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Evidence from Uganda

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Managing Trade in Clunkers: Evidence from Uganda †

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Abstract

Many low-income countries rely on age-based imports restrictions to curb local pollution from motor vehicles. Yet the impact of these policies, unlike that of emission regulations in richer economies, is not well understood. In this paper, we investigate one such import restriction - an environmental tax levied on old vehicles - in the context of Uganda. Using a difference-in-differences framework, we estimate the effect of a stark increase in the levy in 2015 on imports and first-time registrations. In order distinguish the direct impact of the levy from substitution between age groups, we structurally estimate the market for "newly" imported vehicles and decompose the overall effect using counterfactual simulation. We find that the levy increase resulted in a substantial reduction of targeted vehicle imports, but that first-time registrations remain unaffected as end-users increasingly purchase old inventory from traders. In addition, we find that the magnitude of the consumer response is decreasing in vehicle age and evidence of substitution towards older vehicles due to the levy. These findings point to highly progressive levies or outright bans, ideally complemented by domestic regulation, for effective policy aimed at curbing vehicle emissions.

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1 Introduction

Substantial flows of "second hand" durable goods is a key feature of trade between the global North and the global South. Most prominently, hundreds of thousands of used vehicles are imported by low-income countries (LICs) from high-income countries (HICs) every year.[1,2] These used vehicles provide affordable mobility in places where only a small fraction of the population owns a car, but they also entail higher levels of pollution (due to older technology and physical depreciation) than their newer counterparts (Washburn et al., 2001; Bin, 2003; Beydoun and Guldmann, 2006).[3]

In an effort to mitigate the adverse environmental consequences of old vehicles, many LICs rely on age-based import restrictions (UNEP and UNECE, 2017). In contrast to emissions regulations in richer countries, however, these policies have received little attention in the economics literature and their impact is not well understood.[4] In particular, it is not clear how effective import restrictions are at "turning over" the existing vehicle stock in LICs given that these are typically not accompanied by domestic regulation. In addition, evidence of differential preferences for older vehicles and their characteristics (Grubel, 1980; Pelletiere and Reinert, 2006, 2010) suggest that the elasticity estimates from advanced economies do not accurately reflect the responsiveness of demand to tax-based interventions in LIC settings.

In this paper, we begin to fill this gap in the literature by studying one prominent such import restriction - a tariff levied on old vehicles - in the context of a natural experiment in Uganda. We ask the following overarching question: How effective is this "environmental levy" in reducing the influx of targeted vehicles onto Ugandan roads? We focus on the role of the existing vehicle stock (especially inventory among traders) as a buffer and on the relationship between the own-price elasticity and vehicle age. These are

[1] UN Comtrade data reveal that vehicles are consistently among the top-5 import categories for LICs (according to HS2 code), accounting for approximately 7% of value. The other top-5 categories comprise mechanical and electrical machinery, ships, and mineral products, with the durable goods categories accounting for a similar share on average. See Figure 5 in the Appendix for details.

[2] UN Comtrade data and national export statistics from Japan, the EU, and the US also show that the used share among personal vehicles imports into LICs (HS2 code 8703) has been rising from approximately 80% in 2006 to nearly 100% in 2018. See Figure 6 in the Appendix for details.

[3] Motor vehicles are a major source of ambient air pollution in cities around the world. According to the World Health Organization (WHO) and the Global Fuel Economy Initiative (GFEI), they are key contributors of carbon monoxide (CO), nitrogen oxides (NOx), Ozone (O_3), and airborne particulate matter (PM); and these substances are closely linked to adverse health and environmental outcomes, including soil/water acidification, increased risk of cardiovascular and respiratory diseases, cancer, and complications in childbirth. See WHO website at https://www.who.int/sustainable-development/transport/health-risks/air-pollution/en/ and a GFEI report by Macias et al. (2013) for further detail.

[4] Emissions regulations studied in rich countries oftentimes focus on policies targeting new vehicles. Some existing papers study the gains from trade in used vehicles, but these do not focus on LICs.

important aspects from a policy perspective in that they shed light on the relevance of domestic regulation and on the progressiveness of import taxes (i.e., the rate differences by vehicle age) required to incentivize importing younger vehicles.

We estimate the impact of the environmental levy by combining reduced-form and structural methods using administrative data on the universe of Ugandan vehicle imports and registration between 2013 and 2018.[5] Specifically, we first estimate a difference-in-differences (DID) model that makes use of a stark increase in the environmental levy on passenger vehicles in July 2015 while goods vehicles were unaffected. We investigate differences in the impact of this policy change between imports and the inflow of vehicles onto Ugandan roads (registrations). Doing this separately for private importers and traders, we can further assess the role of the import channel and trader inventory in these differences. Secondly, we estimate a structural model of the market for "newly imported" personal vehicles, representing demand as a static discrete choice following the seminal work by Berry et al. (1995) and distinguishing supply again by channel, directly from competitive international markets or from intermediate traders assumed to be Cournot competitors. The structural estimation allows us to distinguish the direct impact of the levy (i.e., effect of the tax increase) from substitution between different vehicle age groups that were all targeted by the policy change; the reduced-form analysis captures only the aggregate effect.

Our main DID model specification aggregates imports and registrations according to vehicle groups that were differentially "treated" by the policy change: passenger vehicles 6-9 years (levy increase from roughly 20% to 35% of import value), passenger vehicles 10 years old and above (levy increase from 20% to 50%), and goods vehicles (no levy throughout).[6] The estimates from this model show that imports of targeted passenger vehicles declined sharply due to the levy increase (by approximately 44% for 6-9 year old and 34% for 10+ year old vehicles). First-time registrations, on the other hand, are affected considerably less. Indeed, total registrations of vehicles 10 years old and above, which account for the vast majority of imports, do not respond to the levy change at all (registrations of 6-9 year vehicles decline by 30% relative to the 44% decline in imports).[7]

Estimating this model separately by supply channel (direct by end-users versus indirect via professional traders), we then shed light on the origin of the relatively low

[5] We also rely on additional data that are described in further detail in section 2. These include, in particular, domestic vehicle prices from two leading online sales platforms and detailed surveys underlying the Ugandan consumer price index (CPI).

[6] The pre-increase levy for 6 and 7 year old passenger vehicles was notably 0%. For the purposes of our study, however, we mostly group all vehicles of ages 6 to 9 years, given the relatively low number of vehicles in these age categories, especially in the 6 and 7 year old group.

[7] A disaggregated version of the DID model at the make/model/age-group level point to heterogeneous effects of the policy as the parameter estimates are qualitatively similar but considerably lower in magnitude than in the aggregated version.

responsiveness among first-time registrations. While registrations of directly-imported vehicles broadly follow imports (decline of 44% among 6-9 year old vehicles and 27% among 10+ year old vehicles), registrations of indirectly sourced vehicles exhibit no statistically significant change (6-9 year old vehicles) or even rise after the levy increase (10+ year old vehicles). Recovering a normalized measure of trader inventories from imports and registrations, we find evidence that the existing stock from before July 2015 contributed considerably to this. Inventories effectively created a buffer between imports and registrations, so that the influx of old vehicles onto Ugandan roads is upheld despite the decline in imports.[8]

The structural model estimated in the second part of our empirical analysis allows us to distinguish the direct effect of the levy from substitution between different targeted vehicle age groups. In response to the levy, end-users might, in principle, switch to younger vehicles or older vehicles, depending on their relative preferences for age and price. Our counterfactual simulations suggest that both types of substitution are present, but that substitution to older vehicles is more prevalent. In addition, we also find that the own-price elasticity is decreasing in vehicle age, so that those most relevant vehicles from a pollution standpoint are least affected by the levy. Combined with the substitution towards older vehicles, registrations of vehicles 16 years old and above do not decline at all in response to the levy increase. These findings suggest that effective policies aimed at reducing the influx of the oldest, most polluting vehicles require a highly progressive tax schedule and/or outright bans (as implemented in Uganda more recently).

This paper contributes most directly to two strands of the existing economics literature, studies of vehicle emissions regulation and those on the international trade in vehicles. The former focuses predominantly on various types of regulation for new vehicles in HICs, including consumer and firm responses to emissions standards (Goldberg, 1998; Reynaert, 2014) and their unintended consequences (Gruenspecht, 1982; Goulder et al., 2012; Jacobsen and van Benthem, 2015) or the impact of a variety of policies on new vehicle purchases, including fuel taxes, energy labels, and feebates (D'Haultfœuille et al., 2016; Grigolon et al., 2017). There are also several studies of emissions regulation in middle-income countries (MICs), but these cover almost exclusively license-plate-based driving restrictions, in cities in Latin America (Eskeland and Feyzioglu, 1997; Gallego et al., 2013; Carrillo et al., 2016; Zhang et al., 2017) or China (Gu et al., 2017; Viard and Fu, 2015; Wang et al., 2014).[9] LIC settings are, to our knowledge, entirely absent from

[8]The disaggregated DID model again points to heterogeneous effects for the reasons mentioned in the previous paragraph.

[9]These policies typically prohibit vehicles with certain license plate numbers (e.g., based on the last digit) from driving in urban areas during some days of the week. The most well-known such policy was probably the "Hoy No Circula" program implemented in Mexico City in 1989. The literature's focus has been on the policies' effectiveness and has uncovered several unintended consequences, including

this literature.

The literature on international vehicle trade also does not cover LIC setting, but it does include at least two studies of age-based import restrictions. The first of these by Clerides (2008) estimates the welfare gains from used vehicle imports into Cyprus and fits into a set of papers estimating the value of trade from (otherwise new) vehicles (Fershtman and Gandal, 1998; Tovar, 2012). The discrete choice models estimated in these papers are similar to the structural model in our study, but they focus on richer countries and do not address environmental considerations. The second study is a paper by Davis and Kahn (2010) analyzing vehicle emissions surrounding the partial liberalization of the secondary market between the United States and Mexico in 2005 (removing a ban on vehicles aged 10-15 years).[10] This paper is closest in topic to our study, but there are also several important differences. First, Davis and Kahn (2010) do not estimate the causal effect of the trade liberalization, but rather base their analysis on comparisons between vehicle groups (emissions of used traded vehicles versus existing stock) or over time (changes in entry/exit rates). The Ugandan setting, by contrast, features a plausible counterfactual group (goods vehicles) that allows us to estimate the causal impact of the import restriction; as do counterfactual simulations using the structural model. Second, the regulation studied in Davis and Kahn (2010) is a ban rather than a tax and therefore does not allow the authors to estimate price elasticities. Third, Mexico is a MIC with substantially higher per-capita income in 2005 than Uganda has today and with domestic production of new vehicles.[11] In addition, our paper, just like Davis and Kahn (2010), also contributes to a recognizedly sparse literature concerning the relationship between international trade and environmental pollution generated via consumption (Cherniwchan et al., 2017; Copeland and Taylor, 2003).

The remainder of this paper is structured as follows. Section 2 provides background information about the Ugandan vehicle sector and describes the data that we use in our analysis. Section 3 introduces the theoretical framework, which motivates both our reduced-form estimation of the levy impact on equilibrium quantities and the structural estimation. In section 4, we present our econometric analysis of the impact of the environmental levy increase. We first estimate a DID model to study the changes in equilibrium outcomes (i.e., imports and first-time registrations) and then the structural model to disentangle the direct impact of the levy from substitution between vehicle age groups. Section 5 discusses the estimation results holistically and, finally, section 6 provides con-

additional vehicle purchases and increased weekend driving.

[10]The trading ban remained for used vehicles outside this age range.

[11]Both consumer behavior and the political economy of trade liberalization may thus well be different from the LIC context we aim to capture. One measure succinctly summarizing the difference between MICs and LICs is the motorization rate: Mexico had a per-capita rate of 264 per mille in 2008, while Uganda today has one of 13 per mille.

cluding remarks.

2 Ugandan Setting & Data

Uganda presents an appropriate setting to study the impact of age-based import restrictions in LICs for a number of reasons. First, its imports reflects common features of international vehicle trade vis-a-vis LICs. Second, it recently implemented a stark change in its "environmental levy" for passenger vehicles while goods vehicles remained unaffected, allowing us to estimate the causal impact of the levy. Third, the available data for Uganda allow us to match imports and registration records at the vehicle level, which provides unusually rich information on vehicle characteristics and distribution channel. In this section, we discuss each of these aspects in more detail and provide descriptive statistics of imports and registrations during the period surrounding the levy change.

Ugandan Vehicle Imports in the Global Context

The share of used vehicles among passenger vehicle imports into LICs has been increasing over time and exceeded 90% since around 2010.[12] Uganda's passenger vehicle imports closely mirror this global pattern with 94% used condition and an average age of over 14 years during our sample period. In addition to the age profile, Uganda's vehicle imports also reflect the pronounced role of Japan as worldwide used vehicle exporter to LICs (not just for vehicles by Japanese manufacturers but used vehicles generally). Globally, Japan has for a long time been the primary origin for LIC vehicle imports with over 40% by value and over 30% by number since 2000 (even more when considering only right-hand-drive destinations).[13] Uganda has imported over over 80% of its vehicles from Japan since 2005 (over 90% since 2012). This matters in the sense that consumers in other LICs likely face similar vehicle choices as Ugandans if the common countries of origin are similar, an important criterion if we seek to draw general lessons from our study.

Environmental Levy Change

The Ugandan government has implemented a series of age-based import restrictions to curb environmental pollution since 2006. Our analysis focuses on an import tax increase on passenger vehicles over the age of 5 years that came into effect in July 2015.[14]

[12]See Figure 6 in the Appendix.

[13]Calculations based on UN Comtrade data.

[14]This "environmental levy" was first introduced in 2006 at 10% of the cost, insurance, and freight (CIF) value of the vehicle (raised to 20% in 2009) and was applicable to all passenger vehicles over the age of 8 years (inclusive). See Republic of Uganda Finance Act, 2006 and Republic of Uganda Finance

Specifically, the so called "environmental levy" was raised from 0% to 35% for passenger vehicles between 6 and 7 years old, 20% to 35% for passenger vehicles 8 and 9 years old, and from 20% to 50% for passenger vehicles 10 years of age or older.[15,16] The legislation for this policy change was notably signed into law on 31 May 2015, leaving one month between the official announcement of the the levy increase and its effective date. Goods vehicles were exempt from the environmental levy since its inception and provide a natural counterfactual group as they are likely subject to similar demand and supply shocks as passenger vehicles.[17] Our study focuses on the period from 2013 until 2017, during which this levy increase for passenger vehicles was the only relevant change.[18] This fortunate policy environment allows us to estimate the causal impact of the environmental levy on imports and registrations.

Distribution Channels

Vehicles imported into Uganda generally reach consumers via one of two "distribution channels".[19] The first and traditionally most common channel is *indirect* via professional traders that keep vehicles in a certified "car bond", an enclosed parking lot that serves as a pre-registration holding facility in country. Vehicles from these bonds are registered in Uganda once they are purchased from the trader, but they typically clear customs and incur the corresponding duties and taxes immediately upon importation.[20] This allows us to calculate the approximate time vehicles remain on inventory among traders, which turns out to be important in our analysis.

The second *direct* channel is characterized by end-users' importing the vehicle without a Ugandan trader as intermediary. In practice, this involves either traveling to the exporting country or purchasing the vehicle through online platforms that have become increasingly popular in recent years. These online platforms typically have a physical

Act, 2009.

[15]See the Republic of Uganda Finance Act, 2015.

[16]For the purposes of our study we mostly group all vehicles of ages 6 to 9 years, given the relatively low number in these age categories.

[17]Passenger vehicles are defined as those with Harmonized System (HS) codes 8702 and 8703 - i.e., "vehicles; public transport passenger type" and "motor cars and other motor vehicles; principally designed for the transport of persons", respectively. Goods vehicles are those with HS code 8704 - i.e., "vehicles; for the transport of goods".

[18]In October 2018, an even stricter set of polices came into effect, namely a ban on vehicles older than 15 years in conjunction with another amendment of the environmental levy. See Republic of Uganda Traffic and Road Safety Act 1998 (Amendment) Bill, 2018 for details.

[19]There is no domestic production of vehicles, although the government-owned company Kiira Motors has been engaged in vehicle development since 2007 and plans completion of a production plant by 2021.

[20]Traders have some flexibility in this timing by delaying customs clearance. If this occurs, they are, however, charged a "demurrage fee", so that most vehicles imported by traders clear customs several months before end-user registration.

office in Uganda to assist with purchases, but do not hold any vehicle inventory.[21] The emergence of these platforms since around 2014 is understood to have reduced barriers for end-users to purchase vehicles directly from international markets by precluding the need for contacts in origin countries or travel for inspection of vehicles that traders traditionally relied on.

2.1 Data

In order to study the impact of the 2015 environmental levy increase on the Ugandan vehicle sector, we rely primarily on two sources of administrative data from the Uganda Revenue Authority (URA), the country's tax authority. These are vehicle imports from the URA's ASYCUDA customs system and vehicle registrations from the URA's e-tax database, covering the period from January 2013 to June 2018.

Crucially, these databases are maintained at the vehicle-transaction level (i.e., import line item / registration-entry) and feature identifiers that allow us to match individual vehicles across the two sources.[22] This is important for two reasons. First, the registrations provide vehicle characteristics beyond the standard HS-code descriptions that are typically captured by trade data, in particular the vehicle make, model, and manufacturing year. In combination with the four-digit HS-code, the manufacturing year allows us to classify imported vehicles into those targeted by the levy increase and those not targeted. Make and model provide detailed vehicle characteristics, which is typically impossible based on public trade data. The import data, in turn, provide information on the date of entry into the country and the delivered vehicle prices at the border - i.e., cost, insurance, and freight (CIF) - that are not available in the registrations.

Second, the matched records allow us to consistently track vehicles from their entry into Uganda right through to their first domestic owner and then subsequent owners if the vehicle is sold on.[23] In combination with the anonymized tax-identification numbers (TIN), this allows us to distinguish between the different distribution channels (i.e., indirect versus direct) and measure the time held in inventory among traders.

In addition to the administrative data, we also bring to bear information on domestic prices from two leading online vehicle sales platforms in Uganda - i.e., Cheki.co.ug and Cars.co.ug - and from surveys by the Ugandan Bureau of Statistics (UBOS) underlying the construction of the consumer price index (CPI). These three sources provide just over 24,000 raw price points for individual vehicles by make, model, manufacturing year, and month of observation and represent, in our opinion, the most comprehensive set of

[21] The most prominent such online platform currently is https://www.beforward.jp/beforward_uganda.

[22] This match was possible for over 90% of imports and over 86% of registrations over our sample period.

[23] Given that changes of ownership after the first registration (i.e., private re-sales) are suspiciously rare in the registrations data, we focus our analysis on first-time registrations.

domestic prices available for the country from secondary sources.[24]

Basic Import and Registration Patterns

Figure 1 shows the monthly number of passenger vehicles imported by age group from 2013 to 2017, separately for the direct channel (top panel) and the indirect channel (bottom panel). The month of the levy increase, July 2015, is marked with a dashed vertical line. Several observations are of note here. First, the vast majority of vehicles imported by both end-users (direct channel) and traders (indirect channel) are at least 10 years old; indeed over one-third of all imports are over 15 years old. Secondly, these age groups show a sharp rise in imports in June 2015 as end-users and traders rush to get vehicles through customs before the new policy comes into effect at the beginning of July of that year. After the policy change, imports collapse markedly and gradually return to pre-period levels in early- to mid-2017.

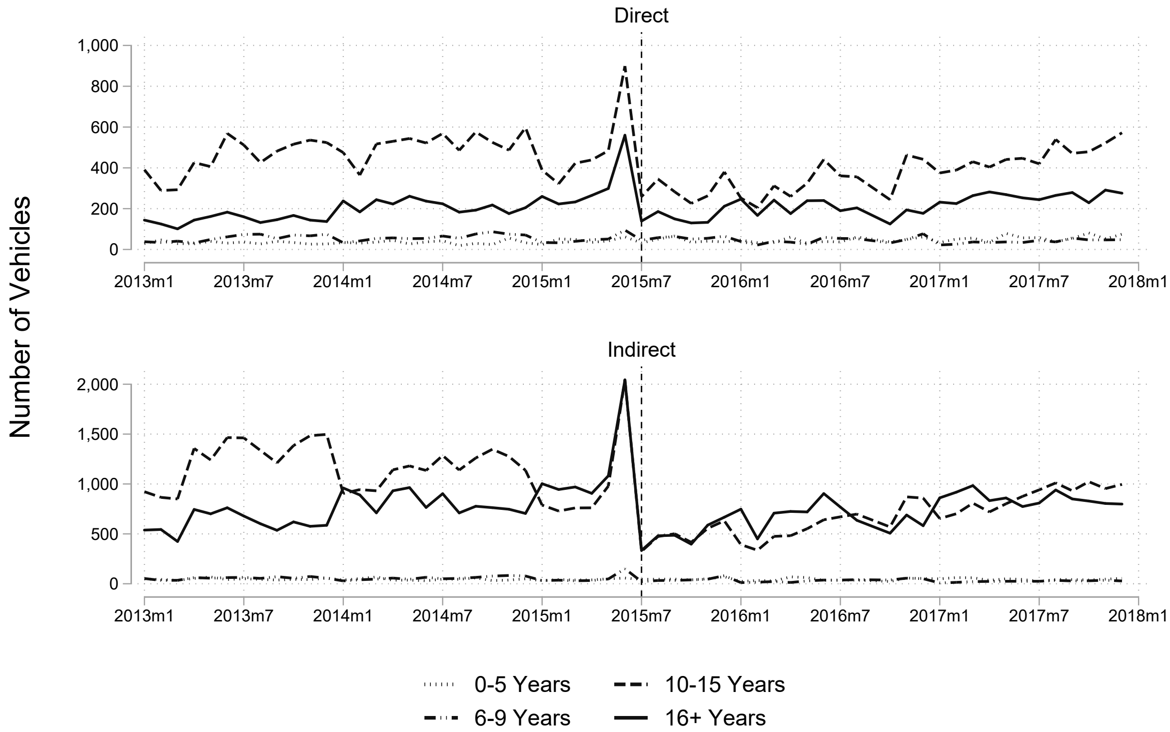
These changes in vehicle imports unsurprisingly map into registrations with some lag, especially via the indirect channel that involves resale to the end-user. This can be seen in Figure 2, which plots the monthly number of new registrations by channel for the same period and age groups as in Figure 1. Registrations from the direct channel broadly follow a smoothed version of the dynamics observed among imports, peaking just before the levy increase, dipping thereafter, and then increasing gradually.

Registrations from the indirect channel, however, show no stark relationship with the levy increase as was the case with imports. Instead, throughout the sample period, they are relatively uniform among 10-15 year old vehicles and steadily increasing among vehicles over 15 years old. There is some indication of an acceleration in the older age group around half a year after the levy change (relative to the 18 months before), but this is much less striking than the dynamics among imports or registrations in the direct channel.

One important difference between the direct and the indirect channel is the dampening effect that trader inventories can have on the relationship between imports and registrations. While we cannot observe the actual stock of vehicles for resale among traders, we can use cumulative net imports (i.e., imports less registrations in the indirect channel) as a measure of the stock normalized to the beginning of the sample period. Figure 3 plot this measure of inventory, in addition to the underlying imports and registrations in

[24]Nonetheless, both international and domestic prices do not cover vehicles (according to make, model, manufacturing year) for all possible time periods required for the structural estimation. We therefore need to interpolate prices to "fill in" the characteristics for the entire choice set and provide a detailed description of the procedure in the Data Appendix. This is a common issue in discrete choice demand estimation, especially for used goods for which posted prices may not be available (see, e.g., Clerides, 2008).

Figure 1: Passenger Vehicle Imports by Channel & Age Category



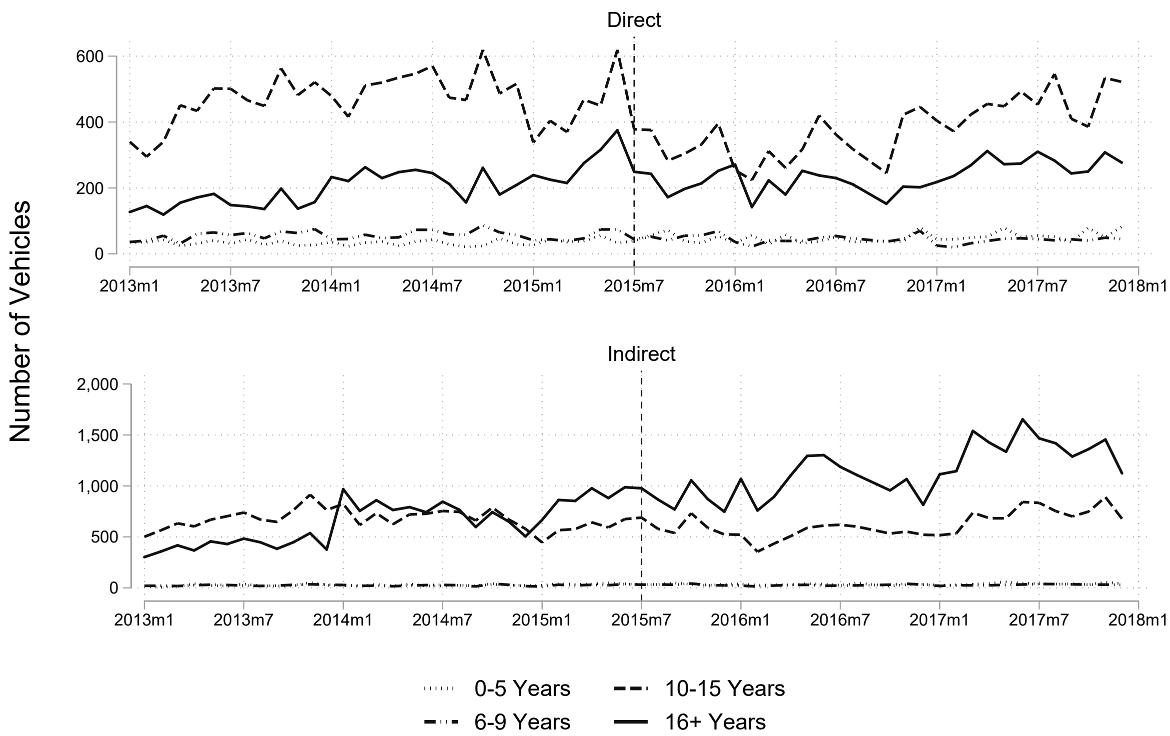
Notes: Imports are limited to passenger vehicles, i.e., those classified under HS-codes 8702 and 8703 and are restricted to vehicles with matching registration entry. The direct channel comprises imports, for which the importer and registering entity are the same (and not a professional trader); the indirect channel comprises imports, for which they differ (or are a professional trader).

the indirect channel. It shows that the inventory of passenger vehicles available for resale in Uganda built up throughout 2013, rising more slowly from then until the beginning of 2015, and peaking in June 2015 sharply due to the spike in imports. With imports depressed after the levy change, the level of registrations appears to be sustained from this previously accumulated stock. The inventory declines sharply as a result and even the gradual recovery of imports by traders does not allow for a catch up in light of the rising number of registrations. Net contributions continue to be negative throughout the remainder of the sample period. These observations are important for the interpretation of the results from the more formal empirical analysis in the next section.

3 Theoretical Framework

We view the motor vehicle sector in Uganda through the lens of a structural model, in which end-users make discrete choices over vehicles and retailers in Uganda compete by

Figure 2: Passenger Vehicle Registrations by Channel & Age Category



Notes: Registrations are limited to passenger vehicles, i.e., those classified under HS-codes 8702 and 8703 and are restricted to vehicles with matching customs entry. The direct channel comprises registrations, for which the importer and registering entity are the same (and not a professional trader); the indirect channel comprises registrations, for which they differ (or are a professional trader).

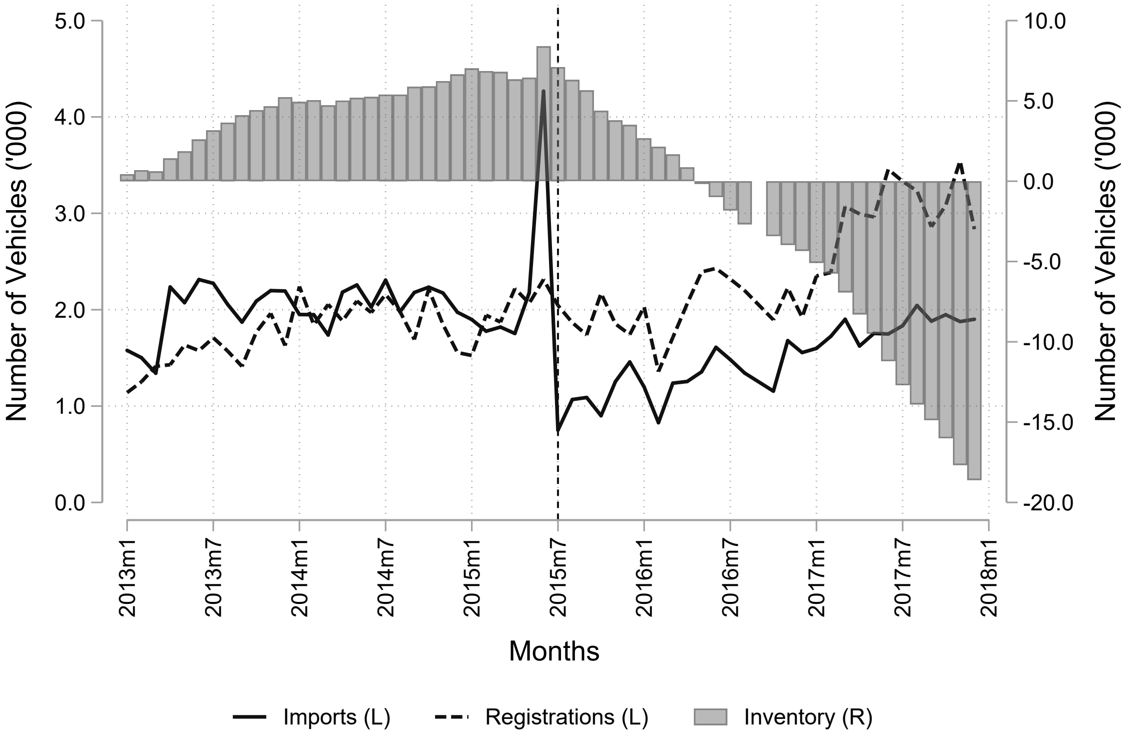
setting quantities.[25] This model provides a framework through which we (i) interpret our (reduced-form) analysis of the levy's impact on equilibrium market outcomes and (ii) disentangle the direct impact of the levy increase from substitution between different age groups.

3.1 Demand

We assume that an eligible part of the Ugandan population corresponding to the current motorization rate, M_t, purchases at most one vehicle in any period $t = 1, \ldots, T$ and denote these end-users by $i = 1, \ldots, M_t$. Vehicle choices are denoted by $j = 0, \ldots, J_t$, where $j = 0$ is the outside good (no purchase) and where vehicles are defined according to their make, model, manufacturing year, and channel (direct import vs. domestic

[25]Our model is closely aligned with the large volume of literature on static discrete choice models following Berry (1994); Berry et al. (1995).

Figure 3: Trader Inventory of Passenger Vehicles



Notes: Data are limited to passenger vehicles, i.e., those classified under HS-codes 8702 and 8703 and are restricted to vehicles with registrations and customs entries. They are also restricted to the indirect channel: different importer and registering entity or the same but a professional trader. Inventory is measured as the cumulative value of imports less registrations relative to the level in January 2013.

purchase from a trader).[26] Consumer i derives indirect utility $u_{ijt} = u(\mathbf{x_{jt}}, \xi_{jt}, \epsilon_{ijt})$ from choosing vehicle j in period t, where the utility is a function of (from our perspective as researchers) observable vehicle characteristics, $\mathbf{x_{jt}}$, an unobservable vehicle-specific valuation, ξ_{jt}, and an unobservable individual-specific valuation ϵ_{ijt}. Consumers maximize utility by choosing a vehicle j and their choices are random from our perspective, with probabilities $s_{ijt} = \mathbb{P}[u_{ijt} > u_{ikt} \ \forall \ k \neq j]$. We obtain the expected vehicle share (out of the eligible population) by averaging s_{ijt} over all consumers:

[26]The distinction between channels is important, because very similar vehicles (in some instances the same make, model, and manufacturing year) are purchased through both channels despite the fact that local prices tend to be substantially higher than effective import prices. This suggests that not all consumers have access to international markets and/or discount the value of direct imports. Such discounting may reflect, for instance, that personal inspection is only possible via travel to the exporting country - a direct importer either incurs the travel cost or takes the additional risk of purchasing a "lemon" from a very distant seller without personal inspection. Such discounting may prevail despite roadworthiness inspections in exporting countries or seller warranties in light of limited trust.

$$s_{jt} = \frac{1}{M_t} \sum_{i=1}^{M_t} s_{ijt} \quad (1)$$

Similarly, the expected number of type j vehicles is $q_{jt} = s_{jt}M_t = \sum_{i=1}^{M_t} s_{ijt}$. Both, s_{jt} and q_{jt} are representations of end-user demand (and, conditional on M_t, equivalent) in this differentiated product context and therefore are a function of all vehicle prices as well as other characteristics.

We then parameterize indirect utility linearly according to a standard "nested-logit" specification:

$$\begin{aligned} u_{ijt} = \mathbf{x_{jt}}\beta + \alpha^p p_{jt} + \alpha^a a_{jt} + \alpha^d d_j + \xi_{jt} \\ + \zeta_{igt} + (1-\sigma)\epsilon_{ijt} \end{aligned} \quad (2)$$

, where $\mathbf{x_{jt}}$, p_{jt}, a_{jt}, and d_j denote a vector of observable vehicle characteristics, the vehicle price, vehicle age, and an indicator for direct imports, respectively; where ξ_{jt} are unobservable vehicle characteristics; and where $\upsilon_{ijt} \equiv \zeta_{igt} + (1-\sigma)\epsilon_{ijt}$ denotes an individual-specific unobservable valuation of the vehicle. Observable vehicle characteristics include engine capacity, tire diameter, and manufacturer country.[27] Nesting groups are denoted as g and σ is the corresponding within-group correlation coefficient. The nesting groups are defined according to engine-size category / channel pairs (i.e., up to 1600 cc, between 1600 and 2500 cc, and above 2500 cc, each for direct and indirect imports) and the outside option. Following the standard variance component structure for nested-logit models proposed by Cardell (1997), we assume that ϵ_{ijt} is i.i.d. type-I extreme value and ζ_{igt} is i.i.d. $C(\sigma)$, independent of ϵ_{ijt}, so that the aggregate term υ_{ijt} is also distributed type-I extreme value. This allows for correlation of the individual-specific error terms within groups, reflecting the notion that a given end-user will view vehicles with similar characteristics (in terms of engine size and channel) as closer substitutes.

We denote mean utility of vehicle j by $\delta_{jt} = \mathbf{x_{jt}}\beta + \alpha^p p_{jt} + \alpha^a a_{jt} + \alpha^d d_j + \xi_{jt}$ and normalize the outside option $\delta_{0t} = 0$, so that $u_{i0t} = \zeta_{i0t} + (1-\sigma)\epsilon_{i0t}$. As shown in Berry (1994), we can then derive the following estimating equation that relates empirical product shares to observable characteristics and nesting-group shares:

$$\begin{aligned} ln(s_{jt}/s_{0t}) = \mathbf{x_{jt}}\beta + \alpha^p p_{jt} + \alpha^a a_{jt} + \alpha^d d_j \\ + \sigma ln(s_{j|g,t}) + \xi_{jt} \end{aligned} \quad (3)$$

[27] These characteristics are defined as the mode or median when more than one value per vehicle is available in the data.

3.2 Supply

Vehicles are supplied to Uganda from the international market, either directly to end-users or via traders. We assume that international supply is competitive, which is supported by two key observations. First, over 90% of vehicles imported into Uganda are already second-hand, so that supply is, in principle, possible from a very diffuse range of sources. Second, the vast majority of of these vehicles come from Japan, a country with a particularly liquid used-car market characterized by a multitude of auction houses and even more exporters.

Unlike the international market, we assume that the domestic market is characterized by an oligopoly of vehicle traders who may, in principle, charge a markup above marginal cost. Specifically, we assume that domestic vehicle traders are Cournot competitors, choosing nonenegative quantities for each make / model / age-group triplet for the vehicles available internationally to maximize per-period profits. While this setup diverges from the differentiated-product Bertrand model that is standard in much of the discrete choice literature, it is more appropriate for our setting. Traders typically import vehicles prior to offering them for sale to end-users, so that quantities are fixed in the short run. They also tend to maintain very similar inventory and locate in business clusters, so that differentiation at the firm-level is minimal.[28]

Suppose the per-period profits of firm f are are given by:

$$\Pi_{ft} = \sum_{j=1}^{J_t} \left[p_{jt}(\mathbf{Q_t}) - c_{jft} \right] q_{jft} \tag{4}$$

, where $p_{jt}(\mathbf{Q_t})$ denotes inverse demand as a function of the vector of market quantities $\mathbf{Q_t}$, c_{jft} the marginal cost, and where q_{jft} is the quantity of vehicle j held on inventory in period t. Let $\left\{1, \ldots, \tilde{J}_t\right\}$ be the set of products that are supplied in equilibrium. Then the necessary first-order condition for profit maximization for each $j \in \left\{1, \ldots, \tilde{J}_t\right\}$ is:

$$\frac{\partial \Pi_{ft}}{\partial q_{jft}} = \left[p_{jt}(\mathbf{Q_t}) - c_{jft} \right] + \sum_{k=1}^{\tilde{J}_t} \frac{\partial p_{kt}}{\partial Q_{jt}} q_{kft} = 0 \tag{5}$$

Stacking equations 5 for all $\tilde{J}_t$ products in period t and denoting by $\tilde{\mathbf{Dp}}(\mathbf{Q_t})$ the conformable matrix of partial derivatives for vehicles held on inventory (with entries $\{\partial p_{kt}/\partial Q_{jt}\}_{jk}$), we then obtain the following system of necessary conditions:

[28] This excludes some traders of very new very new vehicles and official distributors that account for only a very small fraction of sales in Uganda.

$$\mathbf{p_t} = \mathbf{c_{jft}} - \tilde{\mathbf{Dp}}(\mathbf{Q_t})\mathbf{q_{ft}} \tag{6}$$

This is simply the Cournot-equivalent to the standard differentiated-product Bertrand pricing equation (see, e.g., Berry, 1994; Berry et al., 1995). Importantly and similar to the Bertrand case, we can relate equation (6) to the demand system from the previous subsection, by assuming that there are N_t identical traders in period t (with $c_{fjt} = c_{jt}$) and imposing a symmetric equilibrium, so that $q_{fjt} = (1/N_t) \cdot M_t \cdot s_{jt}$. This allows us to rewrite market shares in terms of the aggregate quantity $s_{jt} = Q_{jt}/M_t$ and it follows that $\partial Q_{jt}/\partial p_{jt} = M_t \partial s_{jt}/\partial p_{jt}$. Finally, we recognize that, by the inverse function theorem, we can obtain the Jacobian of the inverse demand function $\mathbf{Dp_t} = \mathbf{Dp(Q_t)}$ for the entire market from the Jacobian of the demand function $\mathbf{DQ_t} = \mathbf{DQ(P_t)}$ by matrix inversion $\mathbf{Dp_t} = [\mathbf{DQ_t}]^{-\mathbf{1}}$.[29] The matrix only containing the entries for vehicles on inventory, $\tilde{\mathbf{Dp}}(\mathbf{Q_t})$, as required for equation (6) above can be constructed using the appropriate elements of the market level Jacobian of the inverse demand function, $\mathbf{Dp_t}$. Let us denote that matrix as $\tilde{\mathbf{Dp}}(\mathbf{Q_t}) = [\mathbf{DQ}(\tilde{\mathbf{p_t}})]^{-\mathbf{1}} = (1/M_t)[\mathbf{Ds}(\tilde{\mathbf{p_t}})]^{-\mathbf{1}}$, and substitute into equation (6), so that:

$$\begin{aligned} \mathbf{p_t} &= \mathbf{c_{jt}} - (1/M_t)[\mathbf{Ds}(\tilde{\mathbf{p_t}})]^{-\mathbf{1}}(M_t/N_t)\mathbf{s_t} \\ &= \mathbf{c_{jt}} - (1/N_t)[\mathbf{Ds}(\tilde{\mathbf{p_t}})]^{-\mathbf{1}}\mathbf{s_t} \end{aligned} \tag{7}$$

Beyond the construction of $[\mathbf{Ds}(\tilde{\mathbf{p_t}})]^{-\mathbf{1}}$ from the market-level Jacobian as outlined above, this expression is very familiar from the existing discrete choice literature. Prices are a linear function of marginal cost plus a markup term that can be derived from the parameters of the demand system and accommodates marginal cost pricing when $(1/N_t)[\mathbf{Ds}(\tilde{\mathbf{p_t}})]^{-\mathbf{1}}\mathbf{s_t} = \mathbf{0}$. It is worth highlighting that equation (7) is now a "market level" equation. This is important, because the demand system is estimated at the market level, so that we require a way to link the market level demand parameters to the firm-specific optimality conditions.

Finally, we assume that marginal costs are linear in product characteristics $\mathbf{w_{jt}}$, so that $c_{jt} = \mathbf{w_{jt}}\gamma + \omega_{jt}$. Substituting this parametrization into equation (7) and denoting the matrix of stacked characteristics by capital $\mathbf{W_t}$, we obtain the following expression for the marginal costs:

$$\mathbf{p_t} + (1/N_t)[\mathbf{Ds}(\tilde{\mathbf{p_t}})]^{-\mathbf{1}}\mathbf{s_t} = \mathbf{W_t}\gamma + \omega_\mathbf{t} \tag{8}$$

[29] This holds under standard regularity conditions. See Sydsaeter et al. (2008) for the exact statement of the theorem.

3.3 Market Clearing

We assume the vehicle market clears period-by-period, so that the number of vehicles demanded as given in equation (1) is equal to the supply of vehicles by traders as given implicitly in equation (8) for the indirect channel and equal to the perfectly elastic supply from the international market for the direct channel. For the remainder of this paper, we denote the market-clearing equilibrium values by an asterisk, e.g., q_{jt}^* as the equilibrium number of type-j vehicles demanded and supplied in period t.

4 Econometric Analysis

We analyze the impact of the 2015 levy change in Uganda via two broad empirical strategies. First, we estimate a reduced-form model of equilibrium imports and first-time registrations, leveraging goods vehicles as the natural "control group" in the Ugandan context to measure counterfactual outcomes. Second, we estimate the structural model from the previous section to investigate how end-users value vehicle price and age. The structural estimates allow us to conduct counterfactual simulations that isolate the impact of the levy change from substitution between different vehicle age groups that were targeted by the levy increase.

4.1 Levy Impact on Equilibrium Quantities

Our reduced-form estimation in this sub-section analyzes the impact of the levy increase on the equilibrium quantities. Specifically, we focus on imports and first-time registrations by channel, as these capture different aspects of the market-clearing quantities. Imports and registrations in the direct channel both measure realized transactions (with slight timing differences) and are the empirical counterpart to the theoretical equilibrium quantities. The same also applies to registrations in the indirect channel. Imports in the indirect channel, however, represent the *additional* vehicles required by traders to optimize inventory; they are the equivalent to the number of vehicles produced in the context of new vehicles. While these should, in the long run, approximately equal the number of vehicles purchased (i.e., first-time registered), this not the case in the years immediately following the levy change.

In line with these differences between imports and registrations and between channels, there are also differences in the interpretation of the levy impact. Given that international supply is competitive, the primary impact on imports and registrations in the direct channel reflects a movement along the demand curve.[30] In the indirect channel, on the

[30]The simultaneous change in the levy for imports in the indirect channel means that there are also second-order effects due to substitution between domestic purchases from traders and direct imports.

other hand, the levy impact may, in principle, be mitigated by the intermediation via traders as these absorb part of the levy increase through lower margins. Imports and registrations in this channel may also respond quite differently as the former measures additions to trader inventory while the latter represent transactions that rely on the entire vehicle inventory as supply.

We estimate the causal impact of the levy change on these different measures by contrasting imports / registrations of passenger vehicles targeted by the policy with those of goods vehicles. Goods vehicles were explicitly excluded from the environmental levy but likely respond to common demand and supply shocks. Specifically, we estimate DID regression models, first disaggregated at the level of vehicle make/model/age-group and second aggregated across vehicles to the treatment group level. We also discuss robustness and the validity of the identifying parallel-trends assumption underlying our causal interpretation in the context of an event-study design that is closely related to the disaggregated DID model.

The estimating equation for the disaggregated DID model takes the following standard two-way fixed effects form (de Chaisemartin and D'Haultfœuille, 2019) at the level of vehicle j and month t, where j is defined according to the make, model, and treatment group g (i.e., passenger vehicles 6-9 years old, passenger vehicles 10+ years old, and goods vehicles of any age group). We notably diverge here slightly from the vehicle j definition as given in the previous section, namely by distinguishing treatment groups (and thereby vehicle age) rather than manufacturing year. In doing so, we avoid concerns about the validity of estimators that have recently been shown to arise in the context of DID models with time-varying treatment (, e.g., Goodman-bacon et al., 2018).

$$y_{jgt} = \lambda_j + \tau_t + \sum_h \left\{ \beta_h^{(p)} D_{jht}^{(p)} + \beta_h^{(l)} D_{jht}^{(l)} \right\} + \epsilon_{jgt} \tag{9}$$

The left hand side variable y_{jgt} denotes the inverse hyperbolic sine of the number of imports / registrations.[31] The variables $D_{jht}^{(p)}$ and $D_{jht}^{(l)}$ are treatment indicators for the passenger vehicles age group h (6-9 years and 10+ years) and the post-intervention *(p)* and lead *(l)* time periods (i.e., months after the policy change and the month prior to its becoming effective). Accounting separately for these periods is important as legislature for the levy change passed one month before its effective date. The terms λ_j and τ_t are vehicle and period-specific fixed effects and ϵ_{jgt} is the error term. The coefficients of interest, $\beta_h^{(p)}$ and $\beta_h^{(l)}$, capture the average impact of the levy change (across vehicle

[31] Similar to the natural logarithm, the inverse hyperbolic sine allows for coefficient estimates to be interpreted as percentage changes. Unlike the natural logarithm, however, the inverse hyperbolic sine is defined at zero (Burbidge et al., 1988). This is useful in our context as many vehicle make/model/age-group triplets have no transactions in certain months.

make/model/age-group cells and months).

The aggregate DID model takes the following form:

$$y_{gt} = \lambda_g + \tau_t + \sum_h \left\{ \beta_h^{(p)} D_{ht}^{(p)} + \beta_h^{(l)} D_{ht}^{(l)} \right\} + \epsilon_{gt} \quad (10)$$

Equation (10) differs from the disaggregated version in that the cross-sectional units, g, are treatment groups (and that the outcome variable, fixed effects, and treatment indicators reflect this). The left hand side variable, y_{gt}, notably is the natural logarithm of imports / registrations as all observations have positive quantities. The coefficients of interest, $\beta_h^{(p)}$ and $\beta_h^{(l)}$, capture the average impact of the levy change across months, but in terms of the aggregate quantities. As such, they implicitly give more weight to large vehicle make/model/age-group cells than the disaggregated model.[32]

Identification

The identification assumption underlying the causal interpretation of these models is the standard parallel-trends assumption. Specifically, we assume that in the absence of the levy increase, passenger groups that were targeted by the policy, would have evolved according to equations (9) and (10) with $D_{ht}^{(p)} = D_{ht}^{(l)} = 0$ for all groups h. In the following paragraphs, we discuss evidence in support of this assumption (details are included in the Appendix).

For the disaggregated model, we estimate the difference between passenger and goods vehicle imports / registrations separately for each month using an event study design. This event study corresponds directly to equation (9), with monthly treatment indicators rather than those for the post and lead-period.[33] The coefficients on the monthly treatment indicator variables from these regressions (normalized for May 2015) are plotted in Figures 7 and 8 in the Appendix. The point estimates are shown as the black line and 95% confidence intervals are shaded in gray. These event studies lend strong support for the validity of the parallel-trends assumption among 10+ year old vehicles, which represent the vast majority of imports / registrations, but less so for vehicles aged 6-9 years. For the older vehicles, the coefficient estimates vary from month to month (more so for registrations than imports), but are broadly centered around and statistically indistinguishable from zero. This is not the case for the younger vehicles, whose point

[32]This relationship can also be confirmed by running weighted regressions of the disaggregated model. We do not report results from these weighted regressions, however, as the coefficient estimates are not unbiased estimators of some (average) treatment effect (Solon et al., 2013).

[33]The precise estimating equation for the event study design is $y_{jgt} = \lambda_j + \tau_t + \sum_t \beta^{(t)} D_{jgt}^{(t)} + \epsilon_{jgt}$, where $D_{jgt}^{(t)}$ denotes the indicator for treatment group g and period t. We estimate this equation separately by treatment group.

estimates diverge from zero more notably. This suggests that the results for 6-9 year old vehicles need to be interpreted with some caution. Given their relatively small share of imports/registrations, however, this does not affect the main findings of this paper.

The aggregated DID model does not allow for an equally rigorous assessment of the parallel-trends assumption as the disaggregated version. This is the case, because there are only a three treatment groups for any given month, so that statistical inference is not possible. Instead of conducting an event study, we therefore plot the difference between treatment and control group in terms of the natural logarithm of the number of imports / registrations, normalized by the average difference in the pre-period (see Figures 9 and 10 in the Appendix).[34] Visual observation suggest that the parallel trends assumption is reasonable in the aggregated case. The pre-period trends appear to be common among treatment and control groups for all treatment groups and channels, possibly with the exception of registrations of 6-9 year old vehicles in the direct channel.[35]

Results

Tables 1 and 2 below report the estimated coefficients on the treatment indicators from the disaggregated and the aggregated DID model, respectively. In each case, we estimate the model for the number of imported / registered vehicles separately by channel and the total for both channels. The results are qualitatively similar across the two levels of aggregation, but the magnitudes of the point estimates and the implied impact of the levy change are substantially higher in the aggregate model. This difference is due to greater-magnitude impacts of the levy among higher-volume vehicles; these receive the same weight as low-volume vehicles in the disaggregated DID model, but are effectively weighted by the number of vehicles in the aggregate version. Both models offer valuable insights. The disaggregated model provides us with an understanding of the levy impact on imports / registrations at the level of our theoretical framework and the structural estimating equations (see next subsection). The aggregate model, on the other hand, provides us with quantitative estimates of the overall impact of the levy to understand the total flow of vehicles onto Ugandan roads.

[34]This approach essentially mimics the point estimate of the event study.

[35]The series for 6-9 year old vehicles also exhibit much more variation from month to month. This is, however, unsurprising given the lower number of vehicles in this age category.

Table 1: Vehicle-Level DID Regressions of Imports and Registrations

	Imports			Registrations		
	Direct	Indirect	Total	Direct	Indirect	Total
Post x Passenger (6-9)	-0.052***	-0.028	-0.061**	-0.082***	-0.010	-0.040**
	(0.017)	(0.022)	(0.024)	(0.016)	(0.016)	(0.017)
Post x Passenger (10+)	-0.082***	-0.086***	-0.118***	-0.094***	0.047**	-0.009
	(0.024)	(0.029)	(0.033)	(0.023)	(0.021)	(0.022)
Lead x Passenger (6-9)	-0.052	0.027	0.001	-0.018	-0.053**	-0.024
	(0.033)	(0.031)	(0.037)	(0.028)	(0.026)	(0.030)
Lead x Passenger (10+)	0.177***	0.148***	0.218***	0.097***	0.015	0.098***
	(0.037)	(0.034)	(0.039)	(0.032)	(0.028)	(0.031)
Obs.	62,068	62,068	62,068	61,242	61,242	61,242
R-Squared	0.729	0.837	0.817	0.781	0.866	0.852

Notes: Table reports the coefficients on the treatment indicators from estimating equation (9). Observations are the inverse hyperbolic sine of make/model-level monthly imports and registrations of passenger vehicles by age group (6-9 years or 10+ years) or goods vehicles (without age distinction) for the period from January 2013 through December 2017. Specifications are estimated separately by channel (direct vs. indirect) and in aggregate as indicated in the column headers. Fixed effects for the vehicle make/model, seasonal variation (month-of-year), and period (month-of-observation) are included in all specifications. Standard errors are clustered at the make/model level and reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

The results from both levels of aggregation yield three key, qualitatively similar, implications for the impact of the levy change. First, imports of targeted passenger vehicles decreased (substantially) as a result of the levy change and this drop is mostly reflected across channels. The point estimates of the post-period treatment indicator implies a reduction in total imports of approximately 44% and 34% among 6-9 year old vehicles and 10+ year old vehicles, respectively (average reduction of 6% and 12% at the vehicle level).[36] Second, the levy impact on registrations in the direct channel roughly mirrors the reduction among imports, but this is not true for the indirect channel. In the latter case, the coefficient on the post-period treatment indicator is not statistically different from zero for 6-9 year old vehicles and even positive for 10+ year old vehicles (increase of 12% at the aggregate level or 5% at the vehicle level). This provides econometric evidence for the notion that registrations are buffered considerably by existing trader inventory (as discussed in relation to Figure 3 in section 2.1), allowing the flow of vehicles onto Ugandan roads to be maintained despite the drop in imports. Third, targeted passenger vehicle imports increased sharply in the month prior to the policy change, especially among 10+ year old vehicles (by approximately 32% at the aggregate level and 22% at the vehicle

[36] Recall that the 6-9 year old group is much smaller in volume than the 10+ year old group, so that the results for the older vehicles are more reflective of the aggregate levy impact across all vehicles.

level).[37] This suggests that end-users and traders import some vehicles earlier than they would have otherwise in an effort to beat the effective date of the higher levy. While this temporal substitution likely contributed to the drop after the policy change, we note that the former only affected a single month while the post-period extends over 30 months from July 2015 to December 2017. Similarly, this spike in imports in the indirect channel certainly facilitated the buffering effect of trader inventories, but its contribution as a share of the overall stock accumulated before the levy change is still rather limited.

Table 2: Aggregate DID Regressions of Vehicle Imports and Registrations

	Imports			Registrations		
	Direct	Indirect	Total	Direct	Indirect	Total
Post x Passenger (6-9)	-0.413***	-0.598***	-0.441***	-0.443***	-0.037	-0.300***
	(0.081)	(0.106)	(0.084)	(0.068)	(0.062)	(0.056)
Post x Passenger (10+)	-0.326***	-0.328***	-0.337***	-0.268***	0.116**	0.002
	(0.064)	(0.078)	(0.064)	(0.052)	(0.045)	(0.041)
Lead x Passenger (6-9)	-0.031	0.682***	0.386***	0.118***	0.240***	0.149***
	(0.056)	(0.054)	(0.051)	(0.041)	(0.046)	(0.035)
Lead x Passenger (10+)	0.186***	0.382***	0.317***	0.224***	0.075**	0.127***
	(0.042)	(0.036)	(0.034)	(0.032)	(0.034)	(0.027)
Obs.	177	177	177	177	177	177
R-Squared	0.978	0.983	0.985	0.987	0.995	0.994

Notes: Table reports the coefficients on the treatment indicators from estimating equation 10. Observations are the natural logarithm of monthly imports and registrations of passenger vehicles or goods vehicles by age group (6-9 years or 10+ years) for the period from January 2013 through December 2017. Specifications are estimated separately by channel (direct vs. indirect) and in aggregate as indicated in the column headers. Fixed effects for seasonal variation (month-of-year), and period (month-of-observation) are included in all specifications. Robust standard errors are reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Meaningful differences between the results from the vehicle-level and aggregate DID models occur predominantly for 6-9 year old vehicles; and they highlight even greater heterogeneity of the levy impact in this younger vehicle group relative to the older group. In contrast to the aggregate model, the vehicle-level regressions show (i) no spike in imports / registrations in the month prior to the levy change and (ii) no impact of the levy change in the post period in the indirect channel. The first of these differences suggests end-users and traders that advanced imports of 6-9 year old vehicles did so among a very small set of vehicles (in contrast to advancing imports proportionally across all vehicle types). Similarly, the second difference indicates that traders' reduction of imports of 6-9

[37] Imports of 6-9 year old vehicles also increased by 39% in this single month according to the aggregate figures, but we do not estimate any impact at the vehicle level. This suggests that this spike is accounted for by imports for a few very popular models.

year old vehicles was focused on a very small set of vehicles.

Overall, the analysis presented in this section shows that the environmental levy increase resulted in a substantial reduction in vehicle imports among the targeted age groups but did not have a similar effect on first-time registrations (i.e., the flow of newly imported vehicles onto Ugandan roads). The main reason for this appears to be that the existing inventory among traders buffered the import shock, aided in part by the opportunity to import additional vehicles when the policy change was announced but not yet effective. Quantitatively, a lot of these dynamics seem to be concentrated among relatively few vehicles as the estimates of the levy change are much higher in magnitude in the aggregated than in the disaggregated model.

4.2 Distinguishing Direct Impact and Substitution

In this subsection, we return to the theoretical framework underlying the equilibrium quantities and estimate the structural parameters $\theta^{\mathbf{D}} \equiv \left[\beta, \alpha^p, \alpha^a, \alpha^d, \sigma\right]$ of the demand system. These parameter estimates allow us to determine the relative value that end-users place on vehicle price and age and assess, through counterfactual simulation, to what extend end-users trade off one versus the other when responding to the levy increase. This is important as the levy impact on equilibrium quantities studied in the previous subsection reflects both the direct impact of the levy increase and substitution from other vehicle groups (that are also impacted by the levy).

The estimation focuses on the demand equation (3), which we reproduce here simply for reference:

$$\begin{aligned} ln(s_{jt}/s_{0t}) = \mathbf{x_{jt}}\beta + \alpha^p p_{jt} + \alpha^a a_{jt} + \alpha^d d_j \\ + \sigma ln(s_{j|g,t}) + \xi_{jt} \end{aligned}$$

Identification

Identification of the structural parameters requires that the explanatory variables in this estimating equation are uncorrelated with the consumer valuation of unobserved characteristics ξ_{jt}. As is standard in the discrete choice literature, we assume that this is the case for the observable vehicle characteristics with the exception of the price. Vehicle prices are of course endogenous in the indirect channel, because they are functions of the quantities demanded of all vehicles in the choice set.[38]. Prices are, however, also endogenous in the direct channel (despite assuming competitive international secondary markets) as they are likely positively related to consumers' valuation of unobservable

[38]See supply equation (6).

characteristics. In addition to vehicle prices, the nesting-group shares $s_{j|g,t}$ are of course also endogenous given that they are functions of ξ_{jt}.

In order to address these endogeneity concerns, we proceed in two ways. First, we assume that the valuation of unobservable characteristics can be decomposed additively into three components, a make/model-specific term, $\xi_{j.}$, a period-specific term, $\xi_{.t}$, and a residual $\tilde{\xi}_{jt} \equiv \xi_{jt} - \xi_{j.} - \xi_{.t}$. We then absorb the make/model and period fixed-effects through within-transformations to eliminate any correlation between vehicle prices and ξ_{jt} due to higher-valued make/model combinations' being more expensive and due to common market-level shocks. Secondly, we estimate equation (3) via generalized method of moments using post-period indicators for vehicles affected by the levy change and the number of vehicles in each nesting group as instrumental variables. The former are valid instruments under the assumption that the set of vehicles targeted by the levy increase is uncorrelated with the residual error term, $\tilde{\xi}_{jt}$. The latter is a type of instrument that is common in the discrete choice literature and represent variants of the ("Differentiation IVs") recently proposed by Gandhi and Houde (2019). The intuition for these instruments (and the number of vehicles per nesting group in particular) is that they measure the density of the characteristic space around any given vehicle, which affects market prices and quantities. The key identifying assumption is that $\tilde{\xi}_{jt}$ is mean independent of the observable vehicle characteristics that are used to construct the instruments. In our chase, these are the distribution channel and engine capacity.

Results

Table 3 reports the results from estimating the demand equation (3). Observations are normalized vehicle shares (according to make, model, manufacturing year and channel) by fiscal year. The vehicle choice set contains all make/model/manufacturing-year combinations up to the oldest such group with positive sales in a given channel. Accordingly, the choice sets differ by channel - the set of direct imports is almost 60 percent larger. The first pair of columns of Table 3 reports the results of a simplified *logit* specification, in which we assume that the nesting coefficient, σ, is zero; the second pair reports the results from the *nested-logit* specification. Within each pair, the first specification is estimated via ordinary least squares (OLS) while the second is estimated via instrumental variable (IV) regression.

The logit and nested-logit specifications yield qualitatively similar results, but the magnitude of the estimated coefficients differs between the two. Most notably, the coefficients on price and age have a higher magnitude in the logit specification. They are, however, comparable in relative terms (1.34 in the logit vs. 1.49 in the nested-logit version) and the implied distribution of own-price elasticities is also very similar (compare

Figures 4 below and 11 in the Appendix). Therefore, we focus primarily on the more general nested-logit specification in the remainder of our discussion.

Comparison of the OLS and IV results confirms the expected bias in OLS estimates. Prices and the nesting group shares are positively correlated with $\tilde{\xi}_{jt}$, so that the OLS estimates are biased upward relative to the IV estimates. The estimate of the price parameter α^p drops from -0.007 to -0.045 (-0.109 to -0.264 in the logit specifications) and that of the nesting group parameter drops from 0.985 to 0.836 when moving from OLS to IV regression. At the bottom of the table, we are also reporting the Kleibergen-Paap rk and the Hansen J statistics for weak identification and validity of the exclusion restriction, respectively. The Kleibergen-Paap rk statistic tests the null hypothesis of underidentification and is rejected. The null hypothesis for the Hansen J statistic is that the instruments are excluded and this hypothesis is, unfortunately, also rejected. We are currently in the process of revising the instrument vector by testing orthogonality conditions for individual instruments.

Table 3: Structural Parameter Estimates

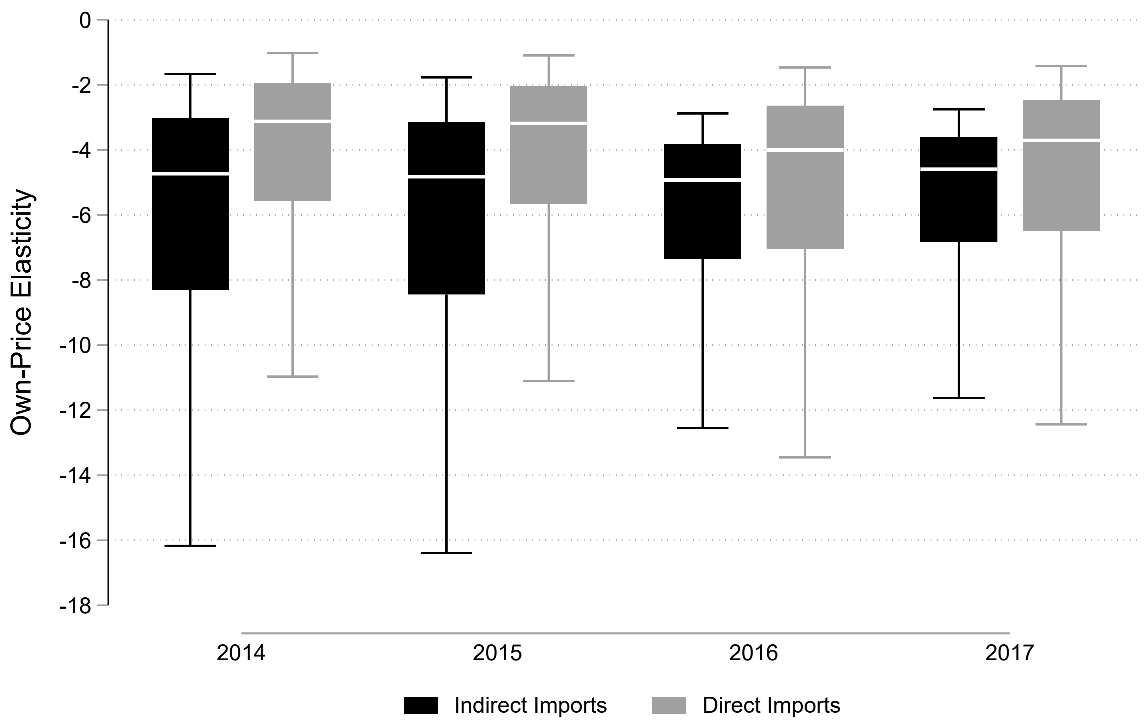
	Logit		Nested Logit	
	(1)	(2)	(3)	(4)
Eff. Price (α^p)	-0.109***	-0.264***	-0.007***	-0.045***
	(0.017)	(0.042)	(0.002)	(0.017)
Age (α^a)	-0.203***	-0.355***	-0.011***	-0.067***
	(0.017)	(0.039)	(0.004)	(0.017)
Direct (α^d)	-0.237**	-0.852***	-0.724***	-0.736***
	(0.106)	(0.207)	(0.021)	(0.073)
ln(Group Share) (σ)			0.985***	0.836***
			(0.004)	(0.026)
Make/Model FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
IV	No	Yes	No	Yes
Obs.	24,186	24,186	24,186	24,186
Underid. (Kleibergen-Paap rk)		45.13		35.83
Overid. (Hansen J)		54.62		41.21

Notes: Observations are annual log-differences the share of the "eligible" Ugandan population purchasing a vehicle (defined by make, model, and manufacturing year) and the share not purchasing any vehicle. Data are restricted to personal vehicles (HS-code 8703) with at least 50 registrations during the fiscal years 2013/14 to 2017/18. Fixed effects for vehicle make/model and fiscal year combinations are included throughout. Standard errors are clustered at the vehicle make/model level and reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

The IV estimates for the nested-logit specification in Table 3 are intuitive for all parameters. The point estimate of $\hat{\alpha^p} = -0.045$ implies a mean own-price elasticity between

-5.4 and -6.1 when evaluated at the given market shares and prices, which is broadly in line with prior estimates found in the literature (Berry et al., 1995; Petrin, 2002; Clerides, 2008). The full distribution of own-price elasticities by fiscal year is illustrated in Figure 4 below.[39] The other parameter estimates can be best interpreted relative to the price parameter. Specifically, $\hat{\alpha^a} = -0.067$ means that Ugandan consumers value a year of vehicle age at approximately 1.5 MMUSh (i.e., -0.067 / -0.045 MMUSh/Year) or 7% of the average vehicle price. Similarly, $\hat{\alpha^d} = -0.736$ means that Ugandan consumers dislike direct imports (or equivalently face a penalty / barriers associated with direct importing) and this is valued at 16.3 MMUSh (i.e., -0.736 / -0.045 MMUSh). This is a substantial penalty of approximately 78% of the average vehicle price. Finally, the nesting group parameter estimate $\hat{\sigma} = 0.836$ shows that there is substantial correlation of preferences within vehicle groups as defined by engine capacity and distribution channel.

Figure 4: Distribution of Estimated Own-Price Elasticity - Nested Logit



Notes: Distribution of own-price elasticity for vehicle make/model/age-group combinations corresponding to specification (4) in Table 3. Elasticities are calculated as $\eta = \alpha^p[1/(1-\sigma_{g_1}) - \sigma_{g_1}/(1-\sigma_{g_1})s_{jt|g_1} - s_{jt}]p_{jt}$. Box shows interquartile range and median; whiskers show upper and lower adjacent values defined as 1.5 times the interquartile range below and above the 25th and 75th percentile, respectively.

[39] The distribution of own-price elasticities for the logit-specification are very similar and illustrated in Figure 4 in the Appendix.

Counterfactuals

Having estimated the structural model of vehicle demand, we now use these estimates to decompose the overall impact of the levy change, Δ_{jt} into the direct impact, Δ_{jt}^{dir}, and the indirect impact via substitution from other vehicles, Δ_{jt}^{sub}. Let $w_{jt}^{(n)}$ denote the variable w_{jt} under counterfactual scenario n (e.g., $s_{jt}^{(n)}$ for shares of vehicle j in period t under scenario n) and consider the following counterfactuals.[40] Let scenario $n = 0$ denote no levy increase in 2015 for any vehicle age groups (i.e., the environmental levy remained at 20% for passenger vehicles of age 8 years and over). Further let scenario $n \in \{1, 2, 3, 4\}$ denote a situation in which vehicles of age group n were not subject to the levy increase with the age groups being 5 years or below, 6 to 9 years, 10 to 15 years, and 16+ years, respectively.

We simulate the counterfactual shares $s_{jt}^{(n)}$ using the estimated coefficient vector from our preferred specification (4) in Table 3, the corresponding fixed effects and residuals, and the data with adjusted prices as required $[\mathbf{x_{jt}}, p_{jt}^{(n)}, a_{jt}, d_j]$. For any vehicle j in period t, we can then use differences between the actual share and these counterfactual shares to distinguish the direct impact of the levy change from substitution. Specifically, we can decompose the actual share of vehicle j in period t as $s_{jt} = s_{jt}^{(0)} + \Delta^{dir}(s_{jt}) + \Delta^{sub}(s_{jt})$. The overall impact of the levy change is $\Delta(s_{jt}) = s_{jt} - s_{jt}^{(0)}$ and for vehicles of age group n the substitution from other age groups is $\Delta^{sub}(s_{jt}) = s_{jt}^{(n)} - s_{jt}^{(0)}$. Combining these expressions, we also have that the direct levy impact on this age group is $\Delta^{dir}(s_{jt}) = s_{jt} - s_{jt}^{(n)}$.

Table 4 below reports this decomposition of the normalized total effect $\Delta(s_{jt})/s_{jt}^{(0)}$ into the direct effect of the levy increase, $\Delta^{dir}(s_{jt})/s_{jt}^{(0)}$, and the "substitution effect", $\Delta^{sub}(s_{jt})/s_{jt}^{(0)}$ aggregated for the four age groups. As expected given the parameter estimates in Table 3, the direct impact of the levy increase is weakly negative and the substitution from other vehicles contributes positively to shares.

The magnitude of the direct impact is decreasing in the vehicle age. This is expected for the last two age groups, because the absolute change in the effective price is lower for older vehicles as these tend to be less expensive but face the same tax rate. The fact that this also holds when considering the 6-9 year old group, however, suggests that the impact of the levy on effective prices is decreasing in vehicle age despite the tiered tax rate. In other words, the rate difference between the tiers is dominated by lower prices among older vehicles. The magnitude of the "substitution effect" is decreasing for the first three age groups (up to 15 year old vehicles). This suggests that consumers indeed substitute towards younger vehicles. Given the relative share of of these younger age

[40] We only describe deviations from the actual in these scenarios; all non-mentioned products, features remain as they were.

groups, however, the dominant impact of the levy is substitution towards the outside option, i.e., no vehicle purchases.

Table 4: Direct and "Substitution" Effect of Levy Increase

	2016			2017			2018		
	Direct	Subst.	Total	Direct	Subst.	Total	Direct	Subst.	Total
Age 5 years or below	0.000	1.757	1.757	0.000	1.406	1.406	0.000	1.332	1.332
Age 6 to 9 years	-1.374	0.665	-0.709	-1.460	0.742	-0.718	-1.498	0.735	-0.763
Age 10 to 15 years	-0.400	0.264	-0.136	-0.418	0.256	-0.162	-0.390	0.245	-0.145
Age 16+ years	-0.200	0.233	0.034	-0.171	0.195	0.024	-0.169	0.201	0.031

Notes: Table reports decomposition of the total impact of the 2015 levy change into direct and "substitution" effects, normalized by the shares from a counterfactual scenario with no levy change.

Combining the two effects, the overall impact of the levy change is positive for the youngest age group, negative for vehicles of the two intermediate age groups (6-9 and 10-15 years), and positive again for the oldest vehicles. From the perspective of the environmental levy's stated objective, the positive impact on the youngest age group is encouraging, but quantitatively not very meaningful, because of the small share these vehicles account for. The positive impact among the oldest group, on the other hand, is discouraging because it shows that a considerable number of consumers substitute towards even older (and less expensive) vehicles in response to the levy increase.

5 Discussion

The analysis presented in the previous two sections provides a number of overarching insights into the impact of the environmental levy in Uganda. First, vehicle imports (unsurprisingly) respond to import taxes, so that the environmental levy meets a minimum standard of effectiveness. Given that international supply of vehicles is unaffected by Ugandan policy, the aggregate DID estimates of the effect on imports represent changes in demand and imply own-price elasticities of approximately -5.1 for 6-9 year old vehicles and -1.9 for vehicles age 10 years and above.[41] These estimates at the aggregate level, however, do not account for substitution between different vehicles and really capture consumer demand only in the direct channel. The results from the discrete choice model of demand therefore provide a more reliable measure of the own-price elasticities and these are substantially higher averaging approximately -8.6 for 6-9 year old vehicles and -4.0 for

[41] Vehicle imports into Uganda during the period of the levy change were broadly subject to a 25% duty, 22.5% VAT, and 6% withholding tax in addition to the environmental levy (20% in the pre-period). The percentage effective price increase as a result of the policy change therefore is $15\%/173.5\% \approx 8.6\%$ for 6-9 year old vehicles and $30\%/173.5\% \approx 17.3\%$ for vehicles aged 10 years and over. Dividing the coefficient estimates from Table 2 by these figures yields the mentioned elasticities.

vehicles age 10 years and above. In any case, these figures suggests that environmental taxes can, in principle, induce meaningful changes in demand for imported vehicles and thereby limit entry of old, more emitting vehicles at the border. These elasticity estimates also highlight, however, that older vehicles are generally less responsive to import taxes. This suggests that policies aimed at reducing the inflow of the oldest, highest emitting vehicles require steeply tiered tax regimes or outright import bans, similar to the one implemented in Uganda in 2018.

The second insight is negative from the environmental levy's stated policy objective. We find evidence of considerable substitution between the international and the domestic markets: First-time registrations were essentially unaffected by the levy change in the months immediately thereafter and even increasing in the later part of our sample period. The fact that this appears to have been driven primarily by running down old vehicle inventory among traders highlights the long-lasting buffering effect of inventories and the need to carefully consider them in the context of changing policy environments. In addition, it is worth emphasizing that this turning to the domestic vehicle stock by end-users goes hand-in-hand with higher vehicle prices domestically that have the potential to delay vehicle scrapping and thereby further undermine the environmental objectives. The intuition for this is that higher prices raise the cost of vehicle replacement and thus reduce scrapping rate at the margin. Unfortunately, a thorough analysis of scrapping extends beyond our theoretical model and available data, but this remains nonetheless an important consideration from a policy standpoint. One way to counter such unintended consequences arising from the domestic market would be complementary regulation that restricts emissions through regular testing of vehicles on Ugandan roads.

Third, our analysis suggests that substitution between age groups at the current levy rates is also not beneficial for the stated policy objectives. While we find substitution to younger age groups, vehicles up to 5 years old continue to account for a very small fraction of the overall purchases. In addition, there is evidence of considerable substitution towards even older vehicles as consumers trade off vehicle price and age, undermining the policy's effort to reduce the reliance on old vehicles. Taken together, these findings again point towards steeply tiered tax regimes or outright import bans as effective age-based import restrictions.

6 Conclusion

This paper analyzes a very common, yet understudied type of regulation in LICs to reduce local pollutants from vehicle emissions, an import tax on old vehicles. Specifically, we estimate the impact of such an "environmental levy" in Uganda in the context of a substantial increase in the tax rate in 2015. This is a suitable setting for such a study, because Uganda matches key features of the global vehicle trade vis-a-vis LICs. Its imports originate mostly in Japan and the vast majority of its imported vehicles are used. Furthermore, the environmental levy does not apply to goods vehicles, which therefore represent a plausible counterfactual group.

Motivated by this contextual feature, we estimate difference-in-differences models of vehicle imports and fist-time registrations. We finds that the environmental levy has a negative impact on the former and a mixed impact on the latter, raising transactions especially among old vehicles. We interpret these findings as evidence for substitution by end-users from imported vehicles in the targeted age groups to the domestic vehicle inventory among traders (and particularly among the oldest vehicles).

Furthermore, in order to distinguish between the direct impact of the policy change (an effective price increase) and the indirect impact via substitution between different vehicle age groups, we estimate a structural model of "newly" imported passenger vehicles. We find that substitution between different age groups (in particular from younger to older vehicles) mitigates the direct impact of the levy increase, especially among the oldest vehicles. In addition, our results also show that the impact of the levy is decreasing in the vehicle age despite the tiered tax profile. This suggests that an even more progressive system or an outright ban on very old vehicles, as implemented in Uganda in 2018, may be required if importing the oldest vehicles is to be effectively discouraged.

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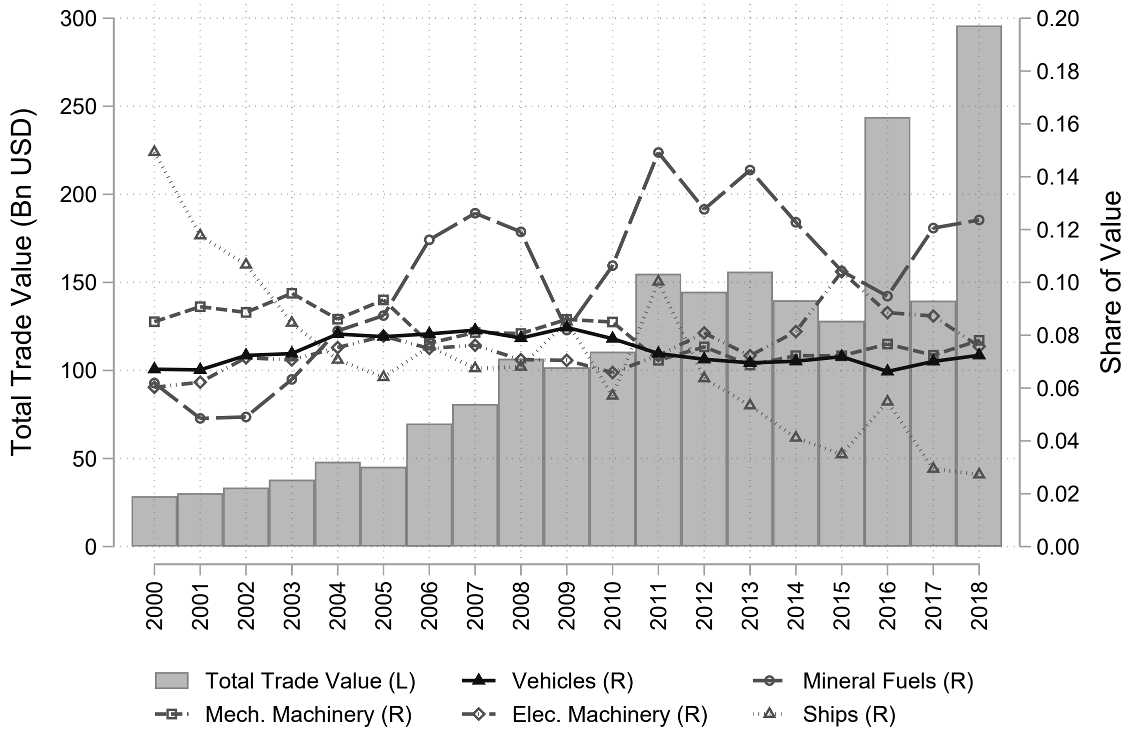
A Additional Output

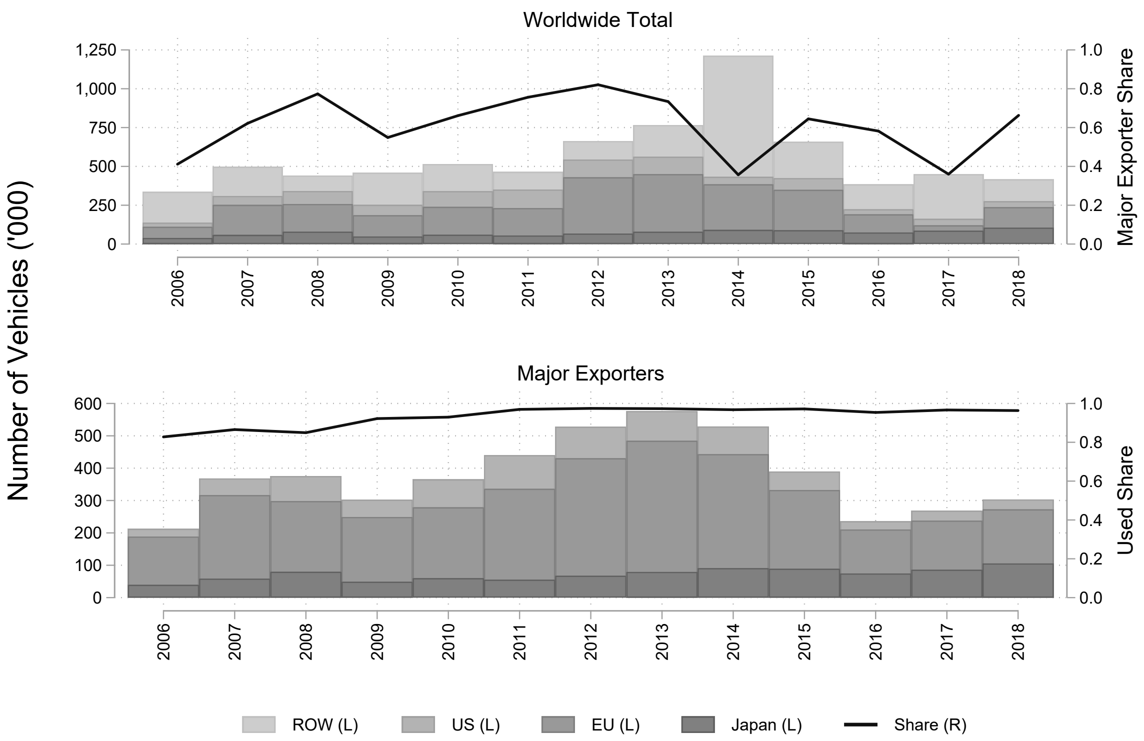
A.1 Additional Descriptive Statistics

Figure 5: Top Exports to Low-Income Countries



Notes: Figure shows the value of exports to LICs (World Bank 2019 classification) by 2-digit Harmonized System (HS2) code according to UN Comtrade data. Bars indicate the total export value and lines show the share thereof accounted for by the top-5 HS2 codes since 2010.
Sources: UN Comtrade.

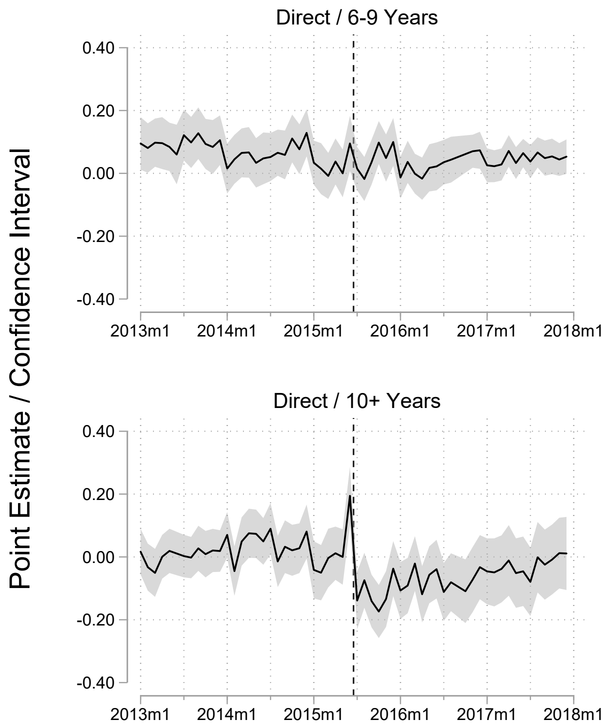
Figure 6: Personal Vehicle Exports to Low-Income Countries



Notes: The top panel shows personal vehicle exports to LICs (World Bank 2019 classification) from major exporters (Japan, EU, and US) and the rest of the world (ROW) according to UN Comtrade data. Stacked bars indicate the total number of vehicles and the line shows the major exporter share. The bottom panel shows personal vehicle exports to LICs from these major exporters according to their national trade statistics, which allow the distinction between new and used vehicles. Stacked bars indicate the total number of vehiclies and the line shows the used vehicle share.
Sources: UN Comtrade; Japan, EU, and US trade statistics.

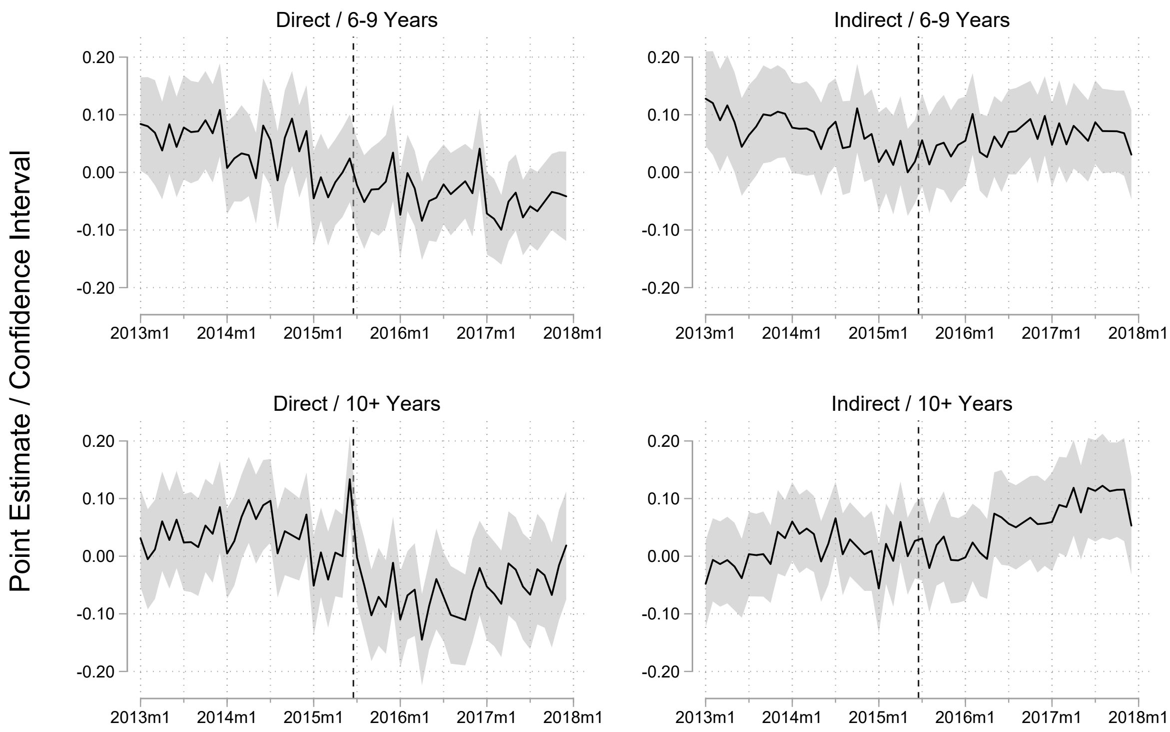
A.2 Evidence on Parallel Trends Assumption

Figure 7: Event Study of Vehicle Imports



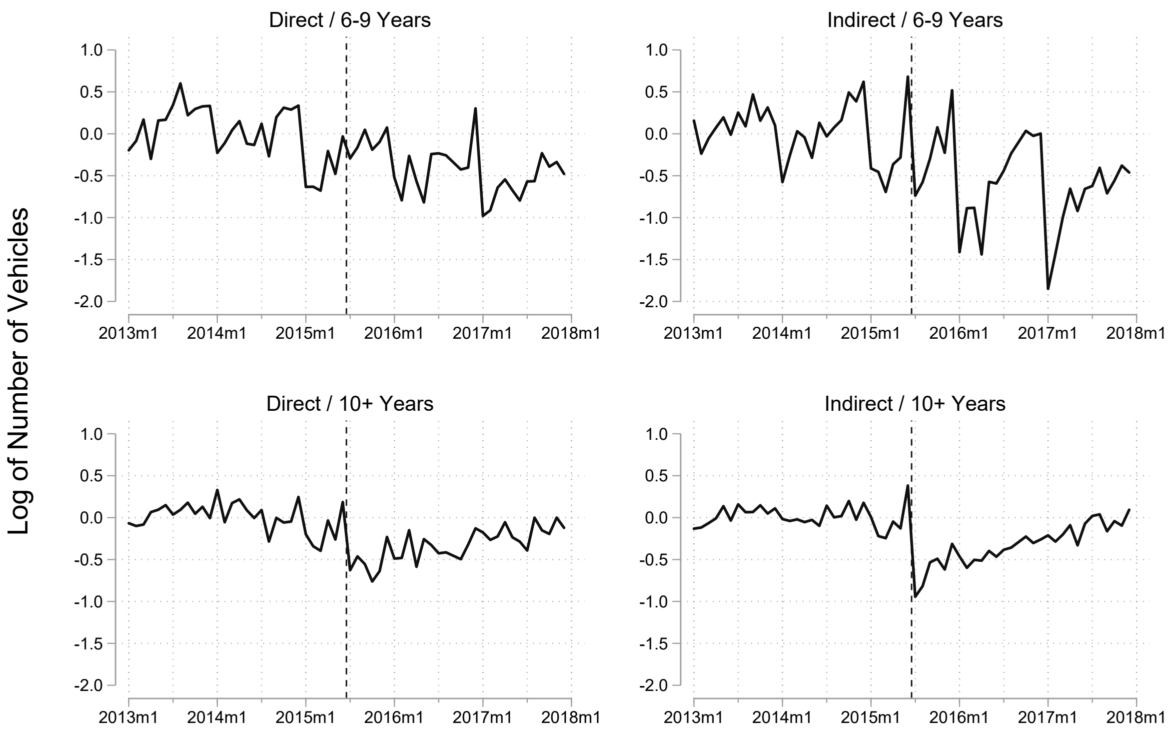
Notes: Figure displays the coefficients on the interaction of the indicator variable for vehicles targeted by the levy change (passenger vehicles by age group) and an indicator for the given month in a regression of IHS-quantities on month and seasonal fixed effects, passenger vehicles dummies and these interaction terms. Estimates are relative to May 2015. Dashed vertical line indicates levy increase effective July 2015.

Figure 8: Event Study of Registrations



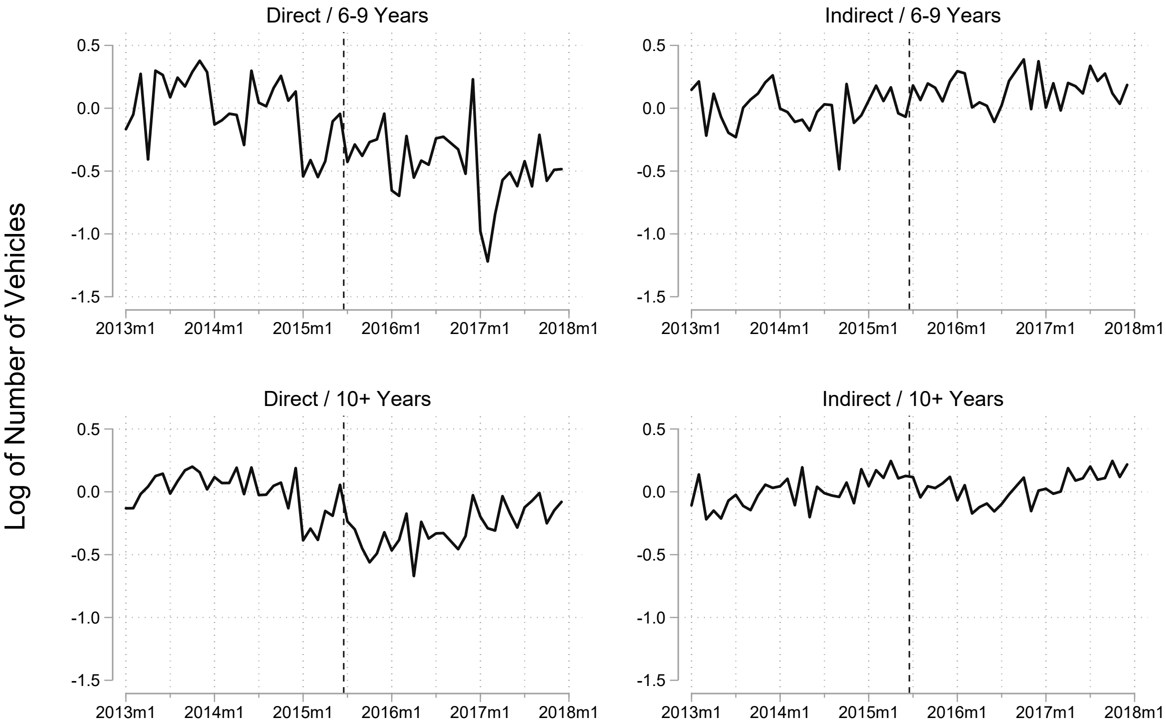
Notes: Figure displays the coefficients on the interaction of the indicator variable for vehicles targeted by the levy change (passenger vehicles by age group) and an indicator for the given month in a regression of IHS-quantities on month and seasonal fixed effects, passenger vehicles dummies and these interaction terms. Estimates are relative to May 2015. Dashed vertical line indicates levy increase effective July 2015.

Figure 9: Log-Difference of Passenger and Goods Vehicle Imports



Notes: Graphs display the differences in the natural logarithm of the number of passenger vehicles and the number of goods vehicles imported by month. These are normalized by subtracting the average monthly difference between January 2013 and May 2015. Dashed vertical line indicates levy increase effective July 2015.

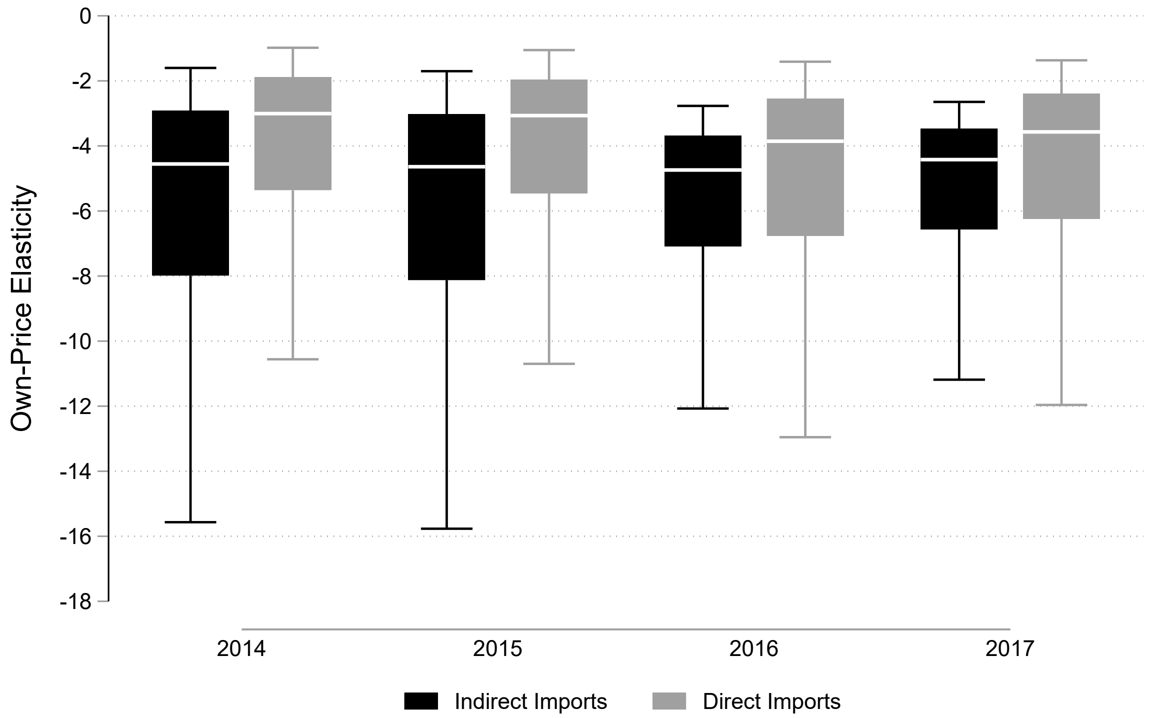
Figure 10: Log-Difference of Passenger and Goods Vehicle Registrations



Notes: Graphs display the differences in the natural logarithm of the number of passenger vehicles and the number of goods vehicles (first-time) registered by month. These are normalized by subtracting the average monthly difference between January 2013 and May 2015. Dashed vertical line indicates levy increase effective July 2015.

A.3 Additional Output from Structural Estimation

Figure 11: Distribution of Estimated Own-Price Elasticity - Logit



Notes: Distribution of own-price elasticity for vehicle make/model/age-group combinations corresponding to specification (2) in Table 3. Elasticities are calculated as $\eta = \alpha^p(1 - s_{jt})p_{jt}$. Box shows interquartile range and median; whiskers show upper and lower adjacent values defined as 1.5 times the interquartile range below and above the 25th and 75th percentile, respectively.

B Data Appendix

B.1 Vehicle Class Definition

We define passenger vehicles as those with HS-codes 8702 (i.e., "vehicles; public transport passenger type") and 8703 (i.e., "motor cars and other motor vehicles; principally designed for the transport of persons") and compare these to goods vehicles with HS-code 8703 ("vehicles; for the transport of goods"). Together with motorcycles (HS-code 8711), these three categories account for approximately 98% of all vehicle imports during sample period; public transport (HS-code 8702) and personal vehicles (HS-code 8703), which have been the primary target of the environmental levy and are thus the focus of this study, account for 5% and 48%, respectively. The registration data are not classified according to the HS-system. In order to create comparable categories for registrations without a corresponding entry in the import data, we therefore map HS-codes by vehicle make and model to the those registrations.

B.2 Generating Complete Choice Sets

Both delivered prices from the import data and these domestic prices of course do not cover all possible make / model / manufacturing year combinations over all the months of our sample period. Import prices are only available for vehicles in the months in which we observe transactions and domestic prices only for vehicles in the months when there were online postings or when they were surveyed.[42] For the structural estimation, however, we also require import and domestic prices for vehicles and months not captured by the raw data. In order to generate a more complete set of prices, we therefore consider all possible combinations of make / model / manufacturing year triplets and months in our sample period and "fill-in" missing values via the following procedure. [43] For import prices, we first estimate an OLS regression of the natural logarithm of observed CIF USD-denoted prices on a fifth-order polynomial of the vehicle age and fixed effects for make / model pairs. Using these estimates, we then predict import prices out of sample for manufacturing years and months when there are no imports for a given make / model. The fixed effects generate predicted prices that correspond to the make / model average while age polynomial flexibly captures depreciation. The estimation results and an accompanying chart of actual vs. predicted average USD-denoted prices are included in the Appendix (see Table 5 and Figure 12). Second, we convert the predicted import prices into Ugandan Shilling (USh) and compute any applicable taxes (e.g., the environmental levy). Third, we compute the effective import price as the USh-denoted CIF price plus taxes using the raw value when available and the predicted values otherwise. Fourth, for domestic prices, we then estimate an OLS regression of the domestic price on the six-month-lagged average effective import price, an indicator variable for the period from July 2015 onwards (after the policy change), and the interaction of these two variables. The results of this regression are also reported in the Appendix (see Table 6, specification (4)). The effective import price captures both variation between vehicles and over time; the post-policy-change indicator allows for a level shift in the average markup of domestic prices over imports surrounding the levy change; and the interaction term captures differential relationship between import and domestic prices in the post-period relative to before the levy change. As before, we predict domestic prices using the estimates obtained when raw domestic prices are unavailable.

[42]The CPI surveys generally cover the same vehicle over many consecutive months, but do this only for a handful of common vehicles.

[43]Any make / model / manufacturing year triplet is assumed to be in the choice set if the make / model has been imported at least once with the given manufacturing year or an earlier one during the sample period.

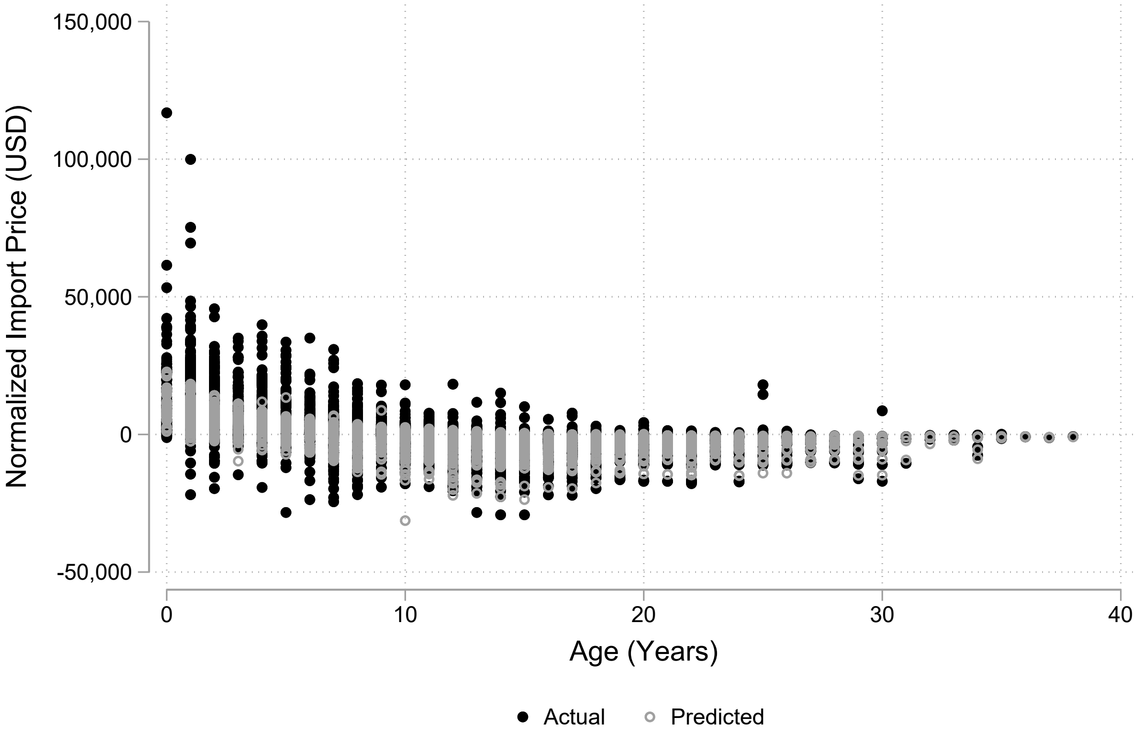
B.3 Generating Complete Set of Prices

Table 5: Import Price Prediction Regressions

Age	-0.12652***
	(0.01442)
Age^2	0.00257
	(0.00264)
Age^3	-0.00025
	(0.00020)
Age^4	0.00001**
	(0.00001)
Age^5	-0.00000**
	(0.00000)
Obs.	9,549
R-Squared	0.821

Sources: Table reports coefficients from regression of log-price on age variables and make/model fixed effects.

Figure 12: Normalized Import Prices - Actual and Predicted



Notes: Observations are pairs of normalized passenger vehicle price and age by make, model, manufacturing year and month. Normalized prices are defined as the deviation from the make/model sample average. Predicted prices are in-sample exponentiated predicted values following a linear regression of the log-price on make/model fixed effects and a order-five polynomial of the vehicle age (in years).

Table 6: Domestic Price Prediction Regressions

	(1)	(2)	(3)	(4)
Import Price	0.838***	0.855***	1.294***	1.458***
	(0.064)	(0.067)	(0.110)	(0.156)
Post Indicator		-5.023***		7.402**
		(1.083)		(3.077)
Post x Import Price			-0.461***	-0.652***
			(0.096)	(0.170)
Constant	9.069***	11.454***	5.697***	0.781
	(1.478)	(1.236)	(1.534)	(2.394)
Obs.	3,411	3,411	3,411	3,411
R-Squared	0.499	0.502	0.518	0.521

Notes: Observations are pairs of average domestic and effective import prices in million USh by fiscal year. Domestic prices are constructed from surveys of vehicles tracked by the Ugandan Bureau of Statistics (UBOS) for the consumer price index (CPI) and posted prices from two leading online sales platforms. Vehicles are defined as make/model/manufacturing year. Only original import prices are considered. The overall sample period is July 2013 to June 2018. Robust standard errors are reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

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