Essays in Development Economics and Industrial Organisation

by

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Declaration

I submit this thesis to the University of Warwick in accordance with the requirements of the degree of Doctor of Philosophy in Economics. I declare that it has not been submitted for a degree at another university. Chapters 1 and 2 are joint work with Dorothy Nakyambadde (Uganda Revenue Authority), who facilitated access to the necessary data and provided valuable institutional insights. I conducted all analysis and composed the text. Chapter 3 is co-authored with Amit Khandelwal (Columbia University), Rocco Macchiavello (London School of Economics), Madhav Malhotra (International Growth Centre), and Matthieu Teachout (International Growth Centre). Amit and Rocco provided high-level direction for the research and Matthieu, Madhav and I conducted the analysis. I composed much of the text after a recent revision following an earlier version.

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Abstract

This thesis studies three topics in development economics and industrial organisation as summarized below.

Chapter 1 explores the effectiveness of import tariffs to reduce the inflow of old, highly polluting vehicles in low-income countries. Specifically, we estimate the impact on imports and first-time registrations of a stark increase in such a tariff levied on passenger vehicles in Uganda. We find that the levy increase was effective in reducing purchases of the targeted vehicles, but also document unintended substitution from younger towards older vehicles that undermines the policy's objective. Our results point to potential policy improvements and we assess several alternatives through counterfactual simulation.

Chapter 2 investigates the relationship between vehicle demand in low-income countries and the existing vehicle stock, through the availability of spare parts and repair services. We study this "indirect network effect" in the context of the passenger vehicle sector in Uganda. We present a structural model that incorporates the spare part market equilibrium into the consumer choice over vehicles and estimate this model using rich data from administrative records, online platforms, and an original survey of spare parts traders. We find strong evidence in favour of the hypothesized indirect network effect.

Chapter 3 studies how political connections affect the gains from trade liberalization in the context of the removal of import license requirements in Myanmar. We provide evidence that (i) the implementation of the reform protected connected firms and (ii) the presence of connected firms is associated with lower sector growth. A unifying thread among both these findings is the role of entry barriers in the form of economies of scale that seem to protect connected firms from potential competition.

1 Curbing Trade in Clunkers: Evidence from Uganda

with Dorothy Nakyambadde

1.1 Introduction

International trade in second-hand vehicles between the global North and the global South is a growing concern among policy makers worldwide (UNEP, 2020). In particular, low-income countries (LICs) import hundreds of thousands of vehicles from high-income countries (HICs) every year and the vast majority of these are used.[1] These 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 than their newer counterparts due to older technology and physical depreciation (Washburn et al., 2001; Bin, 2003; Beydoun and Guldmann, 2006).[2]

In an effort to mitigate the adverse environmental consequences from vehicle emissions, many LICs rely on age-based import restrictions, such as tariffs or outright bans targeting vehicles over some age threshold (UNEP, 2020). 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.[3] In particular, it is not even clear to what extent demand responds to these policies and how end users substitute between vehicles of different age groups. End user valuations of vehicle age and price notably differ between countries along the income spectrum (Grubel, 1980; Pelletiere and Reinert, 2006, 2010), so that existing research on vehicle demand in advanced economies provides little insight into the likely impact of these interventions in LIC settings.

In this paper, we take a step towards filling this gap in the literature by studying one prominent such import restriction — a progressive ad-valorem tariff according to vehicle age — levied on passenger vehicles in Uganda. We ask the following

[1]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 A.2 in the Appendix for details.

[2]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.

[3]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.

overarching question: How effective is this "environmental levy" in reducing imports and first-time registrations of targeted vehicles? In our analysis, we focus on the response of end user demand to this policy and study substitution between vehicles of different age groups that could be aligned with the policy objective (towards younger vehicles) or undermine it (towards older vehicles). We also explore the role of existing inventory among traders that may drive a wedge between imports and first-time registrations and thereby reduce the intended policy impact in the short run. Finally, we shed light on features of alternative import tariff regimes that would improve upon common shortcomings of existing import restrictions.

We study the environmental levy in Uganda by estimating the impact of a 15-30 percentage point increase in this tariff on a subset of passenger vehicles in July 2015. Our main data sources are administrative records from the Ugandan Revenue Authority (URA) on the universe of vehicle imports and first-time registrations in the country between January 2013 and June 2018.[4] Importantly, we are able to match the imports and registration records by vehicle identification number, so that we have unusually rich information at a very high level of disaggregation. The average levy before and after this policy change and the corresponding number of passenger vehicles imported are summarized in Table 1.1 below.

Table 1.1: Environmental Levy on Passenger Vehicles in Uganda

	Levy Rate (%)		Vehicles Imported (#)	
	Pre	Post	Pre	Post
Age 5 years or below	0	0	2,427	2,721
Age 6 to 9 years	15	35	3,388	2,202
Age 10 to 15 years	20	50	49,347	30,774
Age 16+ years	20	50	30,261	26,913

Notes: Table reports the average statutory rate for the "environmental levy" and the total number of passenger vehicles imported in Uganda between January 2013 and December 2017. The pre- and post-period are respectively defined up to June 2015 and from July 2015 onwards. The pre-period levy for 6-7 year old vehicles was 0% and for 8-9 year old vehicles was 20%. Import data are restricted to vehicles with matching registration records.

We begin our econometric analysis by estimating a difference-in-differences (DID) model that leverages goods vehicles that have been exempted from the environmental levy as a natural counterfactual group. We estimate the impact of the levy increase on imports and first-time registrations separately for the four passenger vehicle groups given in Table 1.1. The estimates from this model show that imports and first-time registrations of vehicles in the intermediate age groups — i.e., 6-9 and 10-15 years — declined sharply due to the levy increase (by 41-48% for imports and

[4]We also rely on additional data that are described in further detail in section 1.2. These include, in particular, domestic vehicle prices from two leading online sales platforms and detailed surveys underlying the Ugandan consumer price index (CPI).

roughly 30% for registrations). We also find evidence in favour of substitution from these intermediate age groups to younger and older vehicles. Fist-time registrations, in particular, increase due to the levy change among 0-5 year old vehicles (by 19%) and among 16+ year old vehicles (by 35%).[5]

Estimating this model separately by distribution channel (vehicles imported by end users versus those imported by intermediate traders), we further shed light on the differences in the levy impact between imports and first-time registrations. Registrations of vehicles imported by end users broadly follow the pattern observed for imports, declining by roughly 40% among 6-9 and 10-15 year old vehicles and increasing or showing no effect among 0-5 and 16+ year old vehicles, respectively. Registrations of vehicles purchased from intermediary traders, however, exhibit declines of much lower magnitude or even increases due to the higher levy. Recovering a normalized measure of trader inventory from imports and first-time registrations, we find evidence that the existing inventory among traders from before July 2015 contributed considerably to this. Inventories effectively created a wedge between imports and first-time registrations, shielding the latter from the levy change in the short run.

Turning to our main analysis, we then present and estimate a structural model of the market for newly imported personal vehicles in the spirit of the seminal work by Steven Berry, James Levinsohn, and Ariel Pakes (Berry et al., 1995, henceforth "BLP").[6] We derive demand from a static discrete choice over vehicles among end users and distinguish supply by distribution channel as in the reduced form analysis, directly from competitive international markets or from intermediary traders. We use the structural model to simulate various counterfactuals that achieve three objectives: (i) to provide estimates of the levy impact in terms of vehicle purchases and consumer welfare; (ii) to quantify substitution between different vintages and the extent to which substitution undermines the direct impact of the levy increase through higher prices; and (iii) to offer a comparison of the actual levy increase to potential alternative tariff regimes that seek to address some shortcomings of the actual policy.

The results for the overall levy impact are qualitatively similar to those from the reduced-form model, but tend to differ in magnitude. This is not entirely surprising, as these methods rely on different assumptions to recover the levy impact and as

[5]The impact on imports among the youngest and oldest vehicles is statistically indistinguishable from zero although the point estimate the 0-5 year old vehicles also indicates an increase.

[6]We distinguish these from the broader passenger vehicle category, which also includes vehicles designed for public transport, such as buses. This narrower focus is warranted as personal vehicles account for the majority of passenger vehicles and represent a well-defined set of generally substitutable products.

the structural estimation/simulation only uses data on personal vehicles, rather than the broader passenger vehicle category. According to the structural model, the levy increase led to a reduction of vehicle purchases of the intermediate age groups — by 74% for 6-9 year old and 15% for 10-15 year old vehicles — and increases among the youngest and oldest vehicles — by 153% for 0-5 year old and 3% for 16+ year old vehicles. Taken together, vehicle purchases drop by 6% and consumer surplus by 7% due to the levy increase.

The decomposition of this overall effect provides important insights about the role of substitution between vintages and the origin of the differences in the overall impact across them. First, we find that the magnitude of the direct impact is decreasing in the vehicle age, which suggests that the incremental tariff step in Uganda (between 6-9 and 10+ year old vehicles) was not sufficient to overcome the effect of lower prices among older vehicles. Secondly, we also find that there is considerable substitution from younger towards older vehicles that eliminates an increasing portion of the direct component. Indeed, for vehicles 16+ years old, substitution more than offsets the direct component, so that registrations of these oldest vehicles would have declined by 18% (rather than risen by 3%) had younger vehicles not been targeted. There is also substitution towards the youngest vehicle age group, but these vehicles only account for a small minority of the registrations in the country.

These findings suggest that effective policies aimed at reducing the influx of the oldest, most polluting vehicles require tariff schedules that are steeply increasing in vehicle age and/or outright bans (as implemented in Uganda more recently). In the final part of our analysis, we simulate the impact of a range of alternative tariff regimes that follow this prescription by targeting 16+ year old vehicles with relatively higher tariffs. These simulations show that policies that exclusively apply to the oldest vehicles can achieve reduced imports in this group while limiting the negative welfare implications, as end users have greater incentives to substitute towards younger vehicles. Highly tiered tariff regimes that target a broad range of vehicles yield larger reductions in the number of vehicles overall, but also entail higher welfare costs.

This paper contributes most directly to two strands of the existing economics literature. Most directly, we contribute to studies of international trade in vehicles with the first paper to focus on LICs and, importantly, the unintended substitution towards older vehicles that is expected to be particularly relevant in this context. This is a relatively sparse literature, but includes two closely related papers studying vintage-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 studies estimating the value of trade from (otherwise new) vehicles (Fershtman and Gandal, 1998; Tovar, 2012). The second study is a paper by Davis and Kahn (2010) analyzing vehicle emissions surrounding the partial liberalization of the market for second-hand vehicles between the United States and Mexico in 2005. Despite their focus on import restrictions for used vehicles, both of these papers differ from ours in fundamental aspects. They study richer economies whose end users likely exhibit different preferences than in LICs.[7] They also study import bans rather than tariffs, which preclude substitution towards the oldest vehicle age groups by design. Other papers in this literature have studied the determinants of used vehicle trade flows from richer to poorer countries (Grubel, 1980; Pelletiere and Reinert, 2006, 2010), which underpins the motivation of our paper but is not its core focus.

In addition, we also contribute to the more general literature on vehicle emissions regulations. This literature 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 driving restrictions, in cities in Latin America (Eskeland and Feyzioglu, 1997; Gallego et al., 2013; Carrillo et al., 2016; Zhang et al., 2017; Barahona et al., 2020) or China (Gu et al., 2017; Viard and Fu, 2015; Wang et al., 2014).[8] LICs, by contrast, have received very little attention in this literature. Most of the above-mentioned policies are absent in LICs and vintage-based import restrictions have in the past simply not been the focus. This paper contributes to filling this gap in the literature.

One of the likely reasons for the relatively sparse literature on vehicle markets in LICs are the data required for their analysis. Structural models of differentiated product markets typically rely on detailed product characteristics and even reduced-form estimations on the topic of this paper require information on vehicle age, which

[7]Even Mexico is a middle-income country (MIC) with substantially higher per-capita income in 2005 than Uganda has today and with domestic production of new vehicles. 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.

[8]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 additional vehicle purchases and increased weekend driving.

is usually not available from public sources. We overcome these issues by leveraging matched administrative data on imports and registrations in Uganda that provide us with exceptionally granular information on all vehicles entering the country.

The remainder of this paper is structured as follows. Section 1.2 provides background information about the Ugandan vehicle sector and describes the data that we use in our analysis. In Section 1.3, we study the overall impact of the levy increase, through descriptive statistics and a DID model, and offer indicative evidence of substitution from younger to older vehicles. Recognizing the limitations of the reduced-form analysis to understand substitution, we then introduce our structural model in Section 1.4 and present the corresponding estimation results and counterfactual simulations in section 1.5. The latter also includes our main results of the levy impact, the extent of substitution, and an assessment of alternative tariff regimes that seek to address some of the actual policy's shortcomings. Section 1.6 discusses the implications of our findings for policy and, finally, Section 1.7 provides concluding remarks.

1.2 Background & Data

Uganda presents a unique setting to study the impact of vintage-based import restrictions on vehicles in LICs. It shares common features of international vehicle trade with many other LICs. In addition, it has maintained some of the globally most popular import restrictions for more than a decade and incrementally tightened these over the years. One of these changes is the stark increase in its "environmental levy" on passenger vehicles, which provides considerably tariff variation and is the focus of our study. Finally, administrative data for Uganda provides unusually rich information that facilitate the analysis of the levy's impact. In this section, we provide an overview of vehicle imports into Uganda and discuss each of these aspects in more detail.

1.2.1 Passenger Vehicles in LICs and Uganda

The most fundamental characteristic of international trade in vehicles vis-a-vis LICs is the high share of used vehicles. This has been recognized in the economics literature since the seminal work by Grubel (1980) and still holds true today with the used share increasing and exceeding 90% of LIC vehicle imports since around 2010.[9] 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. Another key characteristic of LIC vehicle imports is the concentration of origins

[9]See Figure A.2 in the Appendix.

in the US, the EU, and Japan, with the third being particularly prominent among former British colonies due to the right-hand drive position of the steering wheel.[10] Uganda's vehicle imports also reflect this pronounced role of Japan with over 80% originating from there since 2005 (over 90% since 2012). This matters in the sense that consumers in other LICs (particularly those with right-hand drive) likely face similar vehicle choices as Ugandans, which speaks to the generalizeability of our findings.

Beyond these trade patterns, Uganda has also engaged in precisely the type of regulation that has been most prominent among LICs globally (UNEP, 2020). In particular, since 2006 the Ugandan government has implemented a series of tariffs and, more recently, outright bans based on vintage to reduce old vehicle imports and curb the corresponding environmental pollution. Our analysis focuses on an increase in the tariff on passenger vehicles over the age of 5 years that came into effect in July 2015.[11] 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 (henceforth, "10+ years").[12][13] 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 hence provide a natural counterfactual group as they are likely subject to similar demand and supply shocks as passenger vehicles.[14] Our study covers the period from January 2013 until June 2018, during which this levy increase for passenger vehicles was the only relevant change.[15] Finally, the levy increase in Uganda provides an opportunity to study substitution patterns in light of the trade off between vehicle price and age that are intrinsically absent in the context of outright bans, on which the literature to date

[10]In addition, 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 according to UN Comtrade data.

[11]This tariff 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 Act, 2009.

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

[13]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.

[14]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".

[15]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.

has focused (Clerides, 2008; Davis and Kahn, 2010).

Distribution Channels

In addition to vehicle imports and their regulation in Uganda, it is also important to highlight two broad "distribution channels", by which the vehicles may reach the first end user in country.[16] The traditionally most common channel involves a professional intermediate traders that import vehicles and ultimately resell them to end user domestically. The traders in Uganda typically keep the 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.[17] The second channel is characterized by end users' importing the vehicle directly from international markets 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.[18] These online platforms typically have a physical office in Uganda to assist with purchases, but do not hold any vehicle inventory. 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. The distinction between these two channels is important, because seemingly identical vehicles are available both internationally and from traders, but at systematically different price levels. International prices tend to be lower and domestic prices higher as traders face additional costs, especially the cost of capital embedded in vehicle inventory.

1.2.2 Data

In order to study the impact of the 2015 environmental levy increase in Uganda, we rely primarily on two sources of administrative data from the Uganda Revenue

[16]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.

[17]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.

[18]The increased prominence of online platforms also appears to apply to other LICs. The currently most popular such platform *Be Forward* from Japan has local offices in 17 African countries.

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.[19] 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 further allow us to add detailed vehicle characteristics beyond those already included with the registrations. 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.[20] In combination with the anonymized tax-identification numbers (TIN), this allows us to distinguish between the different distribution channels (depending on the involvement of intermediate traders) 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 domestic prices available for the country from secondary sources.[21]

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

[20] 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.

[21] 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 "fill in" the prices for the choice set, where they are otherwise missing, and provide a detailed description of this procedure in the Appendix. This is a common issue in the context of used goods for which posted prices may not be available and similar approaches have been used elsewhere (see, e.g., Clerides, 2008).

1.3 Descriptive Statistics & Reduced-Form Analysis

In this section, we present descriptive statistics and reduced-form evidence of the impact of the 2015 levy increase in Uganda on imports and first-time registrations. Specifically, we begin by discussing plots of these quantities surrounding the policy change that provide an intuitive understanding of its impact. We then proceed by conducting a basic econometric analysis that quantifies this notion and offers a more rigorous causal interpretation.

1.3.1 Descriptive Statistics

Figure 1.1 shows the monthly number of passenger vehicles imported by age group from 2013 to 2017, separately for end users (top panel) and intermediary traders (bottom panel). The announcement of the levy increase at the end of May 2015 and the implementation in July 2015 are marked with dashed vertical lines. Several observations are of note here. First, the vast majority of vehicles imported by both end users and traders are at least 10 years old; indeed over one-third of all imports are at least 16 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 among vehicles imported by intermediary traders that first need to be resold to end users. This can be seen in Figure 1.2, which plots the monthly number of new registrations by channel for the same period and age groups as in Figure 1.1. Registrations of vehicles imported by end users broadly follow a smoothed version of the dynamics observed among imports, peaking just before the levy increase, dipping thereafter, and then increasing gradually. Registrations of vehicles purchased from traders, 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 16+ 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 vehicles imported directly by end users.

Figure 1.1: 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 top panel shows vehicle imports by end users; the bottom panel shows vehicle imports by intermediary traders. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

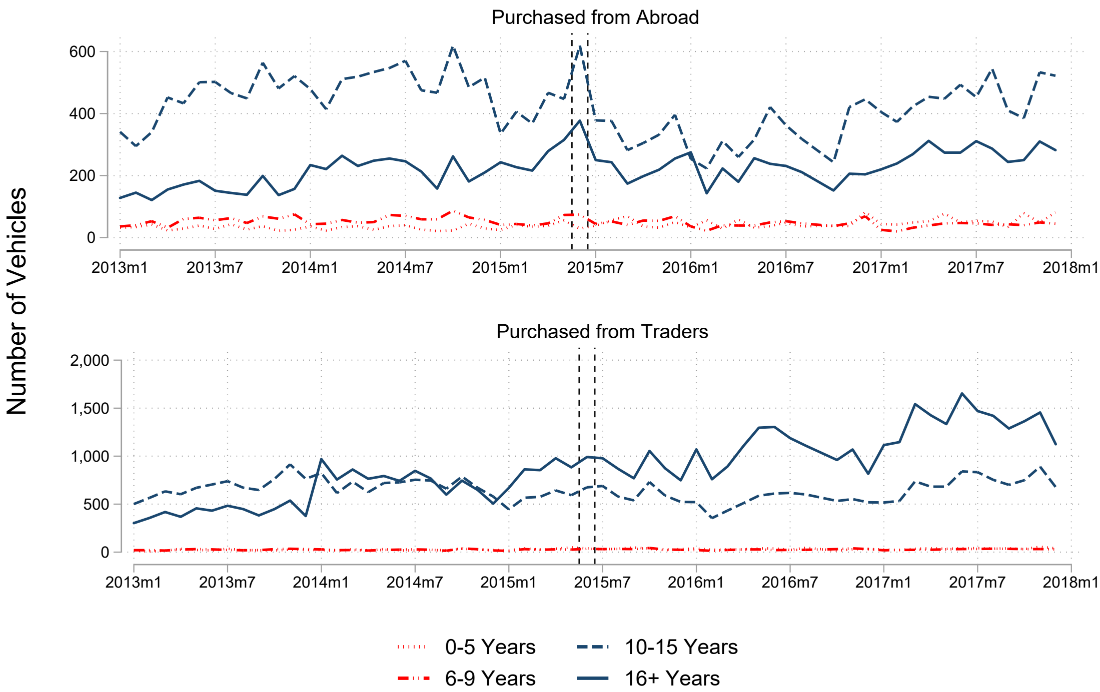
1.3.2 Reduced-Form Analysis

The above descriptive statistics suggest that the levy increase in Uganda reduced overall imports of the targeted vehicle groups but had a mixed impact on registrations. They also highlight considerable size differences between vehicle age groups and heterogeneous responses to the levy between channels, i.e., vehicles imported by end users directly and those imported and resold by intermediary traders. In this subsection, we place this understanding on more rigorous footing by estimating the levy impact using a DID model that leverages exempted goods vehicles as the natural counterfactual group in the Ugandan context. Specifically, we estimate two-way fixed-effects models of the following form:

$$y_{gt} = \lambda_g + \tau_t + \sum_h \beta_h D_{gt}^{(h)} + \epsilon_{gt} \tag{1.1}$$

The left hand side variable y_{gt} denotes the natural logarithm of the number of imports or first-time registrations. The variables $D_{gt}^{(h)}$ are treatment indicators for

Figure 1.2: 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 top panel shows registrations of vehicles imported by end users; the bottom panel shows registrations of vehicles imported by intermediary traders and resold to end users. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

the passenger vehicles groups h (0-5, 6-9, 10-15, and 16+ years) and the post-announcement period (i.e., months from June 2015 onwards). The terms λ_g and τ_t are vehicle treatment group and period fixed effects and ϵ_{gt} is the error term.

The coefficient β_h in equation (1.1) captures the average impact of the levy change for treatment group h (across months) under the standard parallel trends assumption.[22] We test this assumption using plots of the difference between outcome variables for the treatment and control groups (see Figures A.4 and A.6 in the Appendix) and event studies that are implemented at a more disaggregated cross-sectional level (see Figures A.4 and A.6 in the Appendix).[23] These tests lend the strongest support for the parallel trends assumption among 10-15 year old vehicles. Imports and registrations of 0-5 year old vehicles are so few in number that the

[22]Specifically, the parallel trends assumption in our context is that, in the absence of the levy increase, imports and first-time registrations of targeted passenger vehicle groups would have evolved according to equation (1.1) with $D_{gt}^{(h)} = 0$ for all groups h.

[23]The difference between outcomes for the treatment and control groups, normalized by mean difference before the levy change, essentially mimic the point estimate of the event study. Given that there are only a five treatment groups g for any given month, however, there is not sufficient cross-sectional variation for statistical inference.

data series is very noisy and there is some evidence of differential trends between treatment and control among 6-9 and 16+ year old vehicles. The treatment group is declining against the control among 6-9 year old vehicles and increasing among 16+ year old vehicles. Given this mixed support for the parallel trends assumption, we interpret the results of this analysis as indicative rather than definitive evidence of the levy impact.

The estimation results for the β_h parameters are reported in Table 1.2. Specifications (1)-(3) show the results for imports by end users, by traders, and the total across the two channels; and specifications (4)-(6) show the results for first-time registrations, representing end user purchases directly from abroad, from domestic traders, and again the total across the two channels. There are three key findings regarding the impact of the levy change that follow from these results. First, imports and registrations of 6-9 and 10-15 years old vehicles declined substantially due to the levy increase and this drop is broadly consistent across channels. Imports decline by 41% and 48% and first-time registrations decline by 28% and 31% for the two age groups, respectively. These effects of the levy increase align with the policy's objective.

Second, there is evidence of substitution towards non-targeted, younger vehicles but also towards targeted, older vehicles. Specifically, end user purchases of 0-5 year old passenger vehicles increased by 19% relative to goods vehicles; and imports of these vehicles among end users also appear to have increased, although the point estimate of the levy impact is not statistically different from zero. This effect of the levy also aligns with the policy's objective. Among 16+ year old vehicles, the estimated impact of the levy on imports is small in magnitude and not statistically distinguishable from zero, despite the fact that these vehicles experienced a levy increase of the same magnitude as 10-15 year old vehicles. The estimated impact among registrations is even positive. This pattern is indicative of unintended substitution from 6-9 and 10-15 year old vehicles towards 16+ year old vehicles that counters the effect of the higher levy on these oldest vehicles.[24]

Third, the estimation results for registrations differs according to channel, which suggests that existing trader inventory mitigates the levy impact. Registrations of vehicles purchased directly from abroad by end users roughly mirror imports, in particular the declines among 6-9 and 10-15 year old vehicles and the null-effect on 16+ year old vehicles. For vehicles purchased from traders, on the other hand, the coefficients for registrations are substantially lower in magnitude than those for

[24] An alternative explanation one might consider is a very low price elasticity of demand for 16+ year old vehicles. This seems less likely in our case, given the strong response of imports among 10-15 year old vehicles and the positive coefficient among registrations.

imports (among 6-9 and 10-15 year old vehicles) or even positive (among 0-5 and 16+ year old vehicles). These divergent results between channels are indicative of the buffering role that existing inventory plays among vehicles that are imported by intermediary traders and then resold to end users. In the Appendix, we provide further evidence in support of this interpretation. We first show that trader inventory accumulated in the months and years leading up to the levy increase and was run down in its aftermath (see Figure A.3).[25] In addition, we also estimate a version of equation (1.1) that includes separate treatment indicators for the announcement and implementation phase of the levy increase. These regressions show that traders advanced vehicle purchases in the month prior to the policy change to avoid the higher levy, thereby further adding to the existing inventory (see Table A.2).

Table 1.2: Aggregate DID Regressions of Vehicle Imports and Registrations

	Imports By			End User Purchases From		
	End Users	Traders	Total	Abroad	Traders	Total
	(1)	(2)	(3)	(4)	(5)	(6)
0-5 Years	0.127	-0.021	0.085	0.197**	0.198***	0.189***
	(0.078)	(0.084)	(0.065)	(0.084)	(0.076)	(0.059)
6-9 Years	-0.400***	-0.555***	-0.414***	-0.415***	-0.027	-0.281***
	(0.084)	(0.109)	(0.086)	(0.071)	(0.064)	(0.059)
10-15 Years	-0.423***	-0.503***	-0.477***	-0.377***	-0.262***	-0.305***
	(0.057)	(0.071)	(0.060)	(0.055)	(0.049)	(0.043)
16+ Years	-0.065	-0.050	-0.073	0.019	0.443***	0.354***
	(0.070)	(0.082)	(0.071)	(0.062)	(0.066)	(0.061)
Obs.	295	295	295	295	295	295
R2	0.944	0.963	0.966	0.962	0.984	0.981
R2-Within	0.227	0.201	0.243	0.291	0.296	0.410

Notes: Table reports the coefficients on the treatment indicators from estimating equation 1.1. 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 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.

Overall, the descriptive statistics and econometric analysis presented in this section paint a mixed picture of the effectiveness of the environmental levy in Uganda. On the one hand, the levy increase resulted in a substantial reduction in vehicle imports and first-time registrations among the intermediate age groups and an increase in younger, non-targeted vehicles. On the other hand, the levy increase raised imports and registrations of the oldest vehicles, which is likely due to substitution from the intermediate age groups. In addition, we also document differences in the levy impact on imports and registrations that point to the role of trader inventory as a buffer against the levy change in the short run. The remainder of the paper will

[25]In the absence of stock data from prior to January 2013, we measure exiting inventory as the cumulative difference between trader imports and registrations of vehicles purchased from traders. This measure is essentially normalized to an unknown starting value at the beginning of our sample.

analyze in further detail these substitution patterns that appear to have undermined the levy's effectiveness.

1.4 Structural Model & Estimation Strategy

One of the major challenges in analyzing substitution in response to the levy increase in a reduced-form context is that the policy change targeted a broad range of vehicle age groups simultaneously. As such, we are unable to separately identify the levy's effect through substitution and the effect via higher own prices on any targeted vehicle. In this section, we therefore present a theoretical model of the market for newly imported personal vehicles in Uganda that introduces sufficient structure to distinguish these two effects. Demand is given by the end users' discrete choice over vehicles in the spirit of the seminal work by BLP and we distinguish supply according to the two relevant distribution channels, from international markets and via intermediate traders.

Our analysis, both in the presentation of the model and the estimation, notably focuses on vehicle demand. This is necessary, because our data on domestic vehicle prices only cover a subset of the vehicles available for purchase, so that estimating demand and supply jointly is not feasible in our setting. Instead, we use the supply side of the model to motivate an estimating equation of the levy pass-through that we use to fill in domestic prices for vehicles where these are otherwise unavailable. We discuss the most important aspects of vehicle supply below but reserve details of the model that operate in the background for the Appendix.

Our structural model is static despite the fact that we documented changes in trader inventory in the previous section. We take this approach primarily for analytical expedience, but recognize that it diverges somewhat from the empirical reality. To mitigate this difference, we turn to fiscal years as the period of observation rather than months.[26] This diminishes the relevance of changes in inventory, although it does not eliminate it entirely.

1.4.1 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

[26] More realistic dynamics would mostly be warranted on the supply side. We could allow traders to optimize inventory in a forward looking fashion with adjustment cost. The main difference for our analysis would likely be a slower change of domestic prices in response to the levy change as inventory cannot immediately move to the new optimal level.

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. The prices of vehicles purchased from international markets are given by the cost, insurance, and freight (CIF) value at the Ugandan border plus any applicable duties and tariffs.

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, and manufacturing year triplet 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.[27] The prices of vehicles purchased domestically are international prices plus the trader margin according to the symmetric Cournot equilibrium.

1.4.2 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 fiscal year $t = 1, \ldots, T$ 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 (those purchased from abroad vs. from an intermediary trader domestically). 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 higher than the international prices.[28]

Consumer i derives indirect utility u_{ijt} from choosing vehicle j in fiscal year t, where the utility is a function of observable vehicle characteristics, an unobservable

[27] 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.

[28] This suggests that not all consumers have access to international markets and/or discount the value of importing vehicles directly from abroad. Such discounting may reflect, for instance, that personal inspection is only possible via travel to the exporting country — an end user wishing to import a vehicle 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.

vehicle-specific valuation, and an unobservable individual-specific valuation. We parameterize indirect utility linearly according to a standard "nested-logit" specification:

$$
\begin{aligned}
u_{ijt} = &\mathbf{x_j}\beta + \alpha^p p_{jt} + \alpha^a a_{jt} + \alpha^d d_j + \xi_{jt} \\
&+ \zeta_{igt} + (1-\sigma)\epsilon_{ijt}
\end{aligned}
\tag{1.2}
$$

, where $\mathbf{x_j}$, p_{jt}, a_{jt}, and d_j denote a vector of observable vehicle characteristics, the vehicle price, vehicle age, and an indicator for purchasing the vehicle directly from abroad, 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, $\mathbf{x_j}$, are time-invariant and include features, such as engine capacity, tire diameter, and manufacturer country. Nesting groups are denoted as g and σ is the corresponding within-group correlation coefficient. Vehicle prices are international prices p^I_{jt} for any vehicle j available from international markets (with $d_j = 1$), and domestic prices p^D_{jt} otherwise. 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 purchases from abroad and intermediary traders domestically) 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.

Consumers in any fiscal year t maximize utility by choosing at most one vehicle j, or the outside option of no purchase $j = 0$. Given the individual-specific unobservable υ_{ijt} is a random variable, the probability of choosing any vehicle j in period t is $s_{ijt} \equiv \mathbb{P}[u_{ijt} > u_{ikt} \ \forall \ k \neq j]$. It then follows from equation (1.2) and the distributional assumptions on υ_{ijt} that the predicted share of vehicle j in fiscal year t is given by the following expression:

$$
s_{j,t} = \frac{exp(\frac{\delta_{jt}}{1-\sigma})}{D_g^{\sigma}(\sum_h D_h^{1-\sigma})}
\tag{1.3}
$$

, where $\delta_{jt} \equiv \mathbf{x_j}\beta + \alpha^p p_{jt} + \alpha^a a_{jt} + \alpha^d d_j + \xi_{jt}$ denotes the mean utility of vehicle j and $D_g \equiv \sum_{k \in J_g} exp[\delta_{kt}/(1-\sigma)]$. The expected number of type j vehicles is $q_{jt} = s_{jt} M_t$.

The increase in the environmental levy in Uganda is reflected in this model through higher international prices, p^I_{jt}, for targeted vehicles over the age of five years. These also immediately imply higher end user prices for such vehicles available from the international market as $p_{jt} = p^I_{jt}$ in that case. The prices of targeted vehicles available via intermediary traders, p^D_{jt}, also rise, because the levy increase raises their marginal cost of supply, but this may be mitigated as traders absorb some of this cost shock by reducing gross margins.[29] In any case, the first-order effect of the levy increase is that end users face higher prices for vehicles of the targeted age groups across the board.

For any given vehicle j, these higher prices then have two opposing effects on demand and the corresponding market-clearing quantities, as can be seen from equation (1.3). First, demand for targeted vehicles drops following the increase in the own price, provided the parameter α^p is negative.[30] Second, demand for any vehicle (not just targeted) rises following the increase in other vehicles' prices under the same assumption.[31] For a given targeted vehicle, the overall impact of the levy increase that combines these two effects is ambiguous; for non-targeted vehicles, only the second, positive effect applies.

One key determinant for whether the negative effect of increasing own prices outweighs the positive effect due to substitution (or vice-versa) is the relative change in prices. This is especially important in our context, because vehicle depreciation in value implies that a given ad-valorem rate yields an absolute tariff that tends to decline in magnitude with vehicle age. Younger vehicles therefore tend to get relatively more expensive and older vehicles relatively cheaper for a common tariff rate increase, such as implemented for vehicles aged 10+ years in 2015 in Uganda. More formally, if we consider two vectors of prices $\mathbf{p_t}$ and $(1+\tau)\mathbf{p_t}$ with $\tau \in \mathbb{R}^+$, then $(1+\tau)(p_{jt}-p_{kt}) > (p_{jt}-p_{kt})$ for $p_{jt} > p_{kt}$. Fixing all non-price terms of indirect utility in equation (1.2) and viewing it as a function of price, this implies that the $\{u_{ijt}[(1+\tau)p_{jt}] - u_{ikt}[(1+\tau)p_{kt}]\} < [u_{ijt}(p_{jt}) - u_{ikt}(p_{kt})]$ for $p_{jt} > p_{kt}$ assuming $\alpha^p < 0$; the converse holds for $p_{jt} < p_{kt}$.[32] Therefore, the difference between the shares with the tax τ and without, $\{s_{j,t}[(1+\tau)\mathbf{p}] - s_{j,t}(\mathbf{p})\}$ tends to be negative

[29] See details of the profit-maximizing conditions in the Appendix.

[30] It can be shown that $\partial s_{jt}/\partial p_{jt} = s_{jt}[\alpha/(1-\sigma)][1-\sigma s_{j|g,t} - (1-\sigma)s_{jt}] < 0$ if $\alpha^p < 0$ and $\sigma \in [0,1]$.

[31] It can be shown that $\partial s_{jt}/\partial p_{kt} = s_{jt}[\alpha/(1-\sigma)][\sigma s_{k|g,t} - (1-\sigma)s_{kt}]$ if $k \in J_{g(j)}$ and $\partial s_{jt}/\partial p_{kt} = s_{jt}[\alpha/(1-\sigma)]s_{kt}$ otherwise, both of which are negative if $\alpha^p < 0$ and $\sigma \in [0,1]$.

[32] Spare parts are notably not targeted by the types of environmental levies we study in this paper. As such, it is indeed appropriate to "fix the non-price terms of utility" in this argument. If this was not so, the cost of repair would also be higher in the context of the environmental levy and this would disproportionately affect older vhicles, thereby mitigating the tendency of substitution towards older vehicles.

for more expensive (younger) vehicles and positive for cheaper (older) vehicles. In practice, the tariff schedules are progressive in vehicle age, which mitigates this effect around the threshold but possibly not for broad age ranges away from the thresholds with uniform tariff rates.

The ultimate extent of substitution of course also accounts for end user preferences over vehicle age and other characteristics that are associated with price. Assuming end users prefer younger vehicles so that $\alpha^a < 0$, they will trade off the lower-magnitude impact of the levy among cheaper (older) vehicles against the higher age. The optimal choice that gives rise to the equilibrium market shares and quantities after the levy increase will balance these opposing implications for utility.

1.4.3 Estimation Strategy

Given the nested-logit specification of utility, we can derive the following estimating equation that relates empirical vehicle shares to observable characteristics (Berry, 1994):

$$\begin{aligned} ln(s_{jt}/s_{0t}) = \mathbf{x_j}\beta + \alpha^p p_{jt} + \alpha^a a_{jt} + \alpha^d d_j \\ + \sigma ln(s_{j|g,t}) + \xi_{jt} \end{aligned} \tag{1.4}$$

The terms is equation (1.4) are as defined in the previous subsection with the exception of $s_{j|g,t}$, which denotes the vehicle j within-nesting-group share, $s_{j|g,t} \equiv exp[\delta_{jt}/(1-\sigma)]/D_g$.

Identification of the structural parameters in equation (1.4) requires that the explanatory variables 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 endogenous for two reasons. First, on the domestic market, prices charged by intermediary traders are functions of demand for all vehicles in the choice set and therefore also of the unobservable preference shocks.[33]. Second and less obviously, international prices are also endogenous despite assuming competitive supply as they are likely positively related to consumers' valuation of unobservable 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, $\xi_{m(j).}$, a period-specific

[33]See supply equation (A.6).

term, $\xi_{.t}$, and a residual $\tilde{\xi}_{jt} \equiv \xi_{jt} - \xi_{m(j).} - \xi_{.t}$. 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 (1.4) via generalized method of moments (GMM) 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.

We estimate equation (1.4) on vehicle purchases in Uganda (i.e., first-time registrations) covering the fiscal years 2013/14 to 2017/18. The choice sets comprise the complete range of manufacturing years for any given make/model pair imported or registered at least once in a given channel during our sample period. Accordingly, the choice sets differ by distribution channel — the set of vehicles available abroad is almost 60 percent larger. For the estimation, we exclude make/model pairs with less than 50 registrations to focus on vehicles that are quantitatively important for the Ugandan market.

1.5 Results & Counterfactual Simulation

In this section, we estimate the structural parameters of vehicle demand and use them to simulate various policy counterfactuals. The counterfactuals correspond to hypothetical scenarios of alternative levy increases and allow us to achieve two key objectives. First, they allow us to estimate the levy impact on vehicle purchases and consumer welfare without relying on goods vehicles as a control group. Secondly, we can use them to quantify substitution between different vehicle age groups and the extent to which substitution mitigates the direct impact of the levy increase.

1.5.1 Results

Table 1.3 reports the results from estimating the demand equation (1.4). The first pair of columns report 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 more general *nested-logit* specification. Within each pair, the first specification is estimated via ordinary least squares (OLS) while the second is estimated via GMM using the instrumental variables (IVs) as discussed above.

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 (1.35 in the logit versus 1.45 in the nested-logit version) and the implied distribution of own-price elasticities is also very similar (compare Figures 1.3 below and A.12 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 -0.047 (-0.109 to -0.264 in the logit specifications) and that of the nesting group parameter drops from 0.985 to 0.833 when moving from OLS to GMM. At the bottom of the table, we are also reporting the Kleibergen-Paap rk statistic and the p-value of the Hansen J statistics as weak identification and overidentification tests, respectively. The Kleibergen-Paap rk statistic tests the null hypothesis of underidentification and is rejected in both the logit and nested-logit models at the 5% level. This implies that our instrumental variables are sufficiently correlated with endogenous regressors. The Hansen J statistic is a test of the exclusion restrictions and therefore of the instruments' validity as well as the overall model specification. This joint null hypothesis is also rejected, which implies that either some of the instruments are invalid or that other model misspecifications violate the exclusion restrictions (Hayashi, 2000; Hansen, 2021). There is some evidence that the latter is the root cause, as the exclusion restriction cannot be rejected when the levy indicator for 6-9 year old vehicles is added as in included rather than an excluded instrument. We are currently in the process of testing other instrument vectors and specifications to shed further light on this issue.

The IV estimates for the nested-logit specification in Table 1.3 are intuitive for all parameters. The point estimate of $\hat{\alpha}^p = -0.047$ implies a mean own-price elasticity of -5.8 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

Table 1.3: Structural Parameter Estimates in Demand Equation

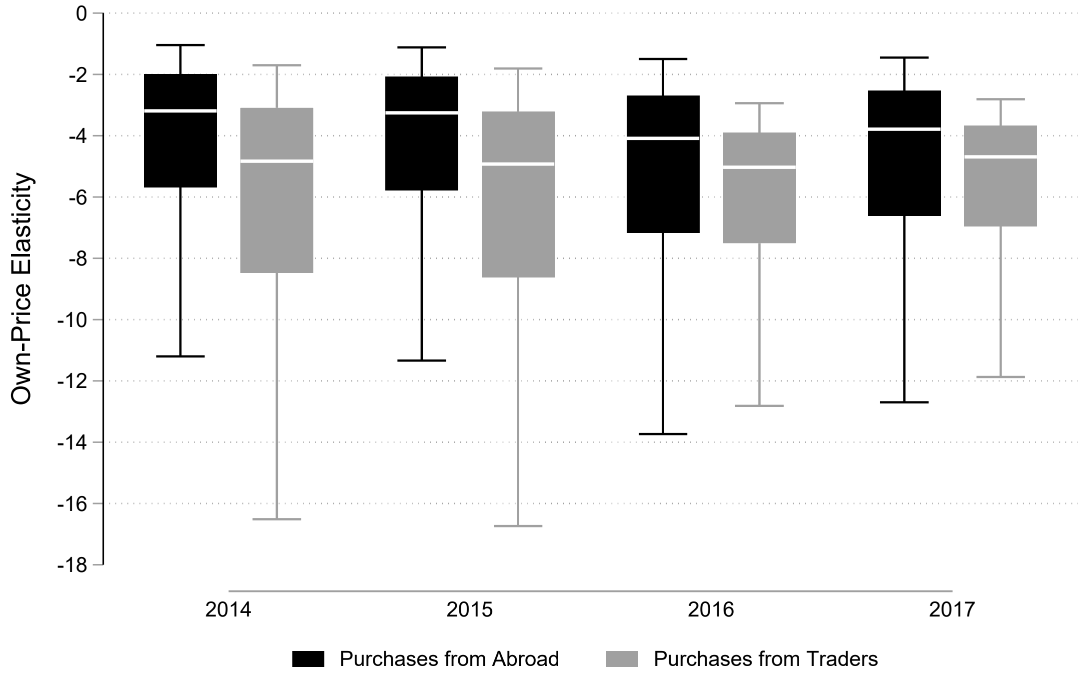
	Logit		Nested Logit	
	(1)	(2)	(3)	(4)
Eff. Price (α^p)	-0.109***	-0.264***	-0.007***	-0.047***
	(0.017)	(0.042)	(0.002)	(0.018)
Age (α^a)	-0.203***	-0.356***	-0.011***	-0.068***
	(0.017)	(0.039)	(0.004)	(0.018)
Direct (α^d)	-0.237**	-0.854***	-0.724***	-0.742***
	(0.106)	(0.206)	(0.021)	(0.075)
ln(Group Share) (σ)			0.985***	0.833***
			(0.004)	(0.027)
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
Kleibergen-Paap rk		45.10		35.94
Hansen J P-Value)		0.00		0.00

Notes: Observations are annual log-differences of share of the "eligible" Ugandan population purchasing a vehicle (defined by make, model, manufacturing year and channel) 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 combinations and fiscal year 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.

year is illustrated in Figure 1.3 below.[34] The higher magnitude of the elasticity for vehicles purchased from traders notably reflects the higher prices of these vehicles; the demand model assumes a constant price parameter across the two channels. The other parameter estimates can be best interpreted relative to the price parameter. Specifically, $\hat{\alpha}^a = -0.068$ means that Ugandan consumers value a year of vehicle age at approximately 1.45 MMUSh (i.e., -0.068 / -0.047 MMUSh/Year) or 7% of the average vehicle price. Similarly, $\hat{\alpha}^d = -0.742$ means that Ugandan consumers dislike importing vehicles directly from abroad (or equivalently face a penalty / barriers associated with doing so) and this is valued at 15.8 MMUSh (i.e., -0.742 / -0.047 MMUSh). This is a substantial penalty of approximately 76% of the average vehicle price. Finally, the nesting group parameter estimate $\hat{\sigma} = 0.833$ shows that there is substantial correlation of preferences within vehicle groups as defined by engine capacity and distribution channel.

[34]The distribution of own-price elasticities for the logit-specification are very similar and illustrated in Figure 1.3 in the Appendix.

Figure 1.3: Distribution of Estimated Own-Price Elasticity - Nested Logit



Notes: Distribution of own-price elasticity for vehicles according to the estimates in specification (4) of Table 1.3. 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.

1.5.2 Counterfactual Simulations

With the structural parameters at hand, we then simulate various policy counterfactuals that allow us to (i) quantify the levy impact on vehicle purchases and consumer welfare, (ii) decompose the overall effect into a direct component and substitution, and (iii) predict the impact of alternative tariff regimes.[35] For any given vehicle age group n (0-5, 6-9, 10-15, 16+ years), we denote the vector of prices for all vehicles with the actual levy increase as $\mathbf{p_n}$ and those with a κ-percent levy increase as $\mathbf{p_n^{(\kappa)}}$. Throughout this subsection, we will be interested in counterfactuals with $\kappa \in \{0, 75, 100\}$, corresponding to no levy increase, an increase to 75%, and an increase to 100%, respectively. We further denote the predicted fiscal year t shares under price vector $\mathbf{p}$ as $\mathbf{s_t}(\mathbf{p})$, where we occasionally separate prices for vehicles of one age group n by splitting the vector into two components $\mathbf{p} = [\mathbf{p_n}, \mathbf{p^{(0)}_{-n}}]$.

The impact of any given levy increase on purchases of vehicle j of age group n is then simply given by the difference between the actual/counterfactual shares with

[35] Specifically, we simulate the counterfactuals using the estimated coefficient vector, fixed effects, and residuals from our preferred specification (4) in Table 1.3.

prices $\mathbf{p}$ and a baseline counterfactual without levy increase on any age groups and corresponding prices $\mathbf{p^{(0)}}$:

$$\Delta s_{jt}(\mathbf{p}) = s_{jt}(\mathbf{p}) - s_{jt}(\mathbf{p^{(0)}}) \tag{1.5}$$

In addition, the impact on consumer welfare due to the levy increase corresponding to this actual/counterfactual scenario is given by the following expression. This simple form is afforded by the nested-logit specification for demand and has been adopted from Trajtenberg (1989).

$$\Delta W_t(\mathbf{p}) = \frac{1}{\alpha^p} ln \left[\frac{\sum_g D_{gt}(\mathbf{p})^{1-\sigma}}{\sum_g D_{gt}(\mathbf{p^{(0)}})^{1-\sigma}} \right] \tag{1.6}$$

, where $D_{gt}(\mathbf{p}) \equiv \sum_{j \in J_{gt}} exp(\frac{\delta_{jt}(\mathbf{p})}{1-\sigma})$.

These measures of the impact of the levy increase under the actual and three alternative tariff regimes are reported Table 1.4. Odd-numbered columns report the impact on purchases relative to the baseline number of vehicles in any given age group.[36] Even-numbered columns report the impact on purchases relative to the total baseline number of vehicles in the market.[37] The impact of the actual levy increase with prices $\mathbf{p}$ is reported in columns (1) and (2). The first alternative tariff regime in columns (3) and (4) only raises the levy on 16+ year old vehicles while the other age groups exhibit no levy increase, i.e., $\mathbf{p} = [\mathbf{p}^{(0)}_{-(16+)}, \mathbf{p}_{(16+)}]$. The second alternative regime in columns (5) and (6) applies a tariff of 75% on 16+ year old vehicles and maintains the actual levy increase on the other age groups, i.e., $\mathbf{p} = [\mathbf{p}_{-(16+)}, \mathbf{p}^{(75)}_{(16+)}]$. Finally, the third alternative regime in columns (7) and (8) applies a tariff of 100% on 16+ year old vehicles and again maintains the actual levy increase on the other age groups, i.e., $\mathbf{p} = [\mathbf{p}_{-(16+)}, \mathbf{p}^{(100)}_{(16+)}]$. The motivation for the focus on 16+ year old vehicles in these counterfactual scenarios is that that registrations in this age group did not respond to the actual levy increase according to the reduced form analysis in section 1.3. We confirm this result in our structural analysis here and further show that it is indeed due to unintended substitution from younger vehicles that were also targeted.

Impact of Actual Levy Increase

[36] That is, they report $\sum_{j\in n} \Delta s_{jt}(\mathbf{p}) / \sum_{j \in n} s_{jt}(\mathbf{p^{(0)}})$

[37] That is, they report $\sum_{j\in n} \Delta s_{jt}(\mathbf{p}) / \sum_{j} s_{jt}(\mathbf{p^{(0)}})$

Table 1.4: Impact of Actual Levy Increase and Counterfactual Scenarios

	Actual		Counterfactuals					
			16+ Years Only		75% 16+ Years		100% 16+ Years	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age 5 years or below	1.531	0.012	0.221	0.002	3.712	0.028	3.865	0.029
Age 6 to 9 years	-0.739	-0.036	0.227	0.011	-0.518	-0.025	-0.494	-0.024
Age 10 to 15 years	-0.150	-0.055	0.187	0.069	0.640	0.235	0.747	0.274
Age 16+ years	0.030	0.018	-0.182	-0.105	-0.669	-0.386	-0.753	-0.435
Total		-0.061		-0.024		-0.185		-0.192
Consumer Surplus		-0.073		-0.029		-0.173		-0.182

Notes: Table reports the impact of the actual and counterfactual levy increases in terms of the number of vehicles purchased by age group (centre part), the total number of vehicles purchased (bottom part), and consumer surplus (bottom part) averaged over the 2015/16-2017/18 fiscal years. All measures are relative to the baseline counterfactual of no levy increase. Odd-numbered columns report the impact on purchases relative to the baseline number of vehicles in any given age group; even-numbered columns report the impact on purchases relative to the total baseline number of vehicles in the market.

The results presented in Table 1.4, column (1) for the actual levy increase are qualitatively similar to those for first-time registrations from our reduced form analysis in section 1.3. The levy increase led to a reduction in vehicle purchases of the intermediate age groups — by 74% for 6-9 year old and by 15% for 10-15 year old vehicles — and an increase in the purchases of the youngest and oldest vehicles — by 153% for 0-5 and by 3% for 16+ year old vehicles. Overall, vehicle purchases drop by 6% as a result of the levy increase and consumer surplus drops by 7%. The magnitudes of the effects by age group notably differ from those in the reduced form analysis, although this is not entirely surprising. First and in contrast to the results presented here, the reduced form analysis is affected by the changes in goods vehicle purchases and there is evidence that these are only an imperfect counterfactual group for passenger vehicles, especially outside 10-15 year old vehicles. Second, the assumptions underlying the structural model of course also contribute to the simulated levy impact. In particular, the constant price coefficient α^p in combination with international prices that are decreasing in vehicle age imply a lower-magnitude response among older vehicles to any given levy increase. This also seems to be reflected in these measure of the levy impact between the different age groups.

Furthermore, the results in column (2) show the contribution of each age group to the overall 6% reduction of passenger vehicle purchases. Vehicles aged 6-9 and 10-15 years contribute reductions of 3.6 and 5.5 percentage points, respectively; and this is mitigated by positive contributions from 0-5 and 16+ year old vehicles of 1.2 and 1.8 percentage points, respectively. The differences in the relative magnitudes to column (1) arise, because the age groups account for vastly different portions of the vehicle purchases in Uganda. Vehicles aged 0-5 years, for instance, exhibit a dramatic rise in registrations relative to the number of vehicles in the age group, but these are still only a small share out of the total number of vehicles purchased.

Most of the levy impact derives from older vehicles, especially those aged 6-9 and 10-15 years.

Distinguishing Direct Impact from Substitution

Up to this point in the empirical analysis, we have focused on the overall impact of the levy change and thereby abstracted from two underling components — the direct impact on any given vehicle due to its own levy's increasing and an indirect impact due to substitution from other vehicles that were targeted at the same time. The results in Table 1.4 and those from the reduced form estimation in section 1.3 all suggest that these two components are important and affect vehicle age groups differently. Substitution, in particular, is obviously fundamental to the positive levy impact on 0-5 year old vehicles and the positive (or neutral) impact on 16+ year old vehicles. We therefore also use the parameter estimates from the structural model to simulate counterfactuals that allow us to distinguish these two underlying components. Specifically, we implement the following two alternative decompositions for the overall impact $\Delta s_{jt}(\mathbf{p})$ on vehicle j of age group n:

$$\Delta s_{jt}(\mathbf{p}) = \underbrace{s_{jt}(\mathbf{p_n}, \mathbf{p^{(0)}_{-n}}) - s_{jt}(\mathbf{p^{(0)}})}_{\Delta s^{Dir}_{jt}(\mathbf{p})} + \underbrace{s_{jt}(\mathbf{p}) - s_{jt}(\mathbf{p_n}, \mathbf{p^{(0)}_{-n}})}_{\Delta s^{Sub}_{jt}(\mathbf{p})} \tag{1.7}$$

and

$$\Delta s_{jt}(\mathbf{p}) = \underbrace{s_{jt}(\mathbf{p}) - s_{jt}(\mathbf{p^{(0)}_n}, \mathbf{p_{-n}})}_{\Delta s^{Dir}_{jt}(\mathbf{p})} + \underbrace{s_{jt}(\mathbf{p^{(0)}_n}, \mathbf{p_{-n}}) - s_{jt}(\mathbf{p^{(0)}})}_{\Delta s^{Sub}_{jt}(\mathbf{p})} \tag{1.8}$$

, where $\Delta s^{Dir}_{jt}(\mathbf{p})$ and $\Delta s^{Sub}_{jt}(\mathbf{p})$ denote the direct and substitution component, respectively, and whose other terms are defined at the beginning of this subsection. The key distinction between both components of the overall impact lies in the vehicle age groups, whose prices are changing: The direct component is defined by changes in the prices of a vehicle's own age group; the indirect component is defined by changes in the prices of all other age groups. This is true across the two alternative decompositions. The difference between the alternative decompositions relates to the prices they hold fixed. Equation (1.7) fixes the baseline counterfactual prices for the direct component (no levy increase) and the actual prices for the substitution component. We can see this for the direct component, because it reflects changes in the prices of the vehicle's own age group while maintaining the baseline counterfactual prices for all other age groups. The substitution component, by contrast, reflects the changes in the prices of all other age groups while maintaining actual prices for the vehicle's own age group. Equation (1.8) does the converse: It fixes actual prices for the direct component and the baseline counterfactual prices for the substitution component. Importantly, none of these decompositions is more appropriate than the other, because they have either the direct or indirect component reflect the true price movement under the policy change, but not both.[38]

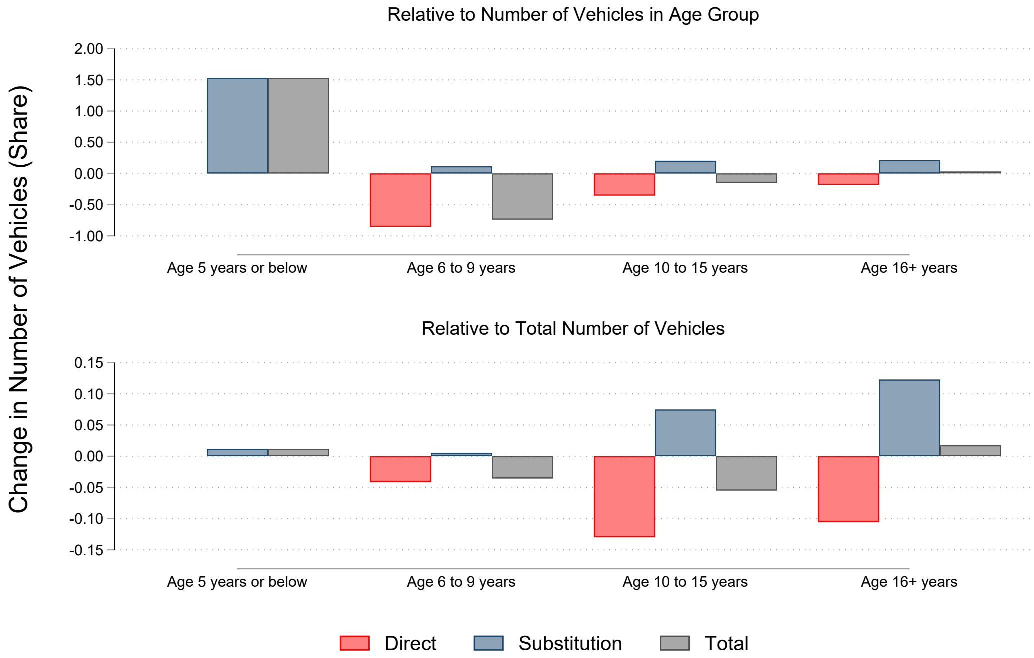
We simulate these decompositions of the overall impact of the levy change and aggregate across vehicles to the age group level. The results from these simulations according to equation (1.7) are illustrated in Figure 1.4 below; the results according to equation (1.8) are illustrated in Figure A.13 in the Appendix. The top panel shows the levy impact relative to the number of vehicles in a given age group and the bottom panel shows it relative the total number of vehicles purchased, both in the baseline counterfactual. As such, the total levy impact in the top and bottom panel (grey bars) correspond precisely to columns (1) and (2) in Table 1.4. The direct component contributes negatively to this total impact (red bars) and the substitution component contributes positively (blue bars).

The decomposition provides important insights for the origin of the relative impact of the levy increase between different vehicle age groups. Focusing on the top panel, it is evident that the decreasing total impact in vehicle age that we noted in relation to Table 1.4 is driven by both components of the decomposition. First, the magnitude of the direct impact is decreasing in vehicle age; and, second, an increasing portion thereof is eliminated by substitution. The decreasing direct impact 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 tariff. The fact that this also holds between 6-9 and 10-15 year old vehicles further suggests that the progressiveness of the tariff in age is not sufficient to overcome effect of lower prices among older vehicles (assuming constant utility of wealth). The increasing impact of substitution suggests that end users tend to substitute from younger towards older vehicles as they trade off vehicle age and price under the new tariff regime. Intuitively, the disutility from a given levy increase is higher for younger vehicles as these are more expensive while the disutility of age is (assumed) constant, so that the former tends to dominate the latter.

Similar to the comparison of columns (1) and (2) in Table 1.4, the bottom panel of Figure 1.4 shows the relevance of the direct and substitution components for the total impact of the levy increase across all age groups. In particular, the bottom

[38]The true price movement under the policy change is from baseline counterfactual to actual prices, keeping other prices fixed at the baseline counterfactual. This applies to the direct component in equation (1.7), but not the substitution component; and it applies to the substitution component in equation (1.8), but not the direct component.

Figure 1.4: Decomposition of Levy Impact



Notes: Figure shows decomposition of the total levy impact in terms of on vehicle purchases by age group (grey bars) into the direct component due to the levy increase on that age group (red bars) and the substitution component due to the levy increase on other age groups (blue bars), following equation (1.7). All measures are relative to the baseline counterfactual of no levy increase. The top panel shows the impact relative to the baseline number of vehicles in any given age group; the bottom panel shows the impact on purchases relative to the total baseline number of vehicles in the market.

panel highlights the diminished role of the younger two vehicle age groups and emphasizes the importance of two older groups. Considering the relative sizes of the vehicle age groups, the largest direct impact occurs among 10-15 year old vehicles closely followed by 16+ year old vehicles. At the same time, the relatively larger impact of substitution (vis-a-vis 6-9 year old vehicles) means that a substantial share of the direct impact is eliminated. This is especially detrimental among 16+ year old vehicles, for which substitution more than offsets the direct impact, so that purchases of these vehicles increase despite the fact that these tend to be the most highly polluting.

Alternative Tariff Regimes

Recognizing the contributions of both components to the overall levy impact, we finally discuss the three alternative, hypothetical tariff regimes that seek to counteract the unintended substitution from younger towards older vehicles. These alternative regimes were precisely defined at the beginning of this subsection and the results concerning the levy impact in terms of the number of vehicles purchased and consumer welfare are included in Table 1.4.

The first alternative regime applies the actual tariff increase (i.e., from 20% to 50%) only to 16+ year old vehicles. It is closely related to the decomposition in equation (1.7) in that it isolates the direct impact on 16+ year old vehicles as no other vehicles are targeted. The other age groups, in turn, are merely impacted via substitution from the oldest vehicles. This alternative regime leads to an 18.2% reduction in the purchases of 16+ year old vehicles and increases of similar magnitudes in 0-5, 6-9, and 10-15 year old vehicles (specifically, 22.1%, 22.7%, and 18.7%). Taken together and accounting for the size differences between the age groups, this implies a reduction of 2.4% of all passenger vehicles and 2.9% of consumer surplus relative to the baseline counterfactual. The large negative contribution to this total impact by 16+ year old vehicles (-10.5%) is countered mostly by substitution to 10-15 year old vehicles (+6.9%); relatively few purchases are diverted to vehicles under the age of 10 years (1.3%). Relative to the actual levy increase, this alternative regime reduces vehicle purchases by 60% less, but focuses the impact on the oldest, presumably most polluting age group and also substantially reduces the adverse impact on consumer welfare.

The second and third alternative regimes apply tariffs of 75% and 100%, respectively, on 16+ year old vehicles and maintain the actual levy increase on the other age groups. We discuss both of these together as they yield similar results. Given that multiple age groups are targeted by the levy increase, both the direct impact and substitution are again broadly relevant.[39] The higher levy increment applied to 16+ year old vehicles leads to a substantial reduction in the purchases of these oldest vehicles (by 66.9% and 75.3%, respectively). The corresponding substitution to lower age groups is best interpreted in comparison to the actual scenario as these lower age groups face the same levy increases in that case and in these two alternative regimes. Most importantly, substitution reverses the overall impact on 10-15 year old vehicles leading to sizable increases (by 64.0% and 74.7% relative to a 15.0% reduction with the actual levy increase). Substitution also reduces the magnitude of the negative impact among 6-9 year old vehicles (albeit only slightly) and more than doubles the positive impact among 0-5 year old vehicles. Given the size differences between the age groups, however, the quantitatively meaningful impacts are still among 10-15 and 16+ year old vehicles. They contribute +27.4 percentage points and -43.5 percentage points to an overall reduction of 15.6% of vehicles and 18.2%

[39]Despite this, the results from these alternative tariff regimes do not correspond directly to our decomposition analysis, because of the higher tariff applied to 16+ year old vehicles.

of consumer surplus. Relative to the actual levy increase these alternative regimes therefore reduce vehicle purchases much more (by roughly 2.5 times as much), but also reduce the consumer surplus by approximately similar proportion.

1.6 Discussion

The analysis presented in the preceding sections of this paper speaks to two fundamental questions concerning the effectiveness of vintage-based import tariffs on vehicles: How does demand for any given vehicle (or vehicle group) respond to an increase in its own tariff? And how do end users substitute in response to this tariff increase, towards other vehicles and no vehicle purchase at all? The first question relates to the own-price elasticity of demand and more broadly what we have termed the direct component of the levy impact. The answer is important, because a certain degree of responsiveness is a necessary condition for the policy to have any meaningful impact, even absent any adverse effects through substitution. The second question relates to the cross-price elasticity of demand between different vehicles and more generally what we have termed the substitution component of the levy impact. The answer to this question is important, because substitution can further the policy's environmental objectives (towards younger vehicles or no purchase) or undermine them (towards older vehicles). An effective policy would be one that, through both of these aspects, reduces demand for old vehicles while limiting the adverse impact on mobility and end user welfare by encouraging substitution towards younger vehicles. The ultimate policy choice should then balance the overall welfare impact arising in this fashion against other effects of the levy, including reduced tax revenue and lower levels of pollution. This all-encompassing welfare analysis notably extends beyond the scope of this paper, but would be a fruitful area for future research.

In relation to the first question, our analysis shows that vintage-based tariffs (unsurprisingly) reduce demand for targeted vehicles. This is most immediately evident from the estimates of the own-price elasticity of demand from our structural model and the simulated direct components of the levy impact on vehicle purchases. Demand in Uganda is elastic for all vehicles in the choice set at the prevailing market conditions and the average own-price elasticity is -5.8. The simulated direct component of the levy impact addresses the question even more precisely and shows that vehicle purchases in Uganda respond well to the levy. Although the magnitude of the effect is decreasing in vehicle age, we still predict an 18% reduction of 16+ year old vehicles in response to the levy increase from 20% to 50%. The reduced-form estimates also provide some evidence of demand's responsiveness to the increase in a given vehicle group's own levy, but should be interpreted as a lower bound given that they also capture substitution from other groups. The DID estimates of the effect on imports, in particular, imply lower bounds (in terms of magnitude) for the own price elasticities of approximately -4.8 for 6-9 year old vehicles and -2.8 for 10-15 year old vehicles.[40] Taken together, our analysis therefore provides robust support for the notion that tariffs can, in principle, induce meaningful changes in demand for imported vehicles in LICs and therefore represent suitable policy instruments.

In relation to the second question, our reduced-form analysis has provided indicative evidence of the most salient substitution patterns and our structural model and counterfactual simulations have confirmed these. While there is substitution towards the youngest, non-targeted vehicles, this age group accounts for only a very small portion of total purchases and is therefore not very meaningful for aggregate outcomes at the national level. More importantly, there is considerable substitution between 10+ year old vehicles that account for the vast majority of vehicles entering the country, including substitution towards older vehicles that undermines the policy's objectives. As pointed out in Section 1.4, a given tariff rate increase actually favors this type of substitution, because used vehicles depreciate in value with age and because the environmental levy does not raise the cost of spare parts and repair (which would disproportionately affect older vehicles). The policy's only incentive favoring younger vehicles lies in the progressiveness of the tariff regime in vehicle age. Our decomposition of the overall impact of the levy increase further shows that this prediction holds empirically. For older vehicles, an increasing share of the direct component is eliminated by substitution — i.e., 13% for 6-9 year old vehicles, 58% for 10-15 year old vehicles, and 117% for 16+ year old vehicles. As a result, the levy increase brings about no reduction in the purchases of the oldest vehicles at all. While the precise figures are particular to the levy increase implemented in Uganda in 2015, these findings imply that the oldest vehicles, which environmental policies seeks to target, tend to be most prone to this unintended mitigating effect from substitution.

These findings suggests that policies aimed at reducing the inflow of the oldest, most polluting vehicles require steeply tiered tariff regimes or outright import bans (similar to the one implemented in Uganda in 2018). These would raise the incentives for substitution towards younger vehicles, but they may also further reduce the overall number of vehicles purchased and consumer welfare. The simulations of

[40] 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 (roughly 20% in the pre-period). The percentage effective price increase as a result of the policy change at the border therefore is $15\%/173.5\% \approx 8.6\%$ for 6-9 year old vehicles and $30\%/173.5\% \approx 17.3\%$ for 10-15 year old vehicles. Dividing the coefficient estimates from Table 1.2 by these figures yields the mentioned elasticities.

three alternative tariff regimes that we present in section 1.5 shed some light on these considerations. Specifically, we find that a high tariff on only the oldest vehicles has the benefit of a limited adverse impact on consumer welfare while reducing purchases in the top age group. Highly tiered regimes targeting a broad range of vehicles, by contrast, achieve the largest reduction in vehicle purchases but also entail higher welfare costs. In both cases, substitution towards somewhat younger vehicles (10-15 years in the Ugandan context) can be achieved, but substitution toward vehicles aged 0-5 years and even 6-9 years remains limited. Tariff regimes that are flat for a wide range of vehicle ages, such as the one implemented in Uganda in 2015, are likely to reduce purchases in the intermediate age groups but less so among the oldest vehicles. [41] The simpler alternative to a steeply tiered tariff regime is an outright ban on the oldest vehicles. This would likely lead to considerable substitution towards younger vehicles just below the cutoff, but it would also involve substantially lower vehicle purchases overall and the corresponding adverse effect on consumer welfare.

1.7 Conclusion

In this paper, we provide first evidence of the effectiveness of environmentally motivated tariffs to reduce demand and therefore ultimately imports of old vehicles in LICs. Understanding the impact of such tariffs is important, because (i) LICs almost exclusively source vehicles from international second-hand markets and (ii) vintage-based tariffs are one of the main policy instruments employed by LICs to reduce emissions from old vehicles. Specifically, we study such an "environmental levy" on passenger vehicles in Uganda by estimating the impact of a substantial increase in the tariff rate for a broad range of vehicles in 2015.

Using a combination of reduced-form and structural techniques, we find that the levy increase (unsurprisingly) reduced vehicle purchases in the targeted groups. This means that these types of tariffs, in principle, represent suitable policy instruments for their intended purpose in LICs. We also find, however, that the levy's effectiveness is undermined by substitution from younger towards older vehicles and existing inventory among intermediary traders that creates a wedge between imports and first-time registrations in the short run. The substitution is a more permanent impediment, because it is rooted in two fundamental market characteristics, namely used vehicles' depreciation and the relative end user preferences over vehicle age and price. The facts that depreciation in value is determined by international markets and that poorer countries tend to import older vehicles suggest that these findings are relevant for LICs more generally. From a policy perspective, they point towards

[41] One could consider introducing further tiers in within the 16+ year old band, e.g., for 16-20 years, 21-25 years, etc. to counter substitution towards older vehicles within this group.

highly progressive tariff regimes or outright bans, as implemented in Uganda in 2018, to be effective for the oldest vehicles.

Finally, we emphasize that in this paper we have only considered the tariff's effectiveness in terms of reducing purchases and imports of the targeted vehicles but not its optimality from a welfare standpoint. While we simulate the impact of the levy increase and various alternative tariff regimes on consumer surplus, the corresponding results of course do not capture aspects beyond the end user valuation. Reduced pollution and lower tax revenues are two such aspects that are especially important in this respect and should be incorporated into a more comprehensive analysis of optimal import restrictions on used vehicles in the future.

2 Indirect Network Effects and Vehicle Choice in LICs

with Dorothy Nakyambadde

2.1 Introduction

Second-hand durable goods and machines from international markets offer low-income countries (LICs) welfare and productivity gains through affordable technology (Sen, 1962; Smith, 1974, 1976; Grubel, 1980). The prominence of old vintages, however, may also slow the adoption of more advanced technologies in the future, thereby reducing welfare and productivity (Janes et al., 2019; Caunedo and Keller, 2020). Specifically, the seminal work on indirect network effects by Farrell and Saloner (1985, 1986) and Katz and Shapiro (1985, 1986) suggests that demand for durables and machines depends on the existing stock of related products in the economy — the *installed base* — via ancillary markets such as those for spare parts and repair/maintenance services. Excess inertia in the adoption of newer vintages can arise in this context, because the ancillary markets specialize in the relatively older technology embedded in the installed base.

This type of indirect network effect is expected to be especially pronounced in LICs due to several characteristic features that relate to their reliance on second-hand items: (i) the higher incidence of breakdown among older vintages; (ii) the relatively thin nature of the markets for durable goods and machinery; and (iii) the lack of dedicated distribution networks by the original equipment manufacturers. Despite this, the relationship between demand for second-hand durable goods and machines in LICs and the installed base has, to our knowledge, not been studied in the economics literature before.

In this paper, we begin to fill this gap by studying the indirect network effects associated with the availability of spare parts in the passenger vehicle sector in Uganda. Specifically, we seek to answer the following main research questions: What is the impact of the installed base, via the availability of spare parts, on demand for vehicles from international markets? And how much does this relationship contribute to the prominence of old vintages? Although we explicitly focus on the availability of spare parts, we want to be clear that we cannot separate this from other related ancillary markets. In particular, mechanics are likely to specialise the the repair of popular vehicles and have greater expertise in older vehicle technology to which they are exposed domestically.[1] These are the same types of vehicles, for

[1]The expertise required for the repair of newer vehicles that rely increasingly on complex electronics and computing elements, by contrast, may well be harder to find.

which spare parts are expected to be more widely available. When discussing the availability of spare parts in this paper, we therefore implicitly also refer to the availability of related services and equipment that are required for repair.

We think of the vehicle sector in Uganda as a natural first case study of this type of indirect network effect, both in terms of product and geographic scope. Similar to other durable goods and machinery, vehicles are quantitatively important, consistently ranking among the top-five import categories among LICs, accounting for approximately 7% of total import value.[2] In addition, they tend to have broad relevance for the economy, as consumer goods in the case of passenger vehicles but also as production inputs in the case of trucks/lorries, agricultural tractors, and construction vehicles. From a more practical standpoint, the vintage and detailed characteristics of passenger vehicles can typically be captured from administrative records on imports and registrations that are not readily available for other products. The Ugandan setting is also opportune for this research as the country is representative of key features among LICs vis-a-vis international motor vehicle trade, including the relatively high age of imported vehicles and the prominence of Japan as a country of origin.[3]

We study the relationship between vehicle imports and the installed base by estimating a structural model of the hypothesized indirect network effect that links the markets for newly imported vehicles and spare parts. Specifically, we follow Nair et al. (2004) by deriving the equilibrium supply of spare parts as a function of the installed base from a constant elasticity of substitution (CES) utility among consumers and monopolistic competition between spare parts traders. Spare parts in this setup are notably supplied for groups of vehicles that have intercompatible parts and we refer to the corresponding vehicle stock as the *compatible base*. We then incorporate the indirect utility from the availability of spare parts into a standard discrete choice model of vehicle demand the spirit of the seminal work by Steven Berry, James Levinsohn, and Ariel Pakes (Berry, 1994; Berry et al., 1995) — henceforth "BLP".

The structural model provides us with two estimating equations, one for spare parts supply and another for vehicle demand. We estimate these equations lever-

[2]According to UN Comtrade data for the top LIC import categories at the Harmonized System (HS) two-digit level. The other top-five categories comprise mechanical and electrical machinery, ships, and mineral products, with the durable goods/machinery categories accounting for a similar share as motor vehicles on average. See Figure B.1 in the Appendix for details.

[3]The value share of passenger vehicle imports by LICs that originated in Japan has consistently been between 40-50% since 2000. The quantity share was also over 50% in 2000 but has recently dropped to around 30% as imports from China, India, and Korea have risen. The corresponding shares among right hand drive vehicles is expected to be even higher. See Appendix Figure B.2.

aging administrative data on the universe of vehicle imports and registrations in Uganda covering the period from 2013 to 2017 and cross-sectional inventory data for 2018/19 from an original survey of spare parts traders. We identify parameters in the context of the indirect network effect using standard instruments from the discrete-choice literature. We also introduce a new measure of spare parts intercompatibility to distinguish the impact of the indirect network effect from direct network effects.[4] Finally, we simulate counterfactuals to assess the contribution of the indirect network effect to the prominence of old vintages among vehicle imports.

Our analysis provides strong evidence in favour of the hypothesized indirect network effect. Estimating the spare parts supply equation, in particular, we find that the number of traders stocking parts is roughly proportional to the installed base for the vehicles compatible with these parts. This is in line with the predictions of our theoretical framework and confirms the fundamental relationship in the spare parts market underlying the indirect network effect. The estimation uses data on spare parts inventory from our survey and on the installed base from administrative records. Given that our survey only covers one year and does not overlap with the imports data, we are unfortunately unable to estimate the spare parts supply equation jointly with vehicle demand.

Our results for the vehicle demand model also indicate the presence of the indirect network effect, revealing a strong dependence of imports on the installed base via the market for spare parts. As our data on spare parts inventory and vehicle imports do not overlap, we substitute the spare parts supply equation into vehicle demand and estimate the latter using the installed base directly. This estimation nonetheless recovers the structural parameters of consumer utility — from both the vehicle choice and the implied spare parts availability — due to convenient functional form. We estimate the demand model starting with the full compatible base — i.e., all vehicles already in country according to their share of intercompatible parts. This definition notably captures indirect network effects and other dependencies between vehicle imports and the installed base, such as direct network effects. In order to eliminate the latter, we then gradually exclude groups of vehicles from the compatible base that have common features unrelated to compatibility. These groups are (i) those of the same make, model, manufacturing year, (ii) those of the same make and model, and (iii) those of the same make. The third exclusion, for instance, only

[4] We allow vehicles of different make, model, and manufacturing year combinations to be partially related according to the share of spare parts that are intercompatible between them. Vehicles with identical make, model, and manufacturing year are fully compatible. Other vehicles might be partially compatible as they share spare parts. This frequently holds for vehicles by the same manufacturer but sometimes even for those by different manufacturers, e.g., if they are produced under a joint venture with common suppliers for components.

leaves the compatible base for vehicles of other makes and therefore has very little in common (beyond spare parts compatibility) with the vehicle being imported. For specifications following the first exclusion, we find that a one percentage point increase in the availability of spare parts raises demand by 0.5-0.8 percentage points. This "spare parts elasticity of vehicle demand" is somewhat lower in robustness tests but still indicates the presence of the hypothesized indirect network effect.

Finally, we simulate a counterfactual scenario to shed light on the contribution of the indirect network effect to the prominence of old vintages among vehicle imports. Specifically, we double the number of traders offering spare parts for all vehicles up to 12 years of age. As expected, this intervention reduces the average age among imported vehicles, but only moderately by approximately by 2-3%. Notably, it also entails a substantial increase in the total number of vehicles imported by 6-7%. Considering both of these effects is important, because the latter may be desirable (as it improves mobility) or counterproductive (as it also raises total emissions) depending on the policy's objective.

This paper contributions to several strands of the economics literature by studying a phenomenon — indirect network effects via spare parts — that is especially pronounced at the intersection of development economics, international trade, and industrial organization. The focus on this intersection allows us to add to topics in each of these three parts of the literature that have their own intrinsic value but benefit from this intersectional perspective.

We contribute to the development and trade literature by introducing indirect network effects as determinants of demand for vintage technology and as a new type of friction impacting the gains from trade in LICs. While several papers in this literature have studied the prominence of second-hand machinery and durables in LICs, none of them incorporate indirect network effects related to the availability of spare parts as an underlying factor. They predominantly focus on the wage differentials between poor and rich countries that render repair less expensive in the former (Sen, 1962; Smith, 1974; Grubel, 1980; Navaretti et al., 2000). Some also address limited endowments of complementary factors, such as skilled labor required for operating machinery (Navaretti et al., 1998, 2000), but these factors are taken as given for a country and are not functions of the installed base. In this sense, our paper differs fundamentally from these previous studies, because the complementary factor in our context — the availability of spare parts — is endogenously determined.

Another, more recent literature, in development and trade focuses on frictions that undermine the gains from trade in LICs. Atkin and Donaldson (2015) and Storeygard (2016), for instance, highlight intra-national trade costs, especially related to poor infrastructure, and market power as key inhibiting factors. These papers highlight that international trade in priciple provides access to many goods that are not produced in LICs, but that various market frictions render these products effectively unavailable to large parts of the population. In the same vein, our paper introduces indirect network effects as another such friction that is particularly relevant for durable goods and machinery. Focusing on these types of products is important, because they account for a large share of imports in LICs and are understood to be key drivers of productivity as production inputs (Lee, 1995; Mazumdar, 2001; Amiti and Konings, 2007; Kugler and Verhoogen, 2009; Goldberg et al., 2009; Koujianou Goldberg et al., 2010; Halpern et al., 2015).

Beyond the development and trade literature, this paper also contributes to the industrial organization literature on indirect network effects. Specifically, it presents, to our knowledge, the first estimation of indirect network effects related to the market for spare parts and repair. This is somewhat surprising as these ancillary markets (even in the motor vehicle sector in particular) serve as prominent examples in the early theoretical literature on indirect network effects (see, e.g., Farrell and Saloner, 1985, 1986; Katz and Shapiro, 1985, 1986). Much of the empirical literature, however, has instead focused on consumer electronics — e.g., videocassette recorders (Park, 2004), DVD players (Gowrisankaran et al., 2014), and video game consoles (Nair et al., 2004; Clements and Ohashi, 2005; Dubé et al., 2010) — or two-sided markets, such as the Yellow Pages and payment cards (Rysman, 2004, 2007). Studies concerning the vehicle sector tend to focus on network effects for broad technological advancements, such as the adoption of electric vehicles (Li et al., 2014). One possible explanation for the absence of spare parts as a topic is that they tend to be broadly available in rich economies, which have traditionally been the focus of this literature, and hence less relevant for purchasing decisions. In LICs, however, the availability of spare parts is expected to be a major consideration when purchasing durable goods and machinery. Therefore, our paper contributes to this literature by providing the first estimate of a prominent indirect network effect in the context where it is expected to be most salient.

The remainder of the paper is structured as follows. In Section 2.2, we provide background information on the vehicle sector in Uganda and the data that we use to analyze the hypothesized indirect network effect. This is followed by the description of our structural model in Section 2.3 and the estimation in Section 2.4. We then present counterfactual analysis based on the estimation results in Section 2.5 and also discuss the broader implications of our findings. Finally, Section 2.6 contains the conclusion.

2.2 Vehicle Sector Background and Data

The vehicle sector in Uganda is particularly suitable for our study, because it exhibits the key conditions, under which we would expect the hypothesized indirect network effects to arise. In addition, the available administrative records offer the type of rich data that is necessary for empirical analysis but oftentimes lacking, especially in LIC contexts. In this section, we discuss in further detail these features of the vehicle sector in LICs and Uganda and provide an overview of the data used in our study.

2.2.1 Vehicle Sector in LICs and Uganda

The motor vehicle sector in LICs is characterized by a strong reliance on second-hand vehicles imported from international markets.[5] Domestic production or assembly is typically absent and vehicle manufacturers have a very limited presence through dedicated distributors.[6] These features are important for two reasons. First, the older fleet implies that the risk of breakdown and the need for repair are higher in LICs than in richer economies, where vehicles tend to be younger. All else equal, this raises the relevance of the availability of spare parts and repair services as an important consideration when purchasing a vehicle.[7] Secondly, these features also suggest that imports in this sector are undertaken predominantly by independent traders (or end users directly) and that, as such, suppliers of vehicles and spare parts may well be different economic entities. The last point is in contrast to new vehicles that are typically supplied through manufacturer-controlled distributors who can easily guarantee spare parts for the vehicles they offer.

The motor vehicle sectors in LICs also tend to be small in comparison to richer economies. This is evident from the much lower motorization rates in LICs, which is typically below 50 per 1,000 inhabitants relative to more than 500 in HICs.[8] These

[5]Data on personal vehicle exports to LICs from the US, the EU, and Japan distinguish between conditions and show that over 95% of these exports between 2011 and 2018 were used vehicles. These exporting origins accounted for roughly 60% of all personal vehicle exports to LICs over this period.

[6]According to data from the International Organization of Vehicle Manufacturers (OICA), there is no vehicle production by major international vehicle manufacturers in LICs. There are examples of some assembly plants, such as Volkswagen's in Rwanda, or nascent production companies, like Kiira Motors in Uganda, but these are few and their output is still very limited even relative to the countries' small markets.

[7]Spare parts for passenger vehicles in Uganda are also are predominently sourced second-hand, from international markets or domestically. Given the prominence of used vehicles, this is likely also the case for other LICs, at least for components that constitute a relatively larger share of the vehicle's value and have a long useful life. These components, for instance, include the chassis, engine, transmission, drive train, and body parts in contrast to lower-value components that require more frequent replacement, such as tires, suspensions, or brakes.

[8]Motorization rates are unfortunately not consistently available for all countries, but several

small (although growing) markets suggest that stocking high-value vehicle components may not be profitable for relatively unpopular vehicles. This further raises the availability of spare parts as an important vehicle characteristic — not only are the relatively old vehicles more prone to breakdown than newer vehicles in richer economies, but spare parts in LICs also tend to be more difficult to obtain (at least for unpopular vehicles).

Vehicle Sector in Uganda

The Ugandan setting of our study reflects these general characteristics of the motor vehicle sectors in LICs. With a total fleet of approximately 500,000 vehicles in 2015, Uganda's motorization rate was merely 13 vehicles per 1,000 inhabitants.[9] Domestic vehicle production or assembly is currently absent, so that the country sources vehicles entirely from international markets.[10] Manufacturer-dedicated distributors account for a very small share of vehicle imports and they focus predominantly on new vehicles. Most vehicles are imported by independent professional traders (65%) or end users via online platforms that facilitate access to used vehicles from Japan (30%). Between 2013 and 2017, Uganda imported approximately 50,000 vehicles per year (35,000 passenger vehicles), the vast majority of which were in used condition (95% in 2015); vehicle exports from the country are negligible. The average age of imported passenger vehicles between 2013 and 2017 was 14 years and has been gradually increasing over time; the average age of the passenger vehicle fleet in country in 2014 was 16 years.

Similar to vehicles, spare parts in Uganda are also imported and typically secondhand. They are available from local retail traders and garages that tend to be located in clusters of relatively close proximity. The capital, Kampala, has multiple such clusters according to vehicle and spare-parts types while other cities tend to have only a single cluster. These retailers source spare parts predominantly from abroad (87%), either via wholesalers (62% thereof) or directly (38% thereof), and to a lesser extent from old vehicles domestically (13%). Most retailers specialize in used spare

indicators show much lower rates in LICs than in richer economies. OICA, for instance, estimated that the average motorization rate per 1,000 in 2015 was 42 in Africa, 85 Asia/Oceania/Middle East (excl. Japan and South Korea, where it as 555), 176 in Central and South America, 281 in Russia/Turkey/Eastern Europe (excl. EU28/EFTA), 581 in EU28/EFTA, and 670 in North America.

[9] This figure from notably includes commercial and passenger vehicles for comparability to the above-mentioned statistics from OICA.

[10] The Ugandan state has notably been engaged in the development of electric vehicles through the Kiira Motors Corporation since 2014, but production has only been scheduled to commence this year in 2021. See details at the company website https://www.kiiramotors.com/.

parts (64%) and offer exclusively spare parts and repair services; essentially none of the spare parts traders also sell vehicles.

There is relatively little regulation of the vehicle sector in Uganda, which is also reflective of LICs more generally. The major environmental regulations are vintage-based import restrictions on vehicles that we study in a separate paper (Forster and Nakyambadde, 2021), but there is no domestic regulation of the vehicle or spare parts markets that is important in the context of the hypothesized indirect network effect. In particular, Uganda does not have any maintenance and inspection programme, so that demand for spare parts is expected to be based on the functionality of the vehicle rather than other incentives, such as passing an emissions test. In our analysis, we therefore focus on the spare parts that are critical for the working condition of vehicles (e.g., the engine, transmission, and drive train) and those that may break most frequently on Ugandan roads (e.g., suspensions and body parts).

2.2.2 Data and Summary Statistics

In this study, we rely on administrative records from the Uganda Revenue Authority (URA), the country's tax authority, to measure vehicle imports and registrations in the country. Specifically, we use data on the universe of vehicle imports covering the 2013 to 2017 calendar years from the URA's ASYCUDA customs system; new registrations and changes in registrations for this period are available from the URA's e-tax database; and we have information on the stock of vehicles from prior work by Mutenyo et al. (2015), who originally retrieved the data from the URA. These databases are notably 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.[11] This is important because both data sources are complementary: The import data 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. The registration data, in turn, provide detailed vehicle characteristics that are typically not captured by trade data, such as the vehicle make, model, and manufacturing year.

We supplement these administrative data with further information from two online sources. The first of these is the Goo-net Exchange website, which, to our knowledge, represents the most comprehensive database of passenger vehicles sold in the Japanese market.[12] We use this website (i) to define the set of vehicles available to consumers in Uganda and (ii) to obtain additional vehicle characteristics,

[11]This match was possible for over 90% of imports and over 86% of registrations.

[12]See vehicle catalog at https://www.goo-net-exchange.com/catalog/.

such as engine capacity, size, weight, and manufacturer-recommended retail price.[13] The focus on the Japanese market is motivated by the fact that it represents the origin for the vast majority of vehicles imported into Uganda (over 90% since 2012). The second source is the Rockauto website, which, to our knowledge, features one of the most comprehensive catalogs for passenger vehicle spare parts globally and from which we draw detailed data on the compatibility of vehicle spare parts.[14] Given that spare parts are frequently compatible with different vehicles (according to make, model, and manufacturing year), we use these data to construct measures of *intercompatibility* of parts between any two vehicles.[15]

Table 2.1 below reports summary statistics based on the URA's administrative data and the supplementary information on selected vehicle characteristics. It provides an overview of the installed base of passenger vehicles at the end of the calendar year 2012 (top panel) and passenger vehicle imports for the calendar years 2013 to 2017 (bottom panel). The statistics for the 2012 installed base (top panel) are separately reported by the year in which the vehicles were imported, going back to year 2000, and for the total accumulated by 2012. Unsurprisingly, fewer vehicles remain in the 2012 base from earlier years than from later years and these tend to have been younger on average at the time of importation. These "surviving" vehicles are typically also lower in value, smaller, lighter, and less powerful (in terms of engine capacity) than those imported later. Imports for the years 2013 to 2017 (bottom panel) notably decline in terms of the number of passenger vehicles in 2015, 2016, and 2017 relative to the two previous years. This is primarily due to a stark tariff increase for vehicles over the age of 5 years in 2015. Relative to the dynamics we observed for the surviving vehicle stock across import years, the characteristics of vehicles imported since 2013 exhibit less change over time (with the exception of rising vehicle value). This suggests that the former is at least partially due to selection among the vehicles that "survive" in the installed base rather than only changes the types of vehicles imported between 2000 and 2012.

One of the key vehicle characteristics for this study is the intercompatibility of spare parts and Table 2.2 reports summary statistics of this measure. Specifi-

[13]The vehicles listed on the Goo-net Exchange vehicle catalog provide information on over 95% of the personal vehicles (according to make, model, and manufacturing year) imported or registered in Uganda over our sample period.

[14]See spare parts catalog at https://www.rockauto.com/.

[15]This intercompatibility arises for various reasons: Vehicles of the same make and model use the same parts across different manufacturing years; different vehicle models by the same manufacturer (and of the same make) have parts in common, e.g., as they use the same "platform" or engine; and even vehicles of different makes have parts in common, e.g., as they are produced by the same manufacturer or as part of a joint-venture between different manufacturers that specialize in different geographic markets.

Table 2.1: Descriptive Statistics of the Passenger Vehicle Installed Base and Imports

	Imports (1)	M/M/MY (2)	MSRP($) (3)	Value($) (4)	Price(MMUSh) (5)	Age(Years) (6)	Weight(kg) (7)	Eng.Cap.(cc) (8)	Size(m^3) (9)
					Panel A: 2012 Passenger Vehicle Stock				
2000	688	167	9,833	.	.	8.1	1,157	1,825	10.7
2001	1,006	215	10,011	.	.	8.4	1,188	1,859	10.9
2002	1,177	213	10,785	.	.	9.0	1,172	1,835	10.9
2003	1,517	249	12,038	.	.	9.3	1,230	1,911	11.2
2004	2,054	295	12,501	.	.	9.7	1,218	1,907	11.1
2005	3,116	371	13,272	.	.	10.2	1,228	1,902	11.2
2006	3,506	389	13,340	.	.	10.6	1,261	1,938	11.5
2007	5,011	481	12,978	.	.	11.0	1,274	1,962	11.6
2008	6,834	592	13,651	.	.	11.4	1,311	2,028	11.9
2009	7,784	699	14,922	.	.	11.5	1,356	2,078	12.2
2010	9,954	726	15,236	.	.	11.8	1,377	2,080	12.4
2011	9,692	781	14,749	.	.	12.7	1,357	2,030	12.3
2012	19,194	979	14,134	.	.	13.3	1,318	1,949	12.1
Total	71,533	1,727	14,007	.	.	11.8	1,315	1,992	12.0
					Panel B: Passenger Vehicle Imports				
2013	35,028	1,314	14,134	3,681	11.6	14.2	1,318	1,951	12.1
2014	39,186	1,346	14,444	3,776	11.2	14.7	1,332	1,974	12.2
2015	26,941	1,287	14,480	4,145	13.8	14.8	1,343	1,982	12.3
2016	21,392	1,153	15,014	4,496	16.0	14.9	1,383	2,042	12.6
2017	26,381	1,101	14,891	4,401	15.1	15.0	1,370	1,977	12.6

Notes: Table reports, by calendar year (column 1), the number of vehicles imported (2) and the number of unique make/model/manufacturing year (M/M/MY) triplets among these (3); columns (4)-(10) report the weighted average of the variables in the column headers. The top panel reports statistics of the passenger vehicle installed base in 2012, by the years in which the vehicles were imported. The bottom panel reports passenger vehicle imports.
Sources: URA registrations and imports; GooNet vehicle characteristics.

cally, it shows for passenger vehicles imported in any given year the average number and share of vehicles in the installed base that are compatible in terms of relevant spare parts — i.e., the compatible base.[16][17] Columns (1)-(2) consider all vehicles in the installed base; columns (3)-(4), (5)-(6), and (7)-(8) consider an increasingly restricted subset thereof by excluding, respectively, vehicles of the same make, model, and manufacturing year (M/M/MY), those of the same make and model (M/M), and those of the same make (M). Intuitively, the later columns incrementally move towards a "purer" measure of intercompatibility by removing vehicles with other common characteristics, such as make and model.

Table 2.2 shows that imported passenger vehicles, on average, have spare parts in common with several thousand vehicles or roughly 5-6% of the installed base in the country. This also holds when considering only vehicles in the base that are not of exactly the same make, model, and manufacturing year as imported vehicles. This is unsurprising given that many vehicles of the same make and model are close to identical in design across proximate manufacturing years. There is a more substantial change in these measures of intercompatibility between imports

[16]The compatible base is measured as those vehicles accumulated by the end of the prior year. Vehicles from the installed base are weighted according to their share of intercompatible parts.

[17]Relevant spare parts are those that were deemed to important in the Ugandan context, either because vehicles are either unable to move without them or because they are particularly likely to break due to accidents or poor road conditions. As such, relevant spare parts are those belonging to the following categories: body, cooling system, drive train, engine, suspension, and transmission.

Table 2.2: Installed Base with Intercompatible Spare Parts

	Full Base		Excl. M/M/MY		Excl. M/M		Excl. M	
	Number (1)	Share(%) (2)	Number (3)	Share(%) (4)	Number (5)	Share(%) (6)	Number (7)	Share(%) (8)
2013	4283.5	6.1	3793.4	5.4	1529.1	2.2	34.5	0.05
2014	6468.5	6.1	5771.9	5.5	2238.2	2.1	42.0	0.04
2015	8549.9	6.0	7676.4	5.4	2903.0	2.0	56.8	0.04
2016	9693.4	5.8	8798.1	5.3	3637.0	2.2	60.7	0.04
2017	9812.7	5.4	8977.7	4.9	4497.2	2.5	61.0	0.03

Notes: Table reports for passenger vehicles imported in any given year the average number and share of vehicles in the installed base that are compatible in terms of relevant spare parts. The installed base is measured as those vehicles accumulated by the end of the prior year. Vehicles in the installed base are weighted according to their share of intercompatible parts. The column groups labeled "Full Base" consider all vehicles in the existing stock; those labeled "Excl. M/M/MY" exclude vehicles of the same make, model, and manufacturing year (M/M/MY); those labeled "Excl. M/M" exclude vehicles of the same make and model (M/M); those labeled "Excl. M" exclude vehicles of the same make (M).
Source: Uganda Revenue Authority; Rockauto.com.

and the installed base when focusing on vehicles that are not of the same make and model. This effectively limits the main source of intercompatibility to different vehicle models of the same make and drops the number of intercompatible vehicles to the low thousands or 2-3% of the installed base. When we focus only on vehicles of a different make, the number of vehicles with common spare parts drop to below 100 on average or less than a tenth or a percent of the existing stock. These differences in the compatibel base between different sets of vehicles are important as they will also be reflected in the econometric analysis to distinguish the indirect from direct network effects.

Finally, our study also relies on information from an original survey of vehicle spare parts traders that was fielded in July/August 2019 in four cities in Uganda — the capital, Kampala, Mbarara, Gulu, and Mbale. These four cities were chosen from the 20 largest population centers in the country to guarantee the presence of an active spare parts market and, among these, to exhibit broad variation in geographic location and relative size. Within each city, we randomly surveyed spare parts traders in all main areas where clusters of these businesses are located. The survey is representative for spare parts traders in these business clusters and allows for comparisons between such clusters across cities. The data from this survey provides information on the supply chain for spare parts, inventory, and sales as well as general information about the traders' businesses for the 12 months ending July 2019.

Table 2.3 reports summary statistics about vehicle spare parts traders in the four cities surveyed. These traders are predominantly retail businesses that only offer spare parts for passenger vehicles and some related repair services.[18][19] They

[18]The only traders that sold spare wholesale were located in Kampala and accounted for less than 5% of the businesses surveyed.

[19]Among spare parts traders for passenger vehicles 27% offered repair services for these vehicles;

source the majority of their inventory in used condition (64%) from international markets (87%), predominantly via wholesale importers although some of the retail traders also import parts directly (43% in Kampala, less than 5% elsewhere). There is essentially no sourcing from original or generic equipment manufacturers; all spare parts are bought from wholesalers or individuals.

Table 2.3: Descriptive Statistics of Spare Parts Traders

	Gulu (1)	Kampala (2)	Mbale (3)	Mbarara (4)	Total (5)
Traders by Parts Sourcing (%)					
Mainly Used Parts	73.9	64.2	44.2	70.6	63.7
Mainly Imported Parts	26.1	87.4	92.3	96.1	87.0
Some Self-Importing	4.3	42.8	3.8	3.9	37.9
Traders by Parts Make (%)					
Toyota	100.0	86.8	100.0	100.0	88.4
Nissan	56.5	25.8	26.9	15.7	25.8
Mitsubishi	34.8	20.1	19.2	5.9	19.5
Subaru	4.3	15.7	11.5	5.9	14.7
Isuzu	21.7	11.3	9.6	0.0	10.8
Other	17.4	27.7	9.6	3.9	25.2
Trader Size and Profitability					
Number of Workers	4.5	1.9	3.6	2.2	2.0
Annual Revenue (MMUsh)	82.2	124.1	152.4	28.9	117.1
Firm Gross Margin (%)	59.9	53.8	66.6	40.3	53.7
Parts Gross Margin (%)	40.2	35.0	24.4	26.0	32.9
Cost of Capital (%)	.	25.4	20.0	25.3	25.3
Time in Inventory (Months)	11.9	12.0	9.1	2.1	11.7
Total Number of Traders	29	1,365	75	90	1,559
Sample Number of Traders	23	159	52	51	285

Notes: Table reports characteristics of passenger vehicle spare parts traders in Gulu, Kampala, Mbale, and Mbarara. Panel A reports the share of traders whose parts are purchased mainly in used condition, whose parts are mainly imported (in contrast to sourced from used vehicles in Uganda), and who import some parts on their own. Panel B reports the share of traders that offer parts for vehicles of the most popular makes. Panel C reports the average across traders of characteristics related to business size and profitability.
Sources: Spare parts trader survey.

The vast majority of traders offer spare parts for Toyota vehicles (87% in Kampala, 100% elsewhere) but not necessarily other makes (less than 26% overall). There is notably some geographic variation in this distribution with Nissan, Mitsubishi, and Isuzu parts also showing broader availability in Gulu.[20] Finally, the statistics show that spare parts traders tend to be small in terms of the number of employees, but generate a relatively large amount of revenue.[21] This high level of revenue

14% offered parts and 8% offered repair services for commercial vehicles; any other products and services were offered by less than 3% of spare parts traders for passenger vehicles.

[20]This likely reflects the different composition of the vehicle stock in Northern Uganda due to long-lasting work by humanitarian organisations, first related to the armed conflict that ended in 2006 and more recently the large number of refugees from South Sudan. Pickup trucks of these makes tend to be particularly popular in this area due to their off road capabilities.

[21]According to the classification by the Ugandan Ministry of Finance, Planning and Economic Development, spare parts traders are micro enterprises by number of employees but small or even medium enterprises by turnover (MTIC, 2015).

reflects chiefly the facts that the inventory at these businesses is high in value and costly (average of 25% interest rate) with gross margins for spare parts barely exceeding the cost of capital (average of 33%). These statistics support the notion of spare parts trading is a risky business because of the high cost of inventory, which is fixed in the short run due to the reliance on imports, and likely variable demand due the randomness of vehicle breakdown and competition with other traders that have access to essentially the same spare parts.

2.3 Model of the Indirect Network Effect

In this section, we present a theoretical framework of the indirect network effect that links the demand for vehicles from international markets to the installed base via the availability of spare parts. Closely following the existing literature (specifically Nair et al., 2004; Dubé et al., 2010), our framework comprises two main parts: (i) a discrete choice model of vehicle demand that incorporates the value of spare parts availability; and (ii) a model of monopolistic competition among spare parts suppliers that determines the equilibrium number of traders offering parts for any vehicle. Demand for spare parts arises from vehicle owners for sets of compatible vehicles and spare parts supply fulfilling this demand generates the indirect network effect.[22]

Consumer choices are static in the interest of tractability despite the durable nature of vehicles and the fact that spare parts are required over the their lifetime. This is appropriate in our context, because we seek to understand demand for vehicles from international markets, so that domestic resale is not a primary concern.[23] In addition, the types of spare parts required are chiefly conditional on vehicle choice, so that dynamic optimization of the repair or replacement decisions would add much complexity with little analytical value. Specifically, we assume that every year $t \in \{1, \ldots, T\}$, consumers $i \in \{1, \ldots, M_t\}$ among an "eligible" share of the Ugandan population (relative to current motorization rate) purchase at most one newly imported vehicle. Vehicle choices in year t are denoted by $j \in \{0, \ldots, J_t\}$, where $j = 0$ is the outside good (no vehicle purchase) and where vehicles are defined according to their make, model, and manufacturing year. We assume that the indirect utility derived from purchasing vehicle j in period t, v_{ijt}, is additively separable into a component for the vehicle itself, u_{ijt}, and a second component for

[22]We abstract from the notion that the installed base also represents a source of spare parts supply as damaged vehicles may scrapped and dissembled for parts. This is appropriate in the Ugandan context, where parts are sourced predominantly from international markets (87%) rather than domestically from scrapped vehicles (13%).

[23]This is approach is also in line with much of the literature on demand for new vehicles, which tends to use static models. Purchases of used vehicles from international markets in the context of LICs are essentially the equivalent of new vehicle purchases in richer countries.

the availability of spare parts, $\tilde{u}_{ig(j)t}$:

$$v_{ijt} = u_{ijt} + \tilde{u}_{ig(j)t} \tag{2.1}$$

The first component, u_{ijt}, will be a standard linear equation in vehicle characteristics in the spirit of the seminal work by BLP. The indirect utility derived from the availability of spare parts, $\tilde{u}_{ig(j)t}$, is given for the set of vehicles $g(j)$ whose spare parts are intercompatible with vehicle j and reflects the equilibrium number of traders supplying these parts.

In the following, we present the details of the theoretical framework separately for the two relevant markets — i.e., spare parts and vehicles. We proceed in this order, because the equilibrium outcomes for the spare part market feed back into the optimal consumer choice over vehicles.

2.3.1 Market for Spare Parts

We assume that the spare parts market in any period t for vehicles of intercompatibility group g is characterized by N_{gt} traders, $n \in \{1, \ldots, N_{gt}\}$. For tractability, we assume that any trader n supplies spare parts from only one vehicle k — these are mostly second-hand parts and thus can be attributed to a particular make, model, and manufacturing year — but faces demand from all existing owners of vehicles $j \in g(k)$. Spare parts available to the owners of vehicles $j \in g(j)$ are differentiated products, because they are sourced from a range of vehicles and because traders vary in specialization.[24]

Demand

Demand for spare parts derives from the owners of the installed base in any given compatibility group, Q_{gt}, according to constant elasticity of substitution (CES) utility. Intuitively, the CES utility reflects the differentiated nature of spare parts for closely related vehicles within any intercompatibility group and consumer preference for trader specialization (corresponding to trader variety in our setup). We adopt a utility specification similar to Dubé et al. (2010) and assume that owner i of vehicle j in period t has the following preferences over spare parts volumes $\{w_{ijnt}\}_{n=1}^{N_{g(j)t}}$ from traders $n \in \left\{1, \ldots, N_{g(j)t}\right\}$:

[24] While we do not consider different types of spare parts in the model — e.g., engine, transmission, or suspension parts — trader specialization, in practice, largely reflects specific knowledge about such types and related repair skills.

$$\tilde{U}_{ijt} = ln \left\{ \left[\sum_{n=1}^{N_{g(j)t}} (w_{ijnt})^{1/(1+\gamma)} \right]^{(1+\gamma)} \right\} + \alpha \tilde{y}_{it} \tag{2.2}$$

, where $\tilde{y}_{it}$ denotes the outside good in monetary units and where $\gamma > 0$ and $\alpha > 0$ are parameters.

Owners of vehicle j maximize utility by choosing the quantity of spare parts demanded from each of the $N_{g(j)t}$ traders offering compatible parts, taking as given the parts prices $\{\tilde{p}_{nt}\}_{n=1}^{N_{g(j)t}}$. As shown in the Appendix section B.2.1, owner i's demand for parts from trader n is given by:

$$w_{ijnt} = \frac{1}{\alpha} \frac{\tilde{p}_{nt}^{-(1+\gamma)/\gamma}}{\tilde{P}_{g(j)t}^{-1/\gamma}} \tag{2.3}$$

, where $\tilde{P}_{g(j)t} \equiv [\sum_{n=1}^{N_{g(j)t}} (\tilde{p}_{nt})^{-1/\gamma}]^{-\gamma}$ is the standard CES price index for group-g spare parts across the $N_{g(j)t}$ traders offering these parts. Summing over the Q_{gt} owners of the existing group-g installed base, aggregate demand for spare parts from trader n is then simply $w_{nt} = \sum_{i=1}^{Q_{gt}} w_{ijnt} = Q_{gt} w_{ijnt}$.

Supply

Spare parts for any group of intercompatible vehicles g are supplied by traders $n \in \{1, \ldots, N_{gt}\}$ who compete by setting prices $\tilde{p}_{nt}$. Traders offering parts for vehicle group g are identical in the sense that they face a common marginal cost, c_{gt}, and per-period fixed cost, F_{gt}. They maximize profits, π_{nt}, which will be eroded in equilibrium through free entry:

$$\pi_{nt} = (\tilde{p}_{nt} - c_{gt}) w_{nt} - F_{gt} \tag{2.4}$$

Profit maximization is given by the standard first order condition of equation (2.4). After substituting the derivative of trader demand $\partial w_{nt}/\partial \tilde{p}_{nt} = -(1 + \gamma)/\gamma (w_{nt}/\tilde{p}_{nt})$, it follows that all traders offering parts for group-g vehicles charge the same prices:[25]

$$\tilde{p}_{nt} = (1 + \gamma) c_{gt} \tag{2.5}$$

[25]The derivation is included in the Appendix, subsection B.2.1

To obtain the number of traders offering parts, we assume that per-period economic profits in equation (2.4) are zero due to free entry. We plug in aggregate demand and equilibrium prices, take the natural logarithm of both sides, and solve for $ln(N_{gt})$ to get:

$$ln(N_{gt}) = ln(Q_{gt}) + \kappa_{gt} \tag{2.6}$$

, where $\kappa_{gt} \equiv ln\left\{[\alpha(1+\gamma)F_{gt}]/(b-1)\right\}$.[26]

Indirect Utility in Equilibrium

Finally, we can also use the equilibrium prices, the number of traders, and the individual's demand to derive the per-period indirect utility of the availability of spare parts for any given vehicle j. Substituting these into equation (2.2), we get:

$$\tilde{u}_{ijt} = \gamma ln(N_{gt}) + \alpha(y_{it} - p_{jt}) + \zeta_{it} \tag{2.7}$$

, where y_{it} denotes individual i's income in period t, p_{jt} the vehicle price, and $\zeta_{gt} \equiv -\left\{ln[\alpha(1+\gamma)c_{gt}] + 1\right\}$.

2.3.2 Market for Vehicles

With the equilibrium conditions for the spare parts market at hand, we turn to the market for vehicles. Given that Ugandan imports account for only a small share of the overall volume of used vehicles traded internationally, we assume that vehicle supply is perfectly elastic. Demand for vehicles follows from a discrete consumer choice over vehicles that accounts for the availability of spare parts in indirect utility, as given in equation (2.1). We assume that the vehicle-specific component of utility takes the standard linear form $u_{ijt} = \mathbf{x'_{jt}}\beta + \xi_{jt} + \epsilon_{ijt}$, where $\mathbf{x_{jt}}$ denotes a vector of K exogenous observable vehicle characteristics (e.g., engine capacity, weight, size, and age), ξ_{jt} is a vehicle-specific unobservable valuation, and where ϵ_{ijt} is an individual-specific unobservable valuation. Substituting this expression and the network component of indirect utility, $\tilde{u}_{ijt} = \gamma ln(N_{gt}) + \alpha(y_{it} - p_{jt}) + \zeta_{it}$ from the previous subsection, into equation (2.1), we get:

[26]The derivation of this expression is also provided in Appendix section B.2.1.

$$v_{ijt} = \mathbf{x'_{jt}}\beta + \alpha(y_{it} - p_{jt}) + \gamma ln(N_{gt}) + \zeta_{g(j)t} + \xi_{jt} + \epsilon_{ijt} \tag{2.8}$$

Consumers in period t choose the vehicle j that maximizes utility — i.e., for which $v_{ijt} > v_{ikt}$ for all $k \neq j$ — and this occurs with probability $s_{ijt} \equiv \mathbb{P}[v_{ijt} > v_{ikt} \; \forall \; k \neq j]$. We succinctly denote mean utilities as $\delta_{jt} \equiv \mathbf{x'_{jt}}\beta - \alpha p_{jt} + \gamma ln(N_{gt}) + \zeta_{g(j)t} + \xi_{jt}$ and normalize the outside option of no purchase, $\delta_{0t} = 0$. Assuming that unobserved individual valuations ϵ_{ijt} are i.i.d. type-I extreme value, then we obtain the following standard logit expression for the expected market shares:[27]

$$s_{jt}(\delta_{\mathbf{.t}}) = \frac{exp(\delta_{jt})}{\sum_{j'=1}^{J_t} exp(\delta_{j't})} \tag{2.9}$$

The expected number of type-j vehicles purchased (imported) in period t is $q_{jt} \equiv s_{jt}M_t$ and the corresponding installed base, Q_{jt}, evolves according to the difference equation $Q_{jt} = (1-\rho)Q_{jt-1} + q_{jt-1}$, where ρ is the exogenously given scrappage rate. Therefore, in any given period t, the type-j installed base is $Q_{jt} = (1-\rho)^t Q_{j0} + \sum_{\tau=0}^{t}(1-\rho)^{t-\tau-1}q_{j\tau}$.

2.4 Estimation Strategy and Results

The model presented in the previous sections predicts two key relationships between the compatible base, the availability of spare parts, and demand for vehicles from international markets that we take to the data. The first is the spare parts supply equation (2.6), which links the number of traders offering parts to the compatible base. The second is the demand system for newly imported vehicles given by equation (2.9), which links any vehicle's share to the availability of compatible parts and thereby the compatible base. In this section, we estimate both of these.

There are notably several features of the data that dictate how we proceed in this estimation. First, the time period, for which we have information on spare part trader inventory unfortunately does not overlap with the period, for which we have data on vehicle imports and the installed base. Spare parts inventories are available from our survey that covers the 12 months ending July 2019 while the administrative data cover vehicle imports and the installed base for the period from 2013 to 2017. This implies that we need to estimate spare parts supply and vehicle demand equations separately. This is not uncommon but suboptimal relative to

[27] The distributional assumption on the ϵ_{ijt} is admittedly quite restrictive and leads to several well-known limitations as detailed, for instance, in Train (2009). Improvements could be achieved through nested-logit or random coefficients specifications of utility.

estimating the system simultaneously.[28] More importantly, it also means that for the period covered by the import data we do not observe the availability of spare parts, which is the key variable of interest in the model of vehicle demand. We therefore substitute spare parts supply into the expressions for vehicle demand and estimate the implicit relationship between vehicle demand and the compatible base that arises due to the indirect network effect.

In addition, the intercompatibility of parts between vehicles is not binary in reality as presented in our model. As described in Section 2.2, some vehicles have many parts in common (e.g., those of the same make and model but different manufacturing years) whereas others have only very few parts in common (e.g., those of different models or even different makes). For our measure of the compatible base, we therefore weight the installed base of different vehicles by an intercompatibility index that measures the share of compatible parts between vehicles. Formally, we let $I_{jj'}$ denote the share of parts that is intercompatible between vehicles j and j', so that $Q_{gt} = \sum_{j' \in g(j)} I_{jj'} Q_{j't}$ with $Q_{j't} = (1-\rho)^t Q_{j'0} + \sum_{\tau=0}^{t} (1-\rho)^{t-\tau-1} q_{j'\tau} \approx Q_{j'0} + \sum_{\tau=0}^{t} s_{j'\tau} M_\tau$.

2.4.1 Spare Parts Supply

For the estimation, we adjust the spare parts supply equation (2.6) to better reflect the particulars of our data and to include control variables that may improve our estimators. Specifically, we incorporate the above-mentioned index of partial intercompatibility rather than assuming a binary measure and rewrite equation (2.6) at the vehicle j level. We also include fixed effects for the vehicle make/model pair and terms for the vehicle age and age-squared. Finally, we allow for a more general relationship than predicted by including a coefficient φ on the compatible base term, which may be different from one. Overall, we therefore get the following estimating equation:

$$ln(N_{g(j)t}) = \kappa_{m(j)} + \varphi ln \left(\sum_{j' \in g(j)} I_{jj'} Q_{j't} \right) + \varphi_a^{(1)} a_{jt} + \varphi_a^{(2)} a_{jt}^2 + \Delta\kappa_{jt} \tag{2.10}$$

, where $\kappa_{m(j)}$ is the make/model fixed effect, $\Delta\kappa_{jt} \equiv \kappa_{jt} - \kappa_{m(j)}$ the corresponding residual, and where a_{jt} denotes the vehicle age, for which the spare part is supplied. The fixed effects absorb correlation between the cost of spare parts and vehicle prices

[28] Nair et al. (2004) and Clements and Ohashi (2005), for instance, estimate hardware demand and software supply separately.

that is due to vehicle differentiation at the make/model-level. The age variables control for another important factor of the cost of spare parts.

We measure $N_{g(j)t}$ as the number of traders that stock any spare parts for vehicle j during the twelve months ending July 2019; and we construct the compatible base $Q_{g(j)t}$ at the end of 2017 using registered vehicles at the beginning of 2013, $Q_{j'0}$, and imports, $s_{j't'}M_{t'}$, for the subsequent five years for all vehicles $j' \in g(j)$. As such, there is approximately a one-year gap between our measures for the left hand side and right hand side variables and the compatible base lacks imports over that period. Considering, however, that the compatible base is predominantly comprised of imports from before 2018 (which we do capture), this is not a major concern.

Identification

We estimate equation (2.10) via general method of moments (GMM) using instrumental variables for the compatible base. The reason for doing so, is that $Q_{g(j)t}$ is potentially correlated with the residual error term, $\Delta\kappa_{jt}$ as both are functions of international vehicle prices. $Q_{g(j)t}$ is the sum of past vehicle imports and $\Delta\kappa_{jt}$ is a function of the international prices of used spare parts, which are clearly related to the vehicles from which they are sourced.

Our identification strategy to address this source of endogeneity relies on a common identifying assumption in BLP-type estimations that is particularly applicable in our context. Specifically, we assume that observable vehicle characteristics from the demand model, $\mathbf{x_t}$, are orthogonal to the costs of spare parts supply in Uganda and extend this assumption also to our measure of intercompatibility, $\mathbf{I}$, and across time periods.[29] That is, $\mathbb{E}[\Delta\kappa_{jt}|\mathbf{x}, \mathbf{I}] = 0$. We then construct so-called "Differentiation IVs" for vehicle shares, $s_{j't'}$ with $t' \in \{0, \ldots, t-1\}$, and use these to create instrumental variables that mimic the definition of the existing stock in period t, $Q_{j't} \approx Q_{j'0} + \sum_{t'=0}^{t} s_{j't'}M_{t'}$.[30] Details of these instrumental variables and our identifying assumption are provided in Appendix Section B.2.2.

[29]The extension to $\mathbf{I}$ is relatively innocuous given that intercompatibility of parts between vehicles reflects design features largely chosen by the vehicle manufacturers similar to other vehicle characteristics. The extension across time periods is a stronger assumption, because it imposes restrictions on the relationship between vehicle age and the cost of spare parts.

[30]There are numerous applications of these and similar "BLP instruments" in the discrete choice literature that involve endogenous prices and some type of "share on the right hand side" specification. These include a wide range of nested-logit specifications following Berry (1994) and models of peer effects/spillovers, such as Bayer and Timmins (2007).

2.4.2 Vehicle Demand

We estimate vehicle demand at the market level broadly following the procedure promulgated by BLP. That is, we first obtain mean utilities δ_{jt} by inverting equation (2.9) and then estimate the structural parameters (α, β, γ) via GMM.[31] Given the logit specification, we obtain mean utilities simply by taking the log-difference of any vehicle's share and the outside option $\delta_{jt} = ln(s_{jt}/s_{0t})$. Substituting the spare parts supply equation (2.6) for the number of traders and accounting for partial compatibility by using $Q_{gt} = \sum_{j' \in g} I_{jj'} Q_{j't}$, we obtain the following estimating equation for vehicle demand:

$$\delta_{jt} = \mathbf{x'_{jt}}\beta - \alpha p_{jt} + \gamma ln\left(\sum_{j' \in g(j)} I_{jj'} Q_{j't}\right) + \upsilon_{jt} \tag{2.11}$$

, where $\upsilon_{jt} \equiv \gamma \kappa_{g(j)t} + \zeta_{g(j)t} + \xi_{jt}$ is the composite error term with $\kappa_{g(j)t} \equiv ln([\alpha(1+\gamma)F_{g(j)t}]/\gamma)$ and $\zeta_{gt} \equiv -\{ln[\alpha(1+\gamma)c_{gt}] + 1\}$ reflecting unobservables from the spare parts market equilibrium. We measure the installed base $Q_{j't}$ as the sum of the number of registered vehicles at the beginning of 2013, $Q_{j'0}$, and imports, $s_{j't'}M_{t'}$, for the subsequent years, t', up until period $t-1$.

Identification

In estimating vehicle demand, we account for the potential endogeneity of two explanatory variables, i.e., vehicle prices p_{jt} and the existing compatible vehicle stock $Q_{g(j)t}$. Vehicle prices are generally correlated with unobservable vehicle-specific valuations ξ_{jt} and also the marginal costs of spare parts embedded in $\zeta_{g(j)t}$.[32] The existing vehicle stock is a function of all past market share realizations and is therefore correlated with υ_{jt} as long as there is any serial correlation in unobservable valuations.

We address these sources of endogeneity in two ways. First, we follow the advice by Nevo (2000) and control for vehicle-specific fixed effects that are likely correlated with prices and the compatible base. Formally, we decompose the error term υ_{jt} into its cross-sectional and time-varying components, $\upsilon_{jt} \equiv \bar{\upsilon}_j + \Delta\upsilon_{jt}$, and eliminate

[31] Recovering mean utilities is especially simple in the logit case due to the closed form expression for market shares. A more general random coefficients model would require numerical inversion and also estimation of the non-linear parameters via simulation.

[32] Such correlation between ξ_{jt} and p_{jt} notably exists even when international markets are competitive (as in our setting), because vehicles with higher unobservable mean valuation tend to be more expensive.

$\bar{\upsilon}_j$ by applying the within transformation to equation (2.11).[33] Secondly, we estimate the within-transformed equation via GMM using instrumental variables for vehicle prices and the compatible vehicle stock. The instruments we include are (i) the "Differentiation IVs" that mimic the definition of the existing vehicle stock and that were already introduced for the spare parts supply equation above; and (ii) the exchange rate between the US Dollar and the Ugandan Shilling as an exogenous cost shifter. We think of the former intuitively as instruments for the existing compatible vehicle stock and of the latter as instruments for vehicle prices. The key identifying assumption is that the time-varying component of the error term, $\Delta\upsilon_{jt}$, is orthogonal to vehicle characteristics $\mathbf{x}$ and the intercompatibility index, $\mathbf{I}$, i.e., $\mathbb{E}[\Delta\upsilon_{jt}|\mathbf{x}, \mathbf{I}] = 0$. Details of these instrumental variables and our identifying assumption are also included in Appendix Section B.2.2.

Distinguishing Indirect from Direct Network Effects

In the theoretical framework presented in Section 2.3, consumer utility depends on the vehicle purchasing decisions of other consumers purely through the indirect network effect via the market for spare parts. In reality, however, such interdependence may also arise for other reasons, including direct network effects such as "peer effects." The key distinction between these and indirect network effects is that consumers value others' purchasing the same or similar vehicles directly, not purely through the ancillary market. One example of such an effect would be higher social status conferred by owning a popular vehicle.

Direct network effects are especially relevant in our study, because we essentially have other consumers' vehicle choices on the right hand side of the estimating equation for vehicle demand (in the form of the compatible base). The estimated γ coefficient will therefore pick up not only the indirect but also any direct network effect, if any is present.

To isolate the indirect network effect, we leverage the fact that the intercompatibility of spare parts not only applies to very similar vehicles — e.g., those of the same make and model — but also to more distantly-related vehicles — e.g., those of different models or even different makes. In particular, we estimate a range of specifications of equation (2.11) in which we incrementally narrow the set of vehicles $g(j)$ over which we compute the compatible vehicle stock. We begin with the broadest measure over all vehicles, then remove (i) vehicles of the same make, model, and manufacturing year, followed by (ii) those of the same make and model, followed by

[33]First-differencing is another common panel-data approach that would be valid in this context.

(iii) those of the same make.[34] This approach increasingly limits our measure of the compatible base to those vehicles, which are related only via the intercompatibility of parts and not external markers of similarity that will be particularly relevant for direct network effects.

2.4.3 Results

In this subsection, we present the results from estimating separately the spare parts supply equation (2.10) and the vehicle demand equation (2.11). The former describes the relationship between the supply of spare parts and the compatible base (given by the coefficient φ). The latter shows the value of spare parts availability to consumers (given by the coefficient γ).

Table 2.4 reports the results from estimating the spare parts supply equation (2.10) with a range of fixed effects and with and without instrumental variables. Specifications (1) and (2) are implemented without any fixed effects; specifications (3) and (4) include fixed effects for the vehicle make; and specifications (5) and (6) include fixed effects for the vehicle make/model pair. Odd-numbered specifications are estimated via OLS and even-numbered specifications via GMM with instrumental variables as described in the previous subsection. All specifications measure the compatible base according to the broadest definition. This is appropriate for the spare parts supply equation as there is no obvious parallel to the direct network effects that might exist for vehicle demand.[35]

The results show a robust positive relationship between spare parts supply and the compatible base and thereby lend strong support for the hypothesized indirect network effect. In specifications (2), (4), and (6), that are implemented via GMM and instrumental variables, the point estimate of the φ coefficient ranges between approximately 1.1 and 1.2.[36] The magnitude of these estimates is notably close to one, which is the value predicted by our model of the spare parts market. This is encouraging as estimates of φ that are considerably different from one would suggest misspecification and potentially call into question the substitution of spare parts supply that we use to estimate the vehicle demand model. We also note, however, that robustness tests included in the Appendix yield φ coefficients that are lower in magnitude and therefore do not view this interpretation as definitive.

[34] These are the same restrictions as those applies in Table 2.2 of summary statistics on our measure of intercompatibility between vehicle imports and the installed base.

[35] Specifications of the spare parts supply equation that restrict the compatible vehicle stock in the same fashion as in the vehicle demand equation are included in the Appendix.

[36] Under-identification of the model is notably rejected according to the Kleibergen-Paap rk statistic and the Hansen J statistic indicates that our instrumental variables are excluded and hence valid.

Table 2.4: Spare Parts Supply Estimation

	(1)	(2)	(3)	(4)	(5)	(6)
Ln(Compatible Base) (φ)	0.796***	1.235***	0.759***	1.164***	0.628***	1.101***
	(0.025)	(0.040)	(0.027)	(0.038)	(0.030)	(0.058)
Age ($\varphi_a^{(1)}$)	-0.156**	-0.026	-0.167***	-0.001	-0.195***	-0.005
	(0.065)	(0.076)	(0.064)	(0.080)	(0.059)	(0.073)
Age^2 ($\varphi_a^{(2)}$)	0.005***	0.004	0.005***	0.003	0.004**	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
M FE	No	No	Yes	Yes	No	No
M/M FE	No	No	No	No	Yes	Yes
IV	No	Yes	No	Yes	No	Yes
R2	0.551	0.411	0.606	0.498	0.743	0.653
Num. Obs.	3,619	3,619	3,619	3,619	3,619	3,619
Kleibergen-Paap rk F-Stat		78.10		116.80		67.10
Hansen J P-Value		0.20		0.98		0.31

Notes: Table reports the estimated coefficients from the spare parts supply equation (2.10). Observations are the number of traders offering parts for a given vehicle during the 12 months ending July 2019. The compatible base is measured according to the broadest definition including all compatible vehicles at the end of 2017. Robust standard errors are reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

It would be worthwhile considering alternative models in the future and exploring their relative fit for the data.

The results in Table 2.4 interestingly also show that vehicle age does not affect spare parts supply conditional on the compatible base.[37] It is not obvious that this should be so. We might expect demand for spare parts to be higher among owners of older vehicles as these break down more frequently. We might also expect, however, that spare parts for older vehicles are more difficult to obtain and thus more costly as there are fewer such vehicles with working parts available on international markets.[38] Our results suggest that these factors related to age are considerably less important than the compatible base or, at least, that they balance each other out on average.

Table 2.5 reports the results from estimating the vehicle demand equation (2.11). In order to account for the potential presence of direct network effects, we run four different types of specifications that incrementally narrow the set of vehicles over which we compute the compatible base, isolating the indirect network effect more and more. We start with the full compatible base and then exclude, first, vehicles of the same make, model, and manufacturing year (Excl. M/M/MY), secondly, vehicles of the same make and model (Excl. M/M), and third, vehicles of the same make (Excl. M). Our preferred specifications exclude all vehicles of the same make and model — retaining different models of the same make. These specifications strike a balance between isolating the indirect network effect and maintaining an

[37] In regressions similar to equation (2.10) without the compatible base (not reported), the coefficient on the linear age term is negative and statistically significant and coefficient on the quadratic term is positive but small.

[38] Anecdotal evidence obtained during our survey emphasized this notion of the relationship between vehicle age and spare parts availability.

appropriate number of vehicles in the compatible base.[39] The odd-numbered specifications are estimated via OLS, thereby ignoring the endogeneity of prices and the compatible base; even-numbered specifications are estimated via GMM and instrumental variables as described in the previous subsection. All specifications include fixed effects for the vehicle make, model, and manufacturing year triplet to capture vehicle-specific unobservable characteristics that may be correlated with the explanatory variables of interest.[40]

Table 2.5: Vehicle Demand Estimation

	Full Base		Excl. M/M/MY		Excl. M/M		Excl. M	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(Compatible Base) (γ)	0.807***	1.702***	0.907***	0.695**	0.635***	0.547	0.318***	0.787*
	(0.020)	(0.328)	(0.183)	(0.348)	(0.184)	(0.369)	(0.112)	(0.477)
Price (α)	0.149***	0.271***	0.149***	0.314***	0.155***	0.303***	0.160***	0.247***
	(0.013)	(0.026)	(0.013)	(0.027)	(0.013)	(0.027)	(0.013)	(0.027)
Age (β^a)	-0.619***	-0.885***	-0.489***	-0.514***	-0.467***	-0.498***	-0.442***	-0.511***
	(0.018)	(0.083)	(0.023)	(0.034)	(0.023)	(0.036)	(0.020)	(0.048)
M/M/MY FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	No	Yes	No	Yes	No	Yes	No	Yes
Num. Obs.	15,010	15,010	15,010	15,010	15,010	15,010	15,010	15,010
Num. Veh.	3,130	3,130	3,130	3,130	3,130	3,130	3,130	3,130
Kleibergen-Paap rk F-Stat		37.28		595.70		558.39		26.89
Hansen J P-Value		0.00		0.00		0.00		0.00

Notes: Table reports the coefficients from the market level logit regression according to equation (2.11). Observations are annual log-differences of the "eligible" Ugandan population share purchasing a vehicle (defined by make, model, and manufacturing year) and the share not purchasing any vehicle. Data are restricted to passenger vehicles and the period from 2013 through 2017. Intercompatible base is installed base quantity of vehicles multiplied by the share of intercompatible spare parts between vehicles. Specifications include all compatible vehicles or incrementally exclude the installed base of the same make/model/manufacturing year (M/M/MY), the same make/model (M/M), and the same make (M), as indicated in the column headers. Fixed effects for vehicle M/M/MY are included throughout. Standard errors are clustered at the vehicle M/M/MY level and reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

The results in Table 2.5 show that there is a strong positive relationship between the demand for passenger vehicles from international markets and the compatible base. The estimated coefficient of interest γ in specifications (4), (6), and (8) implies that consumers value a one percentage point increase in the compatible base at 1.8-3.2 million Ugandan Shilling or 13-24% of the average vehicle price. The point estimate is remarkably robust across these different definitions of the compatible base and mostly statistically different from zero at conventional significance thresholds. The fact that this also holds for specification (8), which excludes all vehicles of the same make from the compatible base, provides strong support for the interpretation that these results reflect indirect network effects via the markets for spare parts and repair. There is notably a considerable drop in the point estimate from roughly 1.7 when considering the full base in column (2) to approximately 0.7 specification (4),

[39] There is a substantial reduction in our measure of the compatible base relative to these preferred specifications when removing all vehicles of the same make. See descriptive statistics in Table 2.2 of Section 2.2.2.

[40] In the Appendix, we present specifications of the vehicle demand equation that instead incorporate period fixed effects or make/model and period fixed effects. While the coefficient estimates differ in magnitude from the results presented in Table 2.5, they are qualitatively similar.

but this is not unexpected given that the former also fully captures direct network effects.[41]

Based on the theoretical framework presented in Section 2.3, the estimated γ coefficient notably has a more precise interpretation than just the reduced-form value of the compatible base. Given that the number of traders stocking parts is predicted to be directly proportional to the compatible base — according to the spare parts supply equation (2.6) — γ also captures the structural value of the availability of spare parts.[42] Furthermore, γ and α are the structural parameters from the model of spare parts utility and their point estimates are confirmed to be within the assumed range with $\hat{\gamma} > 0$ and $\hat{\alpha} > 0$. As such, $\hat{\gamma}$ also reflects the elasticity of substitution in our the CES model of spare parts demand, which can be computed as $(1 + \hat{\gamma})/\hat{\gamma}$ and ranges between 2.3 and 2.8 according to specifications (4), (6), and (8).[43]

The other coefficients from the demand estimation are also plausible and intuitive. Both the vehicle price and age enter indirect utility negatively — the price coefficient α is defined with a negative sign — and statistically different from zero throughout all specifications. According to the preferred specification (6), they imply that demand, on average, is elastic at the prevailing market conditions (mean own-price elasticity of -5.7) and that an additional year of vehicle age is valued at approximately 1.6 million Ugandan Shilling or 12% of the average vehicle price.[44]

Finally, comparing the odd-numbered to even-numbered columns reveals the impact of the endogenous variables — i.e., the compatible vehicle stock and prices — on the estimation results. We do this with some caution, however, as the Hansen J statistic indicates a failed overidentification test, which may imply that our instrumental variables are not fully excluded.[45] Notably, the direction of the bias

[41] In addition, there is a clear difference in measurement of the compatible base between specifications (1) and (2) and the rest, because these specifications include intercompatibility for identical vehicles (by make, model, and manufacturing year) for which we assume $I_{jj} = 1$; for any two vehicles j and j' with $j \neq j'$, we need data to measure $I_{jj'}$ using the data obtained from the website Rockauto.com.

[42] The distinction between reduced-form and structural relationships here is based on the fact that consumers do not value the compatible base for its own sake but only to the extent that it relates to spare parts availability.

[43] The point estimates of γ in robustness checks that are included in the Appendix notably are considerably smaller in magnitude and would thus also imply different elasticities of substitution. They are, however, still within the assumed range and therefore consistent with our theoretical framework.

[44] Figure B.4 in the appendix illustrates the distribution of own-price elasticity across vehicles by calendar year.

[45] The Hansen J statistic is notably an "omnibus" test of the exclusion restriction and other maintained assumption, such as model specification. The current results therefore point towards some problem with the moment conditions that warrants further investigation. It is, however, not clear whether failed exclusion of the instrumental variables is the root problem.

absent instrumental variables is ambiguous given the composite error term $\upsilon_{jt} \equiv \gamma\kappa_{g(j)t}+\zeta_{g(j)t}+\xi_{jt}$ with $\kappa_{gt} \equiv ln\left\{[\alpha(1+\gamma)F_{gt}]/\gamma\right\}$ and $\zeta_{gt} \equiv -\left\{ln[\alpha(1+\gamma)c_{gt}]+1\right\}$. We expect that both vehicle prices, p_{jt}, and the compatible base, $Q_{g(j)t}$, are positively correlated with unobservable mean valuation ξ_{jt} as desirable unobservable characteristics tend to be associated with more expensive vehicles and overall higher market shares (or increases therein). At the same time, both explanatory variables are likely negatively correlated with $\zeta_{g(j)t}$, because this term has an inverse relationship with international prices of spare parts, c_{gt}. The positive correlation with ξ_{jt} appears to dominate for prices, so that the OLS regressions result in upward biased price coefficients. For the compatible vehicle stock, the picture is more mixed with the direction of the bias changing depending on the types of vehicles included in this measure.

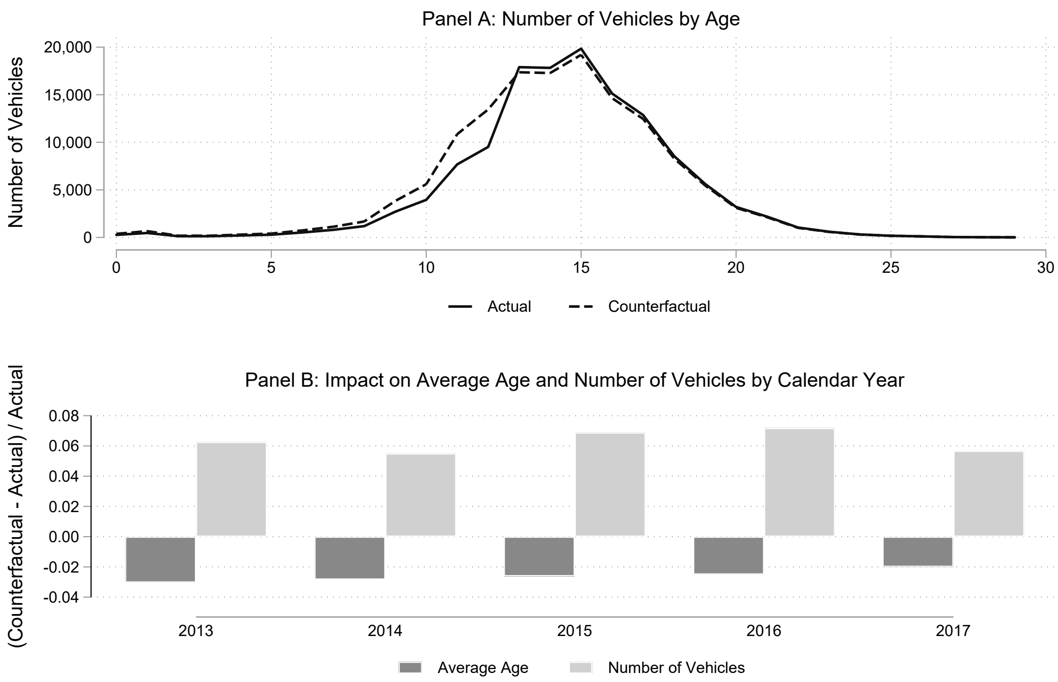
2.5 Counterfactual Simulation and Discussion

The results shown in the previous section demonstrate that the compatible base is a major determinant of demand for vehicles from international markets. They also provide strong support for the notion that this relationship exists due to indirect network effects via the availability of spare parts (and related services for maintenance and repair). Given the relatively high age of the existing vehicle stock, a natural question therefore is to what extent this stock contributes to the importing of further old vehicles. In this section, we conduct counterfactual simulations based on the parameter estimates from the previous section to answer this question. In addition, we also discuss the implications of our results more broadly, in relation to the global transition towards more environmentally friendly vehicle technology and the extent to which lessons from the vehicle sector in LICs might apply to other durable goods and machinery.

2.5.1 Counterfactual Simulation

Specifically, we consider a counterfactual, in which we double the availability of spare parts and repair services for all vehicles up to 12 years of age. While we are not explicit about the policy instrument, through which such an intervention could be achieved, there a several potential candidates. First, one might impose favourable tariffs for spare parts that are compatible with younger vehicles. Given that the majority of spare parts are imported rather than sourced from the scrapped domestic fleet, this would likely reduce the marginal cost of supply of parts for most younger vehicles. Second, one could institute a regular inspection and maintenance programme that tests on-road vehicles for emissions and roadworthiness. Indeed, this is one of the key policy recommendations to target vehicle emissions in LICs (UNEP, 2020) and could the raise repair requirements for older vehicles, thereby mitigating the impact of the indirect network effect on the vehicle age distribution. Third, one could also sponsor training programmes among mechanics in LICs to develop the local expertise required for the repair of newer or more specialized vehicles that is currently lacking.[46]

Figure 2.1: Counterfactual and Actual Passenger Vehicle Imports



Notes: Figure shows comparisons of the actual number of vehicles imported and their age and the simulated counterfactual with doubled spare parts and repair services for vehicles aged 12 years or less. Panel A shows the age distribution among imported vehicles across the calendar years 2013 to 2017. Panel B shows the relative difference between the average age and number of vehicles under the counterfactual and those same measures for vehicles actually imported, separately by calendar year.

The results from this simulation are summarized in Figure 2.1. Panel A shows the age distribution of vehicle imports across the entire sample period according to the actual data (solid line) and according to our counterfactual simulation (dashed line). Comparing both of these reveals, as expected, a leftward shift of the distribution due to the broader availability of spare parts among younger vehicles. In addition to this, it also shows a clear increase in the overall number of vehicles imported as the area between the dashed and solid line on the left of their intersection is

[46]While we have not discussed the market for repair and maintenance services explicitly in most of this paper, availability of these services is, of course, closely related to the availability of parts and undoubtedly also reflected in the empirical relationship between imports and the compatible base that we estimate.

larger than the area between them on the right. This is also unsurprising given that some consumers may substitute from the outside option (no vehicle purchase) to the younger vehicles as a result of the broader availability of spare parts.[47] Panel B sheds some more light on these two measures by showing the impact on the average vehicle age and the number of imported vehicles, separately by calendar year. While the average vehicle age drops by 2-3%, the number of vehicles rises by 6-7%.

Considering these two measures is important, because they may have offsetting or reinforcing effects depending on the policy objective. If younger vehicles are to be favored to reduce emissions, for instance, then the overall increase in vehicles may eliminate any gain from the distributional shift towards younger age. On the other hand, if the objective is to improve welfare and productivity through access to younger vehicles, with a more limited focus on environmental concerns, then the switching from older to younger vehicles and from the outside option to young vehicles may both be considered positive consequences.

2.5.2 Discussion

The above estimation results show that passenger vehicle demand in Uganda depends strongly on the installed base of vehicles via the market for spare parts and related services. The high age of vehicles in country and the counterfactual simulation further suggests that the existing stock of vehicles may slow the adoption of new vehicle technologies as described in prior theoretical work (Farrell and Saloner, 1986). Consumers' purchase decisions have external effects in that they raise the indirect utility derived by others from similar (parts compatible) vehicles. These vehicles tend to be older and hence less preferred, less productive, and more polluting, so that these external effects are predominantly negative and that there is socially suboptimal adoption of new vehicle technology in LICs. The preference for younger vehicles is evident from the negative parameter on age in our demand model and corroborated by previous studies of demand for second-hand vehicles (e.g., Clerides, 2008; Schiraldi, 2011). The relationship between vehicle age and productivity is scarcely studied, but recent evidence by Caunedo and Keller (2020) shows that the vintage of tractors affects agricultural productivity. In addition, the notion that older vehicles generally rely on obsolete technology and are more prone to breakdown suggests that they tend to be less productive.[48] Finally, the positive

[47]Given that we estimate vehicle demand in a simple logit model, the substitution patterns are driven chiefly by vehicles' market shares. It would be worthwhile extending this analysis to a more general nested-logit or random-coefficients model in the future that addresses this concern.

[48]This may of course not hold for some types of vehicles and some applications, especially if newer vehicles are not designed for the driving conditions in LICs.

relationship between vehicle age and pollution, due to lower environmental standards at the point of manufacture and due to physical depreciation, has been well documented in the engineering and transportation literature (e.g., Washburn et al., 2001; Bin, 2003).

The indirect network effect via the availability of spare parts in LICs is also particularly important in light of the global transition from conventional to electric vehicles. The analysis presented in this paper suggests that this transition is expected to be especially costly for early adopters in LICs, as spare parts and repair services for electric vehicles are initially unavailable. Consumers will therefore likely continue to rely predominantly on conventional vehicles and the gradual build-up of spare part inventory and expertise for electric vehicles in LICs following private market incentives will be socially suboptimal. Another important aspect of the global transition to electric vehicles is its potential to ultimately leave large parts of the vehicle stock in LICs as stranded assets.[49] Vehicles in LICs that could previously use intercompatible parts from younger vehicles (e.g., later manufacturing years of the same make and model) may observe a drop in the supply of these parts from used vehicles in high-income countries. This might, in principle, mitigate the inertia in the adoption of electric vehicles due to the indirect network effect, but would also entail substantial welfare consequences. While a detailed analysis of the expected impact of the global transition to electric vehicles extends beyond the scope of this paper, this discussion highlights that LICs face important constraints to adoption beyond the standard indirect network effect arising from the relationship with the market for charging stations.

More broadly, while this paper focuses on passenger vehicles, similar indirect network effects likely also apply to the markets for other durable goods or machinery in LICs. This is the case, because many of the key characteristics that lead to the prominence of the indirect network effect in our context extend to these other goods. In particular, other durables and machinery are typically also produced abroad and tend to be imported in used condition. This leads to frequent breakdown and elevates the availability of spare parts and repair services as an important product characteristic.[50] In addition, distribution networks by manufacturers are likely also very limited, so that the supply of spare parts and repair services is left to inde-

[49] According to the International Energy Agency, several key producing countries have announced zero-emission targets for vehicles or the phase-out of internal combustion engines until 2050 (IEA, 2020).

[50] Data on the condition among imports are unfortunately unavailable for many durable goods and equipment categories. The existing evidence for vehicles and some machinery (Navaretti et al., 2000; Bertinelli et al., 2006), however, points to a higher prominence of used products among LIC imports than those in richer economies.

pendent traders and potentially uncertain, especially for less prominent products. This matters, because durable goods and equipment account for a large share of imports into LICs (over 30% since 2000) and consistently rank among the highest import categories, only surpassed by mineral fuels.[51] Frictions that undermine the gains from trade in LICs for such a large share of imports are expected to have considerable welfare consequences.

2.6 Conclusion

In this paper, we present the first study of an arguably very common indirect network effect via the availability of spare parts among durable goods and machinery that may slow technology adoption in a LICs. Specifically, we focus on the passenger vehicle sector in Uganda and explore, through the lens of a structural model, how demand for such vehicles from international markets depends on the existing stock of vehicles that require compatible parts — i.e., the compatible base.

In this context, we find strong evidence in favour of the hypothesized indirect network effect from two estimating equations that we derive from our model, one for spare parts supply and another for vehicle demand. Estimating the former, we show that the number of traders offering spare parts is proportional to the compatible base. Estimating the latter, we demonstrate a robust positive relationship between vehicle demand and the compatible base, implying a spare parts elasticity of vehicle demand between 0.5 and 0.8. Given the relatively old vehicle stock in Uganda and LICs more generally, these findings suggests that the limited supply of spare parts for younger vehicles likely inhibits the adoption of newer vehicles. We quantify the extent of this through a simple counterfactual simulation that raises the availability of spare parts for vehicles up to 12 years old, finding a moderate impact of spare parts availability on the average vehicle age.

Finally, the results from this paper point to several potential avenues for future research. First, it would be worthwhile exploring in greater detail the likely consequences of the global shift towards more environmentally friendly vehicle technology. The extent to which LICs can participate in this process will depend on the technology and expertise acquired through their existing vehicle fleet and the compatibility of younger second-hand vehicles that may offer a transition to the frontier (e.g., hybrid cars). Secondly, while we believe that many other durable goods and machines in LICs face similarly favourable conditions for these indirect network effects as passenger vehicles, it would be important to confirm this through separate studies. It would be especially interesting to understand indirect network effects in

[51] See Figure B.1 in the Appendix.

the markets for intermediate products (e.g., tractors, industrial machines, or generators) and to estimate their impact on productivity. This could provide evidence for policy makers to determine whether interventions to facilitate the transition to newer technologies would help bridge global productivity gaps.

3 Trade Liberalization and Political Connections: Evidence from Myanmar

with Amit Khandelwal, Rocco Macchiavello, Madhav Malhotra, and Matthieu Teachout

3.1 Introduction

Trade liberalization has been widely recognized as an important driver of economic growth in low- and middle income countries. It provides firms with access to cheaper or higher-quality production inputs and leads to productivity improvements through reallocation of economic activity and exposure to international competition (Pavcnik, 2002; Goldberg et al., 2009; Koujianou Goldberg et al., 2010; Topalova and Khandelwal, 2011). At the same time, there is considerable evidence that political connections in low- and middle-income countries can distort competition and undermine market efficiency. This occurs through a range of anti-competitive practices, such as differential access to production inputs, including capital (Johnson and Mitton, 2003; Khwaja and Mian, 2005; Charumilind et al., 2006; Faccio et al., 2006), favorable treatment in licensing regimes (Mobarak and Purbasari, 2006; Rijkers et al., 2017), or leniency in enforcing tax law (Rijkers et al., 2017).

A natural question therefore is to what extent the promised gains from trade liberalization can be undermined by political connections as the intended pro-competitive effects cannot take hold. While the impact of political connections on trade restrictions themselves is the topic of the large "protection for sale" literature (e.g., Grossman and Helpman, 1994; Goldberg and Maggi, 1999; Mobarak and Purbasari, 2006), the relationship between non-trade barriers associated with connections and gains from trade is not well understood. In particular, it is not clear whether the broad removal of (non-differential) trade barriers achieves its promised gains in the presence of politically connected firms that may benefit from other anti-competitive practices.[1] If political connections and associated barriers to entry rather than trade restrictions are the binding constraint, then the expected answer would be negative.

In this paper, we address this question by studying the role of political connections among importers during an episode of trade liberalization in 2013 in Myanmar. This setting in Myanmar is particularly suitable, because the country at the time had just emerged from decades of a predominantly planned economy under military

[1] The lowering of tariffs or the removal of import license requirements, for instance, may not affect competition in markets where politically connected firms face lower costs of capital or have privileged distribution rights.

control. The continued involvement of the military in government and economic affairs made connections to the former regime a widespread feature among firms; and the economic liberalization under the new government provided a rapid reduction of trade restrictions.[2] In addition to its historical context, Myanmar also provides uniquely detailed data to track connections between firms and the political elite. Until recently, the Directorate of Investment and Company Administration (DICA) published data online on all firms registered in Myanmar and their board members, including names and national identification numbers. In addition, from the late 1990s until the mid 2010s, the US, the EU, and Australia maintained targeted sanctions against firms and individuals connected to the previous military regime. We use these sources to identify connections between firms and the military and combine them with administrative data on imports and domestic prices to measure firm and sector-level outcomes.

Within this general context, we focus on the removal of import license requirements for a broad range of sectors in 2013 and study their implementation and effect by comparing politically connected firms (or sectors with many such firms, henceforth "connected sectors") to non-connected firms (and sectors).[3] We begin by studying the imperfect implementation of the reform to investigate the standard hypothesis in the literature that trade restrictions are used as a means to protect politically connected firms. We then turn to the main contribution of our paper, namely studying the extent to which political connections affect the gains from liberalization conditional on their successful implementation. We analyze how the removal of import license requirements differentially affects sector growth depending on the presence of politically connected firms. We also investigate potential entry barriers of entry associated with connected firms that may preclude the gains from trade liberalization, focusing in particular on scale economies and access to capital.[4] Our main results for each of these pieces of analysis are as follows.

First, we find evidence that import licenses in Myanmar have been used to protect connected firms and that this was made possible through a partial and imperfect de-licensing process. At the aggregate level, connected sectors were less likely to be selected for liberalization than non-connected sectors, mirroring the standard

[2]Case studies of *crony capitalism* in other countries with strong military regimes, including Egypt (Chekir and Diwan, 2014) and Turkey (Demir, 2005), document how privatization of state-owned assets and trade liberalization can facilitate the establishment of far-reaching, opaque rent-seeking networks. The historical experience in Myanmar and current political discourse parallel this narrative and underscore its suitability for our research.

[3]We define sectors at the six-digit Harmonized System (HS) level.

[4]Our analysis focuses mainly on classical entry barriers in the spirit of Bain (1956) rather than barriers that arise from strategic consideration on the part of incumbent firms, although we cannot exclude the latter.

correlation documented in the "protection for sale" literature. In addition, the liberalization process was implemented imperfectly, with only a subset of sectors that were liberalized *de jure* being also liberalized *de facto*. Importers in sectors that were not liberalized *de facto* continued to be asked for licenses despite the official removal of license requirements.[5] Among the sectors liberalized *de jure*, those not liberalized *de facto* are more likely to be connected sectors, especially when they do not exhibit economies of scale that would provide a natural entry barrier in the context of imperfect capital markets.[6] Furthermore, at the transaction level in sectors liberalized *de jure*, non-connected firms are more likely to be asked for a license than connected firms. All these results suggest that the partial and imperfect de-licensing process was used to shield connected firms from competition that might arise from the trade liberalization.

Second, and turning to our main contributions, we show that the license removal accelerated growth in non-connected sectors but did not impact growth in connected sectors. Decomposing the liberalization impact into the intensive and the extensive margins, we also show that the growth acceleration in non-connected sectors is almost entirely attributable to entry of non-connected firms. We interpret these results as evidence that the import license requirements were binding constraints for entry in non-connected sectors but that they were non-binding constraints in connected sectors. Given the fact that connected sectors cover a broad range of industries, this suggests that there are other binding constraints associated with connected firms that effectively prevent entry. These could, in principle, include firm-specific measures that disadvantage potential entrants (or threaten to do so) or sector characteristics that connected firms are better positioned to overcome.

Third, and motivated by the previous finding, we directly focus on differences in entry of non-connected firms between connected and non-connected sectors. We then seek to identify natural sector characteristics that may explain these differences as connected firms are better positioned to overcome them. In particular, we abstract from the license removal and show that a greater presence of connected firms is associated with less entry of non-connected firms across sectors. This correlation holds both in the short and the long run. The low entry rates observed in sectors populated by connected firms is thus not specific to the import license liberalization, but a more general feature of the economy. We then explore whether a range

[5] We observe the imperfect liberalization of sectors as license numbers continue to be recorded for transactions in the import data despite their sectors having been liberalized *de jure*.

[6] We measure economies of scale in importing as a negative relationship between the average unit price and quantity/value among transactions in a given sector. The presence of connected firms and economies of scale are positively correlated.

of sector characteristics that may capture differences in fixed costs or barriers in sourcing and downstream distribution can explain this observed correlation. These characteristics include controls for broad product categories — i.e., two-digit HS codes, BEC product type, and the Rauch (1999) classification — and the measures of economies of scale in importing that were shown to be relevant in the imperfect implementation of the license reform. We find that the correlation between non-connected entry and the presence of connected firms is robust to the various controls for broad product categories, but that economies of scale account for a large share of it. These results suggest that scale economies provide natural barriers of entry for non-connected firms, which is intuitive in light of the capital market imperfections and scarce foreign currency in the country . Connected firms selected into sectors with these natural entry barriers and thus benefited from limited competition with non-connected firms in the aftermath of the import license reform.

Our main contribution to the economics literature is presenting evidence that the presence of politically connected firms can undermine the gains from trade liberalization. The relationship between political connections and trade liberalization more generally has of course been studied extensively in the "protection for sale" literature, predominantly in high-income countries (Grossman and Helpman, 1994; Goldberg and Maggi, 1999) but also in some developing contexts (Mobarak and Purbasari, 2006). This literature, however, has focused on the impact of lobbying/political connections on differential trade restrictions that shield domestic firms from international competition. While we also find evidence of this differential use of trade barriers, our paper emphasizes other constraints associated with connected firms that mitigate the gains from trade liberalization even conditional on the liberalization's successful implementation. Given the wide range of means by which politically connected firms can be protected, especially in low- and middle-income countries, this is a natural extension of the "protection for sale" literature. A further, more nuanced, distinction of this paper is our focus on competition in import markets (between different domestic firms) rather than competition from foreign companies. This focus is natural in the developing country context where many imported products are not produced domestically.

In addition, our paper also relates to the broader literature on the gains from trade liberalization and, in particular, mitigating factors in low- and middle income countries. Entry and the reallocation of economic activity from low- to high-productivity firms has been widely recognized as an important mechanism, by which gains from trade are realized. This is reflected in the seminal work by Melitz (2003) and related empirical studies in developing countries (Pavcnik, 2002; Topalova and

Khandelwal, 2011; Brandt et al., 2017, 2019) as well as advanced economies (Trefler, 2004; Bernard et al., 2006). There is also growing evidence, however, that trade liberalization may not yield the promised gains, especially in environments where other market distortions are rampant. Bai et al. (2018), for instance, show that firm-level distortions (such as taxes/subsidies) can lead to welfare losses from trade liberalization.[7] Similarly, and in research most closely related to our paper, Baccini et al. (2019) demonstrate that private firms in Vietnam experience the predicted effects of trade liberalization during the country's accession to the WTO (higher exit rates, lower profitability and increases in productivity) while state-owned enterprises (SOEs) did not. Overall, the "consensus" that emerges from this literature is that entry of new firms and reallocation to high-productivity firms are very important for the gains from trade liberalization to materialize, but that barriers to entry (regulatory or economic) can undermine this process. Our paper's contribution picks up exactly this point by expanding the scope of barriers beyond SOEs to private politically connected firms.

Finally, our paper also contributes to the literature on political connections in low- and middle income countries. There are many studies in this area that quantify the value of political connections, either for firms (Fisman, 2001; Faccio et al., 2006; Ferguson and Voth, 2008; Chekir and Diwan, 2014; Rijkers et al., 2017) or for politicians (Fisman et al., 2014). The fact that these generally find political connections to be valuable suggests that connections undermine competition and market efficiency. Another set of papers focuses on the mechanisms for market foreclosure and rent extraction that underpin this value, including differential access to capital (Johnson and Mitton, 2003; Khwaja and Mian, 2005; Charumilind et al., 2006; Faccio et al., 2006), foreclosure through licensing regimes (Mobarak and Purbasari, 2006; Rijkers et al., 2017), or tax evasion (Rijkers et al., 2017). We contribute to this literature by focusing on aggregate outcomes (at the sector level) rather than on firm performance and thereby capture adverse effects of political connections on the broader economy. Our results notably contrast with those by Kochanova et al. (2018), who find no evidence of changes in connected sector performance surrounding the Suharto regime change in Indonesia.

The remainder of the paper is structured as follows. In Section 3.2, we provide background information about the historical context of our setting, the de-licensing in 2013, and about the data that we have available to study it. Following this, we

[7]Also notable are several studies on the Chinese economy that attempt to explain the country's growth experience despite the prominence of SOEs, political connections, and rent-seeking relationships, e.g., through reduced frictions from market imperfections (Kang, 2003) or competition between locally favored businesses (Bai et al., 2014).

document in Section 3.3 that the partial and imperfect de-licensing process favored politically connected firms. In Section 3.4, we show the differential impact of the license liberalization on sectors depending on the presence of connected firms and we investigate barriers of entry to explain this finding. Finally, in Section 3.5, we offer some concluding remarks.

3.2 Background and Data

Myanmar provides a unique setting to study the effectiveness of trade liberalization in the context of a strong nexus between firms and the political elite. Its history of several decades under military dictatorship and the managed economic and democratic transition that followed fostered far reaching influence of military affiliates throughout public and private companies. Furthermore, unlike other settings, where the connections are opaque with the exception of those for the largest companies, Myanmar offers public data that allow us to observe company affiliations with the prior military regime for large parts of the economy and map these to administrative import records. The important features of Myanmar's history and the available data are discussed in further detail below.

3.2.1 Historical Background

Myanmar had been under military rule for roughly 50 years when power was officially transferred to a civilian government in 2011. This period forged strong connections between enterprise and the military regime and the managed transition in 2011 guaranteed continued influence by the military in both the economic and political spheres. After the military assumed power in 1962, the Myanmar economy was initially entirely state-owned but later experienced spurts of privatization (in the 1990s, 2008, and 2011). These resulted in private companies with strong patronage networks linked to the military that have continued to loom large after 2011 (James, 2010; Jones, 2014; Larkin, 2015). In addition to the relationships with business, the military had also maintained substantial influence over the political process despite the democratic transition.

The pro-market reforms in the 1990s were largely centered around ceasefire agreements with armed insurgent groups in the resource-rich border regions with Thailand and China.[8] Following these agreements, the military government granted monopoly licenses for extractive industries — prominently mining, logging, and rubber — to a select group of individuals with close personal connections to the military regime,

[8]The origins of these conflicts trace back to different ethnic and religious groups that had been sovereign entities prior to colonial rule by the British, fought on opposing sides in Wold War II, and were then united under one country upon independence.

ensuring a tight network of beneficiaries comprised of ethnic leaders, military officers, and entrepreneurs (Woods, 2011). Many of the businesses that emerged out of this "ceasefire capitalism" are still strong economic entities in Myanmar today.

After this focus on resource extraction in the border regions, more extensive waves of privatization occurred in 2008 and in 2011 and concentrated private asset ownership in the hands of the business elite with personal connections to the military regime. These included primarily family members and close prior business associates, such as the key beneficiaries of the earlier reforms in the 1990s. At this point, the state had notably become reliant on the support of the private sector, with enterprises often supplementing state capacity through the provision of public goods in exchange for import permits or monopolistic concessions. This co-dependence is, for instance, reflected in the connected firms' contributions to the construction of the sprawling new capital city of Naypyitaw in the early 2000s or to relief efforts in the aftermath of the 2008 cyclone Nargis (Jones, 2014).

In addition to these patronage relationships with private companies that were created under pro-market reforms, the military maintains direct official interests in the economy through two military-owned conglomerates, the Union of Myanmar Economic Holdings Limited (UMEHL) and the Myanmar Economic Corporation (MEC). UMEHL and MEC were established in 1990 to directly finance the army's operations and personnel, including retired veterans. The conglomerates own interests in a broad range of companies throughout the economy — some outright, some partially — and also contributed to connections between otherwise independent companies and the military during pro-market reforms, e.g., through requirements for foreign investments to enter a joint venture with subsidiary firms (Myoe, 2009). UMEHL and MEC, which still belong to the largest companies in the country despite partial divestitures, continue to extend the military's reach deep into the business community of Myanmar.

Finally, it is also important to emphasize the continued political relevance of the military during the period after the 2011 democratic transition and military coup in early 2021.[9] As per the 2008 constitution, a quarter of the seats in both houses of the national and regional parliaments are reserved for military personnel appointed by the army. This essentially guaranteed the military continued influence on the legislative process in the country and veto power over constitutional amendments. In addition, the military also fully controlled three powerful ministries — Home Affairs, Defense, and Border Affairs. This influence of the military in Myanmar

[9]Without political relevance, connections to the military would not necessarily be expected to influence firm or sector performance as the connections could not be leveraged into any form of protection from competition and the resulting economic rents.

is particularly explicit, but it likely parallels the effective power held by the army in many other developing countries where civilian institutions are not sufficiently resourced.

3.2.2 Data

In addition to its historical context that forged strong connections between the military and companies throughout the economy, Myanmar also offers unique data to study the relationship between these connections and gains from international trade. These data include (i) information on firms' and individuals' connections to the military regime from sanctions records, (ii) publicly available data to map sanctioned individuals to company boards from the agency responsible for company registration, DICA, and (iii) administrative data on international trade from the Ministry of Commerce. The international trade data cover the universe of shipments during the fiscal years 2011/12 to 2015/16 and are uniquely informative in that they are at the transaction level and allow us to identify firms.

Measures of Connectedness

Our primary measure of firm connections to the former military regime is based on international sanctions lists from the US, the EU, and Australia.[10],[11] In the aftermath of the 1990 elections in Myanmar and the military's refusal to relinquish power, trading partners around the world gradually imposed sanctions targeted at senior figures in the military regime, their family members, and close business associates. We focus on the targeted sanctions that were in effect shortly before the import license liberalization — i.e., those in effect at the outset of the democratic transition in 2010/11, which were then gradually revoked in 2012, 2013 and 2016

[10]The Australian sanctions were initially implemented under the *Banking (Foreign Exchange) Regulations 1959* by the Reserve Bank of Australia and since 2011 under the *Autonomous Sanctions Regulations 2011* by the Minister for Foreign Affairs. The EU sanctions were implemented via various regulations of the Council and Commission of the European Union. The US sanctions were implemented under the *Burma sanctions program* by the Office of Foreign Assets Control (OFAC).

[11]The sanctions lists notably change over time and we consider any firms or individual as being connected to the military regime if they are listed at least once during the following periods. The Australian sanctions were first introduced in October 2007 and we refer to the October 2008 amendment (which includes an extended list) and subsequent amendments to construct a comprehensive list of entities in Myanmar sanctioned by Australia for their connection to the former military regime. Targeted sanctions by the EU against entities in Myanmar were first introduced in April 2003 and, similar to the Australian case, we consider the most substantially expanded list from May 2010 and subsequent amendments for our analysis. Targeted US sanctions against individuals and firms connected to the former military regime were initiated in 2007 and we capture all entities from the Specially Designated Nationals (SDN) list from that point until their removal in October 2016.

for Australia, the EU, and the US, respectively.[12] We notably use these sanctions exclusively to identify connected firms and do not consider their direct impact on trade. This is justified in our context, because the sanctioning jurisdictions only account for a small share of Myanmar's trade and because we measure the impact of the license reform separately for connected and non-connected sectors. [13] In aggregate, these sanctions lists provide a total of 136 firms and 669 individuals with connections to the former military regime.

We then match entities from the sanctions lists to the trade data from the Ministry of Commerce, which are at the transaction-level and include company identifiers.[14] This is done directly via the name for sanctioned firms and indirectly via the DICA company register for sanctioned individuals (matching first the individual to board members and then the corresponding company to the trade data). For individuals, the sanctions lists often contain detailed information, such as various aliases, passport numbers, addresses, affiliated businesses, and family members. In order to maximize accuracy, we employed a local company specializing the investigative research on political connections to conduct the matching of sanctioned individuals to company board members; to the same end, the matching of companies to the trade data was conducted by a team of local researchers in Myanmar.[15]

We supplement this primary measure of firm connections to the former military regime with information from the trade data that identifies SOEs. This is important for a number of reasons. First, SOEs are quantitatively important in Myanmar given the legacy of socialism. Second, they are similar to private connected firms in that they clearly have links to the military through their history under the regime up to 2011 and/or the army's involvement in parliament throughout our period of study. This also implies that they likely benefited from similarly favorable conditions as private connected firms, including protection through licensing regimes and access to capital. Third, some SOEs are not listed in the DICA company register, so that they would be grouped with private non-connected firms in the absence of this supplementary definition.[16] Taken together, these reasons suggest that SOEs need

[12]Some targeted sanctions were re-introduced more recently, in response to the Rohingya crisis in Myanmar's Rakhine state and the takeover of government by the military in early 2021, but these were not considered in our analysis.

[13]Ninety percent of the goods imported in Myanmar come from neighboring and non-sanctioning Asian countries.

[14]The trade data are available for the universe of imports during the fiscal years (starting in April) 2011/12 to 2015/16 and include approximately 4 million transactions.

[15]The research company notably also maintains its own database of firms and individuals connected to the former military regime, which we used to augment our definition of connected firms for robustness tests.

[16]One of the two military conglomerates, MEC, for instance, is not included in the DICA company register.

to be accounted for in the analysis, either by grouping them with private connected firms or by excluding them from the non-connected benchmark group. We opt for the former and report results separately for private connected firms and SOEs where appropriate.

Overall, this process resulted in a total of 300 importers that are connected to the former military regime and 420 SOEs. Tables C.1 in the Appendix provides summary statistics on their relevance among importers, in terms of number and size. As a share of the total number of importers in the country, connected firms and SOEs are a very small fraction (less than 1% taken together), but they are substantially larger on average than non-connected firms and include some of the largest importers by value, accounting for nearly 30% of total imports (11.6% and 17.3% for private connected firms and SOEs, respectively). Figure C.3 in the Appendix documents that there is significant dispersion in the presence of connected firms across sectors. They are not present in approximately 40 percent of sectors and appear marginally (market share lower than 20 percent) in 45 percent. Connected firms have more than 80 percent of the market share in only a handful of sectors. Table C.2 in the Appendix reports the share of import value for HS chapters by the different importer classifications and overall. It is evident that the activity of connected firms is primarily focused on a few sectors: mineral products, especially mineral fuels/oils (approximately 40%), machinery and electrical equipment (13%), metals and metal products (9%), transportation equipment (8%), and animal/vegetable fats and oils (8%). Overall, over 90% of imports by value among connected entities is accounted for 17 two-digit HS codes.

Finally, we use the import data with the matched connected firms to define "connected sectors". Specifically, we define a sector to be connected if privately connected firms and SOEs represent at least 15% of import value in the pre-liberalization period, corresponding to the 66th percentile among sectors of the share of imports by connected firms.[17]

Economies of Scale in Importing

One important aspect of the relationship between political connections and trade liberalization is the extent to which other barriers of entry at the sector level can shield connected firms from competition and undermine the gains from trade. In this paper, we focus on one particular potential entry barrier, namely economies of scale in importing in the form of price discounts for larger shipment sizes. This is expected

[17]Our empirical results are robust to alternative thresholds for this sector definition.

to be an important entry barrier, because capital constraints in developing countries are widespread and because connected firms frequently benefit from preferential access to capital (Johnson and Mitton, 2003; Khwaja and Mian, 2005; Charumilind et al., 2006; Faccio et al., 2006). In addition, access to foreign capital, which is crucial for importing, has also been particularly limited in Myanmar, because of the legacy of the policies established under the military regime that strictly regulated the foreign capital markets (Kubo, 2014).[18]

We measure economies of scale in importing by estimating the sector-specific relationship between the average unit price and the shipment size and then classify sectors accordingly into high and low categories. We do this for two alternative measures of shipment size — quantity and value — and use these sector classifications at various points in our analysis. Further details of the estimation procedure and results underlying the classification are included in the Appendix, Section C.1.

3.3 Partial and Imperfect Import License Removal

Up until March 2013 (the end of the 2012/13 fiscal year), firms and individuals wishing to import goods into Myanmar had to apply for a shipment-specific license from the Ministry of Commerce, which then needed to be presented to the Customs Department for clearance. In April 2013, this license requirement was partially abandoned to align the country's policies more closely with internationally accepted standards on non-tariff barriers and to foster economic growth (Naing, 2014).[19] Specifically, the license requirement was removed for 166 broad goods categories corresponding to roughly 2,700 six-digit HS codes (60% of all sectors) and 40% of the import value in the years surrounding the liberalization. The Ministry of Commerce decided on the goods to be liberalized and published the corresponding list.[20] The Customs Department was in charge of implementing the reform by no longer requiring licenses for clearance in the liberalized sectors. At the time, the Ministry of Commerce in Myanmar was notably known to be reformist and pro-liberalization while the Customs Department, under the control of the Ministry of Finance and Revenue, was more conservative and had closer ties to the former military regime.

The partial license removal is important for two reasons. First, from an empirical analysis standpoint, it provides an opportunity to study the impact of the reform by comparing the change in imports in liberalized and non-liberalized sectors. This

[18] These included, for instance, the "export first and import second" policy and differential exchange rates for the public and private sectors.

[19] The license removal was signed into law in February 2013.

[20] The Ministry of Commerce published a negative list which provides the product codes that still a license post-reform. See Ministry of Commerce Announcement Order No 16/2013.

is precisely what we do in Section 3.4. Secondly, from a contextual standpoint, it introduces one potential margin by which the liberalization can be used to protect importers connected to the military. Maintaining import licenses in connected sectors shields firms in these sectors from potential competitors that might enter under the license removal. In this section, we show that there is some evidence in favor of this type of selective liberalization.

In addition to the partial reform, its imperfect implementation can also be used to protect connected firms. In particular, we find that of the sectors that were liberalized *de jure* by the Ministry of Commerce, a substantial portion appear not to be (fully) liberalized *de facto* by the Customs Department. We can distinguish these cases, because the Customs Department indicates in the transaction-level data if a license was requested for clearing a specific shipment while the official list of liberalized sectors is available publicly. Connected firms can be protected in this fashion by not liberalizing connected sectors *de facto* although there were liberalized *de jure* or by requiring licenses selectively for non-connected firms. In this section, we also show evidence in favor of these mechanisms to protect connected firms.

Partial (De Jure) License Removal

The partial reform of the import licensing regime in 2013 provided the Myanmar government with the flexibility to shield connected firms and sectors from potential competition. Specifically, the Ministry of Commerce's set of "sensitive" commodities for which license requirements were to be maintained could easily be skewed towards connected sectors (Naing, 2014). In order to assess the extent to which this took place, we prepare summary statistics of the share of liberalized sectors by HS chapter and estimate cross-sectional regressions of *de jure* liberalization on indicator variables for connected sectors at the six-digit HS level. Specifically, we estimate the following regressions at the sector j level:

$$\tilde{Lib}_j = \gamma_{g(j)} + \beta \cdot C_j + \epsilon_j \tag{3.1}$$

, where $\tilde{Lib}_j$ denotes an indicator variable for *de jure* liberalization, $\gamma_{g(j)}$ is a two-digit HS code fixed effect, C_j is an indicator for connected sectors, and where ϵ_j is the error term.

This empirical evidence suggests that connected sectors were favored by the partial license removal, although this may follow more from unobserved characteristics of the sectors in which connected firms were active than an intended outcome of the reform. The regression results in Table 3.1 show that, overall, connected sectors are less likely to be liberalized *de jure* than non-connected sectors and that this relationship is driven by private connected firms rather than SOEs. Among the quantitatively most important import sectors, however, this relationship derives from variation between broad product categories (two-digit HS codes) rather than variation within such categories. This is also reflected in Figure 3.1, which shows that the share of sectors liberalized *de jure* varies mostly by HS chapter. Almost none of animal, vegetable and mineral products were liberalized, while for most of the other HS chapters, more than 70 percent of product codes were liberalized. This pattern suggests that, while the reform favored connected sectors, the Ministry of Commerce chose sectors for import liberalization primarily based on broad product characteristics rather than specifically to protect connected sectors.

Table 3.1: Regression of *De Jure* Liberalization

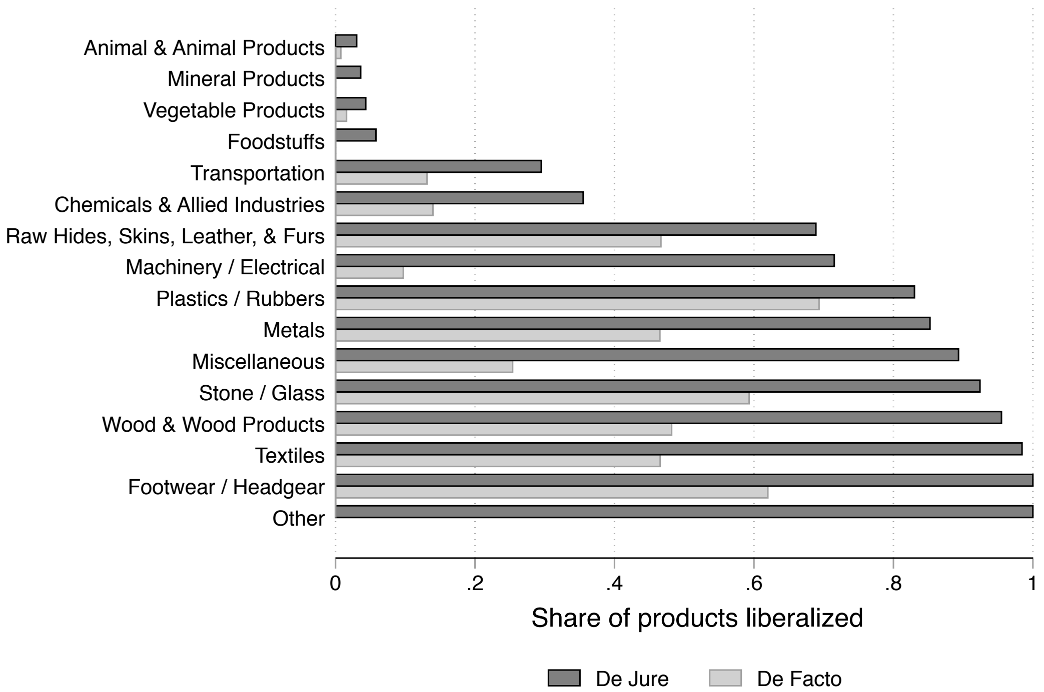
	Full Sample				Top Sectors			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Connected	-0.053**		-0.055***		-0.101*		-0.032	
	(0.022)		(0.018)		(0.053)		(0.048)	
Private Connected		-0.070**		-0.072***		-0.099		-0.044
		(0.027)		(0.021)		(0.061)		(0.052)
SOE		-0.031		-0.032		-0.103		-0.012
		(0.030)		(0.025)		(0.072)		(0.076)
HS2 FE	No	No	Yes	Yes	No	No	Yes	Yes
Obs.	1,888	1,888	1,888	1,888	348	348	348	348
R-Squared	0.003	0.004	0.553	0.553	0.010	0.010	0.508	0.508

Notes: Table reports estimates of β in equation (3.1). Observations are sectors with positive imports throughout the 2011/12-2014/15 fiscal years. Specifications (1)-(4) are estimated on all sectors; specifications (5)-(8) only include sectors with at least USD 3 million in average import value per year. In specifications (1),(3), (5), and (7), the right hand side variable $C_{f(i)}$ is an indicator for connected sectors; in specifications (2), (4), (6), and (8), we include separate indicators for connectedness due to private connected firms or SOEs and correspondingly report estimates for two parameters. Two-digit HS fixed effects are included as indicated in the bottom of the table. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Imperfect (De Facto) License Removal

In addition to the partial liberalization overseen by the Ministry of Commerce, the imperfect implementation of the reform by the Customs Department offered another mechanism to protect connected sectors and firms. To understand the role of this mechanism, we focus on the set of sectors liberalized *de jure* and study how the therein contained subset of sectors and transactions liberalized *de facto* relates to connected firms. Of the import sectors which were meant to be liberalized by the Ministry of Commerce and appear with positive value throughout the periods surrounding the reform, over 80% still required some form of a license for some

Figure 3.1: Share of Sectors Liberalized by HS Chapter



Notes: Figure shows the percentage of products which are liberalized *de facto* or *de jure* by HS chapter. The share of products which are liberalized *de facto* is a subset of the set of products which are liberalized *de jure*.

shipments.[21]

We first analyze the relationship between this imperfect liberalization and connections to the military at the sector level. Specifically, we estimate the following probit model of *de facto* liberalization and connectedness at the sector j level:

$$Lib_j^* = \gamma_{g(j)} + \beta_1 \cdot C_j + \mathbf{X_j'}\beta_\mathbf{2} + C_j \cdot \mathbf{X_j'}\beta_\mathbf{3} + \epsilon_j \tag{3.2}$$

, where $\gamma_{g(j)}$ is a fixed-effect for the HS chapter, C_j is a measure of the sector's connectedness (an indicator or the share of connected firms' imports), $\mathbf{X_j}$ is a vector of sector characteristics, and where ϵ_j is a standard normal error term. Lib_j^* is the standard probit model latent variable that gives rise to observed *de facto* liberalization Lib_j whenever $Lib_j^* > 0$.

We include sector characteristics $\mathbf{X_j}$ for two reasons. First, we would like to to assess the extent to which they explain *de jure* liberalization. This will be reflected in the coefficients $\beta_\mathbf{2}$ on the linear $\mathbf{X_j}$ term. Secondly, we want to capture barriers of

[21] The Ministry of Commerce was aware of the situation and continued to issue import licenses, post-reform, for *de jure* liberalized to satisfy customs agents' license requests.

entry that may shield incumbent firms from potential competition due to the license removal. If the imperfect license liberalization is indeed used for the protection of connected firms, then we would expect *de facto* liberalization to be more likely in connected sectors with other entry barriers. This will be reflected in the coefficient $\beta_{\mathbf{3}}$ on the interaction term $C_j \cdot \mathbf{X_j}$. Given the scarcity of foreign currency around the license reform in Myanmar, we focus on the average shipment value and economies of scale as defined in Section 3.2.2 for these sector characteristics.[22]

Table 3.2: Probit Model of *De Facto* Liberalization

	(1)	(2)	(3)	(4)	(5)	(6)
Connected		-0.313***			-2.097***	-0.554***
		(0.078)			(0.567)	(0.110)
Share Connected			-0.713***			
			(0.133)			
Share Private Connected				-0.567***		
				(0.199)		
Share SOE				-0.807***		
				(0.165)		
Ln(Shipment Value)					-0.089**	
					(0.038)	
Connected × Ln(Shipment Value)					0.203***	
					(0.064)	
Scale Economies						0.032
						(0.098)
Connected × Scale Economies						0.413***
						(0.158)
Constant	-0.325***	-0.200*	-0.155	-0.149	0.576*	-0.164
	(0.106)	(0.111)	(0.112)	(0.113)	(0.337)	(0.116)
HS Chapter FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,405	1,405	1,405	1,405	1,405	1,405
Pseudo R-Squared	0.161	0.169	0.176	0.177	0.175	0.176

Notes: Table reports parameter estimates of equation (3.2). Observations are sectors (six-digit HS codes) with positive imports throughout the 2011/12-2014/15 fiscal years that were liberalized *de jure*. *De facto* liberalized sectors require licenses for less than 80% of transactions. Connected sectors are those with market share of connected firms greater than 15 percent. Ln(shipment value) is the natural logarithm of the average shipment value by sector, leaving out connected firms. Scale economies is an indicator variable equal to one if the sector exhibits economies of scale as defined in Appendix Section C.1 and estimated through equation (C.2). HS chapter fixed effects are included throughout. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Estimating this model on the sectors that were liberalized *de facto*, we obtain the results presented in Table 3.2. We start with a parsimonious specification and gradually include additional terms, ending with the full specification as given in equation (3.2). Column (1) presents the pseudo-R^2 in a specification with only HS chapter fixed effects as a benchmark. Column (2) shows that connected sectors were less likely to be liberalized *de facto* than non-connected sectors. Column (3) uses a continuous version of the connectedness variable, where the sector indicator is replaced by the share of connected firms' import value in the pre-liberalization period. Column (4) splits the connected share into privately connected firms and

[22]Specifically, we use the value-based measure of economies of scale.

SOEs. The presence of both is associated with a lower likelihood of *de facto* liberalization. After this, we include terms for economies of scale and the interaction with the connectedness indicator. Columns (5) and (6) show that while connected sectors were less likely to be *de facto* liberalized, this negative correlation was mitigated by economies of scale.[23] Economies of scale are notably not important in explaining the likelihood of *de facto* liberalization in non-connected sectors. These results suggest that the imperfect reform was used to shield connected firms by limiting *de facto* liberalization, especially in sectors with low economies of scale that could act as natural entry barrier to prevent competition.

Finally, we leverage the fully disaggregated version of the import data at the transaction level and analyze the extent to which non-connected firms are more likely to be asked for import licenses in *de jure* liberalized sectors than connected firms.[24] Specifically, we estimate the following linear model of *de facto* liberalization and connectedness at the transaction i level:

$$Lib_i = h(\gamma_{j(i)}, \tau_{t(i)}, \mu_{m(i)}) + \beta \cdot C_{f(i)} + \epsilon_i \tag{3.3}$$

Analogous to equation (3.2), Lib_i denotes an indicator for *de facto* liberalization, $C_{f(i)}$ is an indicator for connected firms, and ϵ_i is the error term. We also control for a range of different fixed effects at the sector, week, and shipment mode level — $\gamma_{j(i)}$, $\tau_{t(i)}$, and $\mu_{m(i)}$, respectively — and interactions thereof, which we flexibly summarize via the function $h(.)$.[25]

Estimating this model on the 20% of the transactions in *de jure* liberalized sectors with selective licensing, we obtain the results presented in Table 3.3. Columns (1) to (3) use a single indicator variable for all connected firms and employ increasingly flexible fixed effects, controlling first only for unobservables at the sector level,

[23] Sector connectedness and economies of scale notably only explain a small portion of the total variation in the likelihood of *de facto* liberalization, especially relative to other sector characteristics as measured by HS chapters. Our measures of connectedness and economies of scale, however, are noisy, so that a variance decomposition with these variables is challenging.

[24] Selective licensing requirements for individual firms/transactions occur for roughly 20% of the transactions in *de jure* liberalized sectors, of which about half require a license. We confirmed with the Ministry of Commerce that these import records indeed reflect selective licensing by ruling out alternative explanations that apply to other parts of the data. These include entering the license number for shipments that also contained products from sectors that were not *de jure* liberalized (65%) or populating the license field with references to other sector-level license regimes (2%). The remaining transactions (13%) were for sectors that never included licenses in the data.

[25] Different functions generate different fixed effects. When $h(.)$ denotes the sum of its arguments, for instance, we have separate fixed effects for the three categories. When $h(.)$ denotes the interaction between all its arguments, by contrast, we have fixed effects for each value of their triplet.

Table 3.3: Regression of Selective *De Facto* Liberalization

	Full Sample				Top Sectors			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Connected	-0.066***	-0.087***	-0.104***		-0.090***	-0.106***	-0.126***	
	(0.004)	(0.004)	(0.004)		(0.005)	(0.005)	(0.005)	
Private Connected				-0.113***				-0.136***
				(0.005)				(0.005)
SOE				0.032**				0.048***
				(0.014)				(0.016)
HS6 FE	Yes	No	No	No	Yes	No	No	No
HS6 x Week FE	No	Yes	No	No	No	Yes	No	No
HS6 x Week x Overseas FE	No	No	Yes	Yes	No	No	Yes	Yes
Obs.	326,842	326,842	326,842	326,842	239,015	239,015	239,015	239,015
R-Squared	0.546	0.668	0.689	0.689	0.536	0.639	0.659	0.659

Notes: Table reports estimates of β in equation (3.3). Observations are transactions in fiscal years 2013/14 and 2014/15 in *de jure* liberalized sectors with selective *de facto* liberalization at the firm/transaction level. These sectors account for 20% of the transactions in *de jure* liberalized sectors over this period. Specifications (1)-(4) are estimated on all these transactions; specifications (5)-(8) only include sectors with at least USD 3 million in average import value per year. In specifications (1)-(3) and (5)-(7), the right hand side variable $C_{f(i)}$ is an indicator for connected firms; in specifications (4) and (8), we include separate indicators for private connected firms and SOEs and correspondingly report estimates for two parameters. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

then for the sector-week pair, and finally for the sector-week-shipment mode triplet. Column (4) adopts the most flexible set of fixed effects, but estimates separate coefficients for private connected firms and SOEs. The results strongly suggest that connected firms are less likely to be asked for import licenses in *de jure* liberalized sectors than connected firms. Furthermore, this result is driven by private connected firms; SOEs are only marginally less likely to be asked for a license than non-connected firms and this difference is not statistically difference from zero.

Overall, the evidence presented in this section suggests that the 2013 import license reform in Myanmar effectively protected connected firms from the potential competition the reform might bring about. This occurred through the partial liberalization that left connected sectors less likely to be *de jure* liberalized than non-connected sectors (although this may well have been unintended given that broader product groups account for most of the correlation between *de jure* liberalization and connectedness). Our analysis of the imperfect *de facto* liberalization of sectors that were *de jure* liberalized, on the other hand, paints a more intentional picture. The lower likelihood of *de facto* liberalization of connected sectors, especially those with low economies of scale, and the lower likelihood of connected firms' being asked for an import license suggest that the differential implementation of the reform was used to specifically shield connected firms. These findings are in line with the general notion from the "protection for sale" literature that trade restrictions tend to be used for the protection of politically connected firms.

3.4 Liberalization Impact

In this section, we study how the impact of the license liberalization relates to the presence of connected firms. To this end, we first estimate a standard difference-in-difference (DID) model that compares sectors liberalized *de facto* to sectors not liberalized (*de jure* or *de facto*), thereby eliminating sectors with imperfect reform. We do this separately for connected and non-connected sectors and decompose the liberalization impact into the intensive and extensive margin by firm type. The results show no impact in connected sectors, but an acceleration of growth in non-connected sectors, almost exclusively driven via entry by non-connected firms. Given these findings, we then study the relationship between entry and the presence of connected firms more directly and assess the extent to which sector-specific entry barriers explain the observed pattern.

3.4.1 Impact on Connected and Non-Connected Sectors

We closely follow the methodology used by Khandelwal et al. (2013) to study the impact of the import license reform on trade volumes and to decompose this into the various relevant margins. Specifically, we estimate the following DID model of the centered growth rate of imports, y_{jt}, at the sector j and fiscal year t level:[26]

$$y_{jt} = \gamma_j + \tau_{g(j)t} + \beta \cdot D_{jt} + \epsilon_{jt} \tag{3.4}$$

, where γ_j is a sector fixed effect, $\tau_{g(j)t}$ is a two-digit HS code/year pair fixed effect, D_{jt} is an indicator variable for liberalized sectors after the reform, and where ϵ_{jt} is the error term. We estimate this equation on the fiscal years 2011/12-2013/14 and therefore only have one period before and one period after the liberalization. Given the limited pre-period, we are unfortunately unable to test the parallel trends assumption underlying the causal interpretation of the β parameter as the reform impact. We include the $\tau_{g(j)t}$ terms to absorb differential trends at the two-digit HS code level and thereby address some of the potential concerns about identification. These are the appropriate fixed effects for that purpose, because (i) they capture the impact of broad demand shocks and (ii) the *de jure* liberalization across sectors was was predominantly driven by variation between these broader HS categories.[27]

[26]The centered growth rate is defined as $y_{jt} \equiv (Y_{jt} - Y_{jt-1})/(Y_{jt} + Y_{jt-1})$ in terms of the import value Y_{jt} in sector j and period t. The centered growth rate is notably bounded (between minus one and plus one), centered on zero, and defined for all values of Y_{jt} and Y_{jt} provided one of the periods exhibits positive imports. This is in contrast to the standard growth rate, which is bounded below (at zero) but can exhibit very high positive rates (or is undefined) when the Y_{jt-1} is close to zero (in the limit). We work with the centered growth rates, because these features are particularly relevant in our environment, where there is substantial heterogeneity in sector size with many relatively small sectors and where we would like to measure the contribution of the extensive margin, which inevitably involves zero values for Y_{jt-1} terms.

[27]See Section 3.3 for details.

We estimate the regression in equation (3.4) separately for connected and non-connected sectors to determine whether the liberalization impact differs according to the presence of connected firms. We then decompose the effect of the liberalization into the intensive and extensive margins by firm type. The intensive margin corresponds to incumbents, i.e., firms that import the same product in fiscal years 2012/13 and 2013/14. The extensive margin corresponds to entrants and exiters, where entrants are firm-product pairs that appear in fiscal year 2013/14 but not in 2012/13 and where exiters exhibit the converse pattern. For each margin, we distinguish connected and non-connected firms, so that we estimate a total of eight regressions (two connected firm categories for each of two margins for connected and non-connected sectors).

We exclude from our analysis small sectors with imports of less than USD 3 million annually, which leaves us with a sample covering roughly 90% of imports by value. The motivation for this restriction is that such sectors are unlikely to have a sufficiently developed domestic market for the liberalization to have a meaningful impact. With a population of over 50 million, this threshold accounts for under USD 0.1 per person annually. We also conduct robustness tests of this analysis, in which we do not restrict the sectors but instead estimate versions of regression equation (3.4) with sectors weighted according to their pre-liberalization size (see Table C.9 in the Appendix).[28]

Our main results using the USD 3 million threshold are summarized in Table 3.4. Given the large number of regressions underlying this table, we only report the point estimates for the β parameter and their significance, for specifications run at the aggregate level ("All"), separately for the two margins ("Incumbents" and "Net Entry"), and for the different firm types among each of these. The results show that the license liberalization had a notable impact on import growth, but only in non-connected sectors. There is no meaningful impact on growth in connected sectors.[29] Further, the decomposition shows that in non-connected sectors, the positive impact of the reform is almost entirely driven by the net entry of non-connected firms with a 34 percentage point increase in the growth rate, seemingly at the expense of (connected) incumbents. For connected sectors, the point estimates of the decomposition suggest that connected firms experienced a slight uplift through entry at the expense of non-connected firms, but these estimates are mostly statistically

[28]This changes the interpretation of the regressions slightly from estimating the average impact by sector to estimating the average impact by USD imported.

[29]In Appendix Table C.6, we show that these findings at the aggregate level are similar across connected sectors whose connected firm share predominantly belongs to private firms and those whose connected firm share chiefly belongs to SOEs.

indistinguishable from zero.[30]

Table 3.4: Impact of Import License Liberalization

	Connected Sectors	Non-Connected Sectors
Incumbents	0.057	-0.074
Connected Firms	0.033	-0.041 *
Non-Connected Firms	0.024	-0.033
Net Entry	-0.036	0.361 **
Connected Firms	0.074	0.017
Non-Connected Firms	-0.109 *	0.344 **
All	0.021	0.287
Connected Firms	0.107	-0.024
Non-Connected Firms	-0.086	0.311 *

Notes: Table reports the estimates of the coefficient β from regressions of the form given in equation (3.4). Each reported coefficient is from a separate regression with the sample given by the column headers (connected vs. non-connected sectors) and the importers under consideration restricted as given by the row labels. Observations are sectors by fiscal year for the 2011/12 to 2013/14 period that have at least USD 3 million in average import value per year (264 sectors, 114 connected sectors and 150 non-connected sectors). Sectors are defined to be connected if the market share of connected firms in that sector in the pre-reform period is higher than 15 percent. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

The results for non-connected sectors demonstrate that incumbents and connected firms did not benefit much from the license liberalization while entrants, in particular non-connected entrants, benefited the most. This suggests that the import licenses requirement in these sectors predominantly represented a binding constraint for trading among non-connected firms that had not previously been active in the market. Indeed, it is evident that obtaining licenses was not too costly for incumbents (given their presence in the market) and intuitive that the same would also be true to connected firms, whose network may help them navigate the licensing process. Furthermore, the lack of entry in connected sectors suggests that that the import license requirement was a non-binding constraint in these sectors and points to competition with connected firms or sector-specific characteristics associated with connected firms as the binding constraints for trade. Connected firms may, for instance, face lower costs due to preferential access to inputs that may prevent non-connected firms to compete effectively. Alternatively, connected firms may be able to overcome sector-specific entry barriers (without actively creating/reinforcing

[30] In Appendix Table C.10, we show that even if incumbents did not grow significantly post liberalization, they started making smaller shipments but more of them on a given year, consistent with the remark made earlier that removing the licensing process reduced the fixed cost of making an individual shipment.

them) that exclude non-connected firms.

3.4.2 Entry and Presence of Connected Firms

Given the results in the previous sub-section, we now turn directly to studying entry of non-connected firms and assess its relationship with the presence of connected firms and sector-specific characteristics that may shed light on the entry barriers that act as binding constraints. To this end, we abstract from the import license liberalization and estimate cross-sectional regressions of the market share of non-connected entrants, s_{jt}^{ne}, in the short and long run as a function of the market share of connected incumbents, $s_{jt_0}^{ci}$, at the beginning of our sample:

$$s_{jt}^{ne} = \alpha + \beta_1 \cdot s_{jt_0}^{ci} + \mathbf{X_j'}\beta_\mathbf{2} + \epsilon_{jt} \tag{3.5}$$

, where j denotes the sector, t the fiscal year (2012/13 or 2015/16), and where t_0 is the fiscal year at the beginning of our sample (2011/12). The market share of non-connected entrants in fiscal year t is defined as a standard share, $s_{jt}^{ne} \equiv v_{jt}^{ne}/v_{jt}$, where v_{jt}^{ne} and v_{jt} are the non-connected entrant value and the total sector value, respectively. The market share of connected incumbents at the beginning of the sample is defined only out of incumbent firms in 2011/12, $s_{jt_0}^{ci} \equiv v_{jt_0}^{ci}/v_{jt_0}^{i}$, where v_{jt}^{i} is the total incumbent value, to avoid a mechanical correlation between the market share of incumbents and the market share of entrants. The vector $\mathbf{X_j}$ denotes sector characteristics, such as measures of market liquidity and economies of scale, that may capture relevant entry barriers.

We estimate models of this type separately for the fiscal years 2012/13 and 2015/16 to capture the short and long-run relationship between non-connected entry and connected incumbents. The results from these regressions are reported in Table 3.5 for the short run and in Table 3.6 for the long run. In both tables, specification (1) represents a parsimonious version of equation (3.5) in which we exclude sector characteristics $\mathbf{X_j}$ by setting $\beta_\mathbf{2} = \mathbf{0}$. This specification shows, as expected, that connected firms' incumbent share at baseline is negatively related to entry of non-connected firms, both in the short and the long run. In principle, this could be due to connected firms' acting as a deterrent or sector characteristics that represent entry barriers that are correlated with connected firms' presence.

From these parsimonious specifications, we gradually add different sector characteristics as controls $\mathbf{X_j}$ to explore the extent to which they absorb the correlation between entry and connected firms that is captured by the β_1 parameter. We con-

Table 3.5: Non-Connected Entry and Connected Incumbents (Short Run)

	(1)	(2)	(3)	(4)	(5)
Share Connected	-0.080***	-0.076***	-0.072***	-0.073***	0.016
	(0.025)	(0.026)	(0.027)	(0.027)	(0.029)
Ln(Shipment Value)					-0.050***
					(0.007)
HS2 FE	No	Yes	Yes	Yes	Yes
BEC Type FE	No	No	Yes	Yes	Yes
Rauch Class FE	No	No	No	Yes	Yes
Obs.	2,102	2,102	2,102	2,102	2,102
R-Squared	0.006	0.088	0.092	0.092	0.118

Notes: Table reports results from estimating equation (3.5) for non-connected entry in fiscal year 2012/13. Observations are six-digit HS codes. Fixed effects for two-digit HS codes, BEC product type, and Rauch class are included as indicated in the bottom of the table. Ln(shipment value) is the natural logarithm of the average shipment value by sector, leaving out connected firms. Robust standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

sider sector characteristics that might reflect entry barriers, which connected firms are better positioned to overcome and which would thus make them more likely to operate in these sectors. In specification (2), we add two-digit HS code fixed effects; in specification (3), we add BEC product types which classifies six-digit HS codes into intermediate, capital, and final goods; and in specification (4), we add fixed effects associated to the conservative Rauch (1999) classification, which distinguishes goods traded on an organized exchange market, goods with a reference price, and differentiated products. These controls capture differences in fixed costs or barriers in sourcing and downstream distribution between the broad product categories. The β_1 parameter estimate is robust to including these fixed effects, which implies that the observed relationship between non-connected entry and connected firm presence is not due to entry barriers at the level of these broad product categories.[31]

Finally, in specification (5), we turn to controls related to economies of scale in importing as we introduced already in Section 3.3. Specifically, we include a term for the natural logarithm of the average shipment value among non-connected firms in the sector. The average shipment value is again relevant in this context, because it may reflect economies of scale in importing due to a number of reasons, including fixed logistics/distribution cost and quantity discounts. Controlling for shipment value renders the negative correlation between non-connected entry and connected firms' presence statistically indistinguishable from zero, both in the short and the long run. This suggests that connected firms are more prominent in sectors with

[31] In an alternative specification, not presented here, we add controls for the main origins of the goods imported and do not find that it affects the correlation between entry and presence of connected firms

Table 3.6: Non-Connected Entry and Connected Incumbents (Long Run)

	(1)	(2)	(3)	(4)	(5)
Share Connected	-0.087***	-0.079***	-0.073***	-0.073***	-0.012
	(0.022)	(0.023)	(0.024)	(0.024)	(0.025)
Ln(Shipment Value)					-0.034***
					(0.006)
HS2 FE	No	Yes	Yes	Yes	Yes
BEC Type FE	No	No	Yes	Yes	Yes
Rauch Class FE	No	No	No	Yes	Yes
Obs.	2,102	2,102	2,102	2,102	2,102
R-Squared	0.009	0.077	0.080	0.081	0.096

Notes: Table reports results from estimating equation (3.5) for non-connected entry in fiscal year 2015/16. Observations are six-digit HS codes. Fixed effects for two-digit HS codes, BEC product type, and Rauch class are included as indicated in the bottom of the table. Ln(shipment value) is the natural logarithm of the average shipment value by sector, leaving out connected firms. Robust standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

relatively high average shipment value and that these high shipments are related to the more subdued entry of non-connected firms. An intuitive interpretation of these results is that non-connected firms lack access to the foreign capital required to make imports in these sectors and compete in the domestic market downstream. This finding and this interpretation are notably also consistent with the results from Section 3.3, where the evidence suggested that the liberalization process itself was used to shield connected firms precisely in sectors with low economies of scale.

3.5 Conclusion

In this paper, we investigate the extent to which gains from trade liberalization depend on the presence of politically connected firms in the context of an import license reform in Myanmar. We first document evidence in support of the more widely established result that trade restrictions — in our case, import license requirements — can be used to protect connected firms. Secondly, we then show that the effect of the license reform differed depending on the presence of connected firms: it accelerated growth in sectors with few connected firms, but had no impact in sectors with many connected firms. Decomposing the liberalization impact, we further find that the positive impact in non-connected sectors was almost exclusively driven by entry of non-connected firms.

For both of these broad aspect of the license reform, we explore sector characteristics that may act as natural entry barriers for non-connected firms and hence represent key drivers of the observed patterns. In particular, we focus economies of scale in importing that may allow firms with better access to capital (especially foreign capital) to source imported products at lower cost and thereby prevent others to compete effectively in the domestic market. In light of the persistent capital market imperfections in Myanmar and likely differential access for connected firms through a legacy of heavy regulation under the former military regime, this is a natural candidate for a relevant entry barrier. We show evidence that connected firms selected into sectors with high economies of scale and that the imperfect license reform appears to be used especially in their favor in sectors where these are not present. Furthermore, we show that average shipment size accounts for a large share of the negative correlation between non-connected firms' entry and the presence of connected firms.

Taken together, the results suggest that the interaction between entry barriers and connected firms may play an important role in determining the gains that can be realized from trade liberalization. Sectors with higher entry barriers may attract connected firms when they are better positioned to overcome them and earn economic rents due to the relatively low level of competition. Once connected incumbents are present, they may deter potential entrants and thereby dampen the gains from trade liberalization.

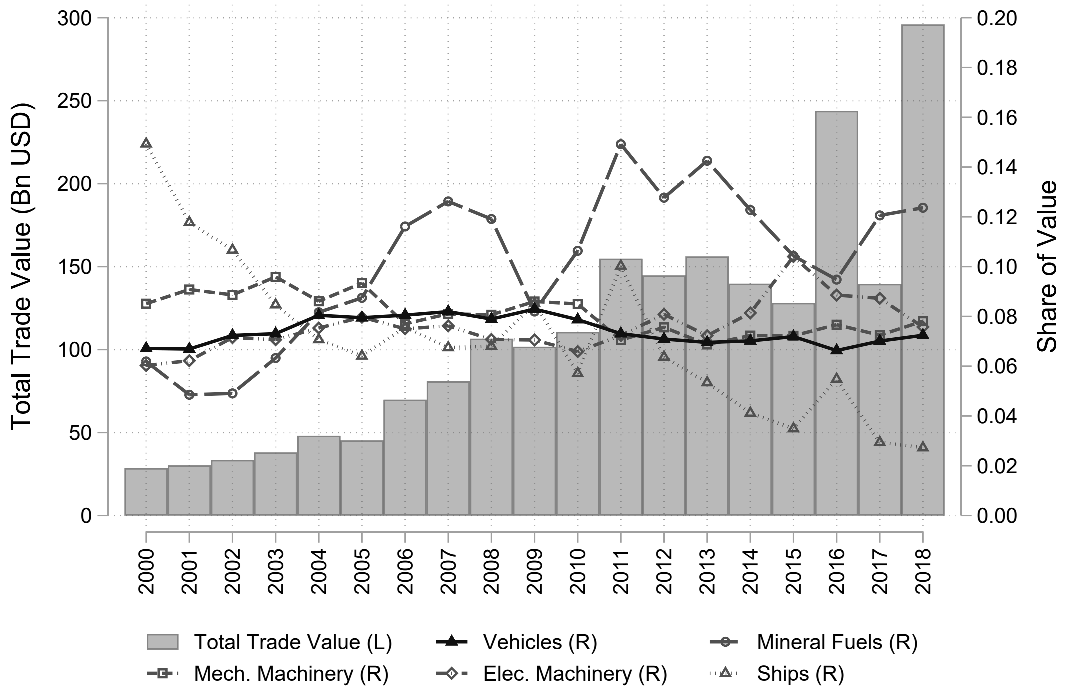
A Chapter 1 Appendix

A.1 Additional Output

A.1.1 Additional Descriptive Statistics

This subsection provides additional descriptive statistics that are referenced in the main text. Figure A.1 shows the top import categories in LICs at the two-digit Hamonized System (HS) level over time. Motor vehicles consistently rank among the top-five categories along with other capital/durable goods and mineral fuels.

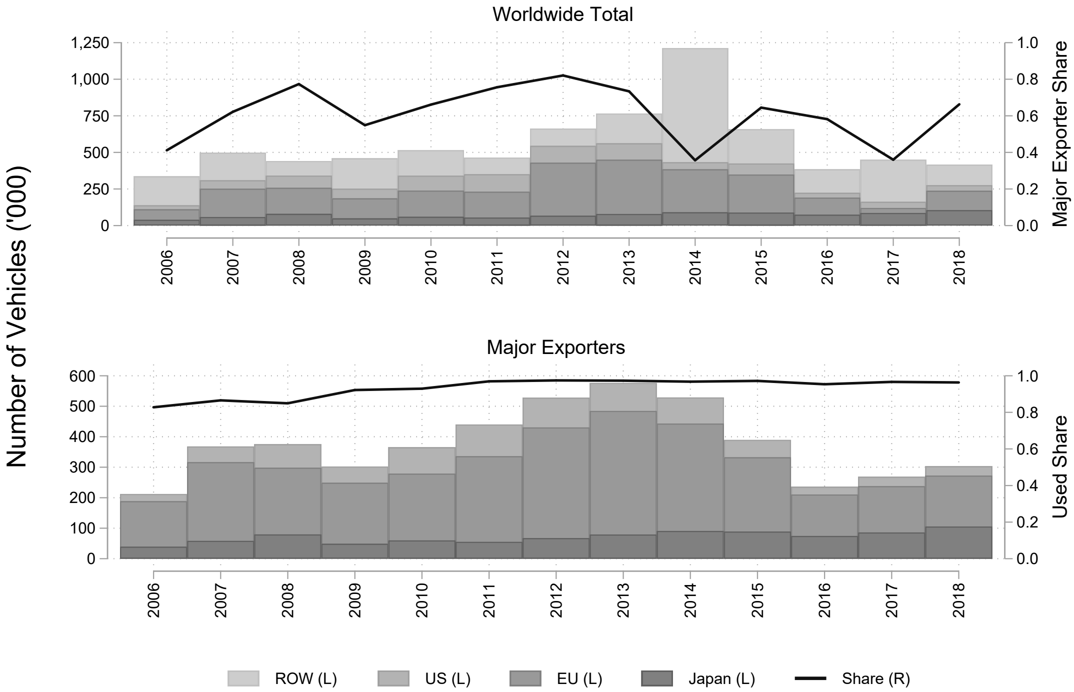
Figure A.1: Top Import Categories in Low-Income Countries



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 A.2 plots personal vehicle imports in LICs overall and from three major regions of origin — i.e., the US, the EU, and Japan — in terms of number of vehicles and the used share. It shows that (i) the three major regions of origin account for a large proportion of total personal vehicle imports in LICs and (ii) the share of used vehicle imports has been increasing over time and has been close to 100% since 2011.

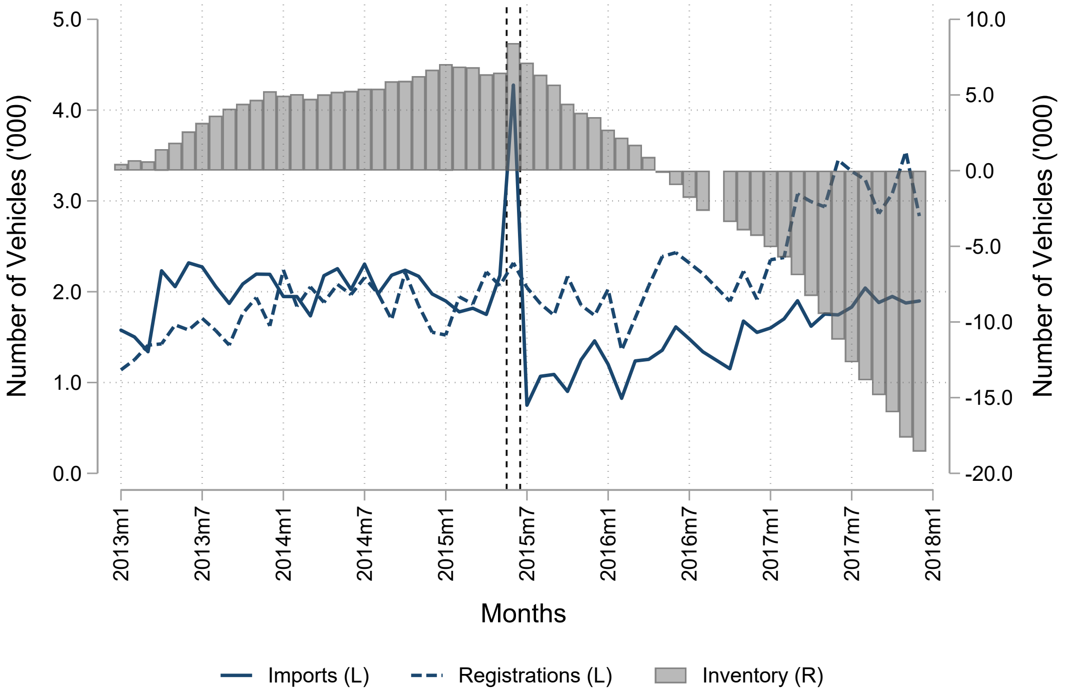
Figure A.2: Personal Vehicles Imported by Low-Income Countries



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.

Figure A.3 focuses specifically on Uganda and plots imports by traders, first-time registrations of vehicles purchased from traders, and their cumulative difference as our measures of existing trader inventory. 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.

Figure A.3: Trader Inventory of Passenger Vehicles



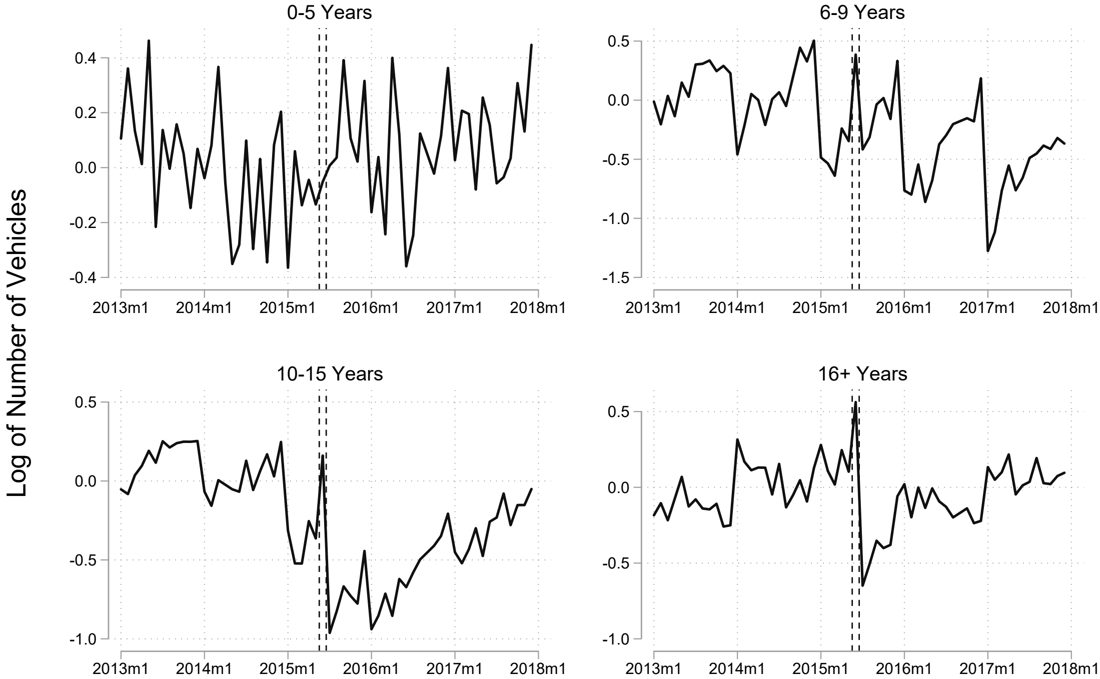
Notes: Data are limited to passenger vehicles, i.e., those classified under HS4-codes 8702 and 8703 and are restricted to vehicles with entires in the imports and registrations data. They are also restricted to vehicles imported by intermediary traders. Inventory is measured as the cumulative value of imports less registrations relative to the level in January 2013.

A.1.2 DID Model Robustness and Identifying Assumption Tests

This subsection provides additional output from our reduced-form analysis corresponding to Section 1.3 of the main text. Specifically, we include (i) evidence regarding the parallel trends assumption that underlies the causal interpretation of the DID parameter estimates as the levy impact, and (ii) a range of robustness tests related to the DID model.

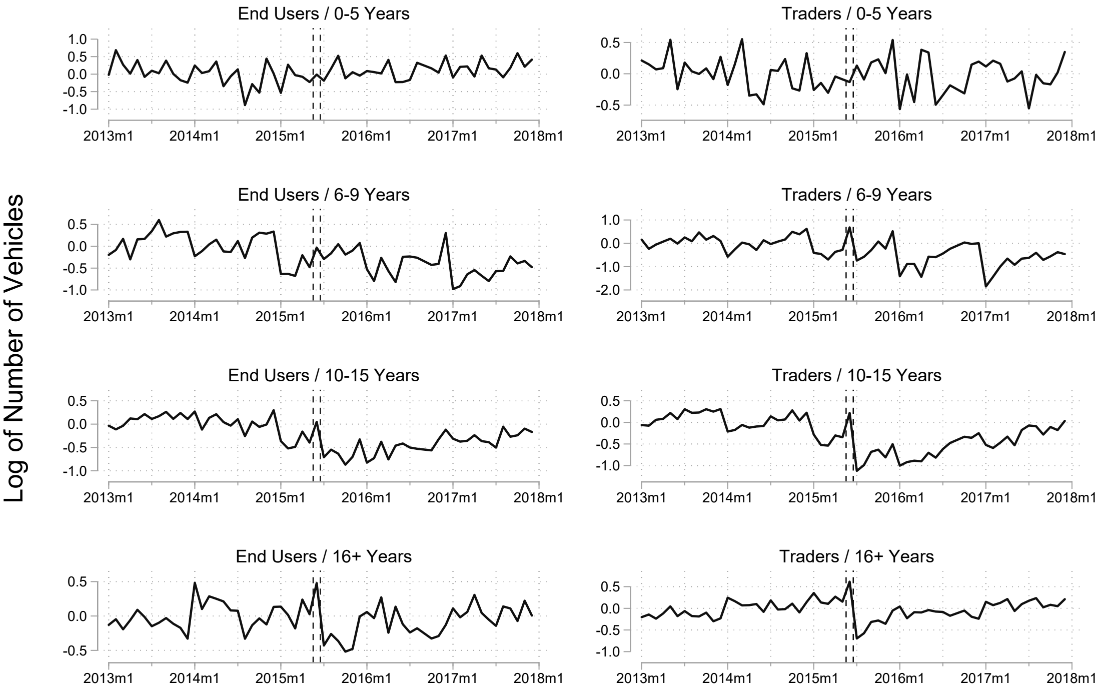
Figures A.4-A.7 plot the differences in outcomes for the treatment and control group, normalized by the mean difference before the annoucement of the levy change (i.e., between January 2013 and May 2015). These provide evidence in favor of the parallel trends assumption to the extent that the graphs are broadly centered around zero and do not exhibit a general upward or downward tendency before June 2015.

Figure A.4: Log-Difference of Passenger and Goods Vehicle Imports



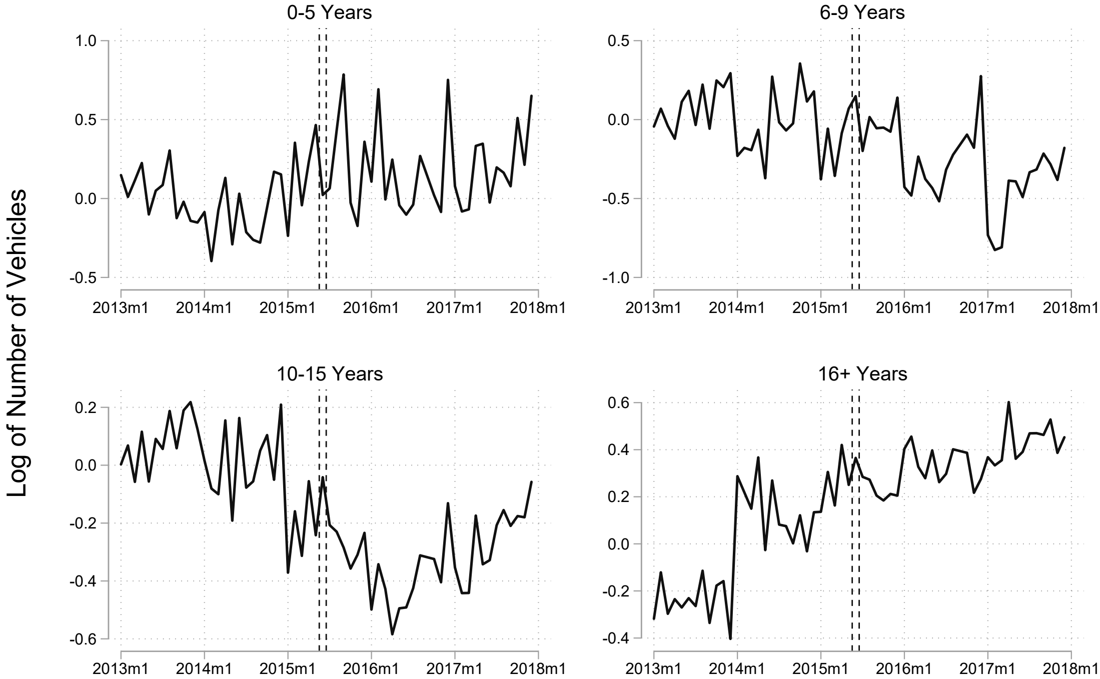
Notes: Graphs display the differences in the natural logarithm of the number of passenger vehicles and the number of goods vehicles imported by month. These are normalized by subtracting the average monthly difference between January 2013 and May 2015. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

Figure A.5: Log-Difference of Passenger and Goods Vehicle Imports



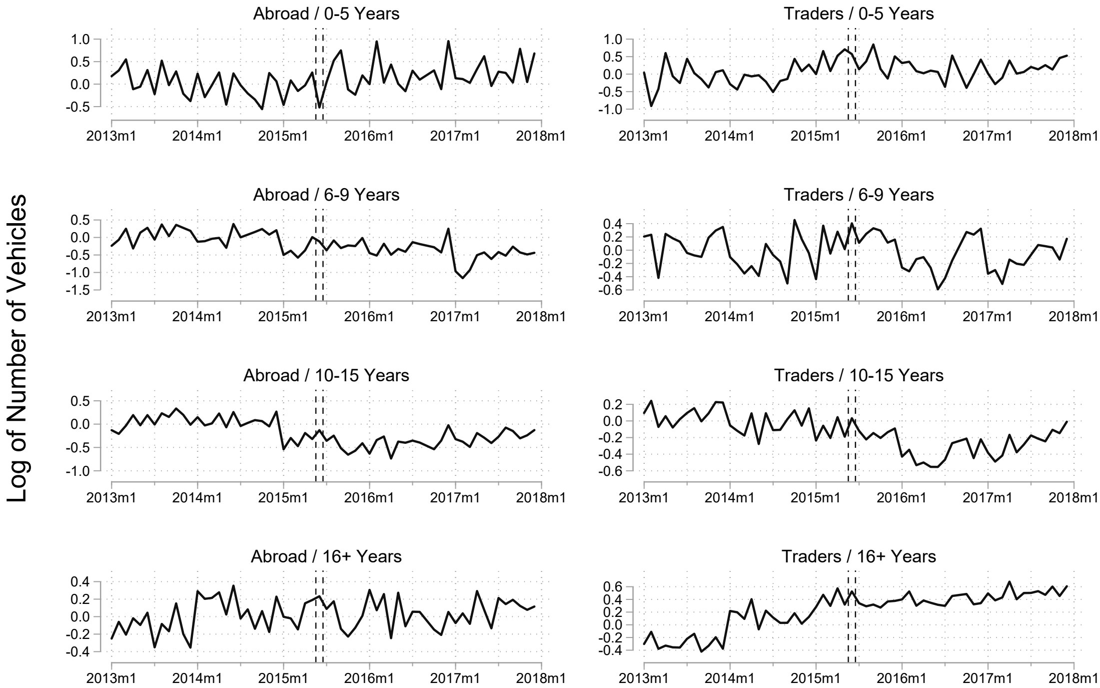
Notes: Graphs display the differences in the natural logarithm of the number of passenger vehicles and the number of goods vehicles imported by month, separately for the two distribution channels. These are normalized by subtracting the average monthly difference between January 2013 and May 2015. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

Figure A.6: 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. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

Figure A.7: 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, separately for the two distribution channels. These are normalized by subtracting the average monthly difference between January 2013 and May 2015. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

From here on, we turn to a range of robustness tests for our reduced-form analysis corresponding to section 1.3 of the main text. Table A.1 reports the results from regressions of a more disaggregated version of equation (1.1), where the cross-sectional unit is a vehicle j according to the make, model, and treatment group g (i.e., 0-5, 6-9, 10-15, and 16+ year old passenger vehicles and goods vehicles of any age group). We notably diverge here slightly from the vehicle j definition as given in the structural model, 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, 2018). Specifically, the model we estimate is of the following form:

$$y_{jgt} = \lambda_j + \tau_t + \sum_h \beta_h D_{jgt}^{(h)} + \epsilon_{jgt} \tag{A.1}$$

The left hand side variable y_{jgt} denotes the inverse hyperbolic sine of the number of vehicles imported or registered, because many vehicle-month combinations at this disaggregated level do not have positive observations. Similar to the natural logarithm, the inverse hyperbolic sine allows for coefficient estimates to be interpreted as percentage changes, but, unlike the logarithm, it is defined at zero (Burbidge et al., 1988). The other terms are defined analogous to those in equation (1.1).

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

	Imports By			End User Purchases From		
	End Users	Traders	Total	Abroad	Traders	Total
	(1)	(2)	(3)	(4)	(5)	(6)
0-5 Years	-0.011	0.013	0.010	-0.029	-0.029	-0.014
	(0.017)	(0.019)	(0.022)	(0.021)	(0.021)	(0.022)
6-9 Years	-0.057***	-0.034*	-0.068***	-0.088***	-0.045**	-0.076***
	(0.016)	(0.020)	(0.022)	(0.021)	(0.020)	(0.022)
10-15 Years	-0.103***	-0.102***	-0.145***	-0.123***	-0.029	-0.090***
	(0.024)	(0.030)	(0.033)	(0.028)	(0.029)	(0.031)
16+ Years	-0.001	0.004	0.005	-0.017	0.114***	0.112***
	(0.020)	(0.025)	(0.028)	(0.023)	(0.029)	(0.029)
Obs.	81,538	81,538	81,538	68,853	68,853	68,853
R2	0.720	0.824	0.802	0.775	0.847	0.825
R2-Within	0.004	0.004	0.006	0.004	0.008	0.009

Notes: Table reports the coefficients on the treatment indicators from estimating equation (A.1). 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 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.

Comparisons between Tables 1.2 and A.1 reveal that 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 DID model at the vehicle j level, but are effectively weighted by the number of vehicles in the aggregate version.[1] Both models offer valuable insights. The disaggregated model provides us with an understanding of the levy impact on imports and first-time registrations that is closer to the structural estimating equations (see Section 1.5). The aggregate model, on the other hand, provides us with quantitative estimates of the overall impact of the levy to understand the total flows of vehicles into the country and onto Ugandan roads.

Table A.2 reports the results from regressions of equation (1.1) that replace each of the $D_{gt}^{(h)}$ terms with separate treatment indicators capturing the announcement (in

[1] 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).

June 2015) and the implementation of the levy increase (from July 2015 onwards). These results show broad spikes in imports and first-time registrations that are consistent with traders' and end users' advancing vehicle purchases in June 2015 to beat the impending levy increase the following month.

Table A.2: Aggregate DID Regressions of Vehicle Imports and Registrations

	Imports By			End User Purchases From		
	End Users	Traders	Total	Abroad	Traders	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Annoucement						
0-5 Years	-0.011	-0.132***	-0.052	-0.272***	0.376***	0.022
	(0.061)	(0.048)	(0.043)	(0.053)	(0.062)	(0.039)
6-9 Years	-0.031	0.682***	0.386***	0.133***	0.208***	0.148***
	(0.060)	(0.054)	(0.051)	(0.044)	(0.048)	(0.037)
10-15 Years	0.049	0.219***	0.161***	0.117***	-0.164***	-0.041
	(0.041)	(0.041)	(0.037)	(0.037)	(0.043)	(0.033)
16+ Years	0.479***	0.616***	0.563***	0.479***	0.329***	0.365***
	(0.051)	(0.056)	(0.050)	(0.046)	(0.057)	(0.050)
Implementation						
0-5 Years	0.132*	-0.017	0.090	0.214***	0.192**	0.195***
	(0.077)	(0.081)	(0.061)	(0.082)	(0.077)	(0.060)
6-9 Years	-0.413***	-0.598***	-0.441***	-0.434***	-0.035	-0.296***
	(0.086)	(0.107)	(0.086)	(0.072)	(0.065)	(0.059)
10-15 Years	-0.439***	-0.528***	-0.499***	-0.394***	-0.266***	-0.315***
	(0.057)	(0.070)	(0.058)	(0.055)	(0.050)	(0.043)
16+ Years	-0.084	-0.073	-0.095	0.003	0.447***	0.353***
	(0.070)	(0.082)	(0.071)	(0.062)	(0.067)	(0.062)
Obs.	295	295	295	295	295	295
R2	0.944	0.965	0.968	0.965	0.984	0.981
R2-Within	0.239	0.250	0.282	0.337	0.290	0.420

Notes: Table reports the coefficients on the treatment indicators from estimating equation (1.1). Observations are the natural logarithm of monthly imports and registrations of passenger vehicles by age group or goods vehicles for the period from January 2013 through December 2017. Specifications are estimated separately by channel and in aggregate as indicated in the column headers. Fixed effects for the treatment group and period are included in all specifications. Robust standard errors are reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Analogous to Table A.2, Table A.3 builds on the vehicle j level regressions by replacing each of the $D_{jgt}^{(h)}$ terms with separate treatment indicators capturing the announcement (in June 2015) and the implementation of the levy increase (from July 2015 onwards).

Finally and building further on our disaggregated version of the DID model, we also estimate the difference between passenger and goods vehicle imports and first-time registrations separately for each month using an event study design. This event study relates closely to equation (A.1), but has treatment indicators for each month:

$$y_{jgt} = \lambda_j + \tau_t + \sum_t \beta_h^{(t)} D_{jgt}^{(h)(t)} + \epsilon_{jgt} \tag{A.2}$$

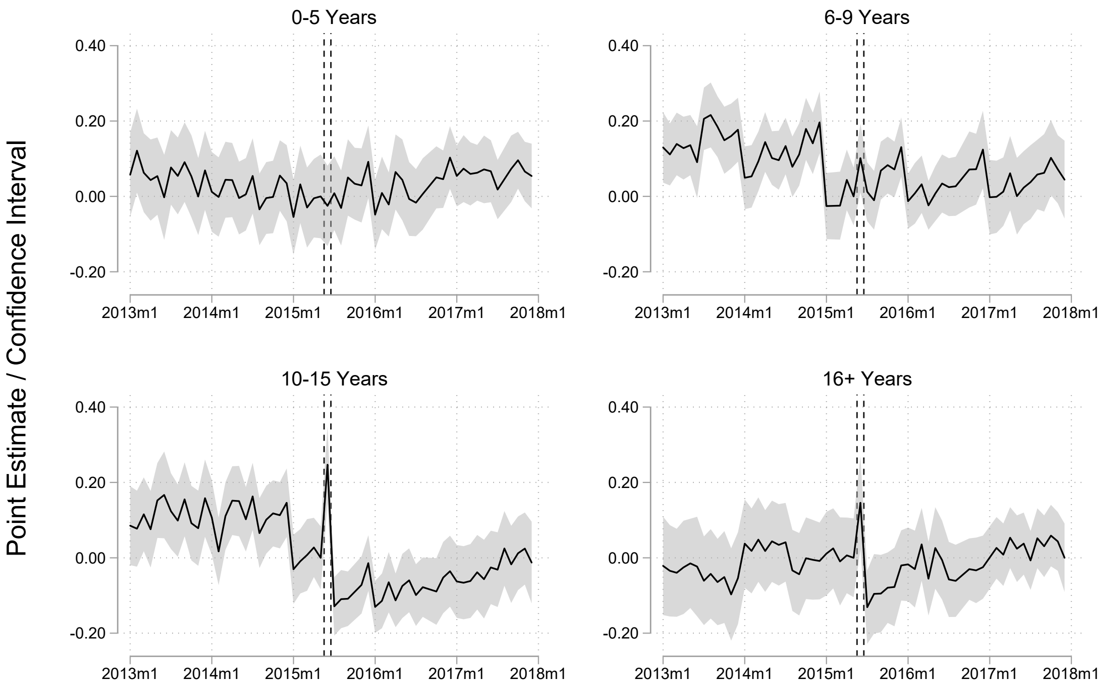
Table A.3: Vehicle-Level DID Regressions of Imports and Registrations

	Imports By			End User Purchases From		
	End Users	Traders	Total	Abroad	Traders	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Annoucement						
0-5 Years	-0.073**	-0.040	-0.054	-0.064*	-0.019	-0.036
	(0.035)	(0.030)	(0.039)	(0.037)	(0.040)	(0.041)
6-9 Years	-0.056	0.021	-0.009	-0.019	-0.031	-0.004
	(0.035)	(0.033)	(0.039)	(0.042)	(0.039)	(0.044)
10-15 Years	0.113***	0.099***	0.153***	0.031	-0.025	0.032
	(0.039)	(0.037)	(0.042)	(0.043)	(0.041)	(0.043)
16+ Years	0.109**	0.109***	0.158***	0.085*	0.043	0.110**
	(0.042)	(0.039)	(0.046)	(0.044)	(0.043)	(0.045)
Implementation						
0-5 Years	-0.009	0.015	0.012	-0.028	-0.029	-0.014
	(0.017)	(0.020)	(0.022)	(0.021)	(0.021)	(0.022)
6-9 Years	-0.057***	-0.036*	-0.070***	-0.090***	-0.046**	-0.079***
	(0.017)	(0.020)	(0.023)	(0.021)	(0.021)	(0.022)
10-15 Years	-0.110***	-0.109***	-0.155***	-0.129***	-0.029	-0.094***
	(0.025)	(0.031)	(0.034)	(0.028)	(0.029)	(0.032)
16+ Years	-0.005	0.000	-0.001	-0.021	0.116***	0.112***
	(0.020)	(0.026)	(0.028)	(0.024)	(0.029)	(0.030)
Obs.	81,538	81,538	81,538	68,853	68,853	68,853
R2	0.721	0.824	0.802	0.775	0.847	0.825
R2-Within	0.005	0.006	0.008	0.005	0.008	0.009

Notes: Table reports the coefficients on the treatment indicators from estimating equation (A.1). Observations are the inverse hyperbolic sine of make/model-level monthly imports and registrations of passenger vehicles by age group or goods vehicles (without age distinction) for the period from January 2013 through December 2017. Specifications are estimated separately by channel and in aggregate as indicated in the column headers. Fixed effects for the vehicle make/model and period 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.

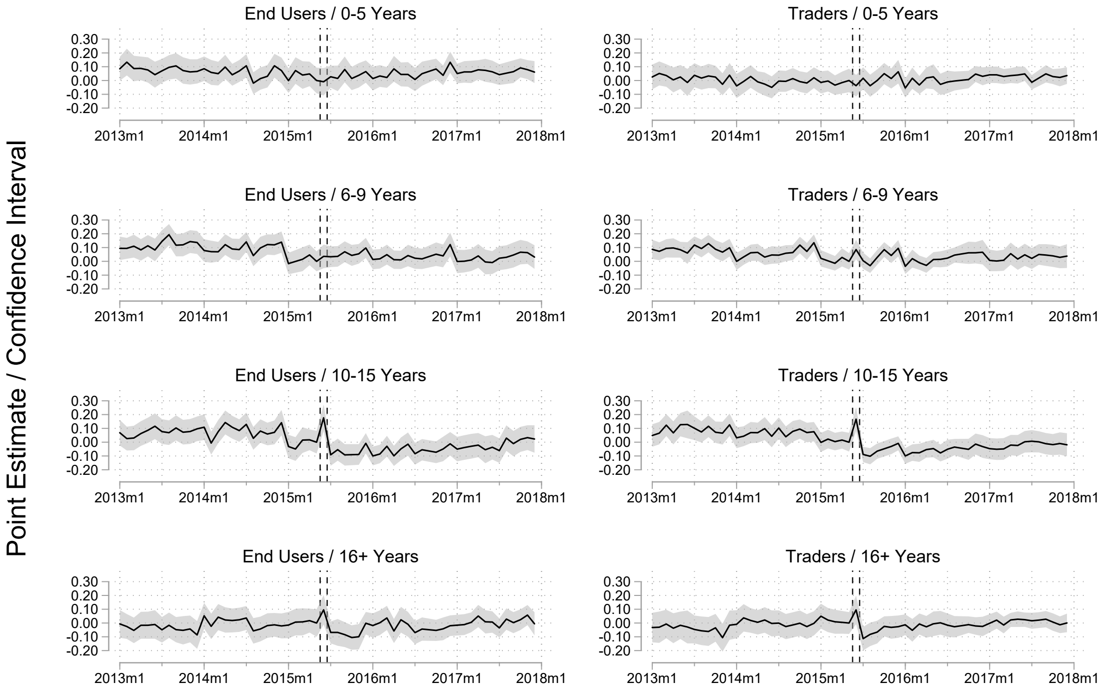
We estimate this equation separately for each treatment group by restricting the sample to that group and the benchmark goods vehicles group. The coefficients on the monthly treatment indicator variables from these regressions (normalized for May 2015) are plotted in Figures A.8-A.11. The point estimates are shown as the black line and 95% confidence intervals are shaded in gray. These event studies provide evidence of the levy impact that qualitatively aligns with the results from the difference in differences model. The confidence intervals, however, are very wide, so that we learn relatively little about the change in the levy impact over time beyond the information contained in the point estimates. Similarly, these event studies also provide an additional test of the parallel trends assumption at the disaggregated level, but they provide few additional insights beyond the simpler plots of the differences in outcomes between treatment and control groups.

Figure A.8: Event Study of Vehicle Imports by Age Group



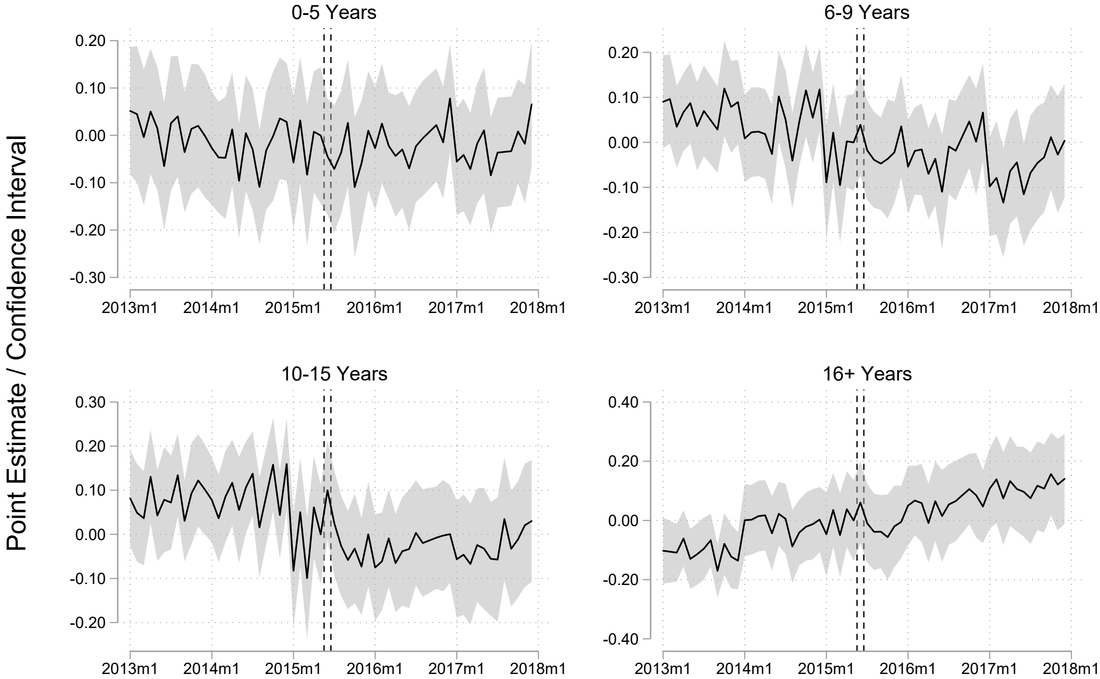
Notes: Figure displays the coefficients on the interaction of the indicator variable for vehicles targeted by the levy change (passenger vehicles by age group) and an indicator for the given month in regressions of equation (A.2). Estimates are relative to May 2015. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

Figure A.9: Event Study of Vehicle Imports by Channel and Age Group



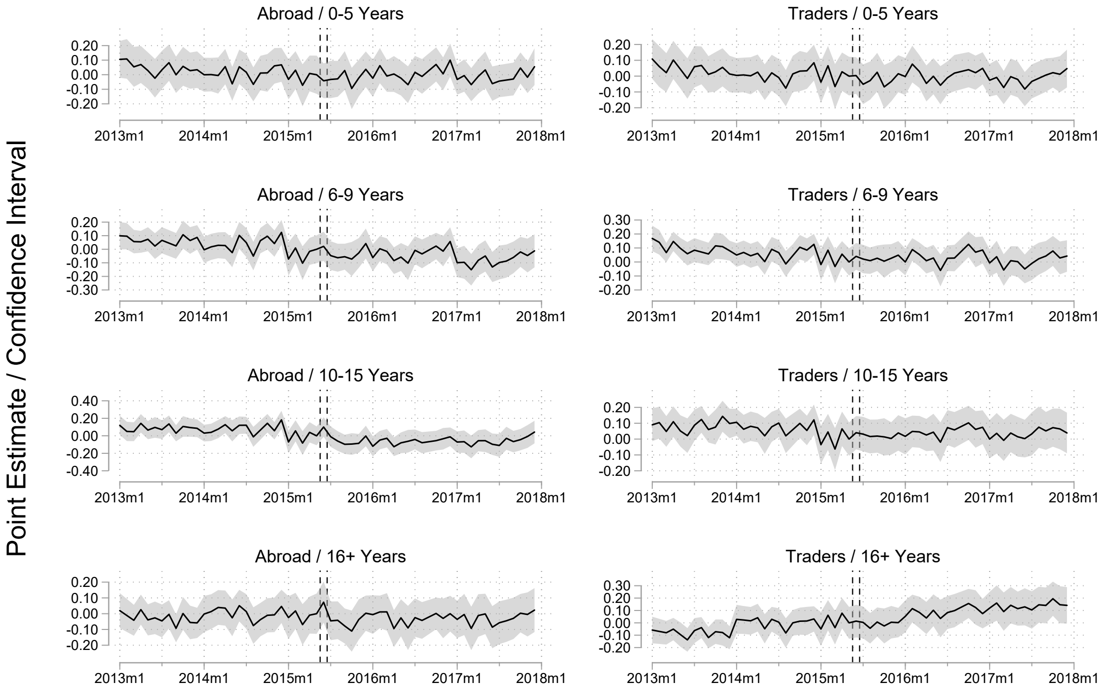
Notes: Figure displays the coefficients on the interaction of the indicator variable for vehicles targeted by the levy change (passenger vehicles by age group) and an indicator for the given month in regressions of equation (A.2). Estimates are relative to May 2015. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

Figure A.10: Event Study of End User Purchases by Age Group



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 regressions of equation (A.2). Estimates are relative to May 2015. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

Figure A.11: Event Study of End User Purchases by Channel and Age Group

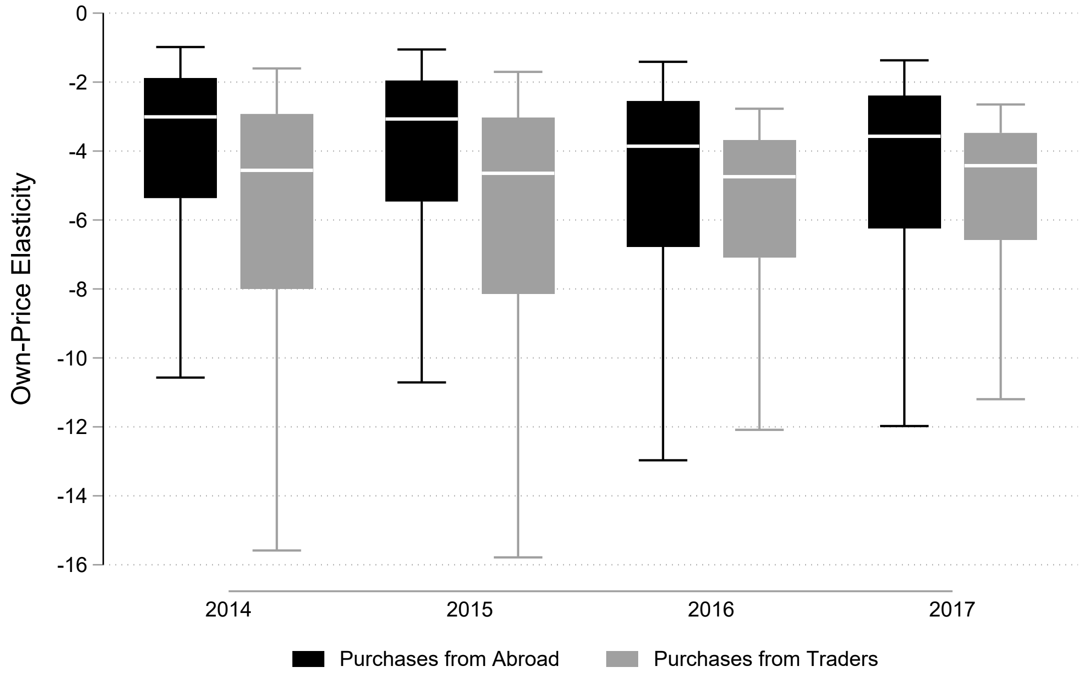


Notes: Figure displays the coefficients on the interaction of the indicator variable for vehicles targeted by the levy change (passenger vehicles by age group) and an indicator for the given month in regressions of equation (A.2). Estimates are relative to May 2015. The vertical lines from left to right indicate the announcement of the levy increase at the end of May 2015 and its implementation at the beginning of July 2015.

A.1.3 Additional Output from Structural Estimation

This subsection provides additional output from our structural analysis corresponding to Section 1.5 of the main text. Figure A.12 shows the distribution of the estimated own-price elasticities according to the logit specification (2) in Table 1.3.

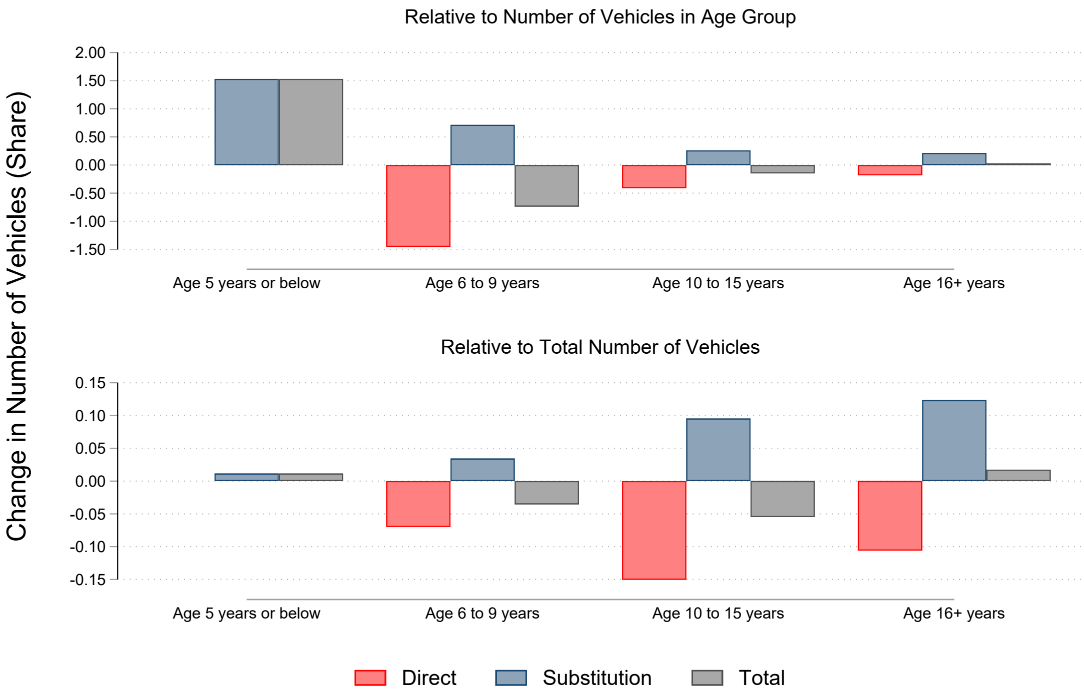
Figure A.12: Distribution of Estimated Own-Price Elasticity - Logit



Notes: Distribution of own-price elasticity for vehicle make/model/manufacturing year combinations corresponding to specification (2) in Table 1.3. 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.

Figure A.13 illustrates the decomposition of the total impact of the levy increase according to equation (1.8). The top panel shows the levy impact relative to the number of vehicles in a given age group and the bottom panel shows it relative the total number of vehicles purchased, both in the baseline counterfactual. Similar to Figure 1.4 in the main text, the total levy impact in the top and bottom panel (grey bars) correspond precisely to columns (1) and (2) in Table 1.4. The direct component (red bars) and the substitution component (blue bars) are different than those in Figure 1.4 due to the different definition of the decomposition.

Figure A.13: Decomposition of Levy Impact Into Direct and Substitution Component



Notes: Figure shows decomposition of the total levy impact in terms of on vehicle purchases by age group (grey bars) into the direct component due to the levy increase on that age group (red bars) and the substitution component due to the levy increase on other age groups (blue bars), following equation (1.8). All measures are relative to the baseline counterfactual of no levy increase. The top panel shows the impact relative to the baseline number of vehicles in any given age group; the bottom panel shows the impact on purchases relative to the total baseline number of vehicles in the market.

A.2 Data Appendix

A.2.1 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 in Uganda 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.

A.2.2 Generating Complete Set of Prices

Given that not all vehicles that appear in our choice set (according to make, model, manufacturing year, and channel) are imported or listed on online sales platforms in all fiscal years, we do not have actual prices for all vehicles. We therefore need to fill in both international and domestic prices, when they are missing, and describe the corresponding procedure in this section.

International Prices

We obtain a complete set of international prices for our choice sets by applying the average vehicle cost, insurance, and freight (CIF) value among imported vehicles and adjusting this for the vehicle depreciation and any applicable duties and tariffs. Specifically, we first estimate the following regression:

$$ln(p^I_{jt}) = \lambda_m(j) + \sum_{n=0}^{5} \beta^{(n)} a^n_{jt} + \upsilon_{jt} \tag{A.3}$$

, where p^I_{jt} is the international price, $\lambda_m(j)$ a fixed effect for the vehicle make and model pair, $\sum_{n=0}^{5} \beta^{(n)} a^n_{jt}$ a fifth-order polynomial of the vehicle age, and υ_{jt} the error term.

The results from this estimation are reported in Table A.4. They show, as expected, that international prices decline at a decreasing rate. The coefficient on the linear term indicates a 12.7% reduction in the vehicle price for each additional year and the coefficient on the quadratic term shows that this reduction diminishes by roughly 0.3 percentage points per additional year.

We then, secondly, predict international prices, $\hat{p}^I_{jt}$ for all vehicles in the choice set. This is possible as each vehicle j from our choice sets appears at least once in the import data.[2] The fixed effects generate predicted prices that correspond to the make/model average while age polynomial flexibly captures depreciation.

Third, we add all applicable duties and tariffs that are listed individually in the URA's ASYCUDA customs system, including the environmental levy, proportionally to the predicted CIF values. Figure A.14 shows a scatter plot of both the actual and predicted international prices normalized to the make and model pair average.

[2]Our structural estimations notably restrict the sample to make/model pairs with at least 50 vehicles in the data.

Table A.4: 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.

Domestic Prices

Domestic prices of newly imported vehicles differ from the international prices, because they incorporate trading costs, such as the cost of capital associated with holding vehicle inventory, and potentially positive trader margins. We therefore present here in detail the model of vehicle supply that we already described broadly in Section 1.4 and that incorporates these determinants of domestic prices.

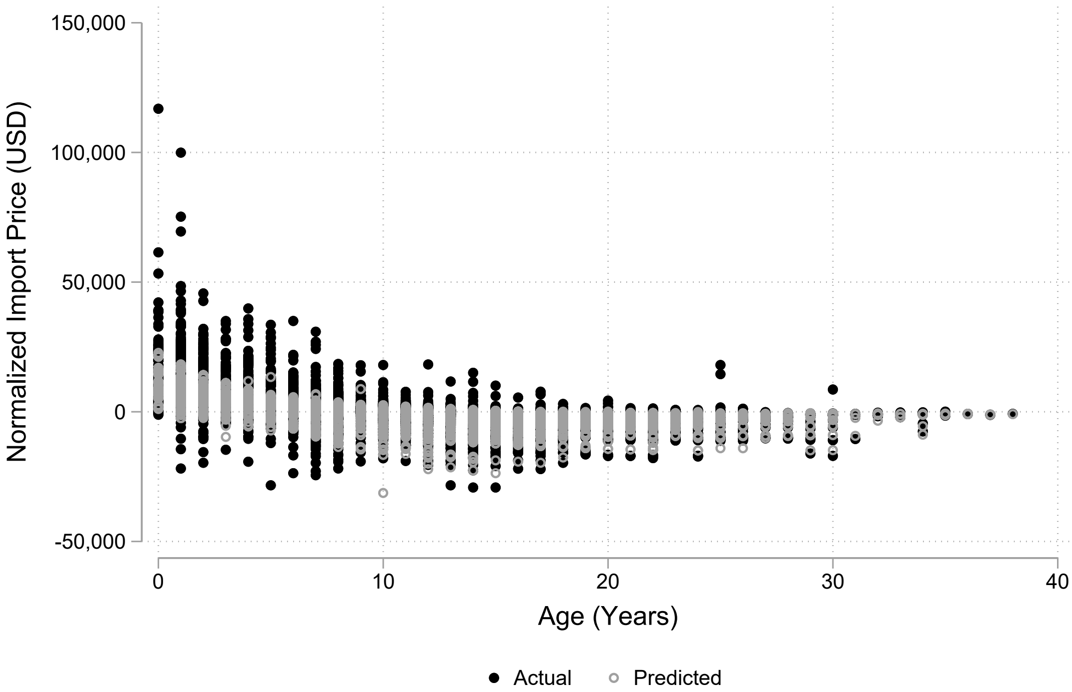
Specifically, we assume that domestic prices correspond to the market-clearing prices for a symmetric equilibrium, in which traders maximize profits by choosing quantities for each make, model, and manufacturing year triplet. Per-period profits are given by:

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

, where $p_{jt}^D(\mathbf{Q_t})$ 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:

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

Figure A.14: 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 the regression in equation (A.3).

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

$$\mathbf{p^D_t} = \mathbf{c_{jft}} - \mathbf{D\tilde{p}^D}(\mathbf{Q_t})\mathbf{q_{ft}} \tag{A.6}$$

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 (A.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 $\mathbf{Dp^D_t} = \mathbf{Dp^D}(\mathbf{Q_t})$ for the entire market from the Jacobian of the demand function $\mathbf{DQ_t} = \mathbf{DQ}(\mathbf{P_t})$ by matrix inversion $\mathbf{Dp_t^D} = [\mathbf{DQ_t}]^{-\mathbf{1}}$.[3] The matrix only containing the entries for vehicles on inventory, $\mathbf{D\tilde{p}^D}(\mathbf{Q_t})$, as required for equation (A.6) above can be constructed using the appropriate elements of the market level Jacobian of the inverse demand function, $\mathbf{Dp_t^D}$. Let us denote that matrix as $\mathbf{D\tilde{p}^D}(\mathbf{Q_t}) = [\mathbf{DQ}(\tilde{\mathbf{p}}_\mathbf{t}^\mathbf{D})]^{-\mathbf{1}} = (1/M_t)[\mathbf{Ds}(\tilde{\mathbf{p}}_\mathbf{t}^\mathbf{D})]^{-\mathbf{1}}$, and substitute into equation (A.6), so that:

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

Beyond the construction of $[\mathbf{Ds}(\tilde{\mathbf{p}}_\mathbf{t}^\mathbf{D})]^{-\mathbf{1}}$ 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 $(1/N_t)[\mathbf{Ds}(\tilde{\mathbf{p}}_\mathbf{t}^\mathbf{D})]^{-\mathbf{1}}\mathbf{s_t} = \mathbf{0}$.

Finally, we assume that marginal costs are linear in the international vehicle purchase price inclusive of all taxes and duties p_{jt}^I and other characteristics $\mathbf{w_{jt}}$, so that $c_{jt} = \rho p_{jt}^I + \mathbf{w_{jt}}\gamma + \omega_{jt}$. We separate the purchase price, because it is arguably the most relevant characteristic in our setting, where suppliers engage in vehicle resale but not production. Substituting this parametrization into equation (A.7) and denoting the matrix of stacked characteristics by $\mathbf{W_t}$, we obtain the following expression for the marginal costs:

$$\mathbf{p_t^D} + (1/N_t)[\mathbf{Ds}(\tilde{\mathbf{p}}_\mathbf{t}^\mathbf{D})]^{-\mathbf{1}}\mathbf{s_t} = \rho\mathbf{p_t^I} + \mathbf{W_t}\gamma + \omega_\mathbf{t} \tag{A.8}$$

It is worth highlighting that equation (A.8) is "market level" equation, which we could, in principle, use to estimate supply conditional on the demand parameters embedded in $[\mathbf{Ds}(\tilde{\mathbf{p}}_\mathbf{t})]^{-\mathbf{1}}\mathbf{s_t}$. With the estimated supply parameters $\hat{\rho}$ and $\hat{\gamma}$ at hand, we would then be able to simulate domestic prices for the complete choice set similar to how one would normally simulate equilibrium prices for counterfactuals (Conlon and Gortmaker, 2020).

Given the complexity involved in this preferred approach, however, we take a simpler route in the first instance. Specifically, motivated by equation (A.8) and making use of the levy change as an exogenous cost-shifter, we estimate the reduced-form relationship between domestic prices p_{jt}^D and international prices p_{jt}^I by running

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

a "pass-through" regressions of the following form:

$$p_{jt}^D = \beta_0 + \beta_1 \tilde{p}_{jt}^I + \beta_2 post_t + \beta_3 \tilde{p}_{jt}^I \times post_t + \upsilon_{jt} \tag{A.9}$$

, where $post_t$ is an indicator variable equal to one from the 2015/16 fiscal year onwards and υ_{jt} is the error term. We notably estimate this regression only on the observations (vehicle and fiscal year pairs), for which we have original international prices and domestic prices.

The results from estimating different variations of equation (A.9) are reported in Table A.5. Specification (1) assumes $\beta_2 = \beta_3 = 0$; specification (2) assumes $\beta_3 = 0$; specification (3) assumes $\beta_2 = 0$; and finally, specification (4) is estimated without any additional restrictions on the coefficients.

Table A.5: 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 international prices, inclusive of any duties and tariffs, in million Ugandan Shilling 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 by make, model, and manufacturing year triplet. 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.

Based on the estimates from the most general specification (4), we then predict the predict the domestic prices for vehicle and fiscal year pairs, where these are otherwise missing. This is possible given the complete set of international prices we have for the complete choice set.

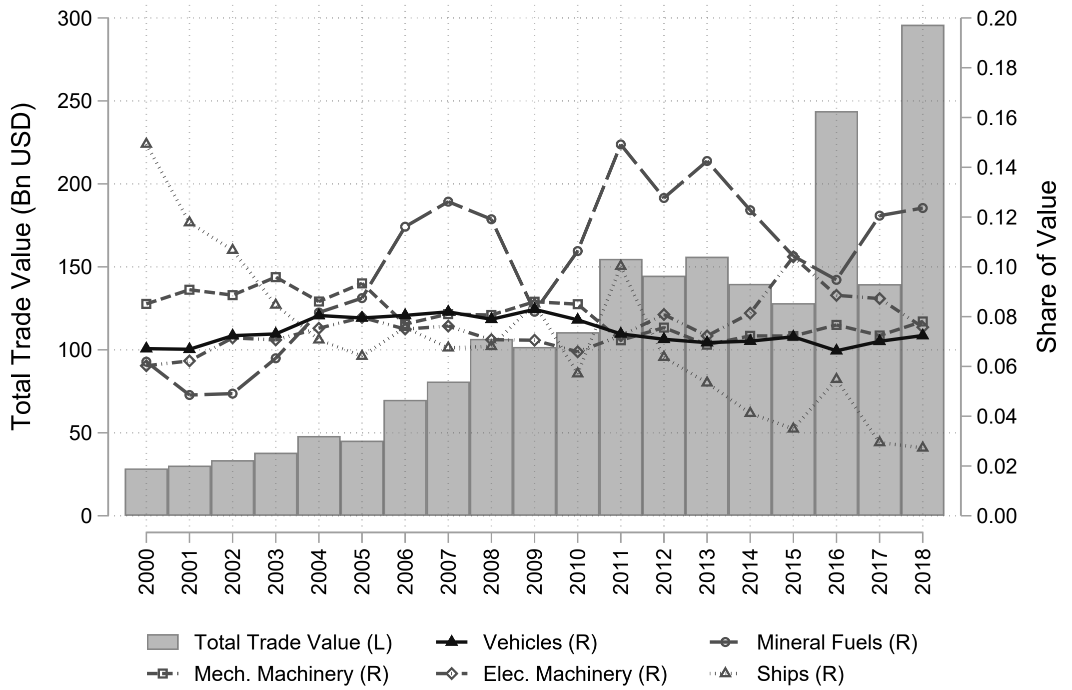
B Chapter 2 Appendix

B.1 Additional Output

B.1.1 Descriptive Statistics

This subsection provides additional descriptive statistics that are referenced in the main text. Figure B.1 shows the top import categories in LICs at the two-digit Hamonized System (HS) level over time. Motor vehicles consistently rank among the top-five categories along with other capital/durable goods and mineral fuels.

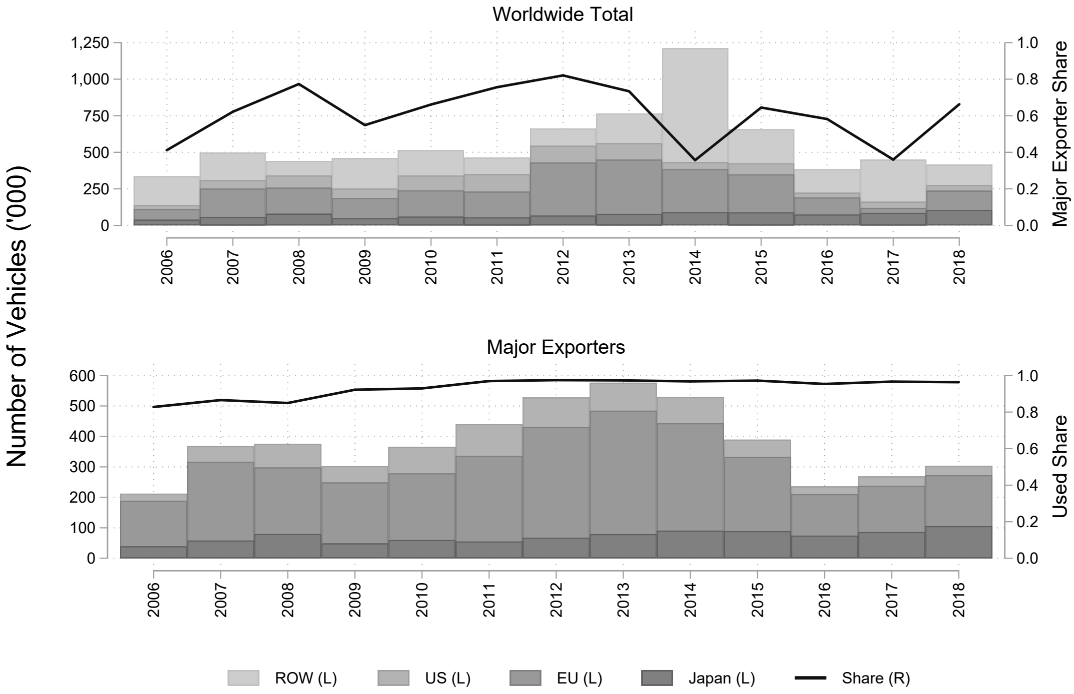
Figure B.1: Top Import Categories in Low-Income Countries



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 B.2 plots personal vehicle imports in LICs overall and from three major regions of origin — i.e., the US, the EU, and Japan — in terms of number of vehicles and the used share. It shows that (i) the three major regions of origin account for a large proportion of total personal vehicle imports in LICs and (ii) the share of used vehicle imports has been increasing over time and has been close to 100% since 2011.

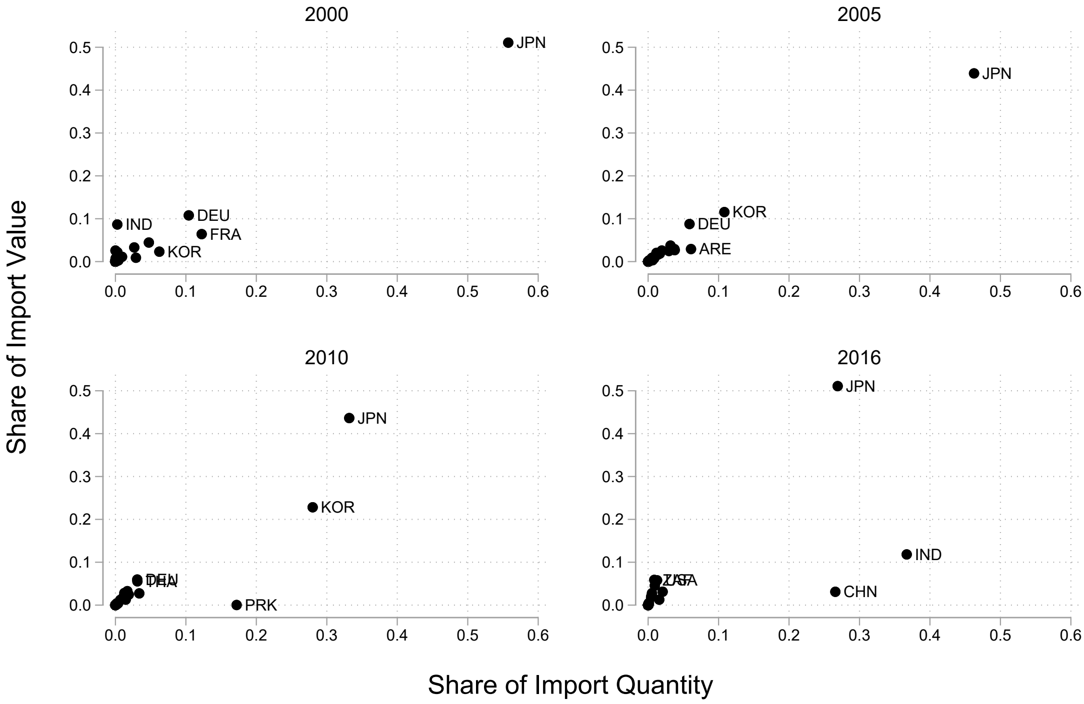
Figure B.2: Personal Vehicles Imported by Low-Income Countries



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.

Figure B.3 plots the origin-country share of personal vehicles imported by LICs, in terms of value and quantity, for the years 2000, 2005, 2010, and 2016. It shows Japan as an outlier, accounting for a substantial share, especially in terms of import value; it also shows India and China recently emerging as top origins in terms of quantity.

Figure B.3: Top Origins of Personal Vehicle Imports by Low-Income Countries



Notes: Figure shows the value and quantity share of personal vehicle exports to LICs (World Bank 2019 classification) for selected calendar years. Personal vehicles are defined as those under HS4 code 8703.
Sources: UN Comtrade.

B.1.2 Model Estimation

This subsection provides additional output from our estimation of the structural model, both for the spare parts supply and the vehicle demand equations. Specifically, Tables B.1 to B.3 report the results from estimating spare parts supply equation (2.10), but with the right hand side variable for the compatible base increasingly restricted. Table B.1 excludes from the compatible base all vehicles of the same make, model, and manufacturing year; Table B.2 excludes all vehicles of the same make and model; and finally Table B.3 excludes all vehicles of the same make.

Table B.1: Spare Parts Supply Estimation - Excl. M/M/MY

	(1)	(2)	(3)	(4)	(5)	(6)
Ln(Compatible Base) (φ)	0.665***	0.782***	0.658***	0.708***	0.672***	0.718***
	(0.029)	(0.027)	(0.028)	(0.025)	(0.029)	(0.038)
Age ($\varphi_a^{(1)}$)	-0.177***	-0.081	-0.189***	-0.167***	-0.173***	-0.154**
	(0.059)	(0.057)	(0.063)	(0.061)	(0.062)	(0.062)
Age^2 ($\varphi_a^{(2)}$)	0.005***	0.003*	0.004**	0.004**	0.004**	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
M FE	No	No	Yes	Yes	No	No
M/M FE	No	No	No	No	Yes	Yes
IV	No	Yes	No	Yes	No	Yes
R2	0.648	0.630	0.709	0.706	0.809	0.808
Num. Obs.	3,619	3,619	3,619	3,619	3,619	3,619
Kleibergen-Paap rk F-Stat		78.26		126.64		68.43
Hansen J P-Value		0.00		0.00		0.00

Notes: Table reports the estimated coefficients from the spare parts supply equation (2.10). Observations are the number of traders offering parts for a given vehicle during the 12 months ending July 2019. The compatible base is measured at the end of 2017 but excludes all vehicles of the same make, model, and manufacturing year (M/M/MY). Robust standard errors are reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table B.2: Spare Parts Supply Estimation - Excl. M/M

	(1)	(2)	(3)	(4)	(5)	(6)
Ln(Compatible Base) (φ)	0.682***	0.795***	0.675***	0.723***	0.687***	0.730***
	(0.029)	(0.028)	(0.028)	(0.026)	(0.030)	(0.039)
Age ($\varphi_a^{(1)}$)	-0.177***	-0.081	-0.188***	-0.167***	-0.173***	-0.156**
	(0.059)	(0.057)	(0.063)	(0.061)	(0.062)	(0.061)
Age^2 ($\varphi_a^{(2)}$)	0.005***	0.003*	0.004**	0.004**	0.004**	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
M FE	No	No	Yes	Yes	No	No
M/M FE	No	No	No	No	Yes	Yes
IV	No	Yes	No	Yes	No	Yes
R2	0.651	0.634	0.712	0.709	0.812	0.811
Num. Obs.	3,619	3,619	3,619	3,619	3,619	3,619
Kleibergen-Paap rk F-Stat		76.18		126.18		68.44
Hansen J P-Value		0.00		0.00		0.00

Notes: Table reports the estimated coefficients from the spare parts supply equation (2.10). Observations are the number of traders offering parts for a given vehicle during the 12 months ending July 2019. The compatible base is measured at the end of 2017 but excludes all vehicles of the same make and model (M/M). Robust standard errors are reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

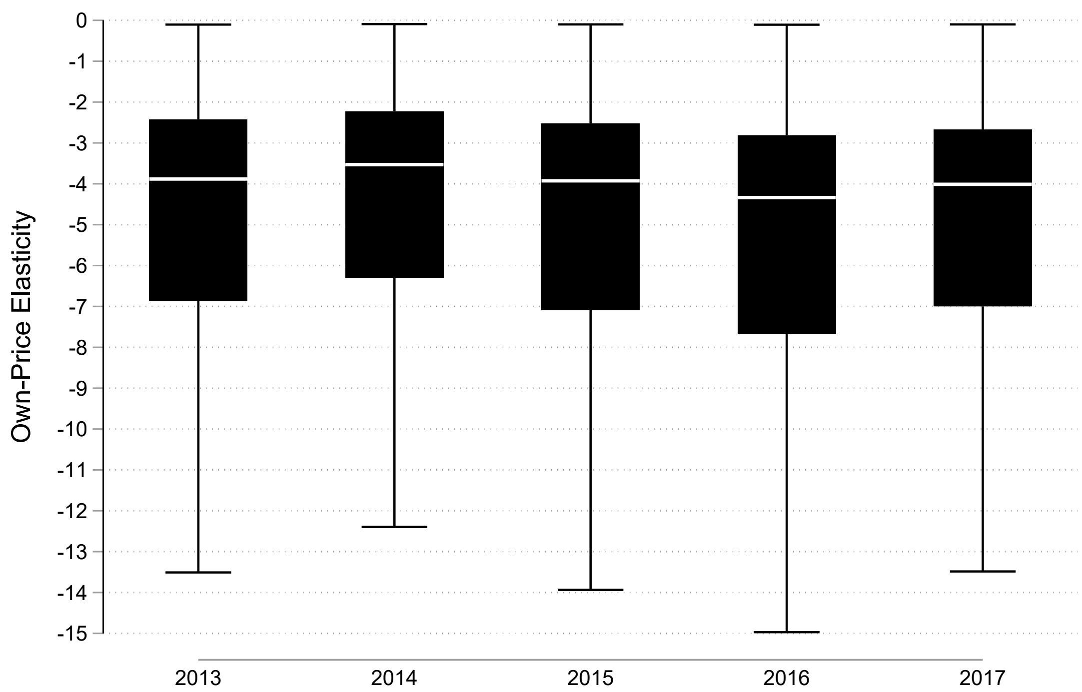
Table B.3: Spare Parts Supply Estimation - Excl. M

	(1)	(2)	(3)	(4)	(5)	(6)
Ln(Compatible Base) (φ)	0.720***	0.918***	0.751***	0.850***	0.745***	0.868***
	(0.034)	(0.038)	(0.030)	(0.031)	(0.038)	(0.046)
Age ($\varphi_a^{(1)}$)	-0.193***	-0.078	-0.192***	-0.155**	-0.195***	-0.153**
	(0.058)	(0.061)	(0.064)	(0.064)	(0.066)	(0.065)
Age^2 ($\varphi_a^{(2)}$)	0.005***	0.002	0.004**	0.003*	0.003*	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
M FE	No	No	Yes	Yes	No	No
M/M FE	No	No	No	No	Yes	Yes
IV	No	Yes	No	Yes	No	Yes
R2	0.601	0.563	0.694	0.686	0.794	0.788
Num. Obs.	3,619	3,619	3,619	3,619	3,619	3,619
Kleibergen-Paap rk F-Stat		75.60		111.28		75.53
Hansen J P-Value		0.22		0.01		0.00

Notes: Table reports the estimated coefficients from the spare parts supply equation (2.10). Observations are the number of traders offering parts for a given vehicle during the 12 months ending July 2019. The compatible base is measured at the end of 2017 but excludes all vehicles of the same make (M). Robust standard errors are reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

We now turn to additional output for the estimation of vehicle demand. Figure B.4 shows the distribution of the estimated own-price elasticities according to the logit specification (2) in Table 2.5 of the main text.

Figure B.4: Distribution of Estimated Own-Price Elasticity



Notes: Distribution of own-price elasticity corresponding to specification (6) in Table 2.5. 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.

Tables B.4 and B.5 show robustness tests of the demand model estimation. Table B.4 shows results for estimating equation (2.11) that incorporates period fixed effects instead of vehicle fixed effects; Table B.5 shows the results with period and make/model pair fixed effects.

Table B.4: Logit Model of Vehicle Demand - Year FE

	Full Base		Excl. M/M/MY		Excl. M/M		Excl. M	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(Compatible Base) (γ)	0.366***	0.261***	0.148***	0.165***	0.144***	0.170***	0.114***	0.020
	(0.009)	(0.018)	(0.009)	(0.012)	(0.010)	(0.013)	(0.010)	(0.014)
Price (α)	0.043***	0.045***	0.048***	0.050***	0.048***	0.048***	0.045***	0.047***
	(0.004)	(0.011)	(0.004)	(0.012)	(0.004)	(0.012)	(0.004)	(0.013)
Age (β^a)	-0.104***	-0.121***	-0.132***	-0.131***	-0.133***	-0.129***	-0.135***	-0.152***
	(0.009)	(0.020)	(0.010)	(0.022)	(0.010)	(0.022)	(0.010)	(0.023)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	No	Yes	No	Yes	No	Yes	No	Yes
Num. Obs.	15,010	15,010	15,010	15,010	15,010	15,010	15,010	15,010
Num. Veh.	3,130	3,130	3,130	3,130	3,130	3,130		3,130
Kleibergen-Paap rk F-Stat		173.30		174.50		175.30		172.97
Hansen J P-Value		0.00		0.01		0.00		0.01

Notes: Table reports the coefficients from the market level logit regression according to equation (2.11). Observations are annual log-differences of the "eligible" Ugandan population share purchasing a vehicle (defined by make, model, and manufacturing year) and the share not purchasing any vehicle. Data are restricted to passenger vehicles and the period from 2013 through 2017. Intercompatible base is installed base quantity of vehicles multiplied by the share of intercompatible spare parts between vehicles. Specifications include all compatible vehicles or incrementally exclude the installed base of the same make/model/manufacturing year (M/M/MY), the same make/model (M/M), and the same make (M), as indicated in the column headers. Fixed effects for vehicle M/M/MY are included throughout. Standard errors are clustered at the vehicle M/M/MY level and reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table B.5: Logit Model of Vehicle Demand - Vehicle & Year FE

	Full Base		Excl. M/M/MY		Excl. M/M		Excl. M	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(Compatible Base) (γ)	0.421***	0.306***	0.180***	0.185***	0.180***	0.192***	0.187***	0.134***
	(0.026)	(0.055)	(0.027)	(0.039)	(0.027)	(0.042)	(0.030)	(0.036)
Price (α)	0.119***	0.263***	0.133***	0.296***	0.133***	0.302***	0.134***	0.306***
	(0.017)	(0.048)	(0.020)	(0.050)	(0.020)	(0.049)	(0.021)	(0.049)
Age (β^a)	-0.229***	-0.480***	-0.276***	-0.537***	-0.278***	-0.547***	-0.286***	-0.573***
	(0.027)	(0.077)	(0.032)	(0.080)	(0.032)	(0.078)	(0.033)	(0.077)
M/M FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	No	Yes	No	Yes	No	Yes	No	Yes
Num. Obs.	15,010	15,010	15,010	15,010	15,010	15,010	15,010	15,010
Num. Veh.	203	203	203	203	203	203	203	203
Kleibergen-Paap rk F-Stat		20.22		22.19		21.92		24.61
Hansen J P-Value		0.42		0.48		0.17		0.33

Notes: Table reports the coefficients from the market level logit regression according to equation (2.11). Observations are annual log-differences of the "eligible" Ugandan population share purchasing a vehicle (defined by make, model, and manufacturing year) and the share not purchasing any vehicle. Data are restricted to passenger vehicles and the period from 2013 through 2017. Intercompatible base is installed base quantity of vehicles multiplied by the share of intercompatible spare parts between vehicles. Specifications include all compatible vehicles or incrementally exclude the installed base of the same make/model/manufacturing year (M/M/MY), the same make/model (M/M), and the same make (M), as indicated in the column headers. Fixed effects for vehicle M/M/MY are included throughout. Standard errors are clustered at the vehicle M/M/MY level and reported in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

B.2 Mathematical Appendix

B.2.1 Spare Parts Market Equilibrium and Indirect Utility

In this subsection, we derive the spare parts market equilibrium conditions, specifically prices and the endogenous number of traders offering parts within any compatible group of vehicles. We first derive spare parts demand and then use this to derive the equilibrium prices and number of traders. We also use demand and the equilibrium conditions to derive the indirect utility from spare parts.

Spare Parts Demand

Owner i of vehicle j in period t receives utility $\tilde{U}_{ijt}(\mathbf{w_t}, \tilde{y}_{it})$ from purchasing spare parts quantities $\mathbf{w_t} = [w_1 t, \ldots, w_{N_{g(j)}t}]$ from traders $n \in \left\{1, \ldots, N_{g(j)}\right\}$ and outside goods $\tilde{y}_{it}$, where $\tilde{U}_{ijt}(\mathbf{w_t}, \tilde{y}_{it})$ with parameters $\gamma > 0$ and $\alpha > 0$ is given by equation (2.2). Owners maximize utility by solving the following optimization problem:

$$\begin{aligned} \max_{\mathbf{w_t}, \tilde{y}_{it}} \quad & \tilde{U}_{ijt} = ln \left[\left(\sum_{n=1}^{N_{g(j)t}} (w_{ijnt})^{1/(1+\gamma)} \right)^{(1+\gamma)} \right] + \alpha \tilde{y}_{it} \\ \text{s.t.} \quad & \sum_{n=1}^{N_{g(j)t}} \tilde{p}_{nt} w_{ijnt} + \tilde{y}_{it} = y_{it} - p_{jt} \end{aligned} \tag{B.1}$$

, where $\tilde{p}_{nt}$ and p_{jt} denote the trader n spare parts price and the vehicle j price, respectively.

To solve this problem, we substitute the budget constraint for $\tilde{y}_{it}$ into the objective function and then differentiate $\tilde{U}_{ijt}$ with respect to w_{ijnt} to obtain the following first order conditions:

$$\begin{aligned} & \frac{w_{ijnt})^{-\gamma/(1+\gamma)}}{\left(\sum_{n=1}^{N_{g(j)t}} (w_{ijnt})^{1/(1+\gamma)} \right)} = \alpha \tilde{p}_{nt} \\ \Leftrightarrow & \frac{w_{ijnt})^{1/(1+\gamma)}}{\left(\sum_{n=1}^{N_{g(j)t}} (w_{ijnt})^{1/(1+\gamma)} \right)^{-1/\gamma}} = (\alpha \tilde{p}_{nt})^{-1/\gamma} \end{aligned} \tag{B.2}$$

Summing both sides across all traders offering group-g parts and defining the standard CES price index as $\tilde{P}_{gt} \equiv \left(\sum_{n=1}^{N_{g(j)t}} \tilde{p}_{nt}^{-1/\gamma} \right)^{-\gamma}$, we get:

$$
\begin{aligned}
& \frac{\sum_{n=1}^{N_{g(j)t}} w_{ijnt})^{1/(1+\gamma)}}{\left(\sum_{n=1}^{N_{g(j)t}} (w_{ijnt})^{1/(1+\gamma)}\right)^{-1/\gamma}} = \alpha^{-1/\gamma} \sum_{n=1}^{N_{g(j)t}} \tilde{p}_{nt}^{-1/\gamma} \\
\Leftrightarrow \quad & \left(\sum_{n=1}^{N_{g(j)t}} (w_{ijnt})^{1/(1+\gamma)} \right)^{(1+\gamma)/\gamma} = \alpha^{-1/\gamma} \sum_{n=1}^{N_{g(j)t}} \tilde{p}_{nt}^{-1/\gamma} \\
\Leftrightarrow \quad & \left(\sum_{n=1}^{N_{g(j)t}} (w_{ijnt})^{1/(1+\gamma)} \right)^{-(1+\gamma)} = \alpha \left(\sum_{n=1}^{N_{g(j)t}} \tilde{p}_{nt}^{-1/\gamma} \right)^{-\gamma} \\
\Leftrightarrow \quad & \left(\sum_{n=1}^{N_{g(j)t}} (w_{ijnt})^{1/(1+\gamma)} \right) = (\alpha \tilde{P}_{gt})^{1/(1+\gamma)}
\end{aligned}
\tag{B.3}
$$

We then substitute the last expression of equation (B.3) back into the original first order condition (B.2) to obtain the demand function for spare parts from trader n:

$$
\begin{aligned}
& (\alpha \tilde{P}_{gt})^{1/(1+\gamma)} w_{ijnt}^{-\gamma/(1+\gamma)} = \alpha \tilde{p}_{nt} \\
\Leftrightarrow \quad & w_{ijnt} = \frac{1}{\alpha} \left(\frac{\tilde{p}_{nt}^{(1+\gamma)}}{\tilde{P}_{gt}} \right)^{-1/\gamma}
\end{aligned}
\tag{B.4}
$$

We obtain demand for the outside good by plugging the demands for spare parts according to equation (B.4) into the budget constraint and solving for $\tilde{y}_{it}$. That is:

$$
\begin{aligned}
\tilde{y}_{it} &= y_{it} - p_{jt} - \sum_{n=1}^{N_{g(j)t}} \tilde{p}_{nt} w_{ijnt} \\
&= y_{it} - p_{jt} - \sum_{n=1}^{N_{g(j)t}} \tilde{p}_{nt} \frac{1}{\alpha} \left(\frac{\tilde{p}_{nt}^{(1+\gamma)}}{\tilde{P}_{gt}} \right)^{-1/\gamma} \\
&= y_{it} - p_{jt} - \frac{1}{\alpha \tilde{P}_{gt}^{-1/\gamma}} \sum_{n=1}^{N_{g(j)t}} \tilde{p}_{nt}^{-1/\gamma} \\
&= y_{it} - p_{jt} - \frac{1}{\alpha}
\end{aligned}
\tag{B.5}
$$

Finally, aggregate demand for spare parts from trader n is equation (B.4) summed over all owners of group-g vehicles. Given that individual demands within this group are identical, aggregate demand is simply $w_{nt} = w_{ijnt} Q_{g(j)t}$.

Spare Parts Supply

Spare part traders $n \in \{1, \ldots, N_{g(j)}\}$ in period t maximize profits as given in equation (2.4) of the main text by setting prices $\tilde{p}_{nt}$. From the demand equation (B.4) and assuming that the contribution of an individual traders' price on the index $\tilde{P}_{gt}$ is negligible, it is easy to see that $\partial w_{nt}/\partial \tilde{p}_{nt} < 0$ and $\partial w_{nt}/\partial \tilde{p}_{nt} > 0$.[1] This implies that the following first order condition of equation (2.4) is both necessary and sufficient for profit maximization.

$$w_{nt}(\tilde{p}_{nt}) = -(\tilde{p}_{nt} - c_{gt}) \frac{\partial w_{nt}}{\partial \tilde{p}_{nt}} \tag{B.6}$$

The left hand side represents the gain from an incremental price increase and the right hand side the corresponding forgone margins due to lower demand. We differentiate demand to get $\partial w_{nt}/\partial \tilde{p}_{nt} = -(1+\gamma)/\gamma(w_{nt}/\tilde{p}_{nt})$ and plug this into equation (B.6) to obtain the explicit expression for optimal prices as given in equation (2.5) of the main text:

$$\begin{aligned} w_{nt} &= (\tilde{p}_{nt} - c_{gt}) \frac{(1+\gamma)}{\gamma} \frac{w_{nt}}{\tilde{p}_{nt}} \\ \Leftrightarrow \quad \gamma \tilde{p}_{nt} &= (\tilde{p}_{nt} - c_{gt})(1+\gamma) \\ \Leftrightarrow \quad \tilde{p}_{nt} &= (1+\gamma) c_{gt} \end{aligned} \tag{B.7}$$

Finally, we impose that traders earn zero profits in equilibrium due to free entry. Setting equation (2.4) to zero and substituting aggregate demand and equilibrium prices, we get:

[1]We follow Nair et al. (2004) and Dubé et al. (2010) in the simplifying assumption that $\partial \tilde{P}_{gt}/\partial \tilde{p}_{nt} = 0$.

$$
\begin{aligned}
& (\tilde{p}_{nt} - c_{gt})\frac{1}{\alpha}\left(\frac{\tilde{p}_{nt}^{(1+\gamma)}}{\tilde{P}_{gt}}\right)^{-1/\gamma} Q_{gt} = F_{gt} \\
\Leftrightarrow \quad & \gamma c_{gt}\frac{1}{\alpha}\left(\frac{[(1+\gamma)c_{gt}]^{b}}{(1+\gamma)c_{gt}N_{gt}^{(1-b)}}\right)^{-1/\gamma} Q_{gt} = F_{gt} \\
\Leftrightarrow \quad & \left(\frac{[(1+\gamma)c_{gt}]^{\gamma}}{N_{gt}^{-\gamma}}\right)^{-1/\gamma} Q_{gt} = \frac{\alpha F_{gt}}{\gamma c_{gt}} \\
\Leftrightarrow \quad & \frac{Q_{gt}}{(1+\gamma)c_{gt}N_{gt}} = \frac{\alpha F_{gt}}{\gamma c_{gt}} \\
\Leftrightarrow \quad & Q_{gt} = \left(\frac{\alpha(1+\gamma)}{\gamma}\right) F_{gt}N_{gt} \\
\Leftrightarrow \quad & ln(N_{gt}) = ln(Q_{gt}) - ln\left[\left(\frac{\alpha(1+\gamma)}{\gamma}\right) F_{gt}\right]
\end{aligned}
\tag{B.8}
$$

Indirect Utility from Spare Parts in Equilibrium

We obtain the indirect utility owner i received from the availability of spare parts for vehicle j by substituting equilibrium prices into the demand for spare parts w_{ijnt} and the outside good $\tilde{y}_{it}$ and then, in turn, substituting these into $\tilde{U}_{ijt}(\mathbf{w_t}, \tilde{y}_{it})$. Specifically, noting that in equilibrium $w_{ijnt} = 1/[\alpha(1+\gamma)c_{gt}N_{gt}]$ and $\tilde{y}_{it} = (y_{it} - p_{jt} - 1/\alpha)$, we have:

$$
\begin{aligned}
\tilde{u}_{ijt} &= ln\left(\left\{\sum_{n=1}^{N_{g(j)t}} [\alpha(1+\gamma)c_{gt}N_{gt}]^{-1/(1+\gamma)}\right\}^{(1+\gamma)}\right) + \alpha(y_{it} - p_{jt} - 1/\alpha) \\
&= ln\left\{[\alpha(1+\gamma)c_{gt}N_{gt}]^{-1}N_{g(j)t}^{(1+\gamma)}\right\} + \alpha(y_{it} - p_{jt}) - 1 \\
&= \gamma ln(N_{gt}) + \alpha(y_{it} - p_{jt}) - ln[\alpha(1+\gamma)c_{gt}] - 1
\end{aligned}
\tag{B.9}
$$

B.2.2 Identifying Assumptions and Instrumental Variables

Our main identifying assumption to address endogeneity concerns in the spare parts supply and vehicle demand equations (2.10) and (2.11) is that vehicle characteristics $\mathbf{x}$ and the intercompatibility index $\mathbf{I}$ are orthogonal to the error terms $\Delta\kappa_{jt}$ and υ_{jt}, respectively. This assumption is very similar to the standard identifying assumptions for many applications of instrumental variables in the estimation of discrete choice demand models. Specifically, papers in this literature typically assume that $\mathbb{E}[\xi_{\mathbf{t}}|\mathbf{x_t}] = 0$, which implies that functions of the vehicle characteristics $\mathbf{x_t}$ can be used as excluded instruments. We extend this identifying assumption to also include the intercompatibility index $\mathbf{I}$ and characteristics from other periods $\mathbf{x_{t'}}$ as conditioning variables:

$$\mathbb{E}[(\upsilon_{\mathbf{t}}, \Delta\kappa_j)|\mathbf{x}, \mathbf{I}] = 0 \tag{B.10}$$

Similar to the standard case, it then follows that, for any arbitrary function $f(.)$, we also have $\mathbb{E}[(\upsilon_{\mathbf{t}}, \Delta\kappa_j)f(\mathbf{x}, \mathbf{I})] = \mathbb{E}\left\{f(\mathbf{x}, \mathbf{I})\mathbb{E}[(\upsilon_{\mathbf{t}}, \Delta\kappa_j)|\mathbf{x}, \mathbf{I}]\right\} = 0$. Hence, we can construct instrumental variables for vehicle prices and the compatible base using functions of the complete $(\mathbf{x}, \mathbf{I})$ vectors.

Instrumental Variables

In particular, we follow the recent work by Gandhi and Houde (2019) to define variants of their so-called "Differentiation IVs". Intuitively, these measure of the density of the characteristic space around any given vehicle j in period t and affect prices and vehicle shares through changes from the vehicle supply side. Vehicles that are close to each other in the characteristic space are relatively close substitutes and impact each others equilibrium prices and shares. Intuitively, the higher the density of these close substitutes, the lower producer margins and the lower retail prices of the new and used vehicles. Similarly, the higher the density, the lower any given vehicle's market share. In addition, these instrumental variables also incorporate exogenous vehicle supply shifters that vary over time and/or between vehicles. We focus on the US Dollar - Ugandan Shilling exchange rate as the only such exogenous supply shifter.[2]

Let $d^k_{jtj'} \equiv (x^k_{jt} - x^k_{j't})$ denote the difference in terms of the k-th characteristic between vehicles j and j'. Then the instrumental variables are constructed as the counts of competing products in close proximity in the characteristic space and the interaction of these counts for one characteristic with other exogenous variables (i.e., other characteristics or the US Dollar - Ugandan Shilling exchange rate as an exogenous supply shifter). In particular, we define:

1. Counts of competing products in close proximity — i.e., within one standard

[2]Other common instruments include vehicle prices in other markets, that reflect common cost shocks conditional on mean vehicle valuations.

deviation σ^k — in the characteristic space:

$$z_{jt}^{k} = \sum_{j' \neq j} \mathbb{1}(|d_{jtj'}^{k}| < \sigma^k)$$

2. Interactions of (1) with distances in terms of another characteristic:

$$z_{jt}^{kl} = \sum_{j' \neq j} \mathbb{1}(|d_{jtj'}^{k}| < \sigma^k) d_{jtj'}^{l}$$

3. Interactions of (1) with the US Dollar - Ugandan Shilling exchange rate:

$$z_{jt}^{kz} = \sum_{j' \neq j} \mathbb{1}(|d_{jtj'}^{k}| < \sigma^k) \tilde{z}_t$$

4. Interaction of (1) with intercompatibility:

$$z_{jt}^{kI} = \sum_{j' \in \check{J}_{jt}} I_{jj'} \sum_{t'=\underline{T}}^{t} \sum_{j'' \neq j'} \mathbb{1}(|d_{j't'j''}^{k}| < \sigma^k)$$

The first three instrumental variables closely follow the definition by Gandhi and Houde (2019) and are appropriate instruments for vehicle prices and shares. We include the vehicle engine capacity, weight, size, and age in x_{jt} ($K = 5$ when counting the intercept) and use the US Dollar - Ugandan Shilling exchange rate as the only exogenous cost shifter. This yields a total of $(K-1) + (K-1) \times K = 24$ instrumental variables of types (1), (2), and (3).

The fourth type of instrument seeks to provide exogenous variation directly for the availability of spare parts. It not only combines characteristic-space differences with contemporary measures of intercompatibility, but also incorporates such differences for past choice sets to mimic our measure of the compatible vehicle stock. The nested term $\sum_{j'' \neq j'} \mathbb{1}(|d_{j'tj''}^{k}| < \sigma^k)$ is the standard type-(1) instrumental variable as given above and we sum this across lagged terms $t' \in \{\underline{T}, \ldots, t\}$. Notably, this nested term captures the density of the characteristic space surrounding a given vehicle j', which may be different than vehicle j. The interaction with intercompatibility $I_{jj'}$ then measures the extent to which vehicle j' parts are also suitable for vehicle j and we sum this interaction across all vehicles j' that fall into some pre-defined subset $\check{J}_{jt}$ of the overall choice set $\{1, \ldots, J_t\}$. We consider only a subset $\check{J}_{jt}$ of the choice set to mimic the exclusions of the full compatible base as discussed in Section 2.4 in order to distinguish the indirect network effect via spare parts availability from direct network effects.

C Chapter 3 Appendix

C.1 Economies of Scale in Importing

We measure economies of scale in importing by estimating the unit price discount associated with shipment size, according to quantity and value. Specifically, for each sector (six-digit HS code), we divide import transactions i into five equally-sized bins and estimate the following regression equation:[1]

$$Ln(p)_i = \alpha_{j(i),o(i),t(i)} + \sum_{n=1}^{5} \delta_n \cdot \mathbf{1}\{q_i \in Q_n\} + \epsilon_i \tag{C.1}$$

, where $Ln(p)_i$ denotes the natural logarithm of shipment i's unit price, $\alpha_{j(i),o(i),t(i)}$ is a fixed effect for the triplet of shipment sector j, origin o, and month t, q_i is the shipment quantity, Q_n the quantity bin, and where ϵ_i is the error term. The δ_n coefficients capture to the average price residual for quantity bin Q_n after accounting for sector-origin-month fixed effects. Economies of scale are assessed by the degree to which the estimated δ_n decrease with n.

Sectors with limited economies of scale might potentially never make very large shipment over our sample period, so that quantity bins in different sectors would not correspond to shipments of similar values. We therefore also estimate economies of scale as given in equation (C.1) but with value bins rather than quantity bins. That is, we estimate the following regression:

$$Ln(p)_i = \alpha_{j(i),o(i),t(i)} + \sum_{n=1}^{5} \gamma_n \cdot \mathbf{1}\{v_i \in V_n\} + \epsilon_i \tag{C.2}$$

, where v_i and V_n, respectively, denote the shipment value and value bins, defined by absolute rather than relative value and cutoffs \$1,000; \$10,000; \$100,000 and \$1,000,000; and where the terms are otherwise defined as in equation (C.1).

Given that the unit price is just the shipment value divided by the shipment quantity, there is a mechanical negative correlation between the dependent variable and the quantity bins in equation (C.1) and a positive correlation between the dependent variable and the value bins in equation (C.2). The δ_n estimates are therefore a lower bound of the actual economies of scale in the considered sectors while the γ_n estimates constitute an upper bound. We are, however, not interested

[1]Bins are not of equal density as sectors with steeper price discounts are expected to have transactions concentrated at higher values.

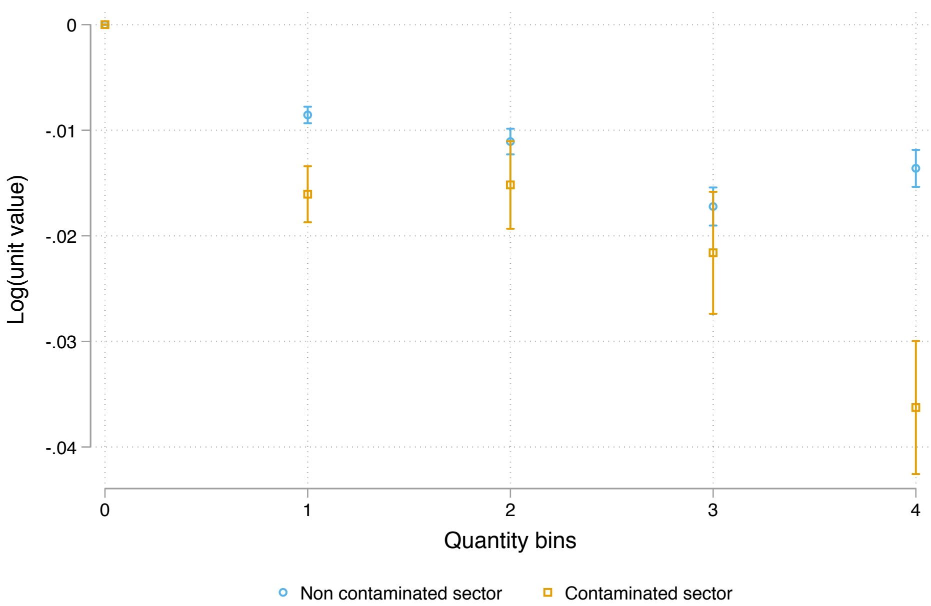
in the level of economies of scale for any given sector per-se but rather in their relative economies of scale. Thus, we need to assume that the bias to which the δ_n and γ_n estimates are subject is the same across sectors.

We estimate equations (C.1) and (C.2) separately by sector, excluding shipments by connected firms as these might potentially benefit from lower prices due to factors that are unrelated to sector-specific scale economies. This yields the sets of coefficients $\{\delta_n^{(j)}\}_{j,n}$ and $\{\gamma_n^{(j)}\}_{j,n}$ and we define a particular sector j to exhibit economies of scale if the estimated coefficient for the largest bin — $\delta_5^{(j)}$ or $\gamma_5^{(j)}$ — is negative.[2]

Connected vs. Non-Connected Sectors

In addition to defining economies of scale at the sector level, we also seek to understand how economies of scale differ between connected and non-connected sectors. To this end, we estimate equations (C.1) and (C.2) separately for both sector types but across the sectors within any one sector type. The coefficients δ_n and γ_n from these regressions are reported in Figures C.1 and C.2.

Figure C.1: Estimated Economies of Scale by Quantity Bins



Notes: Figure reports the point estimates of the δ_n parameter on quantity bins in equation (C.1). The vertical bars represent the corresponding 95 percent confidence intervals. The equation is estimated separately for connected and non-connected sectors.

[2]For sectors in the sample without at least one shipment in excess of USD 1 million, we extrapolate the coefficient from the price slope in the bin index n for higher index values.

Figure C.2: Estimated Economies of Scale by Value Bins

Notes: Figure reports the point estimates of the γ_n parameter on quantity bins in equation (C.2). The vertical bars represent the corresponding 95 percent confidence intervals. The equation is estimated separately for connected and non-connected sectors.

Both figures display larger economies of scale for connected sectors than non-connected sectors, and especially so for the highest quantity and value bins. These results show that connected firms are more prominent in sectors with high economies of scale. This makes intuitive sense if connected firms have better access to the foreign capital required to make large shipments and as such, capture the benefits from importing goods with high price discounts. These economies of scale generate opportunities for rents to be captured by importing these goods in bulk at low prices and reselling to the domestic market. Potential wholesale competitors may face higher per-unit costs from binding constraints on foreign capital and may thus be deterred from entering these markets.

C.2 Additional Tables and Figures

Table C.1: Connected and Non-Connected Importers

		Connected		
	Non-Connected	Private	SOEs	Total
	(1)	(2)	(3)	(4)
Num. Firms	118,300	349	420	119,069
Share of Firms (%)	99.4	0.3	0.4	100.0
Value (USD Million)	45,556	7,739	11,034	64,329
Share of Value (%)	70.8	12.0	17.2	100.0

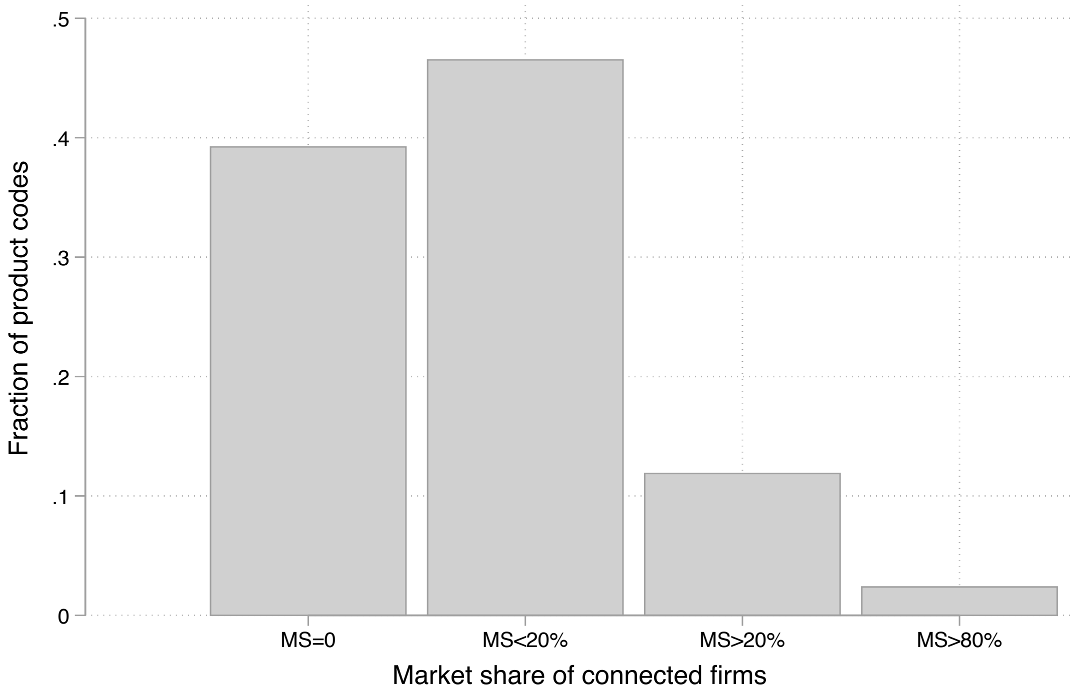
Notes: Table presents summary statistics of imports by firm connectedness status for the fiscal years 2011/12 to 2015/16. Privately connected firms are those directly sanctioned by the US, the EU or Australia or those with at least one sanctioned individual on the company board. SOEs are government companies according to the customs data. Import value is total over sample period.

Table C.2: Import Share by HS Chapter and Connectedness Status

		Connected		
	Non-Connected	Private	SOEs	Total
	(1)	(2)	(3)	(4)
Animal/Animal Products	1.1	0.5	0.0	0.9
Vegetable Products	5.8	8.5	0.0	5.1
Foodstuffs	5.8	1.9	0.2	4.4
Mineral Products	16.3	40.5	11.7	18.5
Chemicals/Allied Industries	8.0	4.5	1.9	6.5
Plastics/Rubbers	5.9	1.6	0.5	4.4
Raw Hides, Skins, Leather	0.3	0.3	0.0	0.2
Wood/Wood Products	1.7	1.7	0.9	1.5
Textiles	5.7	1.5	0.2	4.3
Footwear/Headgear	0.4	0.3	0.0	0.3
Stone / Glass	1.6	1.5	0.2	1.3
Metals	11.0	9.3	15.9	11.6
Machinery / Electrical	14.9	13.4	30.6	17.4
Transportation	18.4	8.0	28.0	18.8
Miscellaneous	3.2	6.5	10.0	4.7
Total	100.0	100.0	100.0	100.0

Notes: Table reports share, in percent, of HS chapter level imports for non-connected firms, private connected firms, SOEs, and all firms for the fiscal years 2011/12 to 2015/16. Privately connected firms are those directly sanctioned by the US, the EU or Australia or those with at least one sanctioned individual on the company board. SOEs are government companies according to the customs data. Shares are calculated out of total imports in connectedness category.

Figure C.3: Sector Distribution by Connected Firms' Market Share



Notes: Figure shows the sector distribution by connected firms' market share in the pre-liberalization period, i.e., fiscal years 2011/12 and 2012/13. Sectors are defined by their six-digit HS code. Market share of connected firms includes private connected firms and SOEs.

Table C.3: Probit Model of *De Facto* Liberalization By Year

	(1)	(2)	(3)	(4)	(5)	(6)
Connected		-0.306***			-1.062***	-0.568***
		(0.055)			(0.336)	(0.079)
Share Connected			-0.718***			
			(0.095)			
Share Private Connected				-0.574***		
				(0.142)		
Share SOE				-0.838***		
				(0.119)		
Ln(Shipment Value)					-0.106***	
					(0.024)	
Connected × Ln(Shipment Value)					0.085**	
					(0.037)	
Scale Economies						-0.029
						(0.070)
Connected × Scale Economies						0.472***
						(0.113)
Constant	-0.442***	-0.322***	-0.066	-0.261***	0.566***	-0.270***
	(0.081)	(0.084)	(0.080)	(0.085)	(0.215)	(0.087)
HS Chapter FE	Yes	Yes	Yes	Yes	Yes	Yes
Fiscal Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,732	2,732	2,732	2,732	2,732	2,732
Pseudo R-Squared	0.160	0.168	0.160	0.176	0.173	0.174

Notes: Table reports parameter estimates of equation (3.2). Observations are sector (six-digit HS code) - fiscal year combinations during the years 2013/14-2014/15 with positive imports throughout the 2011/12-2014/15 fiscal years that were liberalized *de jure*. *De facto* liberalized sectors require licenses for less than 80% of transactions. Connected sectors are those with market share of connected firms greater than 15 percent. Ln(shipment value) is the natural logarithm of the average shipment value by sector, leaving out connected firms. Scale economies is an indicator variable equal to one if the sector exhibits economies of scale as defined in Appendix Section C.1 and estimated through equation (C.2). HS chapter fixed effects are included throughout. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table C.4: Probit Model of *De Facto* Liberalization (Excl. Bundled Shipments) By Year

	(1)	(2)	(3)	(4)	(5)	(6)
Connected		-0.298***			-1.113***	-0.559***
		(0.056)			(0.337)	(0.080)
Share Connected			-0.779***			
			(0.096)			
Share Private Connected				-0.585***		
				(0.143)		
Share SOE				-0.928***		
				(0.122)		
Ln(Shipment Value)					-0.094***	
					(0.023)	
Connected × Ln(Shipment Value)					0.091**	
					(0.037)	
Scale Economies						-0.006
						(0.070)
Connected × Scale Economies						0.457***
						(0.114)
Constant	-0.522***	-0.407***	-0.170**	-0.332***	0.379*	-0.361***
	(0.082)	(0.085)	(0.081)	(0.086)	(0.214)	(0.088)
HS Chapter FE	Yes	Yes	Yes	Yes	Yes	Yes
Fiscal Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,732	2,732	2,732	2,732	2,732	2,732
Pseudo R-Squared	0.160	0.168	0.167	0.179	0.172	0.175

Notes: Table reports parameter estimates of equation (3.2). Observations are sector (six-digit HS code) - fiscal year combinations during the years 2013/14-2014/15 with positive imports throughout the 2011/12-2014/15 fiscal years that were liberalized *de jure*. *De facto* liberalized sectors require licenses for less than 80% of transactions, excluding shipments of companies with at least one *de jure* non-liberalized entry on the same day. Connected sectors are those with market share of connected firms greater than 15 percent. Ln(shipment value) is the natural logarithm of the average shipment value by sector, leaving out connected firms. Scale economies is an indicator variable equal to one if the sector exhibits economies of scale as defined in Appendix Section C.1 and estimated through equation (C.2). HS chapter fixed effects are included throughout. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table C.5: Impact of Import License Liberalization (Baseline)

	Connected Sectors		Non-Connected Sectors	
	(1)	(2)	(3)	(4)
Lib × Post	-0.001	0.021	0.130	0.287
	(0.131)	(0.167)	(0.091)	(0.184)
HS6 FE	Yes	Yes	Yes	Yes
Fiscal Year FE	Yes	No	Yes	No
HS2 × Year FE	No	Yes	No	Yes
Obs.	228	228	300	300
R-Squared	0.441	0.485	0.449	0.513

Notes: Table reports the estimates of the coefficient β from regressions of the form given in equation (3.4). Observations are sectors by fiscal year for the 2011/12 to 2013/14 period that have at least USD 3 million in average import value per year (264 sectors, 114 connected sectors and 150 non-connected sectors). Sectors are defined to be connected if the market share of connected firms in that sector in the pre-reform period is higher than 15 percent. Fixed effects for the six-digit HS code, fiscal year, and two-digit HS code and fiscal year pair are included as indicated. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table C.6: Impact of Import License Liberalization (Private Connected vs. SOEs)

	Connected Sectors				Non-Connected Sectors	
	Private		SOEs			
	(1)	(2)	(3)	(4)	(5)	(6)
Lib × Post	0.034	0.016	-0.068	-0.031	0.130	0.287
	(0.163)	(0.245)	(0.225)	(0.249)	(0.091)	(0.184)
HS6 FE	Yes	Yes	Yes	Yes	Yes	Yes
Fiscal Year FE	Yes	No	Yes	No	Yes	No
HS2 × Year FE	No	Yes	No	Yes	No	Yes
Obs.	144	144	84	84	300	300
R-Squared	0.415	0.505	0.486	0.523	0.449	0.513

Notes: Table reports the estimates of the coefficient β from regressions of the form given in equation (3.4). Observations are sectors by fiscal year for the 2011/12 to 2013/14 period that have at least USD 3 million in average import value per year (264 sectors, 114 connected sectors and 150 non-connected sectors). Sectors are defined to be connected if the market share of connected firms in that sector in the pre-reform period is higher than 15 percent. Columns (1) and (2) are estimated on the sample of connected sectors with majority private connected firms; columns (3) and (4) are estimated on the sample of connected sectors with majority SOEs; columns (5) and (6) are estimated on the sample of non-connected sectors. Fixed effects for the six-digit HS code, fiscal year, and two-digit HS code and fiscal year pair are included as indicated. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table C.7: Impact of Import License Liberalization (5% Connected Threshold)

	Connected Sectors		Non-Connected Sectors	
	(1)	(2)	(3)	(4)
Lib × Post	0.016	0.072	0.061	0.270
	(0.099)	(0.141)	(0.123)	(0.264)
HS6 FE	Yes	Yes	Yes	Yes
Fiscal Year FE	Yes	No	Yes	No
HS2 × Year FE	No	Yes	No	Yes
Obs.	356	356	176	176
R-Squared	0.422	0.472	0.455	0.552

Notes: Table reports the estimates of the coefficient β from regressions of the form given in equation (3.4). Observations are sectors by fiscal year for the 2011/12 to 2013/14 period that have at least USD 3 million in average import value per year (264 sectors, 114 connected sectors and 150 non-connected sectors). Sectors are defined to be connected if the market share of connected firms in that sector in the pre-reform period is higher than 5 percent. Fixed effects for the six-digit HS code, fiscal year, and two-digit HS code and fiscal year pair are included as indicated. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table C.8: Impact of Import License Liberalization (30% Connected Threshold)

	Connected Sectors		Non-Connected Sectors	
	(1)	(2)	(3)	(4)
Lib × Post	0.041	0.111	0.105	0.222
	(0.154)	(0.202)	(0.082)	(0.150)
HS6 FE	Yes	Yes	Yes	Yes
Fiscal Year FE	Yes	No	Yes	No
HS2 × Year FE	No	Yes	No	Yes
Obs.	190	190	350	350
R-Squared	0.433	0.499	0.463	0.509

Notes: Table reports the estimates of the coefficient β from regressions of the form given in equation (3.4). Observations are sectors by fiscal year for the 2011/12 to 2013/14 period that have at least USD 3 million in average import value per year (264 sectors, 114 connected sectors and 150 non-connected sectors). Sectors are defined to be connected if the market share of connected firms in that sector in the pre-reform period is higher than 30 percent. Fixed effects for the six-digit HS code, fiscal year, and two-digit HS code and fiscal year pair are included as indicated. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table C.9: Impact of Import License Liberalization (Weighted)

	Connected Sectors	Non-Connected Sectors
Incumbents	0.153 ***	-0.002
Connected Firms	0.144 ***	-0.001
Non-Connected Firms	0.009	-0.000
Net Entry	-0.107 *	0.388 ***
Connected Firms	-0.052	0.029 **
Non-Connected Firms	-0.055 *	0.360 ***
All	0.046	0.386 ***
Connected Firms	0.092	0.027 *
Non-Connected Firms	-0.046	0.359 ***

Notes: Table reports the estimates of the coefficient β from regressions of the form given in equation (3.4) with observations weighted according to their pre-liberalization import value. Each reported coefficient is from a separate regression with sample given by the column headers (connected vs. non-connected sectors) and the import value under consideration restricted as given by the row labels. Observations are sectors by fiscal year for the 2011/12 to 2013/14 period (1,432 sectors, 535 connected sectors and 897 non-connected sectors). *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

Table C.10: Liberalization Impact on Shipment Size and Number of Transactions

	Ln(Shipment Size)			Number of Shipments		
	All Sectors	Connected	Non-Connected	All Sectors	Connected	Non-Connected
	(1)	(2)	(3)	(4)	(5)	(6)
Lib × Post	-0.029*	-0.161***	-0.017	7.856***	6.328***	8.757***
	(0.016)	(0.047)	(0.017)	(1.798)	(1.252)	(2.347)
Company × HS6 FE	Yes	Yes	Yes	Yes	Yes	Yes
Fiscal Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	92,732	13,276	79,456	92,732	13,276	79,456
R-Squared	0.836	0.857	0.823	0.639	0.580	0.640

Notes: Table presents the result of a standard difference-in-differences model estimating the effect of import liberalization on the average size of shipments and the number of shipments per year. Observations are six-digit HS sectors by fiscal year in the years 2011/12 to 2014/15. Standard errors are reported in parentheses and *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.

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