://www.nhtsa.gov/cars/rules/cafe/overview.htm>. The two-fleet rule remains in place for cars.

However, two loopholes exist to get around the two-fleet constraint, with these loopholes forming the basis for our empirical strategy. First, firms could simply offshore production to Mexico that is CAFE exempt. Ironically, light-duty trucks are exempt from fuel efficiency rules if they are sufficiently inefficient (large) - above 8,500 lbs gross vehicle weight (GVW). Returning to the example, offshoring their exempt truck is a viable option, since it does not affect compliance of production located in the US and is not itself subject to CAFE so the import fleet is in compliance. Further, the firm could exploit economies of scale in offshoring the exempt truck. The alternative loophole is to offshore final assembly of vehicles to Mexico, but to utilize sufficient US/Canadian inputs (eg. parts) to classify the final assembly in Mexico as US/Canadian production. To be included in the US/Canadian Fleet requires having more than 75% US/Canadian value-added. Hence, there is a general disincentive to use inputs from Mexico for varieties subject to CAFE standards. Additionally, more specific to offshoring, while firms could send inputs from the US to Mexico to achieve something closer to optimal specialization, this too would be a costly strategy in that transportation costs would be incurred for the inputs. Overall, manufacturers could employ two constrained-cost-minimizing options, *given the two-fleet rule*, (1) offshore exempt varieties and/or (2) engage in costly input trade. Note that whichever route they take, the existence of these apparently location neutral product standards has distorted production. When the two-fleet rule is removed, it relaxes a constraint on non-exempt varieties since costly input trade was no longer necessary to exploit comparative advantage. However, for varieties that are exempt to begin with, removing the policy has no direct effect. This distinction and its differential implications for the cost of exempt/non-exempt trucks is the basis for our empirical approach.

To test this hypothesis, we employ an exceptionally detailed database of trade flows based on vehicle registrations. In particular, using two industry sources, we construct a dataset that tracks the location of production for every permutation of vehicle characteristics. For example, we have information on the share of production in Mexico for the 1996 Dodge Ram 2500 8 cylinder 4X4 full size truck separately from the same version of truck but with an extended cab. As different product attributes may lead to *different* applications of fuel economy rules, this information is crucial.

Examining the offshoring behavior of the Dodge Ram pick-ups to Mexico prior to NAFTA, we find that 54% of these trucks were exempt from CAFE standards based on the 8,500 lb GVW threshold, with this percentage approaching 90% in years with relatively large pre-NAFTA production. In contrast, prior to NAFTA, only 25% of the Dodge Rams sold in the US were above the exemption threshold.

After NAFTA, production in Mexico and the US were indistinguishable from one another, where 27% of Rams were exempt from CAFE. Clearly, production around the GVW threshold was harmonized across locations after NAFTA, which is consistent with a pre-NAFTA constraint being removed that was a function of vehicle weight. Furthermore, while we do not have full information on the sourcing and value of inputs, we are able to identify which Dodge Ram engines were only built in Mexico pre and post NAFTA.⁴ Indeed, we find that the use of engines from Mexico increased to a larger degree after NAFTA for varieties subject to CAFE standards, which suggests that there was a pre-NAFTA disincentive to incorporate value-added from Mexico for CAFE-relevant varieties.

At a more formal level, we evaluate changes in pricing behavior around the 8,500 lb GVW threshold resulting from NAFTA. For our preferred regressions, we adopt a within-variety specification to condition on the basic characteristics of each Dodge Ram variety, and then evaluate the differential response of NAFTA for those varieties that are subject to CAFE standards. Overall, we find that NAFTA lowered prices for CAFE relevant varieties roughly 5-10% relative to similar CAFE exempt varieties. In a falsification test, we show that this effect is not present for similar trucks made by other manufacturers that were never offshored to Mexico while the two-fleet rule was in place, but otherwise shared similar pricing trends before the policy change. Further, these effects were persistent after the rule change took place, and are robust when allowing for variety-specific trends.

Finally, we use our estimates and dataset to provide a back-of the envelope calculation of how the removal of the two-fleet rule corresponds to changes to the cost of CAFE compliance. Specifically, using our baseline estimates, we calculate that the implied cost to Chrysler of increasing the aggregate CAFE standard by one mile per gallon decreased by \$308 per vehicle as a result of NAFTA. The bootstrap confidence band of this estimate is consistent with the difference in implied compliance costs between Chrysler cars and trucks in Jacobsen (2013), which uses the 1997-2001 period for analysis. Interestingly, the period was notable in that the two-fleet rule was still present globally for cars, and Chrysler merged with Mercedes-Benz in 1998. Hence, Chrysler was faced with significant global production of cars to balance in compliance with two-fleet, and our estimates of costs of the two-fleet rule rationalizes Jacobsen's difference in estimates for Chrysler cars and trucks.

This paper adds to the growing literature examining trade and investment decisions as a function

⁴Representing up to 20% of value added, the sourcing of the engine is a critical factor determining whether the US share of value added is sufficiently high for a vehicle to be deemed as part of the domestic fleet.

of product and firm characteristics. Our model is most closely associated with Davis and Kahn (2010), which offers a unique analysis of used-vehicle trade with Mexico using a regression discontinuity design over vehicle age. In our case, the motivations for trade are affected by a policy discontinuity which is a function of gross vehicle weight, though we cannot use a regression-discontinuity design given the “gaming” of the threshold by firms. In our companion paper, McCalman and Spearot (2013), we document the precise characteristics of offshored vehicles post-NAFTA vis-a-vis vehicles inshored to new or retooled domestic capacity. Specifically, we find that automakers offshored varieties within models that were less-complex, of older design vintage, lower scale, and of lower input quality. In our current work, rather than focusing on the post-NAFTA composition of production across domestic and foreign plants, we evaluate the differential effect of NAFTA on vehicle pricing as function of CAFE status, and to what degree offshored production prior to NAFTA evaded the two-fleet rule.⁵

In terms of the CAFE program, Goldberg (1998) compares the CAFE program with alternative policy instruments using a nested-logit demand framework. While her analysis is conducted at a relatively aggregate level (aggregates all domestic firms and only considers 9 broad vehicle classes), her results suggest that the CAFE program potentially has an important impact on the location of production for domestic firms. Gramlich (2010) estimates the shadow value of CAFE using a Berry et al. (1995) estimator that is six times larger than the statutory fine. Concomitant work in Jacobsen (2013) finds a similarly large estimate using a different strategy. Anderson and Sallee (2011) evaluate alternative fuel loopholes within the CAFE program, and the shadow value of CAFE implied by these loopholes. In their case, the estimates for the cost of the CAFE program are substantially smaller than the existing literature. In terms of multiple fleets, our paper is also similar to Goulder et al. (2012), though in their case they examine independent California CAFE-type requirements nested within the national CAFE averages. Our paper is similar to Sallee and Slemrod (2012) in that we leverage a policy “notch” that distorts pricing and production incentives. Finally, our paper provides novel evidence for a wider class of policies (worldwide) that govern the average characteristic of a product or production process within a pre-specified group or geographic region.⁶

⁵Other papers on auto trade and investment include Feenstra (1988), Berry et al. (1995), Goldberg (1995), Goldberg and Verboven (2005), Blonigen and Soderbery (2010), and Sly and Soderbery (2014). In terms of the broad literature on offshoring, our work is motivated by Feenstra and Hanson (1997), who evaluate the effect of an increase in capital stock in the south on relative wages in the north and south, and Keller and Yeaple (2013), who develop an information based model of sourcing tasks. Other models that evaluate trade as a function of product characteristics include Byrne et al. (2011). For work on vehicle size and safety outcomes, see Anderson and Auffhammer (2013).

⁶For example, the Clean Air Act allows “a company to comply with performance standards through averag-

2 CAFE and the Two-Fleet Rule

Since 1975, Corporate Average Fuel Economy (CAFE) standards have been the centerpiece of US environmental policy toward passenger vehicles. Broadly, the CAFE program mandates that manufacturers meet an average fuel efficiency standard, weighted by sales, within car and truck vehicle fleets. The focus of our analysis will be on the relationship between fleet definitions and the international location of value-added for light-trucks.

In terms of the overall parameters of the program, all trucks with GVW less than 8,500 lbs are included in the CAFE average for a given fleet. Those trucks that exceed 8,500 lbs GVW are exempt from CAFE, and important for our purposes, any international provisions of CAFE. This threshold is crucial for our identification strategy (it is discussed at length below). In each year, firms calculate their sales weighted average miles-per-gallon for a given fleet, and total units sold within that fleet. If their sales-weighted average falls short of the CAFE standard for trucks (20.2-20.7 miles per gallon during our sample), a fine is incurred of \$55 per mile per gallon per vehicle. This fine can be reduced if the manufacturer has exceeded the standard for that fleet in the previous three years.

Over time, a trichotomy has developed regarding which firms meet the standard, which firms exceed the standard, and which firms violate the standard in almost every year. Asian producers tend to exceed the standard in every year due to their comparative advantage in small cars. Many European producers, especially luxury brands, view the fine as a cost of doing business and violate the standard on a frequent basis. Lastly, domestic producers view the standard as a binding policy, and meet the standard very closely in every year. Indeed, Jacobsen (2013) estimates that the revealed pricing behavior of US automotive firms is consistent with an implied CAFE cost that is in large part higher than the \$55 statutory fine.⁷

This behavior is confirmed for truck fleets across manufacturers in Figure 1. Specifically, we find that domestic manufacturers hover around the CAFE average for trucks throughout the 90's. In contrast, Asian manufacturers exceed the standard in almost every year. We will present further evidence of a

ing emissions among the vehicles it manufactures, or by averaging emissions among multiple emission points" (<http://www.epa.gov/air/caa/flexibility.html>). Along with the US, Japan, Canada, Australia, China, and South Korea regulate fuel economy standards using a "numeric standard averaged over fleets or based on vehicle weight-bins or sub-classes" (An et al. (2011)). Outside of the automobile sector, many policies that aim to reduce carbon emissions require average compliance within a pre-specified region (eg EU, California).

⁷As domestic producers have many existing public relations issues, willfully violating a US environmental policy is not something in the interest of the firms or their shareholders.

Figure 1: CAFE Truck Averages - Domestic and Foreign

Notes: The above figure presents the CAFE truck averages for US and selected foreign producers for the sample period. Data obtained from the National Highway and Traffic Safety Association

binding standard after discussing the data.

International Production, NAFTA, and CAFE

We now turn to how the international location of production is relevant for the CAFE program. The pre-NAFTA policy environment for trucks consisted of two major policies. First, likely the most restrictive, and unlike passenger cars which was subject to a minimal 2.5% duty, was the remnants of a 1963 trade dispute with the EU - the “chicken tax”. Specifically, in response to increased restrictions on the import of poultry to the EU, the US responded with a 25% MFN tariff on brandy, potato starch, dextrin, and light-duty trucks. While duties on the former three categories have since been liberalized, the 25% duty on pick-up trucks still remains in force.⁸ However, as a part of NAFTA, *all* light-duty truck imports from Mexico were reassessed duty free. Hence, the signing of NAFTA led to the removal of a very large duty on light-duty trucks, and subsequently, automotive producers increased production of all trucks in Mexico to a significant extent.

The second policy affecting light-duty trucks, and the focus of this paper, was the CAFE two-fleet

⁸This has been a particularly significant sticking point in the negotiations over the Korea-US Free Trade Agreement.

rule. Unlike the tariff on light-duty trucks, the two-fleet rule only affected varieties within the light-duty truck segment that were subject to CAFE guidelines. As mentioned above, the CAFE averages are broken down by fleets, where each firm may have a maximum of four fleets: domestic cars, international cars, domestic trucks, and international trucks. For purposes of CAFE, US and Canadian production has always been considered jointly “domestic”. Domestic and international fleets are defined by the value-added in production and not necessarily the location of final vehicle assembly (though they are obviously highly correlated). In particular, for CAFE calculations, a vehicle is considered domestic if it contains more than 75% domestic content. The role of NAFTA in adjusting the rules of the CAFE program was subtle, but nevertheless, important. Upon implementation of NAFTA, all value-added in Mexico was reclassified as domestic value-added. Hence, post-NAFTA, firms had more flexibility in meeting CAFE rules if they chose to offshore production to Mexico. In particular, they only had to balance one constraint based on fuel economy rather than two, and were unconstrained in using value-added from the US, Canada, or Mexico.

Pre-NAFTA, the two-fleet rule raised a number of issues in terms of offshoring trucks to Mexico. Simply put, firms had to balance two CAFE averages in each year, and were not allowed to balance CAFE averages across fleets. This was particularly important for trucks since there are essentially two different types of trucks, compact and full size, the former being more efficient than the CAFE average, and the latter being less efficient. Hence, production offshored to Mexico that exactly met the CAFE average would have to replicate the U.S./Canadian structure of production by offshoring *two* types of truck. However, this issue can be alleviated if there are ways to get around the CAFE constraint or the two-fleet rule by using program loopholes. We now turn to discussing these loopholes.

As has been a focus in the energy literature (eg. Anderson and Sallee (2011)), the CAFE program is rife with loopholes that allow firms to get around certain policy provisions. The two-fleet rule is no different. For one, firms could simply offshore production to Mexico that is CAFE exempt. Producing the largest trucks in Mexico would allow firms to exploit economies of scale in producing one type of large truck while also using as much local content as is optimal. However, if producing heavy trucks in Mexico is not optimal from a perspective of specialization, this may be a costly strategy in the presence of the regulatory barrier. Further, if optimal, firms could produce the largest trucks in the US, but use whatever Mexican value-added that is optimal. In both cases, firms are not constrained by the two-fleet rule when producing CAFE exempt trucks.

The alternative loophole within the two-fleet rule is to assemble vehicles in any location, but to utilize sufficient US/Canadian inputs (eg. parts) to classify the final assembly in Mexico as US/Canadian production. Hence, there is a general disincentive to use inputs from Mexico for varieties subject to CAFE standards. Further, more specific to offshoring, while firms could send inputs from the US to Mexico and achieve something closer to optimal specialization, this too would be a costly strategy in that transportation costs would be incurred for the inputs. Overall, manufacturers could avoid the two-fleet rule by offshoring exempt varieties and/or engaging in costly input trade. Crucially, when two-fleet was removed, it relaxed a constraint on non-exempt varieties since costly input trade was no longer necessary for offshore final assembly. However, for varieties that were exempt to begin with, removing the policy had no direct effect. This distinction is the basis for our empirical approach.

3 Data

The data for this project comes from two industry sources, which are merged into a large dataset of vehicle characteristics, plant of production, and sales information for the period 1990-2000. We now discuss each dataset, outline the merging procedure, and provide descriptive statistics for the light truck industry over the sample period.

3.1 Sales and Vehicle Characteristics

The source for production information is a custom dataset constructed by *R.L. Polk* (Polk), which is an automotive data firm based in Southfield, Michigan.⁹ Polk maintains a number of datasets for a range of countries that are based on vehicle registrations. We acquired a dataset of gross vehicle weight (GVW) class 1-3 light truck sales for the period 1990-2000. The dataset itself is constructed from the population of vehicle registrations in the US and Canada. We have acquired sales information for every observed permutation of vehicle characteristics and plant of production, both types of information available in the vehicle identification number (VIN).

A critical part of our analysis is choosing the appropriate level of refinement at which to define varieties. Previous analyses, including Feenstra (1988), Berry et al. (1995), Goldberg (1995), Blonigen and Soderbery (2010), and Sly and Soderbery (2014), define varieties by their model (eg. Dodge Ram),

⁹Since the writing of this paper, it has been acquired by IHS Global Insight.

and if applicable, country of origin. However, facilitated by our dataset, we can do so at a finer level of aggregation. Specifically, we define varieties as permutations of model (eg. Dodge Ram 1500), and “large” vehicle characteristics including # of cylinders, engine size (liters), wheels driven (2X4 or 4X4), engine type (diesel or gas), and cab size (regular, extended or crew). This level of detail is crucial for our research questions, as certain vehicle characteristics determine when trucks are subject to US fuel economy rules. We expand on this point below.

The primary focus of our analysis will be the Dodge Ram full-size pickup, and to a lesser degree, other full size trucks. As the former underwent a rather large transformation over the sample period, it requires additional discussion. In the early 1990’s, the Dodge Ram was broken down into the D-Series and W-Series, with the former being the designation for 2X4 wheel drive vehicles, and the latter being the designation for the 4X4 varieties. The trucks were further classified into 150, 250, and 350 versions, with the leading number (roughly) referring to GVW class of the vehicle.¹⁰ Complicating matters is that a new generation of Dodge Ram was introduced in model year 1994, which was approximately around the time that the two-fleet rule was eliminated for trade with Mexico. While we address this issue specifically in our empirical analysis, for now we focus on the new labeling of the models: Ram 1500, Ram 2500, and Ram 3500. Since there was no separate designation for 2X4 and 4X4 vehicles, we relabel the D-Series and W-Series 150, 250, and 350 as simply Ram 1500, Ram 2500, and Ram 3500, and integrate the 4X4 designation with the 4X4 indicator variables in the dataset.

3.2 Price and Fuel Economy Characteristics

Unfortunately, the Polk dataset does not report supplementary information outside of what is contained in the VIN, including suggested retail prices and information relevant for the CAFE program. This information is obtained from the *Wards Automotive* dataset of vehicle characteristics (Wards). The Wards data provides all information that is in the Polk dataset with the exception of sales and location of production, along with more refined data on characteristics, manufacturer suggested retail prices (MSRP), and fuel economy.¹¹ The Wards dataset is in most cases more refined than the Polk dataset, and as such, when there are multiple Wards matches for one Polk observation, we take averages of

¹⁰GVW class 1 includes vehicles of 6,000 lbs GVW or less, GVW class 2 includes vehicles between 6,000-10,000 lbs GVW, and GVW 3 includes vehicles of GVW 10,000-14,000 lbs.

¹¹Ideally we would have access to transaction prices, but these are not reported in our dataset. However for the purposes of production planning, we believe that MSRP in conjunction with vehicle characteristics provides the necessary information.

Table 1: Full-size Truck Platforms: 1990-2000

Full-size Truck Platform	Avg. Price	Total Units	Share GVW<8,500	Avg. # Varieties
GM CK Pick-up	19,712	5,339,505	0.902	84.1
Ford F-Series Pick-up	19,825	6,333,259	0.766	38.9
Dodge Fullsize Ram Pick-up	20,873	2,329,677	0.741	32.5
GM Large SUV	27,612	2,074,907	0.944	18.7

Notes: Averages and shares are weighted by units sold.

prices and fuel economy within each match.

The crucial loophole that we exploit for identification is that manufacturers are not required to report fuel economy, either to consumers or the National Highway Traffic and Safety Administration, when the vehicle has a GVW over 8500 lbs. GVW is defined as the maximum fully loaded weight of the vehicle, including carrying capacity (but not towing capacity). We will leverage this GVW exemption to identify the effects of fuel economy rules in the following sections of this paper. In Table 1, we summarize the four primary vehicle platforms in our empirical analysis, their average price over the sample period, total units sold, the share of those units that were subject to fuel economy rules (GVW<8,500), and the average number of varieties within each vehicle platform in the typical year. Focusing on the share of sales that are below 8,500 lbs, even for these larger trucks, a clear majority of units sold are below this threshold. However, in some cases (Ford F-Series and Dodge Ram), there was a non-trivial share of these varieties with GVW>8,500.

We choose variety definitions to be as detailed as possible (closest to the choice available to the consumer). However, the attributes that define varieties also have a natural impact on weight, which will determine treatment status in our empirical work. As an example, consider the following two cases of the Dodge Ram full size pick-up. The largest selling Ram over the sample period is the Ram 1500 8cyl 5.2L, which sold an average of 23,825 units per year it was offered. This truck is fairly simple, where it lacks additional variety-defining attributes such as four-wheel drive, larger cab configurations, or heavy-duty/long frame features. As such, it is also a fairly “light” full-size truck, averaging 5,963 lbs gross vehicle weight, and is always below 8,500 lbs. In contrast, consider the Dodge 3500 4x4 with a crew cab, long bed, and a 6 cyl, 5.9L diesel engine. This truck averaged 4,855 units sold each year it was offered, which is a relatively large market for an extremely large truck. Moreover, every unit sold was above 8,500 lbs, at 11,000 lbs gross vehicle weight. Clearly, the attributes that define varieties will

also determine the likelihood of being above or below the gross vehicle weight threshold.

For more detail on varieties, in Appendix B, we present the entire list of Ram varieties, their offshoring shares before and after NAFTA, sales, and the share of each variety that is subject to CAFE standards. There are some interesting features of the table that are consistent with a pre-NAFTA policy that is a function vehicle characteristics. For example, there is a fairly strict segmentation of production across borders prior to NAFTA. Of note, some of the varieties that are only produced in Mexico are CAFE varieties, but *do not* use Mexican engines. Specifically, many vehicles produced in Mexico that are subject to CAFE standards use diesel engines produced in North Carolina.¹² This is consistent with a feasible offshoring strategy that helps avoid the value-added required to be classified as a foreign vehicle. After NAFTA, varieties are spread across borders much more than pre-NAFTA, which suggests that a policy was loosened that affects the composition of trade. Below, we present evidence that the two-fleet rule is this policy.

4 Two-fleet and Offshoring: A First Look at the Data

As described above, the CAFE GVW exemption is the primary way to identify the effects of the two fleet rule. Implicit in our discussion is that the rule is binding, and hence, domestic manufacturers must adopt nuanced production strategies around this threshold. If not, then the two-fleet rule should matter little for production decisions. To demonstrate the plausibility of this assumption, we show that manufacturers exploit this exemption threshold more generally.

First, consider Figure 2, which reports the distribution of sales for big three manufacturers over the period 1990-2000. Here, the black-line represents the GVW threshold above which trucks are no longer included in the CAFE calculations. Clearly, there is significant bunching just above the threshold, which is reminiscent of the bunching outlined in Saloner and Slemrod (2012) related to gas-guzzler taxes. Intuitively, if the CAFE constraint is binding on a broad level, it benefits the firm to price such that consumers purchase vehicles above the threshold rather than below the threshold. Additionally, from a long-term point-of-view, it is optimal for firms to place a larger share of their products above this threshold. In both cases, this would lead to a discontinuous jump in sales above this threshold.

To foreshadow the precise mechanism behind the two-fleet rule, and our broad identification strategy,

¹²See <http://www.allpar.com/mopar/cummins-diesel.html> for a discussion of the Cummins diesel engine used in the Ram.

Figure 2: Sales Distribution by GVW

Notes: The above figure presents the sales distribution by gross vehicle weight for all light-duty trucks produced by Chrysler, Ford, and GM over the period 1990-2000. Each bin is 200 lbs GVW. The dark black line is the policy threshold of 8,500 lbs as stipulated in the CAFE program. The dashed black line is the sales weighted average GVW for vehicles subject to CAFE regulations.

we now evaluate average pricing behavior around this GVW threshold for two samples. First, we calculate the average price for varieties of Dodge Ram below the GVW threshold in each model year, and separate averages for those varieties that are above the threshold. The Dodge Ram is an important vehicle to consider around NAFTA since it was offshored both pre and post NAFTA, and hence, any policy changes related to CAFE constraints resulting from NAFTA may induce changes in the price schedule. These averages are presented in the left-hand panel of Figure 3. Clearly, after model year 1994 (which was in part sold before NAFTA was implemented), there is a break in the pricing distribution for the Dodge Ram that raises the relative price of varieties with $GVW > 8500$. However, the pricing trends for exempt and non-exempt varieties are fairly constant both before and after NAFTA.

In the right-panel of Figure 3, we construct the same averages for exempt and non-exempt varieties for other full-size trucks; the Ford F-Series, GM C/K, and GM Suburban. Importantly, these trucks were not offshored prior to NAFTA, and therefore did not actively balance constraints and/or loopholes related to the two-fleet rule. Clearly, there is no such break for all other full-size light-duty trucks. Lastly, while it appears from the left-hand panel that prices rose for the exempt varieties (who received no CAFE policy adjustment) instead of the CAFE relevant varieties falling in price due to the change in policies, note that the overall trend of exempt varieties is fairly similar for both Ram and Non-Ram varieties. Hence, relative to the overall trend, it appears that the Ram varieties under CAFE jurisdiction experienced a reduction in prices relative to the overall trend in trucks over this period.

What could cause this break in the price schedule specifically for Dodge Rams, but not other trucks? Although tariffs did change over this period, they were not specific to varieties, and thus likely orthogonal to variation we see within each truck segment. A more likely culprit is the two-fleet rule. As discussed earlier, vehicles with $GVW > 8,500$ were unconstrained in terms of the amount of foreign value-added in production. In contrast, trucks with $GVW < 8,500$ were constrained before NAFTA in the amount of foreign value-added, and hence, trucks offshored to Mexico would likely require a significant amount of US value-added to meet this requirement. More generally, there was a large pre-NAFTA disincentive to including value-added from Mexico (eg. an engine), regardless where the truck was produced. Overall, if these constraints were binding relative to optimal international production, then we should see a differential effect on prices as we do in Figure 3. We now discuss the particulars of the two-fleet rule for the Dodge Ram, and provide suggestive evidence that loopholes were used prior to NAFTA that enabled Dodge to offshore certain varieties. Then, we address these issues rigorously

Figure 3: Price Evolution and the Gross-Vehicle Weight Exemption

Notes: The above figure presents sales-weighted price averages for varieties below 8,500 lbs GVW, and varieties above this threshold. The left panel calculated these averages for the Dodge Ram pick-up platform, and the right-panel the other platforms from Table 1.

using hedonic regressions.

4.1 A Case Study of the Dodge Ram

Perhaps not surprisingly due to the policy environment, and unlike car production for which the big three had plants in Mexico long before NAFTA was implemented, there was very little truck production in Mexico pre-NAFTA. Indeed, truck production was limited to one brand, Dodge, and two trucks. The primary import from Mexico was the Dodge “Ram” full size pick-up truck. The secondary import from Mexico, at a very small scale, was the Dodge “Ram Charger”, which was a full-size SUV (comparable in size to the Chevy Suburban) primarily sold in the Mexican auto market. It was discontinued after 1993. Dodge imported an additional truck from Japan before NAFTA, the “Ram 50”, which was a re-badged Mitsubishi compact pick-up truck. This truck was also discontinued in 1993. To be clear, while they all shared the same “Ram” designation, they were in fact very different trucks.

In the latter two cases, which were relatively small in scale, Dodge was importing a vehicle type that was not currently in their US/Canadian product portfolio. Both vehicles were produced with a high amount of foreign content, the Ram Charger with a high share of Mexican content, and the Ram 50 with primarily Japanese content. As such, both were imported under the two-fleet rule as “captive imports”, which refer to imports by a domestic automobile producer from abroad.¹³

In contrast to the Ram Charger and Ram 50, the Ram Full Size pick-up was assembled in relatively large quantities in Mexico, but *never* classified as a captive import. How did Dodge avoid the two-fleet rule and still produce its largest truck brand in Mexico? As discussed above, one option was to produce only CAFE exempt varieties in Mexico. As displayed below in the left-panel of Figure 4, this is largely what happened, where approximately 54% of pre-NAFTA production in Mexico was CAFE exempt. By year, as is illustrated in Figure 4, this is extremely noisy given that relatively few exempt varieties were offered in the very early 1990s. However, as offerings increased over time, the exempt varieties were in large part assembled in Mexico, and this segmentation of varieties is consistent with the two-fleet rule. Remarkably, after NAFTA, the share of CAFE exempt Dodge Rams produced in Mexico was roughly equal to the share of CAFE exempt production in the US and Canada.¹⁴

As for the other varieties of Dodge Rams that were under the jurisdiction of CAFE, these varieties must have been produced with enough domestic content to also avoid the two-fleet rule. While we do not have a precise accounting of value-added by input and location, we are able to decode the location of engine assembly. Conveniently (at least for descriptive purposes), there were two types of V-8 engine produced for the Dodge Ram, one with 5.2 liters displacement and another with 5.9 liters displacement. The latter was produced at Toluca Assembly in Mexico for the entire sample period, and the former at Mound Road Assembly in Michigan for the same period. In the right-panel of Figure 4, we calculate by year the sales share of varieties that use an engine built in Mexico for CAFE relevant and CAFE exempt varieties. Prior to NAFTA, they are relatively constant, but after NAFTA there is a clear increase in the number of engines produced in Mexico that are used in varieties under the jurisdiction of CAFE. This is despite the relative budget and production shares of each vehicle class remaining fairly constant

¹³While the Ram 50 - given its relative efficiency - could have been used to balance out production of the Ram full-size pick-up in Mexico, the scale of this product was extremely low and would not have been sufficient to balance Mexican production of full-size Rams.

¹⁴In earlier draft, we broke down the compositional shift by weight class (1500, 2500, or 3500), and documented a shift toward a greater share of sourcing from Mexico for “lighter” varieties (1500, and less so 2500) after NAFTA. For the heavy weight class (3500), which is always exempt from CAFE standards, there was a reduction in the share of offshoring after NAFTA.

Figure 4: CAFE Loopholes: Dodge Ram

Notes: The left-panel presents the share of Dodge Ram production in US/CAN and Mexico that are exempt from CAFE regulations by virtue of weight pre and post NAFTA. The right-panel presents the share of Mexican Engines used within Dodge Ram varieties as a function CAFE status.

over this period.¹⁵ Clearly, the additional use of engines produced in Mexico that are below the CAFE exemption threshold for trucks is consistent with the removal of the two-fleet rule.

While not directly measurable, one can infer the overall effect of the removal of domestic content rules through the price schedule. Indeed, if these domestic content rules presented another cost of offshoring (costly input trade) that was only relevant for varieties subject to CAFE standards, we should expect to see a differential effect of NAFTA on the pricing schedule of Dodge Rams. We now analyze exactly this issue.

5 Pricing and the Two-fleet rule

Using a subset of the dataset detailed in section two, we now analyze the removal of the two fleet rule and the corresponding effects on pricing. The main focus will be on the sample of Dodge full-size pick-up trucks that were registered as new vehicles between 1990 and 2000. Within this sample of sales, we restrict our analysis to the model years 1990-2000, which includes 324 variety-year observations.¹⁶ We

¹⁵See section six.

¹⁶This removes pre-1990 model years that were sold in 1990 and beyond, and 2001 model year trucks that were sold in 2000.

will also use a sample of other full-size trucks produced by other manufacturers that were comparable, and in some cases offshored after NAFTA, as an additional control group in the analysis. We describe these other trucks below.

5.1 CAFE jurisdiction and pre-NAFTA trends

As described above, the primary identification strategy is based on the reduced costs of offshoring for varieties regulated under the CAFE program. Specifically, to avoid the two-fleet rule pre-NAFTA, manufacturers were required to either produce vehicles in Mexico that were very large, thereby avoiding CAFE all together, or use a sufficient amount of value-added from the US or Canada to re-classify production as domestic. Hence, in this latter case, offshored varieties that were regulated under CAFE standards required a significant amount of costly input trade to complete production in Mexico. Further, any domestically-produced, regulated varieties that would naturally use content from Mexico were constrained from doing so pre-NAFTA. Post-NAFTA, this constraint no longer exists, and both CAFE regulated and CAFE exempt varieties could be offshored subject to the same basic constraints.

Below, we evaluate whether there is a differential effect of NAFTA by CAFE group (exempt and regulated) on the price schedule. For this difference-in-difference strategy to be appropriate, we first need to check whether there are any pre-existing trends in the price schedule prior to NAFTA for each group. While the results in Figure 3 suggest that there are no pre-NAFTA price trends that differ across groups, we rigorously test for trends by regressing the price of each variety on a time trend, a regulation indicator, and an interaction between the two:

$$\log(price_{i,t}) = \alpha_1 \cdot REGULATED_{i,t} + \alpha_2 \cdot REGULATED_{i,t} \cdot t + \alpha_3 \cdot t + \alpha_i + \epsilon_{i,t} \quad (1)$$

In (1), $price_{i,t}$ is the MSRP price of variety i in year t , $REGULATED_{i,t}$ is a dummy variable identifying when variety i in year t has a gross vehicle weight below 8,500 pounds, and t is a linear time trend (starting from zero in 1990). We also include variety fixed effects, α_i , to control for the significant price variation that occurs across varieties. The primary interest in (1) is the coefficient on the interaction term, α_2 , which will identify any existing pre-trend in prices that varies according to CAFE status.

The results from estimating (1) are presented in Table 2 for the sample of Dodge Rams, along with a few other samples that will be discussed momentarily. To begin, focus on column one, where

Table 2: Pricing and CAFE Jurisdiction - Pre-NAFTA Trends

	(1)	(2)	(3)	(4)
REGULATED	0.018 (0.028)	-0.036 (0.022)	-0.023 (0.019)	-0.036 (0.022)
REGULATED x t	0.004 (0.010)	0.010 (0.007)	0.010 (0.006)	0.010 (0.007)
t	0.057*** (0.009)	0.046*** (0.007)	0.046*** (0.006)	0.046*** (0.007)
REGULATED x Ram				0.054 (0.035)
REGULATED x t x Ram				-0.006 (0.012)
t x Ram				0.011 (0.011)
Observations	89	549	638	638
# Varieties	29	237	266	266
R^2	0.82	0.71	0.73	0.73
Sample	All Ram	All Non-Ram	All Trucks	All Trucks

Notes: The dependent variable is $\log(\text{price}_{i,t})$, the log price of variety i in model year t . Variety fixed effects in all regressions. Sample includes observations from 1990-1993. In column four, the Ram dummy is absorbed by the variety fixed effects. Robust standard errors, clustered by variety, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

we find that there is a highly significant trend in prices over time within the pre-NAFTA period, but that this trend does not depend on whether or not the variety is regulated under CAFE standards. In column two of Table 2, we estimate the same regression but for a pooled sample of other full size trucks produced by other manufacturers, which include GM CK pick-up trucks, Ford F-Series pick-up trucks, and GM large SUVs (Tahoe, Yukon, and Suburban). The later two truck platforms were offshored post-NAFTA, but not pre-NAFTA, and hence never offshored subject to the two-fleet rule. In the case of the F-Series, very little offshoring took place post-NAFTA (less than 10%). However, all have some share of production that is not subject to CAFE standards, and hence, we use these as an additional layer of control to account for a shift in preferences toward trucks over this period, but production that did not take place abroad subject to the two-fleet rule. Estimating the pre-NAFTA price trends for these trucks leads to a similar conclusion. That is, while prices were generally rising over time, there was no differential effect of being in the group subject to CAFE standards. In column three of Table 2, we run this same regression but for all trucks, finding the same result. Finally, in column four, we run a triple difference of the trend, CAFE jurisdiction, and whether or not the truck is a Ram pickup. Here, we find that not only are there no significant differences in price trends across regulated and exempt groups, but also no differences in this differential effect across Ram and Non-Ram varieties.

5.2 CAFE Jurisdiction and Pricing Regressions

The crucial intuition for our argument is that while NAFTA relaxed many tariff and non-tariff barriers to trade that were independent of product characteristics, NAFTA also relaxed the two-fleet rule for Mexican production, which we argue provided an additional reduction in the cost of offshoring vehicles to Mexico for those varieties regulated by CAFE standards. We search for this effect via the price schedule, and in particular, whether NAFTA reduced prices more so for varieties that were below 8,500 lbs GVW.

Using the dataset described above, we run the following hedonic pricing regression over varieties (i) and years (t):

$$\log(\text{price}_{i,t}) = \alpha_c \cdot \text{REGULATED}_{i,t} + \alpha_{cn} \cdot \text{REGULATED}_{i,t} \cdot \text{NAFTA}_t + \alpha_{char} \cdot \text{Char}_{i,t} + \alpha_t + \epsilon_{i,t} \quad (2)$$

In (2), $\text{Char}_{i,t}$ is a vector of vehicle characteristics for variety i in year t , which include the characteristics

that define varieties, along with length, width, height, and curb-weight (all in logs). To begin we estimate (2) with only time fixed effects (α_t), so the patterns that we document are understood as relative prices as a function of characteristics, program status, and an interaction between program status and NAFTA, within each year. Importantly, since MSRP prices are in current dollars, the use of log prices and year fixed effects will account for any year-specific inflation scalar. Later, we will add variety fixed effects for our preferred specification.

The term of interest is $REGULATED_{i,t}$ and its interaction with $NAFTA_t$, the latter being a dummy variable identifying model years post-NAFTA (1994 and onward). The primary hypothesis is that α_{cn} is significantly less than zero, which would imply that the removal of the two fleet rule after NAFTA provided an extra cost-reducing effect for those varieties that were regulated by CAFE standards. We have no specific hypothesis for the coefficient on α_c , where although one might expect the effects of CAFE to increase prices, the colinearity with other time-invariant characteristics (that correlate with size or variety definitions) requires caution in interpreting this estimate. The results from estimating (2) for the sample of Dodge Rams are presented in Table 3.

To begin, focus on the results in column one, which uses the full sample of Dodge Rams over the period 1990-2000. Here, we see that the coefficient on the interaction between $REGULATED_{i,t}$ and $NAFTA_t$ is negative and significant. In terms of interpretation, prices were 4.8% lower post-NAFTA for varieties regulated by CAFE compared with those exempt from CAFE. This supports the hypothesis that NAFTA reduced an additional cost for varieties within the jurisdiction of CAFE. In column two, we estimate the same specification but removing 1994 from the sample. As the year in the data corresponds to model year, it is possible that 1994 model varieties were sold in 1993, which is prior to the harmonization of fleets between the US/Canadian and Mexican vehicle markets. Hence, one might expect the role of the two-fleet rule to be stronger when changes to the treatment are measured between 1993 and 1995 model years. In column two, we find that if anything the differential effect of NAFTA as a function of CAFE standards is stronger when removing 1994 from the sample. Finally, in columns three and four, we use the same sample periods as in columns one and two, but restrict the sample of Ram varieties to be class two and above (GVW > 6000). Using this restriction essentially balances the support of gross vehicle weight on either side of the 8,500 GVW threshold.¹⁷ Using this alternate sample of varieties in conjunction with the different sample period restrictions does not change the

¹⁷The maximum in the sample of Dodge Rams is 11,000 lbs.

Table 3: Pricing and CAFE Jurisdiction - Dodge Ram

	(1)	(2)	(3)	(4)
REGULATED	-0.005 (0.016)	-0.003 (0.016)	-0.004 (0.016)	-0.003 (0.016)
REGULATED x NAFTA	-0.048*** (0.018)	-0.060*** (0.018)	-0.056*** (0.019)	-0.063*** (0.019)
ln(# Cylinders)	-0.020 (0.078)	-0.009 (0.077)	0.009 (0.083)	0.005 (0.081)
ln(Liters Displacement)	0.112** (0.054)	0.097* (0.054)	0.093* (0.056)	0.091 (0.056)
Diesel Fuel?	0.112*** (0.025)	0.117*** (0.025)	0.120*** (0.027)	0.121*** (0.026)
ln(Length)	0.905*** (0.224)	1.058*** (0.222)	0.760*** (0.239)	0.983*** (0.229)
ln(Width)	0.086 (0.069)	0.098 (0.069)	0.123* (0.070)	0.123* (0.070)
ln(Height)	0.303 (0.203)	0.288 (0.204)	0.305 (0.211)	0.163 (0.213)
ln(Curb Weight)	0.130*** (0.042)	0.118*** (0.041)	0.122*** (0.041)	0.111*** (0.041)
Heavy Duty Option?	0.007 (0.017)	0.021 (0.018)	0.018 (0.017)	0.021 (0.018)
Long Bed Option?	0.020 (0.013)	0.011 (0.013)	0.019 (0.013)	0.011 (0.013)
Extended Cab?	0.029 (0.021)	0.016 (0.021)	0.040* (0.022)	0.020 (0.021)
Crew Cab?	0.052** (0.021)	0.038* (0.021)	0.062*** (0.022)	0.043** (0.021)
4X4?	0.104*** (0.010)	0.110*** (0.010)	0.105*** (0.010)	0.114*** (0.010)
Observations	324	313	311	303
# Varieties	82	82	82	82
R^2	0.96	0.96	0.95	0.95
GVW Class	All	All	2 and Above	2 and Above
Sample	All	No 1994	All	No 1994

Notes: The dependent variable is $\log(\text{price}_{i,t})$, the log price of variety i in model year t . Year fixed effects included in all regressions. Sample includes observations from 1990-2000. Robust standard errors, clustered by variety, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

results in a meaningful fashion.

Given the redesign of the Dodge Ram for the 1994 model year, one concern with the regression specified in (2) is that new and/or dying varieties are contaminating the effects of NAFTA interacted with regulation status. To more precisely evaluate the effect of CAFE and NAFTA using varieties that were present both before and after NAFTA, we add variety fixed effects (α_i) into the regression equation in (2):

$$\log(\text{price}_{i,t}) = \alpha_c \cdot \text{REGULATED}_{i,t} + \alpha_{cn} \cdot \text{REGULATED}_{i,t} \cdot \text{NAFTA}_t + \alpha_{char} \cdot \text{Char}_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad (3)$$

In (3), the use of variety fixed effects removes all varieties that were not present before NAFTA and those that died before NAFTA from the variation that identifies α_{cn} (about half of all varieties are present before and after NAFTA). Hence, we are identifying α_{cn} within varieties that were present both before and after NAFTA. The results from estimating the within-variety regression in (3) are presented in Table 4, noting that all characteristics that do not measure dimension or weight are absorbed by the fixed effects.¹⁸ Further, each column corresponds to a similar sample restriction as in the previous table. The results indicate that the differential effect of NAFTA as a function of regulation status is larger in magnitude when evaluating this effect within varieties and years. Since we are only identifying the effects of NAFTA by regulation status on varieties that are present before and after NAFTA, we use the within-variety approach for the remainder of the analysis.

Though the focus in Tables 3 and 4 is on pricing as a function of the policy change and characteristics, the mechanism is predicated on offshoring becoming easier for Dodge Ram varieties that were subject to additional CAFE regulations prior to NAFTA. Hence, the policy should also be associated with increased sales of these varieties, and in particular, increased sales that originate from Mexico. To test this complementary hypothesis, in column one of Table 5, we regress the log of total units sold of variety i in year t , $\ln(\text{sales}_{i,t})$, on the same policy and size characteristics as in Table 3. Here, we find that the effect of NAFTA on units sold is larger for CAFE regulated varieties. In column two of Table 5, we focus on units sold that originate from Mexico for variety i in year t , $\text{mexsales}_{i,t}$. Since there are a large number of zeros, we follow Silva and Tenreyro (2006) and use Poisson pseudo-maximum-likelihood to estimate $\text{mexsales}_{i,t}$ as a function of policy changes and characteristics. Here, we again find that

¹⁸We have also run regressions with higher-order weight and dimension characteristics for robustness, and the results do not change significantly.

Table 4: Pricing and CAFE Jurisdiction - Dodge Ram - Within variety

	(1)	(2)	(3)	(4)
REGULATED	0.063*** (0.018)	0.050*** (0.017)	0.054*** (0.019)	0.044** (0.017)
REGULATED x NAFTA	-0.073*** (0.025)	-0.096*** (0.030)	-0.069** (0.026)	-0.088*** (0.030)
ln(Length)	0.433* (0.258)	0.633** (0.312)	0.455* (0.266)	0.700** (0.293)
ln(Width)	0.156 (0.171)	0.074 (0.183)	0.150 (0.177)	0.062 (0.181)
ln(Height)	-0.462* (0.251)	-0.340 (0.255)	-0.370 (0.246)	-0.339 (0.250)
ln(Curb Weight)	0.092*** (0.021)	0.076*** (0.024)	0.094*** (0.024)	0.072*** (0.024)
Observations	324	313	311	303
# Varieties	82	82	82	82
R^2	0.90	0.90	0.89	0.89
GVW Class	All	All	2 and Above	2 and Above
Sample	All Ram	No 1994	All Ram	No 1994

Notes: The dependent variable is $\log(\text{price}_{i,t})$, the log price of variety i in model year t . Year and variety fixed effects included in all regressions. Sample includes observations from 1990-2000. Robust standard errors, clustered by variety, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5: Production and CAFE Jurisdiction - Dodge Ram

	(1) $\ln(\text{sales}_{i,t})$	(2) $\text{mexsales}_{i,t}$	(3) $\frac{\text{mexsales}_{i,t}}{1000}$
REGULATED	-0.782** (0.332)	-2.391*** (0.522)	-0.934 (1.024)
REGULATED x NAFTA	1.659*** (0.584)	3.690*** (0.580)	6.654** (2.837)
$\ln(\text{Length})$	-6.186 (4.460)	12.114** (4.822)	12.636 (22.050)
$\ln(\text{Width})$	-2.479 (2.246)	2.412 (3.472)	-3.794 (8.132)
$\ln(\text{Height})$	-0.823 (4.299)	-13.180*** (4.694)	-27.890 (24.265)
$\ln(\text{Curb Weight})$	-1.030*** (0.391)	-1.885 (2.717)	-6.233*** (2.248)
Observations	324	324	324
R^2	0.63		0.30
#Varieties	82	82	82
Estimation	OLS	PPML	OLS
Sample	Ram	Ram	Ram

Notes: The sample includes Dodge Ram full-size pick-ups, model years 1990-2000. In column (1) $\log(\text{sales}_{i,m,t})$ is the log units sold of variety i in model year t . In column (2), $\text{mexsales}_{i,t}$ is units sold that were produced at plants in Mexico. For interpretation, in column (3), we scale by \$1000. Variety and year fixed effects included in all regressions. Robust standard errors, clustered by variety, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

the policy change implemented under NAFTA had a larger effect on offshoring for varieties that were regulated by CAFE. In column (3), we evaluate the robustness of PPML by regressing $\text{mexsales}_{i,t}$ in levels on the policy changes and characteristics using OLS. The results are robust.

5.2.1 Robustness

During the course of the 1990's there was a large shift in sales toward trucks, in particular large trucks. For our analysis, this suggests an omitted variable that would likely drive up prices disproportionately for larger trucks relative to smaller trucks. Unfortunately, this effect can work in two ways, both of which in the same direction as the effects described in Table 3. On one hand, consumers shifted from

cars to compact trucks, and hence, the increase in product offerings on the lower-end of the weight distribution would provide more direct competition to CAFE regulated Dodge Rams and other smaller full-size trucks. Overall, this may reduce prices more for varieties regulated by CAFE standards relative to those exempt from them. Further, if there is a fundamental shift in demand within the full-size truck sector toward large trucks, the demand shock would drive up prices of larger trucks compared with smaller trucks. Again, this would produce the same effect as we document in Table 3.

We examine this issue in two ways. First, we augment the within-variety specification in by interacting a dummy variable for each variety with a linear time trend. Hence, we are allowing for certain varieties to have a differential trend in prices relative to other varieties in the sample. This could be due to the demand channel above, or perhaps some other trend that is unobserved but correlated with CAFE regulation status, the implementation of NAFTA, and prices. For example, perhaps certain engine types were viewed more favorably in the late 90's and that these engine types are also associated with regulation status. Since engine type (and other attributes) are accounted for in the definition of varieties, allowing for such trends can account for variety specific shifts in the price schedule over time that are not precisely coincident with NAFTA. Finally, perhaps the redesign of the Ram for model year 1994 was more successful for particular varieties, and is reflected in a gradual improvement in the price schedule. With all these alternate stories in mind, the results from the within-variety specification with variety trends are presented in Table 6. The interaction between the regulation indicator and NAFTA is still negative and significant, and remarkably similar in size to the estimates without variety trends. Hence, the results are robust to variety-specific trends in prices.

For the remainder of the paper, we will adopt a different strategy for robustness, running a falsification test by estimating the same hedonic regression as in (2) but for a number of other products that were either not offshored, or only offshored after the two-fleet rule was removed. The idea is that if some shift in consumer tastes is driving the results in Table 3, we should see a similar negative sign and significance for the interaction between $REGULATED_{i,t}$ and $NAFTA_t$ when estimating the model on a sample of trucks that were never offshored. These results are presented in Table 7, estimating the model on GM CK pick-up trucks, Ford F-Series pick-up trucks, and GM large SUVs (Tahoe, Yukon, and Suburban). In column one, we find no significant negative interaction between $REGULATED_{i,t}$ and $NAFTA_t$ for GM CK pick-ups. The later two truck platforms were offshored during the sample period, but not before NAFTA and hence never offshored subject to the two-fleet rule. For the F-series,

Table 6: Pricing and CAFE Jurisdiction - Dodge Ram - Within-variety and variety time trends

	(1)	(2)	(3)	(4)
REGULATED	0.003 (0.023)	-0.030 (0.025)	-0.017 (0.026)	-0.026 (0.026)
REGULATED x NAFTA	-0.051* (0.031)	-0.104** (0.047)	-0.078** (0.039)	-0.094* (0.048)
ln(Length)	0.419 (0.415)	0.563 (0.434)	0.511 (0.438)	0.634 (0.433)
ln(Width)	-0.073 (0.169)	-0.133 (0.172)	-0.100 (0.169)	-0.158 (0.174)
ln(Height)	-0.314 (0.238)	-0.259 (0.299)	-0.145 (0.279)	-0.185 (0.314)
ln(Curb Weight)	0.110*** (0.019)	0.177 (0.107)	0.145*** (0.024)	0.171 (0.106)
Observations	324	313	311	303
R^2	0.96	0.96	0.95	0.95
# Varieties	82	82	82	82
GVW Class	All	All	2 and Above	2 and Above
Sample	All Ram	No 1994	All Ram	No 1994

Notes: The dependent variable is $\log(\text{price}_{i,t})$, the log price of variety i in model year t . Year, variety fixed effects, and variety-specific time trends included in all regressions. Sample includes observations from 1990-2000. Robust standard errors, clustered by variety, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7: Pricing and CAFE Jurisdiction - Falsification Tests

	(1)	(2)	(3)
REGULATED	-0.034** (0.016)	-0.009 (0.018)	
REGULATED x NAFTA	0.006 (0.015)	0.004 (0.018)	0.019 (0.012)
ln(Length)	-0.034 (0.027)	0.348** (0.168)	2.044*** (0.494)
ln(Width)	0.042 (0.053)	-0.254** (0.105)	2.187 (2.362)
ln(Height)	-0.026** (0.011)	-0.023 (0.015)	-0.662** (0.266)
ln(Curb Weight)	0.054 (0.047)	0.405*** (0.098)	0.083 (0.079)
Observations	876	403	181
# Varieties	284	105	42
R^2	0.88	0.93	0.94
Sample	CK	F-Series	Suburban

Notes: The dependent variable is $\log(\text{price}_{i,t})$, the log price of variety i in model year t . Variety and year fixed effects included in all regressions. Sample includes observations from 1990-2000. Robust standard errors, clustered by variety, in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

reported in column two of Table 7, the interaction between $REGULATED_{i,t}$ and $NAFTA_t$ is also insignificant. In column three using the sample of large GM SUVs, the price schedule does not reflect any effect of CAFE regulation that is coincident with NAFTA. Overall, the effect of NAFTA on the pricing schedule is only a function of CAFE jurisdiction when the offshoring occurred while the two-fleet rule was in effect - as was the case for the Dodge Ram.

One caveat with the above falsification tests is that we are allowing not only the effects of CAFE to differ across vehicle platforms, but also the effects of characteristics. To focus on the effects of regulation status and the interaction with NAFTA, we now pool the Ram, CK, F-Series, and Suburban and estimate the model restricting that the coefficients on characteristics are common across vehicle platforms. Using a difference-in-difference-in-difference approach, we estimate the differential effect of NAFTA as a function of CAFE jurisdiction separately for the Dodge Ram. Using this approach, in

Table 8: Pricing and CAFE Jurisdiction - Triple Difference

		(1)	(2)
Ram	REGULATED	0.017 (0.015)	0.006 (0.013)
	REGULATED x NAFTA	-0.062*** (0.014)	-0.045*** (0.014)
Not Ram	REGULATED	-0.019 (0.012)	0.031** (0.014)
	REGULATED x NAFTA	-0.003 (0.011)	-0.018* (0.010)
	ln(Length)	0.001 (0.025)	0.008 (0.024)
	ln(Width)	-0.032 (0.058)	-0.095 (0.069)
	ln(Height)	-0.033*** (0.011)	-0.046*** (0.012)
	ln(Curb Weight)	0.125*** (0.033)	0.111*** (0.029)
	Observations	1,784	3,011
	# Varieties	513	764
	R^2	0.87	0.81
	Sample	Ram, CK, F-Series GM Fullsize SUV	All Light-Duty Trucks

Notes: The dependent variable is $\log(\text{price}_{i,t})$, the log price of variety i in model year t . Year and variety fixed effects included in all regressions. Sample includes observations from 1990-2000. Robust standard errors, clustered by variety, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

column one of Table 8, we report that the differential effects of NAFTA for the Dodge Ram are in-line with those reported for the baseline results in Table 3. Further, as in Table 7, the effects on other trucks (“Not Ram”) are insignificant. In column two of Table 8, we extend the sample to include all light-duty trucks (eg. jeeps, compact suvs and pickups). While the results for non-Ram trucks are moderately significant and in-line with the proposed direction of the policy for Ram trucks, they are very small in magnitude. Overall, the results are supportive of the hypothesis that removing the two-fleet rule reduced prices for trucks regulated by CAFE standards *and* offshored while the rule was in place.

Finally, as the removal of the two-fleet rule was a permanent change in policy, the results should also indicate that the subsequent change in pricing for the Ram as a function of regulation status does not

fluctuate wildly in the post-NAFTA period. To evaluate this possibility, we extend the base model in (2) by using year dummies interacted with regulation status rather than a simple post-NAFTA dummy. The results from doing so for all truck platforms are presented in Table 9. Here we see that for the Ram, relative to the baseline year (1990), prices post-1994 fell between 8 and 11% for CAFE regulated varieties. Indeed, this is important in that we see no effect in 1994, which as described earlier, was the model year in which a new generation of Ram truck was introduced, and partially sold in 1993 (before the policy change took effect). Hence, the main treatment effect does not coincide exactly with the model redesign, which itself occurred prior to NAFTA. Further, the persistence of the effect is reassuring given the noisy yearly features of the loophole shares in Figure 4. Finally, for none of the placebo varieties did prices fall significantly on a consistent basis, and the effects of regulation status by year seem to be much more variable. Overall, the evidence points to a permanent shock occurring after NAFTA that is consistent with the two-fleet rule lowering the costs of offshoring for vehicles regulated by CAFE standards *and* offshored prior to NAFTA.

6 Two-fleet and Post-NAFTA offshoring

As discussed above, virtually no light trucks were imported under two-fleet other than two niche brands (the Ram Charger and Ram 50) that were primarily geared toward other domestic markets and discontinued post-NAFTA. While Dodge did offshore production of its Dodge Ram to Mexico using CAFE exemptions and sufficient domestic content, prior to NAFTA, no other varieties of truck built primarily for the US market were offshored to Mexico. This changed after NAFTA, with Ford offshoring some production of its “F-Series” full-size pick-up to Mexico, and GM offshoring a large amount of Suburban, Yukon, and Tahoe production to Mexico. In this section, we ask a simple question: had two-fleet been active under this offshoring strategy, what sort of fines would have been paid by the domestic manufacturers if they had violated CAFE averages for their import fleet? Further, what does the revealed pricing and production behavior say about changes to environmental compliance costs that are attributable to the relaxation of the two-fleet rule?

Our dataset is uniquely equipped to answer these questions. To do so, we first assume that all production in Mexico would have used sufficient Mexican content to be considered part of the import fleet of trucks produced by Chrysler, Ford, and GM, respectively. On one hand this is sensible, since

Table 9: Pricing and CAFE Jurisdiction - Year Interactions

	(1)	(2)	(3)	(4)
REGULATED	0.051** (0.023)	-0.037 (0.030)	-0.060*** (0.021)	
REGULATED x 1991	-0.014 (0.016)	-0.001 (0.011)	0.014 (0.015)	-0.019 (0.013)
REGULATED x 1992	0.004 (0.022)	0.007 (0.023)	-0.012 (0.014)	0.011 (0.018)
REGULATED x 1993	-0.005 (0.025)	-0.012 (0.028)	0.125*** (0.028)	0.004 (0.017)
REGULATED x 1994	-0.006 (0.032)	-0.020 (0.032)	0.032 (0.023)	0.012 (0.028)
REGULATED x 1995	-0.097*** (0.035)	-0.029 (0.035)	0.101*** (0.032)	0.029 (0.028)
REGULATED x 1996	-0.113*** (0.036)	-0.000 (0.035)	0.049* (0.027)	0.052 (0.040)
REGULATED x 1997	-0.094** (0.043)	0.003 (0.031)	0.146*** (0.035)	0.018 (0.015)
REGULATED x 1998	-0.099** (0.044)	-0.001 (0.032)	0.459*** (0.018)	0.007 (0.016)
REGULATED x 1999	-0.084* (0.043)	0.040 (0.037)	0.052* (0.028)	0.028 (0.018)
REGULATED x 2000	-0.090** (0.041)	0.088** (0.034)	-0.009 (0.028)	-0.083* (0.046)
Observations	324	876	403	181
# Varieties	82	284	105	42
R^2	0.90	0.88	0.94	0.95
Sample	Ram	CK	F-Series	Suburban

Notes: The dependent variable is $\log(\text{price}_{i,t})$, the log price of variety i in model year t . Variety and year fixed effects included in all regressions, and REGULATED x Year reports the coefficient on the interaction between these year effects and the REGULATED indicator. Sample includes observations from 1990-2000. Robust standard errors, clustered by variety, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

many input producers also located in Mexico after NAFTA was implemented. However, due to domestic content requirements under two-fleet, it is unlikely that they would have done so had two-fleet still been in place. Further, if product reshuffling was relatively low-cost, then again this may not be the proper counterfactual. Hence, the estimate we are about to provide is meant to be an upper-bound, conditional on the revealed pattern of truck assembly post-NAFTA, not a proper counterfactual looking at what would have happened post-NAFTA had two-fleet still been in place.

To begin, we calculate that the Mexican fleet of CAFE regulated trucks, whether produced by Chrysler, Ford, or GM, were 3 miles per gallon *less* efficient than each firm's average mpg over the period 1994-2000. Given that firms almost always operated at the CAFE average, and that the statutory CAFE fine is \$55 per mile per gallon per vehicle under the CAFE standard, this amounts to a total industry fine over this period of approximately \$192 million or \$165 per vehicle. This is a relatively large number, especially when considering that this was a fine spread out across only four plants and three manufacturers. As a point of comparison, over the period 1983-2004, the entire CAFE program has collected \$651 million in fines. Hence, a six-year period of production in Mexico - had the two fleet rule still been in place - would have increased the total fines collected under the program by 29.4%.¹⁹

An alternative perspective is to consider how changes to the program - at least as implied by the hedonic regressions - compare to existing estimates of the shadow value of the CAFE constraint. To back out an estimate of the implied changes to the CAFE constraint, we start by representing the pricing strategy of firms for CAFE relevant varieties as

$$p_i = MU_i + MC_i + \lambda_i (standard - mpg_i),$$

where for variety i , p_i is the profit maximizing price, MU_i is the mark-up, MC_i the marginal cost, mpg_i the fuel efficiency in miles per gallon, *standard* the CAFE standard, and λ_i the reduction in profits for variety i given a one-unit increase in the standard. The derivation of this pricing equation is available in the appendix. Since we focus on the representative CAFE regulated and CAFE exempt varieties, we drop i 's for the remainder of this section.

The difference-in-difference estimates in the previous section are decomposed into changes in mark-

¹⁹See <http://www.nhtsa.gov/cars/rules/cafe/FINES-COLLECTED-SUMMARY.html>.

ups, marginal costs, and regulatory costs:

$$\Delta p_{cafe} - \Delta p_{exempt} = \Delta MU_{cafe} - \Delta MU_{exempt} + \Delta MC_{cafe} - \Delta MC_{exempt} + \Delta \lambda (standard - mpg_{cafe})$$

where the operator Δ represents the pre-post change resulting from NAFTA, and subscript *cafe* represents CAFE relevant varieties, and *exempt* the alternate group. Of interest is the change in the implied shadow value of the CAFE constraint, $\Delta \lambda$, for the representative CAFE variety, and to calculate this we need to assign values to the change in prices, mark-ups, marginal costs, and the wedge between the regulatory standard and the miles per gallon. In the process of doing so, we will use a simple bootstrap technique to account for the underlying sampling variation. The summary of average effects of each difference-in-difference will be presented in Table 10.

Before proceeding with the bootstrap procedure, we first make an assumption about changes in mark-ups during the sampling period. As our empirics are reduced form, we do not explicitly estimate changes to mark-ups over this period. However, crucial to our back of the envelope calculation is whether the difference-in-difference of mark-ups, $\Delta MU_{cafe} - \Delta MU_{exempt}$, changes. Following intuition from Berry (1994), where mark-ups are determined by market shares, we note that the market shares for CAFE-regulated Dodge Ram varieties (within all Rams) pre and post NAFTA were remarkably constant (around 74% pre and post NAFTA).²⁰ Further, within the light-truck sector, Dodge Rams have a relatively small market share, never above 5% overall. Hence, it is unlikely that there was a large *differential* change in mark-ups over this period, and we set the differential change in mark-ups to zero.²¹

The basic bootstrap procedure involves constructing 1000 bootstrap samples of the same size as the sample of Dodge Rams from our dataset (324). For each bootstrap sample, we must calculate a number of statistics that may vary within each sample. The first is the difference-in-difference estimates for the change in prices, $\Delta p_{cafe} - \Delta p_{exempt}$. To estimate this term for each bootstrap sample, we use our within-variety specification in (3) as a baseline, as well as our within-variety specification with variety time-trends for robustness. Precisely, we capture the coefficient on the interaction between

²⁰Expenditure shares of regulated varieties, on the other hand, did change due to the price effects that we document, from 67% to 69%.

²¹We have explicitly estimated mark-ups and their changes using formulae from Berry (1994) and one parameter estimate from BLP, and we find that while the mark-ups have sensible magnitudes (approximately between \$40 and \$165), the difference-in-difference in mark-ups max out at \$1. Hence, we believe that our assumption of zero differential changes in mark-ups is sensible given revealed market shares and the overall impact of the Ram on the light-truck sector.

Table 10: Decomposition of Changes in CAFE Shadow Value

	$\Delta p_{cafe} - \Delta p_{exempt}$	-\$1219.25	Exponentiated difference-in-difference estimate from Table 4
–	$(\Delta MU_{cafe} - \Delta MU_{exempt})$	0	Assumed to be zero (see footnote 21)
–	$(\Delta MC_{cafe} - \Delta MC_{exempt})$	(-\$293.50)	Labor cost savings from offshoring at observed production shares
		-\$925.75	
	$(standard - mpg_{cafe})$	$\frac{3mpg}{}$	Divide by the average distance from CAFE standard
=	$\Delta \lambda$	-\$308.58	Estimated change in the shadow value of CAFE

Notes: This table presents the decomposition of the difference-in-difference price estimate. Confidence bands for this estimate for different scenarios are presented in Table 11

REGULATED and NAFTA, exponentiate to get the price effect, and then apply this percentage change to the average price of varieties between 1993 and 1995 (when the policy changed) within the bootstrap sample. That is, for each bootstrap sample b , $\Delta price_{cafe}^b - \Delta price_{exempt}^b = \bar{p}_{93-95}^b \cdot (\exp(\hat{\alpha}_{cn}^b) - 1)$.

In terms of the change in marginal costs, we focus on the labor cost advantage of offshoring, choosing to load any other changes to costs (eg. input trade) into the implied shadow value of meeting the CAFE constraint. To calculate the labor cost advantage, we first compare the average labor intensity of US plants producing the same varieties as those in Mexico. Using the *Harbour Report*, the industry standard source for plant-level productivity, we run a simple regression for all plants producing the Ram of the labor-hours required per vehicle on year fixed effects, scale at the plant, and a dummy variable identifying plants that operate in Mexico. We find that after controlling for scale and year variation, plants in Mexico require 30.8% more labor hours per vehicle than similar domestic plants.²² Assuming the industry standard union wage of \$30/hr, and \$3.50/hr for Mexican workers, at 36 hours per vehicle in the US the estimated direct labor cost advantage of offshoring to Mexico is \$915.20. Since this does not vary by variety, it is not calculated for each bootstrap sample.

²²Precisely, using the sample of plants produces the Ram, we estimate that:

$$\ln(hpv_{p,t}) = \underset{(0.125)}{.268} Mex_p - \underset{(.082)}{0.084} Scale_{p,t} + Year + \epsilon_{p,t} \quad (4)$$

where $hvp_{p,t}$ is the hours per vehicle for plant p in year t , Mex_p identifies whether plant p is in Mexico, $Scale_{p,t}$ is the total production at plant p in model year t , and $Year$ is a vector of year dummy variables. The sample includes observations from 1994-2000. Robust standard errors in parentheses. Exponentiating the coefficient on Mex_p gives the desired result.

What does vary by variety, however, is the share of CAFE and exempt varieties produced in Mexico before and after NAFTA. We calculate these shares for each bootstrap sample b , where $\Delta MC_{cafe}^b - \Delta MC_{exempt}^b$ is calculated using:

$$\Delta MC_{cafe}^b - \Delta MC_{exempt}^b = -915.20 \cdot \left(\left(s_{cafe,post}^b - s_{cafe,pre}^b \right) - \left(s_{exempt,post}^b - s_{exempt,pre}^b \right) \right).$$

The final piece of the estimate is the difference in efficiency between the fleet of CAFE relevant Dodge Rams and the standard, $(standard - mpg_{cafe})$. While this can change with each bootstrap sample, we assign its sample average of 3 miles per gallon short of the standard for each bootstrap sample. The reason is that allowing for the constraint to bind implies that vehicles just short of the standard exactly balance out those vehicles in excess of the standard. Hence, allowing for a bootstrap sample to give a less efficient fleet of Rams compared with the sample implies that more efficient Chrysler models must become even more efficient. Since we do not estimate the costs of the latter, we abstract from this entire question and assign $(standard - mpg_{cafe}) = 3$ for all our bootstrap calculations.

With this final piece of the puzzle, in Table 11 we report our bootstrap estimates, standard errors, and percentile intervals of the estimates, for both the within-variety specification, and the more demanding within-variety specification with variety-specific trends. The latter is noisier, but still suggestive of a large drop in the shadow value of the CAFE constraint. The former baseline specification suggests that the removal of the two-fleet rule had a significant effect on loosening the constraints related to CAFE. Precisely, NAFTA reduced the shadow cost of CAFE by approximately \$308.58 per vehicle.

Are these sensible estimates? Jacobsen (2013) estimates (in his Table 2) that the implied shadow costs of the CAFE constraint for 1997-2001 are between \$52 (Ford, cars) and \$438 (GM, cars) per vehicle. Hence, the estimates presented in Table 11 per vehicle are meaningful, but within the across-manufacturer range. More specific to Chrysler, these estimates are remarkably similar to \$216, which is the difference in implied compliance costs between Chrysler cars and trucks in Jacobsen (2013) over the period 1997-2001. This is notable in that the two-fleet rule was still present globally for cars but not trucks, and Chrysler merged with Mercedes-Benz in 1998. Hence, Chrysler was faced with significant global production of cars to balance for two-fleet compliance, and our estimates of costs of the two-fleet rule rationalizes Jacobsen's difference in estimates for Chrysler cars and trucks.

Table 11: Changes in CAFE Shadow Value

	Est/(se)	$\Delta\lambda$ [$\Delta\lambda_{05}$, $\Delta\lambda_{95}$]
Within Variety	-308.58 (135.51)	[-518,-86.6]
Within Variety, with Variety Trends	-227.24 (217.5)	[-566.2,121.7]

Notes: $\Delta\lambda$ represents the change in the shadow costs of the CAFE constraint upon implementation of NAFTA. 'Est/(se)' report the average value from this statistic over 1000 bootstrap trials, and the standard error of the statistic using the 1000 trials, and [$\Delta\lambda_{05}$, $\Delta\lambda_{95}$] reports a 90% confidence interval for the statistic. "Within-Variety" corresponds to diff-in-diff price estimates using the within-variety specification, and "Within-Variety, with Variety Trends" corresponds to diff-in-diff price estimates using the within-variety specification with variety-specific trends.

7 Discussion and Conclusion

In this paper we have demonstrated that apparently location-neutral policies can nevertheless distort the location of production and limit the gains from trade. Using the US CAFE standards that treat the domestic and foreign production of an automaker as if being from two different firms, we show that this forces firms to allocate their portfolio of production in ways that are not strictly cost minimizing. We identify this production distortion utilizing a natural experiment owing to changes in the CAFE program due to NAFTA. Through the hedonic analysis of the Dodge Ram - the only model offshored to Mexico pre-NAFTA - we show that vehicles subject to the two-fleet rule experienced a 5-10% reduction in prices relative to those vehicles not subject to the two-fleet rule. Far from being location neutral, the application of the two fleet rule results in a costly production distortion. These are novel estimates of how multinational firms balance production subject to policies that impose national treatment, and are relevant to assessing whether "fair" policies can limit the the gains from production location and comparative advantage.

The implications of these estimates and other calculations are relevant for the broader policy application of national treatment to labor and environmental standards. Central to the criticism of such standards is the assertion that equally applied labor and environmental standards will distort patterns of comparative or competitive advantage. Our case study confirms this for the automotive sector, and it is therefore likely that other firms that have capacity across regulatory regions in other industries will

face similar distortions. Indeed, recent policy proposals suggesting carbon markets within regions, but without trading across regions.²³ Our results suggest that these policies will result in similar distortions since regions likely vary in their natural production competencies, but firms operating within multiple regions must adjust the average characteristics of their production process for compliance.

²³Within the US, recent proposals by the Obama Administration have included average CO2 emissions standards that must be met within each state, but with no averaging across states.

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A Pricing Equation

In section 6 we used a sample pricing equation to back-out changes to the CAFE compliance cost as a function of our difference-in-difference estimates. In this appendix, we derive the pricing equations used in the analysis.

The basic maximization problem for a firm producing N possible varieties of truck (indexed by i) is the following:

$$\begin{aligned} \max_{q_i} \Pi &= \sum_i P(q_i, q_{i'}, y) q_i - TC_i(q_i) \\ \text{s.t.} \quad & \frac{\sum_i q_i \mathbf{I}(gvw_i < 8500)}{\sum_i \frac{q_i}{mpg_i} \mathbf{I}(gvw_i < 8500)} \geq \text{standard} \end{aligned}$$

where $P(q_i, q_{i'}, y)$ is the demand function for variety i , q_i the quantity sold of variety i , $q_{i'}$ a vector of other (potentially substitutable) varieties within the firm, y a vector of potentially substitutable varieties outside the firm. $TC_i(q_i)$ is the total cost of producing variety i . The second line represents the CAFE constraint, which is calculated as a harmonic average. $\mathbf{I}(gvw_i < 8500)$ is an indicator taking on a value of 1 if the variety of truck is within the CAFE jurisdiction, mpg_i the fuel efficiency of variety i , and standard the cafe standard. Rearranging the constraint as $\sum_i \frac{q_i}{mpg_i} \mathbf{I}(gvw_i < 8500) (mpg_i - \text{standard}) \geq 0$, and writing the problem in Lagrangian form, we have:

$$\max_{q_i} \Pi = \sum_i P(q_i, q_{i'}, y) q_i - TC_i(q_i) + \delta \sum_i \frac{q_i \mathbf{I}(gvw_i < 8500)}{mpg_i} (mpg_i - \text{standard})$$

The first order condition for variety i is written as:

$$\frac{\partial P(q_i, q_{i'}, y)}{\partial q_i} q_i + \sum_{j \neq i} \frac{\partial P(q_j, q_{j'}, y)}{\partial q_i} q_j + P(q_i, q_{i'}, y) - MC_i(q_i) + \delta \frac{\mathbf{I}(gvw_i < 8500)}{mpg_i} (mpg_i - \text{standard}) = 0$$

Hence, prices are written as,

$$P(q_i, q_{i'}, y) = -\frac{\partial P(q_i, q_{i'}, y)}{\partial q_i} q_i - \sum_{j \neq i} \frac{\partial P(q_j, q_{j'}, y)}{\partial q_i} q_j + MC_i(q_i) + \delta \frac{\mathbf{I}(gvw_i < 8500)}{mpg_i} (\text{standard} - mpg_i),$$

or as in section 6,

$$P(q_i, q_{i'}, y) = MU_i + MC_i(q_i) + \lambda_i (standard - mpg_i),$$

where $MU_i = -\frac{\partial P(q_i, q_{i'}, y)}{\partial q_i} q_i - \sum_{j \neq i} \frac{\partial P(q_j, q_{j'}, y)}{\partial q_i} q_j$ is the mark-up, and λ_i is the shadow cost of the CAFE constraint for variety i .

B List of Dodge Ram Varieties

Variety Name	CAFE	Offshoring Share		Average	Years in Sample	
	Share	1990-1993	1994-2000	Yearly Sales	First	Last
DODGE RAM1500 6CYL 3.9L	1	0	0.042	7332	1990	2000
DODGE RAM1500 6CYL 3.9L 4X4	1	0	-	652	1990	1993
DODGE RAM1500 8CYL 5.2L	1	0	0.106	13794	1990	2000
DODGE RAM1500 8CYL 5.2L 4X4	0.862	0	0.081	9238	1990	2000
DODGE RAM1500 8CYL 5.2L CREWCAB	1	-	0.558	13121	1998	2000
DODGE RAM1500 8CYL 5.2L CREWCAB 4X4	1	-	0.635	6738	1998	2000
DODGE RAM1500 8CYL 5.2L EXTENDED CAB	1	1	0.88	9881	1990	2000
DODGE RAM1500 8CYL 5.2L EXTENDED CAB 4X4	1	1	0.81	6354	1990	2000
DODGE RAM1500 8CYL 5.9L	1	0	0.066	5534	1990	2000
DODGE RAM1500 8CYL 5.9L 4X4	0.852	0	0.051	6970	1990	2000
DODGE RAM1500 8CYL 5.9L CREWCAB	1	-	0.531	10478	1998	2000
DODGE RAM1500 8CYL 5.9L CREWCAB 4X4	1	-	0.612	17527	1998	2000
DODGE RAM1500 8CYL 5.9L EXTENDED CAB	1	1	0.883	5758	1990	1999
DODGE RAM1500 8CYL 5.9L EXTENDED CAB 4X4	1	1	0.837	8153	1990	1999
DODGE RAM2500 10CYL 8.0L	0	-	0	328	1997	1997
DODGE RAM2500 10CYL 8.0L 4X4	0	-	0	1844	1997	1997
DODGE RAM2500 10CYL 8.0L 4X4 HD LONGBED	1	-	0	3253	1995	1996
DODGE RAM2500 10CYL 8.0L 4X4 LONGBED	0	-	1	960	1998	2000
DODGE RAM2500 10CYL 8.0L CREWCAB	0	-	0.198	887	1998	2000
DODGE RAM2500 10CYL 8.0L CREWCAB 4X4	0	-	0.194	3351	1998	2000
DODGE RAM2500 10CYL 8.0L EXTENDED CAB	0	-	0.763	1091	1995	1999
DODGE RAM2500 10CYL 8.0L EXTENDED CAB 4X4	0	-	0.772	1928	1995	1999
DODGE RAM2500 10CYL 8.0L HD LONGBED	1	-	0	847	1995	1996
DODGE RAM2500 10CYL 8.0L LONGBED	0	-	0.998	139	1998	2000
DODGE RAM2500 6CYL 3.9L	0.799	0	-	384	1990	1993
DODGE RAM2500 6CYL 5.9L CREWCAB DIESEL	0	-	0.277	5671	1998	2000
DODGE RAM2500 6CYL 5.9L CREWCAB DIESEL 4X4	0	-	0.276	16035	1998	2000
DODGE RAM2500 6CYL 5.9L DIESEL	0	-	0	1720	1997	1997
DODGE RAM2500 6CYL 5.9L DIESEL 4X4	0	-	0	3617	1997	1997
DODGE RAM2500 6CYL 5.9L DIESEL 4X4 HD LONGBED	0.581	-	0	9927	1994	1996
DODGE RAM2500 6CYL 5.9L DIESEL 4X4 LONGBED	0	-	1	4051	1998	2000
DODGE RAM2500 6CYL 5.9L DIESEL HD	1	0	-	4446	1990	1990
DODGE RAM2500 6CYL 5.9L DIESEL HD LONGBED	1	-	0	5572	1994	1996
DODGE RAM2500 6CYL 5.9L DIESEL LONGBED	0	-	1	1255	1998	2000
DODGE RAM2500 6CYL 5.9L EXTENDED CAB DIESEL	0	1	0.797	3356	1993	1999
DODGE RAM2500 6CYL 5.9L EXTENDED CAB DIESEL 4X4	0	-	0.801	5613	1995	1999
DODGE RAM2500 8CYL 5.2L	0.794	0	-	1473	1990	1993
DODGE RAM2500 8CYL 5.2L 4X4	0.755	0	-	1162	1990	1993
DODGE RAM2500 8CYL 5.2L 4X4 HD LONGBED	0.529	-	0	493	1994	1996
DODGE RAM2500 8CYL 5.2L EXTENDED CAB	0.752	1	-	170	1990	1993
DODGE RAM2500 8CYL 5.2L EXTENDED CAB 4X4	0.781	1	-	94	1990	1993
DODGE RAM2500 8CYL 5.2L HD LONGBED	1	-	0	1004	1994	1996

List of Dodge Ram Varieties (cont.)

Variety Name	CAFE	Offshoring Share		Average	Years in Sample	
	Share	1990-1993	1994-2000	Yearly Sales	First	Last
DODGE RAM2500 8CYL 5.9L	0.859	0	-	1961	1990	1993
DODGE RAM2500 8CYL 5.9L 4X4	0.737	0	-	2543	1991	1993
DODGE RAM2500 8CYL 5.9L 4X4 HD LONGBED	0.686	-	0	6635	1994	1996
DODGE RAM2500 8CYL 5.9L 4X4 LONGBED	0	-	0.698	3421	1997	2000
DODGE RAM2500 8CYL 5.9L CREWCAB	0	-	0.299	1460	1998	2000
DODGE RAM2500 8CYL 5.9L CREWCAB 4X4	0	-	0.259	4599	1998	2000
DODGE RAM2500 8CYL 5.9L EXTENDED CAB	0.109	1	0.779	1201	1990	1999
DODGE RAM2500 8CYL 5.9L EXTENDED CAB 4X4	0.024	1	0.826	2418	1991	1999
DODGE RAM2500 8CYL 5.9L HD LONGBED	1	-	0.004	2077	1994	1996
DODGE RAM2500 8CYL 5.9L LONGBED	0	-	0.816	1476	1997	2000
DODGE RAM3500 10CYL 8.0L	0	-	0	119	1997	1997
DODGE RAM3500 10CYL 8.0L 4X4	0	-	0	243	1997	1997
DODGE RAM3500 10CYL 8.0L 4X4 LONGBED	0.185	-	0.17	265	1994	2000
DODGE RAM3500 10CYL 8.0L CREWCAB 4X4 LONGBED	0	-	0	721	1998	2000
DODGE RAM3500 10CYL 8.0L CREWCAB LONGBED	0	-	0	450	1998	2000
DODGE RAM3500 10CYL 8.0L EXTENDED CAB	0	-	1	808	1997	1997
DODGE RAM3500 10CYL 8.0L EXTENDED CAB 4X4	0	-	1	1110	1997	1997
DODGE RAM3500 10CYL 8.0L EXTENDED CAB 4X4 LONGBED	0	-	0.978	889	1995	1996
DODGE RAM3500 10CYL 8.0L EXTENDED CAB LONGBED	0	-	0.985	835	1995	1996
DODGE RAM3500 10CYL 8.0L LONGBED	0.376	-	0.113	341	1994	2000
DODGE RAM3500 6CYL 5.9L CREWCAB DIESEL 4X4 LONGBED	0	-	0	6328	1998	2000
DODGE RAM3500 6CYL 5.9L CREWCAB DIESEL LONGBED	0	-	0	8075	1998	2000
DODGE RAM3500 6CYL 5.9L DIESEL	0	0	0	2695	1991	1997
DODGE RAM3500 6CYL 5.9L DIESEL 4X4	0	0	0	875	1990	1997
DODGE RAM3500 6CYL 5.9L DIESEL 4X4 LONGBED	0.351	-	0.234	854	1994	2000
DODGE RAM3500 6CYL 5.9L DIESEL HD	0	0	-	2643	1990	1990
DODGE RAM3500 6CYL 5.9L DIESEL LONGBED	0.321	-	0.166	1434	1994	2000
DODGE RAM3500 6CYL 5.9L EXTENDED CAB DIESEL	0	1	1	6881	1992	1997
DODGE RAM3500 6CYL 5.9L EXTENDED CAB DIESEL 4X4	0	1	1	3734	1992	1997
DODGE RAM3500 6CYL 5.9L EXTENDED CAB DIESEL 4X4 LONGBED	0	-	0.974	3237	1995	1996
DODGE RAM3500 6CYL 5.9L EXTENDED CAB DIESEL LONGBED	0	-	0.997	3996	1995	1996
DODGE RAM3500 8CYL 5.9L	0	0	-	542	1991	1993
DODGE RAM3500 8CYL 5.9L 4X4	0	0	-	360	1990	1993
DODGE RAM3500 8CYL 5.9L 4X4 LONGBED	0	-	0.46	77	1995	2000
DODGE RAM3500 8CYL 5.9L CREWCAB 4X4 LONGBED	0	-	0	123	1998	2000
DODGE RAM3500 8CYL 5.9L CREWCAB LONGBED	0	-	0	102	1998	2000
DODGE RAM3500 8CYL 5.9L EXTENDED CAB 4X4 LONGBED	0	-	0.985	67	1995	1997
DODGE RAM3500 8CYL 5.9L EXTENDED CAB LONGBED	0	-	0.987	74	1995	1997
DODGE RAM3500 8CYL 5.9L HD	0	0	-	538	1990	1990
DODGE RAM3500 8CYL 5.9L LONGBED	0	-	0.501	107	1995	2000