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# Determinants of firm boundaries and organizational performance: an empirical investigation of the Chilean truck market

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## Abstract

The boundaries of a firm, particularly those of manufacturers that import heavy-duty Class 8 trucks and tractors into the Chilean automotive market, depend on economizing transaction costs. This empirical study investigates the vertical integration of these manufacturers and their respective dealers. By conducting a transaction cost analysis, this study results in two distinct cases. For the first case, the generalized linear models' estimations and hypothesis tests for the count data of the 'types of units sold' consider the firms' specificity as emissions standards, asset specificity as brand culture, and firms' endowments as offering finance for their dealers. The second case examines environmental uncertainty with respect to dynamic indicators that interfere with manufacturers' external transaction-based efficiency. Overall, the results strengthen transaction cost theory, suggesting that European manufacturers with vertical integrated structures economize on brand reputation, while their industry competitors derive gains from uncertainty of the exchange rate. The evolution of their boundaries coincides with the immediate adaptations of price of the truck, uncertainty concerning the demand for Chile's leading export commodity, and technology uncertainty of emissions regulations. To reduce transaction costs, manufacturers avoid the production of off-assembly-line trucks and tend to circumvent integration with their dealers through investments.

**Keywords** Vertical integration · Transaction cost analysis

**JEL Classification** B52 evolutionary economics · D23 transaction costs · D22 firm behavior: empirical analysis

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## 1 Introduction

The study of boundaries of a firm began with Coase (1937). Williamson (1975, 1985) advanced the determination of the boundaries of a firm to depend on efficiently economizing transaction costs (TC) (Holmström and Roberts 1998). The fundamental foundation to their research became the hallmark of transaction cost economics (TCE). TCE analyzes alternative governance structures while addressing the firm's performance, its transaction attributes, and its external environment (Masten 1993). Carroll et al. (1999) stated that TCE, as a theory of organization, deliberates on 'efficiency'. Moreover, Mahoney (1992) maintained the premise that 'efficient' transaction costs and 'efficient' organizational structures embodied a symbiotic relationship. Incurring transaction costs embody the costs, both *ex ante* and *ex post*, that are coupled with the decision to internalize market-transactions under a hierarchy (Williamson 1985; Mahoney 1992). Currently, most TCE empirical studies focus on contracts (Macher and Richman 2008). Consequently, this empirical study broadens its perspective to include the potential sources of transaction costs that limit the boundaries of a firm, particularly with regards to manufacturers competing in the Chilean truck market. Hence, by undergoing a transaction cost analysis (TCA) through two distinct empirical cases, this study will identify transactions as the number of units of heavy-duty truck sold between the contracting parties, namely the manufacturers (sellers) and dealers (buyers) in the Chilean market. The measurement of '*efficient*' *organizational performance* among manufacturers is represented as the *boundaries of the firms* with respect to quantity of brands, which closely resemble the firms' competitive market share. A firm's boundaries remain of significant importance to economic theorists when determining internal and external determinants that impact their size, shape, and organizational performance (Belcher 1997). With regards to the theory of a firm's boundaries, this empirical study investigates the Chilean truck market by applying three generalized principles: (1) brand culture as *asset specificity* of manufacturers' intangible resources in order to conduct market penetration and evaluate competition within the Chilean market, (2) the *firms' resource endowment*, that is, to financially offer international financing for their dealers, and (3) the *firm's specificity* as the functionality of the firm, which is to efficiently satisfy market demand for specific environmental emission-efficient heavy-duty vehicles (Zott et al. 2006). Two empirical analyses on transaction cost determinants of the manufacturers competing in the Chilean truck industry assist to address these three principles pertaining to the boundaries of these producers. From the introduction in Sect. 1, the study proceeds to review the market relevance and industry background of Chile in Sect. 2; followed by highlights of the related literature, parameter selection, and hypotheses in Sect. 3. Section 4 describes the data and outlines the study's methodology. Empirical results and robustness checks are covered in Sect. 5. Section 6 elaborates on the overall discussion and limitations of this article, followed by Sect. 7 that presents the concluding remarks and assessments.

## 2 Industry background

The Chilean market, as a whole, is driven by and significantly remains dependent on exports (Ballón and Molina 2017, Roch 2017). Because Chile is a non-manufacturer of heavy-duty trucks, consequently relying on European, American, and other providers and manufacturers, these competing producers become this study's population. Given this scenario, the central focus of this study is the interaction of transaction-specific economic indicators with regards to the impact on firms' boundaries and specificity, measured as *types of units sold*, accompanied by the second case analysis of the manufacturers' capabilities and response to external environmental uncertainty, as measured by *heavy-duty trucks sales*.

Heavy-duty trucks and other commercial vehicles play a key role to transport merchandise as in the mobility of raw materials in large production industries across Chile's diverse regions such as fishing in the south, mining in the north, and manufacturing in metropolitan areas, along with forestry and agriculture (Elías, 2015, 2016, 73). According to United Nations (UN) Comtrade data from 2004 to 2013, Chile's leading commodity export is copper, followed by copper ores (Kohlscheen et al. 2016). Presumably, a reduction of units sold is indicative of the downward trend in commodity prices as a source of economic instability (Elías 2015, 77–78, OECD Economic Surveys: Chile 2018, 8–9).

Generalizability of this research study on heavy-duty truck manufacturers competing in Chile is preferred given its broader economic applicability when compared to other emerging South American automotive markets in the Andean region, wherein Peru, Ecuador, and Chile are geographically located (Smith 1904). For example, the Peruvian market data are extremely small and lack verifiable accessibility of environmental information, which may render inadequate support of generalizations and applications to relevant markets (Romero, et al. 2016, 40). At the time of this study, Peru operated on lower emissions standards (EURO 3 or US Tier 1 instead of the current European Standards, EURO 6). According to the Central Reserve Bank of Peru, Peru imports manufactured vehicles from China, U.S., Brazil, and Mexico, which obstructs the external validity of this study. The limitation of the Ecuadorian market stems from the Ecuadorian government imposition of economic barriers, that is, high import duties during the economic crisis; hence, the market data may generate a selection bias, which threatens internal validity (International Trade Administration 2020a, b). Lastly, the Chilean market compatibility lends itself legislatively to favor importation of European products. For instance, the mandate of the high EURO 6 emissions standards in Chile are comparable to those in the European Union (EU).

### 3 Related literature

#### 3.1 Case 1: Determinants of transaction costs affecting the firms' boundaries in the truck market

Williamson's (1975) *Markets and Hierarchies* underpinned the competitive advantage gained by firms, by selecting appropriate governance structures to maintain their economic transactions (Steenkamp and Geyskens 2011). In TCA, Rindfleisch and Heide (1997) and many TCE scholars had relied on the *mode* or *mechanism of governance* as the prevalent *dependent variable*. Other studies departed from this norm and selected alternative dependent variables such as contractual agreements or safeguards (Osborn and Baughn 1990; Parkhe 1993), contracts (Joskow 1987), percentage of manufacturer's sales (John and Weitz 1988) or the utilization of direct sales force instead of the manufacturers (Anderson 1985; Anderson and Schmittelein 1984). Irrespective of the unit of analysis selected for TCA, Williamson (2002) maintained the three dimensions of transaction, which defines the consequences for firm governance as follows: asset specificity, such as brand name, the distribution of transactions, and the frequency of transactions. When Love (1997) critiqued Hallwood (1994), he emphasized the multinational enterprise's (MNE's) existence to be based on economizing on the *final market product*, reducing search costs [i.e., ex ante transaction costs (Williamson 1985; Mahoney 1992)] for customers. Love's (1997) keen observation implied that the sole reliance on transaction costs as dependent on vertical integration through internalization may be unpersuasive. With this justification, the specific 'type of transaction' internalized by the MNE, namely 'the type of truck sold' as the market end-products, becomes relevant for efficient integration among manufacturers and their respective dealers. Given the literature related to the TCE theory<sup>1</sup> of the firm, the determination of boundaries among competing firms lies with the assignment of *the number of types of units sold* as the basic unit of analysis in market transactions (Williamson 1981; David and Han 2004). Based on the premise that the basic unit of analysis is the transaction itself, the following hypothesis is derived:

*Hypothesis 1.1: Type of Units Sold as Firm Performance and Complexity Indicator:* To gauge market penetration and the boundaries of competitive manufacturers in the Chilean market, the quantification of types of Class 8 heavy-duty vehicles sold per contractual order remains a suitable unit of analysis for firm performance and reflect transaction costs of product complexity.

Selecting transactions, namely as the indicator of number of types of vehicles sold, as the *unit of analysis* and as the *dependent variable* does encounter some challenges. The final transaction of a vehicle, being a single exchanged transaction between the producers and their dealers, may reflect more than transaction costs. In fact, it may more accurately signify the production costs or the cumulative sum

<sup>1</sup> TCE theory of the firm affirms two notions to the organization and existence of firms. First, the existence of firms is to reduce transaction costs. Second, uncertainty within a market is eliminated by the firm (Shin 2003).

of transactions to assemble the heavy-duty truck under the manufacturers' hierarchy (Holmström and Roberts 1998; Milgrom and Roberts 1992, 32–33). Nevertheless, a contractual order does generate transaction costs among contracting parties. The challenge of selecting *independent variables* as proxies for transaction costs lies with the *methodological diversity* present across empirical works of TCA (Rindfleisch and Heide 1997), which in turn serves as a leeway on parameter selection.

TCE also assumes that all contracts are incomplete given the cognitive assumption of bounded rationality. Given the *ex post* hazards of opportunism which stem from this behavioral assumption as presented by Williamson (1995), this first case examines transaction-specific investments operating in the capacity as *ex ante* safeguards, which circumvent the holdup problem to vertical integrate under uncertainty between the transacting parties of manufacturers (sellers) and their dealers (buyers). *Firms' resource endowments*, as best indicated by the ability to offer *international financing* for their dealer, establish the firms' boundaries as compared to their non-financing competitors. Perhaps being a pressing concern would be *transportation resources* and *investments* and their impact on the evolution of producers. Resource endowments in the industry are now available and indicative of trending investments; for example, electric heavy-duty trucks broaden the firm's capacities<sup>2</sup> and boundaries (Elías 2016, EY Future of Automotive Retail Survey 2015, Coughlin et al. 2008, Sripad and Viswanathan 2019).

*Hypothesis 1.2: Resource Endowment Capabilities:* Given that enlarged resource endowment of a firm increases its boundaries of operations within a market, then those manufacturers that offer international financing to their dealers in the Chilean market will positively affect the number of types of units sold per contractual order.

Holmström and Roberts (1998) pointed out that boundaries are not solely influenced by transaction-specific investments. Given opportunism, the manufacturers adapt to contractual breakdowns by renegotiating the price bid for their truck. Hence, TCE draws the assumption that contracts are problematic to governance structures. For instance, when efforts fail to delineate a cooperative governance structure by offering financing, the *price setting* of a firm's vehicles, despite its rigidity, indicates the 'efficiency' of its organizational structures and potential to evolve its boundaries through price bids. The father of complexity economics, Hayek (1945), asserted price signaling *within a market* to usher the *immediate adaptations* of economic agents, in this case, the truck manufacturers. According to Williamson (2002), the truck market communicates information through the *price system*. Moreover, Williamson (1975) and Coase (1937, 1988) upheld the assumption of 'the price mechanism' to obtain market efficiency through information signaling between economic agents, namely the sellers as the manufacturers and the buyers as the dealers (Habimana 2015; Williamson 1975; Coase 1937, Bylund 2015). In

<sup>2</sup> The term (heterogeneous) 'capacities' coincides with the "underlying determinants of the efficiency" whereby truck manufacturers produce capital- and labor-intensive heavy-duty vehicles (Jacobides and Winter 2012, Jacobides and Winter 2005). Consequently, the expectation is to increase a heavy-duty truck market that supports technological investments that is geared for electric trucks with fuel cells over the current status of conventional hybrid vehicles (KPMG's Global Automotive Executive Survey 2016, Sripad and Viswanathan 2019).

economic theory, Hayek (1945) identified the price system as an *autonomous adaptation* of economic agents to the *market*, which parallels this case's determinant, *the price of the units sold* (Williamson 2008).

*Hypothesis 1.3: Autonomous Adaptation of Price Setting Capabilities:* The price of the trucks sold per contractual order to Chilean dealers reflect *immediate adaptations*, such that a price increase by its manufacturer will immediately decrease the number of types of capital- and labor-intensive heavy-duty trucks sold per order.

Plainly, the price of each unit sold assesses, as Hayek (1945) emphasized, the *market aggregation of information*, allowing the manufacturer and its competitors to efficiently assemble and conduct feasible operations (Zenger et al. 2011). However, the theory of the firm remains mostly silent on this matter (Felin and Zenger 2011). Moreover, as the production decisions of the manufacturers become more interdependent with the demand for orders by their dealers, the autonomous adaptation of price becomes more implicitly dependent on coordinated adaptation by offering international financing.

In organizational theory, Barnard (1938) defined *coordinated adaptation* to be a slower, yet “deliberate and conscious” process of organization adaptation via administration (Williamson 2008; Barnard 1938; Alonso et al. 2015). Barnard (1938) suggested that, within a market, hierarchies' *coordinated adaptation* are *not immediate* changes (Williamson 2002). To address the existential problem of economic organization, Williamson (2002) reconciled adaptations, both autonomous and coordinated, by asserting that a high-performance economic system must depend on adaptations from both hierarchies and markets. The purpose of TCE has been enthroned with understanding *adaptation* within the context of economizing transactions with their various attributes which coincide with their respective governance structures, capabilities, and costs (Williamson 2008; Steenkamp and Geyskens 2011, Cordes et al. 2020). Thus, TCE intrinsically introduced the tradeoff between adaptation and incentive intensity between the market and hierarchy (Argyres 2009). In the case with Chilean truck importers, to ease the rigidity of the price system when conducting market transactions, the capacity to offer *international financing* to their dealers addresses contractual impasses while assessing their resource endowment capabilities. In addition, a higher market's incentive intensity to offer financing for dealers becomes a response to increased competition among manufacturers (Zenger et al. 2011, 96).

*Coordinated adaptation* among manufacturers stems largely from *uncertainty*, where the manufacturers encounter their decision to pursue higher integration of structures to deter transaction costs. For example, Coles and Hesterly (1998) concluded higher uncertainty caused only integration among lower levels of asset specificity across firms. Despite the conflicted investigations by Ruzzier (2009), Gibbons (2005, 207), and Holmström and Roberts (1998), mainstream TCE affirms that higher uncertainty and asset specificity imply (vertical) integration (Holmström and Roberts 1998, 92, Kvaløy 2007). This consequence is not few and far between in academia as interdisciplinary research has always demonstrated the effects of a volatile and uncertain environment on performance and organizational structures (Bourgeois III, 1985, Hrebiniak and Snow 1980). Under the assumption of *imperfect markets* in TCE, uncertainty drives up transaction costs, particularly concerning bargaining



and decision costs per contractual order. Given the Chilean peso (CLP) was under a floating regime with the United States dollar (USD) and that transactions (units sold) are transacted between the USD and the euro currency (EUR), exchange rate flexibility plays a uniquely defensive role to reduce volatility of capital inflows, even operating as an integral tool for inflation targeting policies in emerging economies (De Gregorio 2010, Cifuentes and Jara 2014, Morandé and Tapia 2002, Rodrigo and Michael 2020, Goldberg and Tille 2006, Maggiori et al. 2019). Likewise, Reinhart and Rogoff (2004) presented the market-determined exchange rate as an indicator of monetary policy. More so, growing literature support exchange rate market to be an indicator of *uncertainty* (Olanipekun et al. 2019, Ricca 1998, Bahmani-Oskooee 1991). The effect of the exchange rate on transaction costs, on pricing, and on the evolution of trade links among countries has also been highlighted by other studies (e.g. Sercu et al. 1995; Antich 2018; Amelung 1991). Consequently, the frequency of types of trucks sold per order depends on exchange rate uncertainty (e.g., Elías 2016, 10–11), such that a surge in the foreign exchange rate between EUR and USD may likely share an inverse evolutionary effect on the boundaries of European truck manufacturers. The outcome of an uncompetitive exchange rate translates into transactional inefficiency and limited marginal profits. The result would pivot dealers away from integration and induce the evolutionary expansion of boundaries in favor of their competitors, whose structural operations and internal transaction efficiency (shipping, handling, and coordination and assembly costs of each unit at their production sites) are not based in euros.

**Hypothesis 1.4: Coordinated Adaptation, Transaction-based Efficiency and Evolution of Manufacturers Under Uncertainty:** Exchange rate has an interaction effect with the origin and structural transactional efficiency of the producer such that an increased exchange rate of the EUR to USD increases the transaction costs of European based manufacturers, while enhancing the transaction-based efficiency of non-European producers by increasing their number of trucks sold per contractual order.

To grasp transaction attributes within the Chilean truck market entails not only investigating *uncertainty* within the external environment, which generates the *adaptation of producers*, but also *asset specificity* (Williamson 2002). Bounded rationality, as opposed to *homo economicus*, emphasizes the opportunistic behavior of a firm to capitalize on the transaction (Dugger 1983; Cordes, et al. 2011). As argued by Williamson (1985), without opportunistic behavior the need for a hierarchy can never usurp the market (Williamson 1998). Again, given the TCE assumption of opportunism, truck manufacturers rely on consumer preferences and brand behaviors to opportunistically enlarge their market share (Macher and Richman 2008). Besides exchange rate fluctuations, the willingness-to-pay of end users of heavy-duty vehicles is also influenced by brand culture and biased consumer preferences, which interfere with firm's specificity and performance (Koschate-Fischer et al. 2012; Richardson 1988). Thus, among the six acknowledged multidimensional constructs of asset specificity, *brand name capital* among subgroups of heavy-duty truck manufacturers is assessed (Williamson 1985; De Vita et al. 2011).

**Hypothesis 1.5: Brand Culture:** Asset specificity, defined as brand name capital, has a positive impact on the number of truck units sold in Chilean transportation market.



Studies (e.g., Williamson and Ghani 2011; Seggie 2012; Chen 2010) explored the link between TCE and marketing. This case contributes to their discussion by abridging the connection between brand image, as a high valued intangible asset, and transactions, that is organizational performance. Williamson took a step further, indicating “misaligned incentives attributable to the opportunistic nature” among the transacting agents, given their bounded rationality, induces transaction costs (Habimana 2015; Williamson 1975, 255). Concerning bargaining and decision costs on price negotiations for an order, high brand capital specificity of the manufacturer, such as offering repair services for their vehicles, strengthens overall firm performance when perceived with higher asset specificity and quality of trucks. TCE effects, spearheaded by *culture*, in the determination of manufacturers’ boundaries might interfere with their specificity when operating within the commodity-export economy. *Brand culture* becomes a synonymous marker for the *human factor*<sup>3</sup> of transaction costs (Appendix A, Table A-1) (Yang 2010; Williamson and Ghani 2011).

*Firm’s specificity*, moreover, may be superimposed by Chilean legal restrictions on emissions standards. Among competitors, the specificity of the manufacturers must achieve market standards. Meeting legal demand is not the only hurdle of manufacturers’ specificity in the region. The *environmental factor*<sup>4</sup> of transaction costs that is legally imposed by the market is indicated by *emissions standards*, conceivably acting as another intrusion in a firm’s specificity, while increasing transactional complexity. *Emissions standards* and the *quality of fuels* play a critical role in the economy of Chile as measured by the truck industry (López, et al. 2010). A study performed by the Asociación Nacional Automotriz de Chile (ANAC) (Elías 2016), under the title *Estimación y Proyección de Emisiones del Modo Camionero en Chile*, described the projections of estimates of emissions standards with regards to the analysis of the *evolution* of the firms within the market segment of trucks and other commercial vehicles for the year 2030, as well as the impact of the emissions norms of nitrogen oxides (NO<sub>x</sub>) and carbon dioxide (CO<sub>2</sub>). Research shows that heavy-duty trucks vary in terms of their cargo role or task. Heavy-duty vehicles can be identified according to their use for long haulage, distribution, and special tasks outside and within city limits (Elías 2016; López, et al. 2010). For the most part, these vehicles are being fitted with technologically advanced equipment and engines that depict better standards of emissions and quality of fuel consumption (Muncrief and Rodríguez 2017). In 1992, the standards of emissions in Chile were introduced for the entry of new vehicles with the purpose to control and limit the quantity of environmental air contaminants emitted by these vehicles (López, et al. 2010, 14). The first norms were applied in the Metropolitan region and regions V and VI for light and medium-duty vehicles, which corresponds to the Environmental Protection Agency (EPA) that regulates the US emission standards Tier 2 Bin 8 or

<sup>3</sup> The human factor pertains to strategic or behavioral uncertainty driving transaction costs (Windsperger 1994, Habimana 2015, Yang 2010, Williamson and Ghani 2011).

<sup>4</sup> The environmental factor corresponds to increased transactional complexity and transactional uncertainty existing within the Chilean market (Windsperger 1994). Within the first case, the most observable environmental factor, as relating to asset specificity, transactional uncertainty and complexity, becomes *emission standards* determinant (Masten et al. 1991).

EURO 4 for regular fuel vehicles, and EPA Tier 2 Bin 5 or EURO 5 for diesel vehicles. Previous national standards are currently at the same levels as the European standards, EURO 5, for light and medium vehicles (Posada, et al. 2018, 4). However, heavy-duty trucks are not currently at the level of the European emission standards (Elías 2016). In Chile, the implementation of the EURO VI (6) standards was projected, at the time of this study, to be implemented by September 2020 (Ministerio Del Medio Ambiente; Subsecretaria del Medio Ambiente 2016, International Council of Clean Transportation 2018).

Under the optimal ‘efficiency’ assumption in TCE, Williamson (1975) determined that governance structures produce a ‘competitive advantage’ by economizing on transaction costs. Therefore, the technological feasibility to reach EURO 6 requires intensive capital and labor investments. This prospect removes competition. In other words, emissions standards not only reflect higher asset specificity (as in TCE), but also operate as a competition barrier (as ‘competitive advantage’ in classical economics and organizational management). The result impacts firm’s market share and their boundaries (performance). Nevertheless, not all transactions are equal. The *type* of asset being traded matters, not only for the selection and maintenance of the cost of transaction-specific administrative structures, but also for opportunistic behavior (Habimana 2015). Anderson’s (1988a) findings induced that asset specificity leads to a rise in opportunistic behavior (Habimana 2015). Additionally, David and Han (2004) found across TCE empirical studies that asset specificity as an independent variable greatly forecasts integration between sellers and buyers. Asset specificity may materialize further from emission regulations, yet it may be best estimated by the *type of trucks* being sold (Elías 2015, 75, 80). Identifying variables among the subgroups that determine the complexity between the *types* of heavy-duty Class 8 trucks sold, i.e., the boundaries among subgroups, becomes a focal point of the study.

*Hypothesis 1.6: Asset Specificity and the Firm Specific Factors of Emissions Standards and Types of Trucks:* Given that increasing asset specificity coincides with increased integration, then higher asset specificity of trucks, whether defined as higher emission standards and/or higher complexity of types of trucks, positively impacts the boundaries of the technologically invested manufacturer.

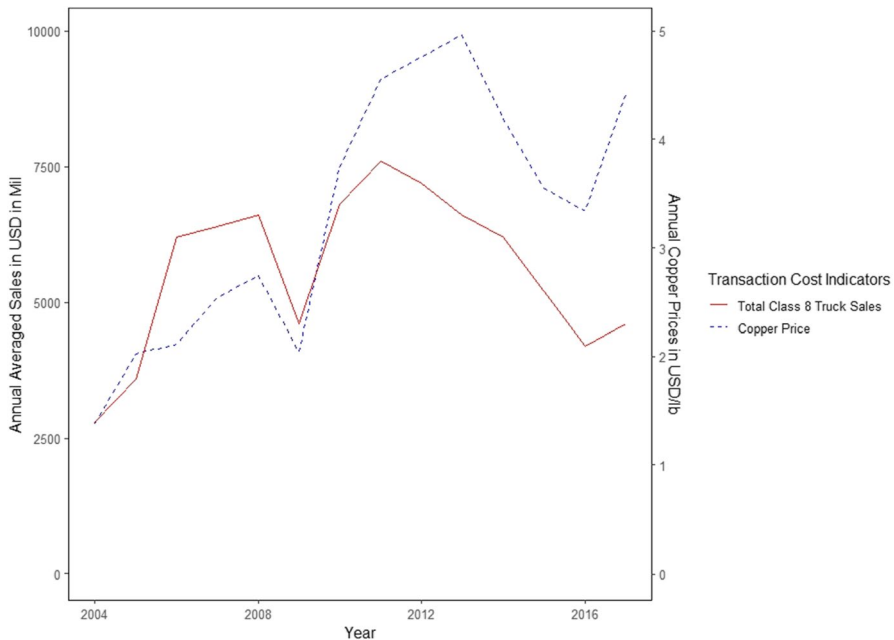
Thus, the TC determinants for the first case are measured as follows: the resource endowment capacity by offering international financing for their dealers, the autonomous adaptation of price of the type of truck, the coordinated adaptation and evolutionary effect of the exchange rate, the asset specificity through brand name capital, and the firm’s specificity by emission standards and complexity of the type of heavy-duty trucks produced. The consequential assumption of *uncertainty* is advanced in the second case.

### 3.2 Case 2: Determinants of uncertainty affecting the economy in Chile & firms’ boundaries

The uncertainty assumption of TCE theory states that contracts are incomplete given that agents suffer from bounded rationality (Shelanski and Klein 1995). A hierarchy of an MNE establishes contracts to lessen uncertainty, which may lead

to the assertion that uncertainty prompts vertical integration as claimed by Anderson (1988a). Moreover, environmental uncertainty has long plagued organizations (Buchko 1994; Thompson 2003, 159). Specifically, transactional uncertainty generates transaction costs (Windsperger 1994). Slater and Spencer (2000) further advanced the discussion of uncertainty with TCE. For instance, under the U.S. private trucking fleet industry, Maltz (1993) demonstrated the importance of a firm's evolution with TCA, whether to establish a distribution channel or alternatively to pursue industrial production. Through TCA, Klein et al. (1990) further stressed a positive relationship between external environmental volatility and the likelihood of establishing a foreign sales subsidiary, an integration channel. For a more comprehensive TCA, an uncertainty analysis of the Chilean truck sector provides insights on the determinants (See Appendix C<sup>5</sup>) that may directly impact the importation of trucks into the country and their integration with domestic dealers. The automotive market, specifically the truck sector (Appendix A, Table A-2), has been one that has had major growth within the last decade (Elías 2016). Consequently, this trend has been registered as an average expansion of real economic growth of 7.4% in the period between 2004–2014, resulting in more than 3 percentage points over the average annual growth of the total activity of the *Gross Domestic Product (GDP)* in the same period (OECD Economic Surveys: Chile 2018, 8). Harvie et al. (2009) reiterated policy-makers' importance of measuring GDP on a *per capita* basis for precise comparisons of purchasing power, while cautioning against its mischaracterization with regional well-being (Kravis et al. 1978). Overlapping with contingency and classical organizational theories, higher environmental volatility of open export markets, namely the Chilean market in this case, would reduce the centralization of manufacturers' structures as importers in the market (Flynn et al. 2016, Lawrence and Lorsch 1967). With the findings of Bejan (2006) and Haddad et al. (2013) on open trade, Chile's lack of export diversification may result in higher volatility (Čede, et al. 2016). As alternative sources of uncertainty, reciprocal interdependence and interconnectedness across the producers' supply chains generate complexity of governance structures accompanied with their transaction costs (Wu and Pagell 2011, Flynn et al. 2016). The investigation into uncertainty induced by environmental turbulence becomes a requirement for further analysis via empirical research of asset specificity (Macher and Richman 2008; Harrigan 1986). Nevertheless, conventional TCE establishes that the involvement of vertical integration of a hierarchy is to defy higher uncertainty and to attain higher asset specificity (Holmström and Roberts 1998, 92, Kvaløy 2007). Other studies refute such an oversimplification

<sup>5</sup> Appendix C (Figure C-1 through Figure C-8) illustrates and defines a comprehensive outlook of the impact of the total sales of trucks in Chile from 2004 to 2014 relating to (1) the tendency of the GDP (PIB), (2) real investments, namely gross fixed capital formation (GFCF) or the inversion real as Formación Bruta de Capital Fijo (FBKF), the macroeconomic concept used in official national accounts like the European System Accounts, where only the net additions to fixed assets are measured (Lequiller and Blades 2014), (3) investments of equipment of transportation, (4) copper prices, (5) the parity between CLP and USD, (6) interest rate in Chile, (7) Monthly Consumer Confidence Index in Chile as referred to as Monthly Indicator of Business Confidence (IMCE), and (8) tax revenues in the automotive sector in Chile (Elías 2015, 76–77, 79).



**Fig. 1** Co-movement of truck sales in USD (in Mil) & the price of copper in USD/lb

(Ruzzier 2009, Gibbons 2005, 207, Holmström and Roberts 1998). Hence, pursuing integrated processes within a MNE truck manufacturer in order to reduce uncertainty may not always translate into efficiency. Evaluating *hypotheses 2.1* and *2.2* becomes the second case for a more inclusive TCA of truck manufacturers. Given the wide variety of measurement constructs for an TCE empirical analyses of environmental uncertainty (Macher and Richman 2008), this case examines the measurement of *demand uncertainty* of truck sales to be dependent upon factors such as rare earth metals, particularly copper prices, and GDP per capita, interchangeably referred to in this study as *Producto Interior Bruto (PIB)* tendencies (Elías 2015).

Figure 1 displays the historical comovement trend between seasonally adjusted heavy-duty truck sales and copper prices, which suggests higher commodity prices; that is, copper price in the short-run may cause an appreciation of the domestic currency, CLP, because of a higher supply of the foreign exchange. Higher value of the CLP improves foreign direct investment (FDI) and transportation investments. These mechanisms of economies of commodity exporters, namely increased export revenues and GDP (PIB), may suggest a connection between commodity price movement of copper and those of exchange rate movements, which affect the boundaries of truck manufacturers that compete in the Chilean market (OECD Economic Surveys: Chile 2018, 8–9, Kohlscheen et al. 2016, Roch 2017, Elías 2015, 77–78). With Chile being a commodity-dependent country, *commodity prices* and *exchange rates* are likely determinants to shape large-scale transaction-based trade (Pedersen 2015, Cashin et al. 2004, Jiménez-Rodríguez and Morales-Zumaquero 2020). The upwards trend between sales and copper prices in Fig. 1 (and in Appendix C, Figure C-4),

provides evidence of this phenomena. Additionally, a weaker USD brings forth increased commodity prices (Akram 2009). Numerous studies in the U.S. such as Boivin and Giannoni (2006) and Clarida et al. (2000) noticed that the *interest rate*, i.e., the monetary policy rate, generates demand shocks that change sales in the automotive industry through reduction of output volatility (Ramey and Vine 2006). This relationship coupled with the global crisis of “super cycle of commodities” has not only contributed to domestic political initiatives and uncertainties in the country’s current economic model, but on how manufacturers organizationally respond to counter environmental uncertainty with respect to transaction costs (Roch 2017, Ballón and Molina 2017, 15–16). Both Gruss (2014) and Roch (2017) presented and expounded on the principle that the *confidence index* serves to gauge the Chile’s country specific commodity price index.

Hypothesis 2.1: External Uncertainty on Demand: Because copper is the main commodity in Chile, when annual copper prices decrease along with GDP and consumer confidence, so should the sales of units within the year.

Likewise, the study by Roch (2017) suggests that *tax revenues* of transportation may interfere with the mechanisms of impulse response functions (Parry 2008). As mentioned, the transaction specific investments, such as *transportation and equipment (capital goods) investments*, may narrow business strategies (Ellman 2006, Lian, et al. 2019, Elías 2015, 77). High technological investments incentivize manufacturers to forfeit alternative trade, by rewarding a more desirable prospect of higher price purchases with high-quality trade (Ellman 2006).

Hypothesis 2.2: Facilitation of Transaction Cost Efficiency of Firms: Policies of transportation and equipment (capital goods) investments within the domestic Chilean market positively impact sales by enhancing the capital formations and capabilities of manufacturers, while higher tax revenues on the truck sector hinder sales.

As developed by Williamson (1983), intentional specificity through specialized or the transaction specific investments, such as technological investments, may create ‘maladaptations’ among the integrated governance structures of manufacturers that emerge given complexity and uncertainty induced by political factors, a process known as *contractual hazards* (Macher and Richman 2008). Likewise, Maher (1997) noted the potential of ex post opportunistic behavior emerging from relationship-specific investments; however, transaction specific investments are not without benefits. As these investments increase, coordinated adaptations likewise increase in relevance, steering the market to internalize and form more coordinated and centralized hierarchies (Macher and Richman 2008; Alonso et al. 2015). Even with such findings in TCE, challenges with connecting empirical analyses with TCE theory remain an ongoing research endeavor (Klein and Shelanski 1995). Kaiser and Obermaier (2020) also voiced concern identifying the *direction of causality* between vertical integration and firm performance, which alternates on the firm’s precarious situation given competitive pressure. By this premise, TCE fails to predict hierarchical structures in the context of uncertainty (Macher and Richman 2008; Klein et al. 1990); or at best, TCE empirical results remain inconclusive (Klein et al. 1990). David and Han (2004) also noted further limitations of current TCE empirical studies, such as conflicting interpretations and disparities with measurement constructs of asset specificity, uncertainty, and transaction costs. However, the interpretations

of their findings must be viewed with caution, given that TCE research studies show that uncertainty affects governance structures where asset specificity is relevant to the transaction (David and Han 2004).

For this reason, the Chilean market indicators of external environmental uncertainty and unanticipated changes are addressed. Consequently, this second case prioritizes the impact of averaged annualized *total truck sales* in USD as the basic unit of analysis with respect to PIB, copper prices, investments in equipment for transportation, Monthly Consumer Confidence Index as Indicador Mensual de Confianza Empresarial (IMCE), and tax revenues from the automotive sector (Elías 2015, 77–78). Unlike the panel vector autoregressive (VAR) approach undertaken by Roch (2019) from commodity price shocks, for this uncertainty analysis, a time series VAR will estimate the impulse response functions of shocks to PIB and sales. Since the dynamics of trucks sales are derived from residuals, then the shocks of VAR times series and panel VAR should remain comparatively similar (Canova and Ciccarelli 2013, Enders 2015, 314).

#### 4 Data description and methodology

Despite panel analysis being adequate for the estimation of transaction costs across these firms, several fundamental issues emerge from dynamic cross-sectional analysis (Macher and Richman 2008). First, as Macher and Richman (2008) assessed, the most obtrusive shortcoming of panel data estimation is the lack of control for unobserved heterogeneity (Certo and Semadeni 2006). Next, when treating the dependent variable as a transaction for each truck unit sold as count, panel VAR models will likely have dynamic interdependency, leading to estimation problems (Canova and Ciccarelli 2013). A panel generalized linear model (GLM), or multi-level model as well as other extensions of GLMs, would likely violate the conditional independence assumption of dataset given the covariates; that is, complex autocorrelation (McCulloch 2000; Certo and Semadeni 2006). Second, estimation of each firm will require a higher number of degrees of freedom, which results in inadequate estimates of parameters given the remaining degrees of freedom. In like manner, GLM coefficient estimates are similar to those of generalized estimating equations (GEE) regression, which are intended for longitudinal data structures (McCulloch 2000). To properly address these empirical hurdles, the two sets of hypotheses in this study correspond to each case's respective dataset as follows: the cross-section count data for the first case on TC determinants, and the times-series dataset for the second case on determinants of uncertainty. Both sets of empirical models similarly follow the Box and Jenkins (1976) method for model fittings (McCullagh and Nelder 1998, 21).

#### 4.1 Design for first set of hypotheses: count data models for Case 1

Pertaining to the first set of hypotheses, this first dataset details unique TC determinants that ultimately influence the number of types<sup>6</sup> of trucks sold as external market transactions. Notably, the firm's inter-organizational structures hold a positive relationship with transaction frequency, degree of environmental uncertainty and asset specificity (Habimana 2015). Thus, the dependent count variable selected is the quantity of types of units sold as recorded for each  $i^{\text{th}}$  observation entry that is impacted by TC determinants with regards to the producers' boundaries. Each  $i^{\text{th}}$  observation reflects *each contractual order* placed for a specific *quantity* and *type* of truck sold:

$$\text{typesold}_i = y_i \forall i = 1, \dots, 1,481. \quad (1)$$

The strict positively skewed distribution of the dependent values ( $y_i = 0$ ) indicate that zero units were sold or that the information about a particular order is unavailable (Appendix D, Figure D-1). The dataset for the first case was retrieved from Asociación Nacional Automotriz de Chile (ANAC) between years 2014 to 2017. This dataset consists of 8 collected, brand-based, cross-sectional data variables compiled from among 12 countries, and are comprised of a random sample of 21,742 heavy-duty trucks and tractors sold in the Chilean market. These 1,481 observed transactional orders placed by the dealers consists of the 21,742 trucks sold within this sample. The 1,481 contracted orders consist of 10 types of trucks that are produced across 21 out of 28 distinct brands of manufacturers that compete in the Chilean market (from 2014 to 2017). (See Appendix A, Figure A-2). Determinants are labeled accordingly: type of truck unit sold ( $\text{typesold}_i$ ) as dependent count variable; while price of the type of unit sold in thousands USD ( $\text{price}_i$ ), whether internationally financed by manufacturer ( $\text{interfin}_i$ ), whether manufactured truck and its structural operations originate from the EU ( $\text{origin}_i$ ), annual exchange rate of EUR to USD ( $\text{erate}_i$ ), emissions standards of the truck unit ( $\text{emissions}_i$ ) for complexity, type of heavy-duty truck ( $\text{type}_i$ ), and brand culture of the manufacturer ( $\text{brand}_i$ ) as regressors. Of the listed variables,  $\text{interfin}$  and  $\text{origin}$  are binary, such that  $\text{origin}_i \text{erate}_i$  becomes an interaction term; and  $\text{emissions}$ ,  $\text{brand}$ , and  $\text{type}$  are qualitative variables. (Refer to Appendix A, Table A-3 and Table A-4, for descriptive statistics of the dataset.)

For each of the 1,481 observed truck orders, the number or count of types of units sold can retain an input value of zero truck sales and can strictly only take on such

<sup>6</sup> *Types of units* refer to strictly both heavy-duty tractors and trucks without trailers or equipment that are categorized into Class 8, i.e., weighing above 15 tons or around 32,000 lbs. The ten types of units within the study loosely follows the U.S. Federal Motor Carrier Safety Administration (FMCSA) vehicle configurations under the U.S. Department of Transportation (DOT) and are defined as follows: *cargo* for general freight, *faena* for dump trucks, *forestall* for forestry, *mixer* for cement trucks, cement mixers, or concrete mixer, *other* for miscellaneous or other complex and off-assembly line trucks, *reparto* for general straight trucks that are non-tractors designed for wide application, *rigids* for rigid trucks, *tolva* and *tolva6x4* for severe (dump) duty application such as mining or construction sites, *tractor* for tractors (Condon 2012, Elías 2015, 75).



nonnegative integers. Consequently, this analysis hinges on the population regression as expressed by  $E(Y_i|x_i)$ , such that the linear models are as follows (McCullagh and Nelder 1998, 26, Wooldridge 2013, 604–5):

$$E(Y_i|x_i) = \mu_i = \sum_1^p x_{ij}\beta_i \text{ s.t. } i = (1, \dots, n). \quad (2)$$

For each count observation of  $i^{\text{th}}$ , the value of  $j^{\text{th}}$  covariate is denoted as  $x_{ij}$ , where the vector of unknown parameter signifies  $\beta$  (Ver Hoef and Boveng 2007; Smyth 1989). However, count data models, particularly linear models, possess several shortcomings as the estimator of ordinary least-squares (OLS),  $\hat{\beta}$ , namely retaining values of explanatory regressors, rendering the condition  $X\beta < 0$ . The model matrix is denoted by  $X$  with the notion of  $c$  as the constant, such that  $X\beta = c + X_1\beta_1 + \dots X_i\beta_i$  (Abdulkabir, et al. 2015; Haberman 1977; Wooldridge 2002, 645). The simplest remedy to guarantee strict positivity of variables would be the implementation of a natural log transformation, among other solutions such as to use  $\log(x+1)$ , in order to linearize each model and ensure normality<sup>7</sup> (Wooldridge 2013, 605). However, log transformations possess drawbacks (Wooldridge 2002, 662). Thus, for count data models, their asymptotic properties would be optimal to select functional forms with *natural links* as to guarantee positivity for any value of  $x$  as well as any parameters (Kaufmann and Fahrmeir 1985). As prescribed in the usual treatment of count data models, empirical research opined and opted for the most popular exponential functional form for GLMs, which is  $E(Y_i|x_i) = \exp(x_i^T \beta)$  to ensure positivity, knowing that  $y_i$  cannot reach any upper bound limit (Zeileis et al. 2008, 132–3, Smyth 1989, Wooldridge 2002, 645). Among such GLMs, Poisson and Negative Binomial (NB) models possess the ability to assess their mean count by discrete probability distributions and provide minimal upward or downward bias, the deviation between a fit parameter and its true value within a population (Plan 2014). These GLMs<sup>8</sup> for count data imply heteroscedasticity, i.e., non-normal error distributions, while the other classical assumptions still apply (Zeileis et al. 2008). Accurate assessment of the boundaries of competing heavy-duty truck firms entails identifying the best fit GLM given over-dispersion. Thus, in this TCA, the Poisson, Quasi-Poisson (quasi-maximum likelihood estimation, QMLE), Negative Binomial (NB), and Zero-Inflated Poisson (ZIP) models are evaluated. (See Appendices B-1 through B-8 for technical derivations and model assumptions.) For the corresponding GLMs, *model 1* through *model 4*, the reference vehicle for the regression analysis is defined as follows: *cargo* as type of unit, *Chevrolet/Isuzu* as brand culture, no international financing options as offerings, *EPA2004* as the emission standards, and non-EU units as manufacturing origin. Due to perfect

<sup>7</sup> See Appendix C for normality check of count data models.

<sup>8</sup> Such GLMs comprise of three distinct characteristics: (1) the linear predictor  $\eta_i = x_i^T \beta$  such that the expected response  $\mu_i$  must depend on the observations of vector  $x_i$  and on the parameters  $\beta$ , (2) the distribution of dependent variable  $y_i|x_i$  is linear exponential family, and (3) monotonic transformation can link  $\eta_i$  and  $\mu_i$ :  $\eta_i = g(\mu_i)$ . Hence, the linear predictor is regarded as:  $\eta_i = \log(\mu_i)$  (McCullagh and Nelder 1998, 27, Zeileis, Kleiber and Jackson 2008, Kleiber and Zeileis 2008, 121–2).

multicollinearity, country origin ( $country_i$ ) was removed. (See Appendix D). Perfect multicollinearity in  $x_i$  within the exponential Poisson model (*model 1*) will demonstrate that multiple solutions exist for the intercept ( $\beta_0$ ), namely  $\beta_0$  is not a unique solution to  $\max_{\beta \in B} E[\downarrow_i(\beta)]$  as follows:

$$y_i = \exp(x_i^T \beta + \beta_1(D_{1i}erate_i) + \beta_2(D_{2i}erate_i) + \varepsilon_i) \forall i = 1, \dots, 1,481, \quad (3)$$

where  $\beta$  is the vector of unknown parameters and the transposed vector is  $x_i = (\text{constant} + price_i + interfin_i + emissions_i + type_i + brand_i)$ . The variables  $interfin_i$  and  $origin_i$  are binary dummies, and  $emissions_i$ ,  $type_i$ , and  $brand_i$  are qualitative dummy variables. The interaction term  $D_{1i}$  defines *origin-nonEU*, at a value of 1 for non-European origin, else  $D_{2i}$  is 0. Term  $D_{2i}$  captures European as origin (*origin-EU*). Likewise, the quasi-Poisson model (*model 2*) addresses the issue of over-dispersion (See Appendix B2) within a Poisson model as follows:

$$y_i = \exp(x_i^T \beta + \beta_1(D_{1i}erate_i) + \beta_2(D_{2i}erate_i) + \varepsilon_i) \forall i = 1, \dots, 1,481, \quad (4)$$

where  $x_i$  and other indicators remain unaltered. To determine the adverse effects of transaction costs with respect to heavy-duty producers' boundaries, consider the NB model (*model 3*) as shown in Eq. (5):

$$y_i = \exp(\alpha + x_i^T \beta + \beta_1(D_{1i}erate_i) + \beta_2(D_{2i}erate_i) + \varepsilon_i) \forall i = i = 1, \dots, 1,481, \quad (5)$$

where  $\varepsilon_i$  denotes unobserved heterogeneity, which follows a gamma distribution,  $\alpha$  accounts for overdispersion, and  $x_i$  and other indicators remain unaltered. To account for inputted zero entries, the ZIP model (*model 4*) is as follows:

$$y_i = 0 * \pi_i + (1 - \pi_i) * \exp(x_i^T \beta + \beta_1(D_{1i}erate_i) + \beta_2(D_{2i}erate_i) + \varepsilon_i) \quad (6)$$

$$\forall i = i = 1, \dots, 1,481$$

where  $\pi_i$  denotes the inflated probability of observing zero count such that the zero-inflation model coefficients are  $type_i$  and  $brand_i$ . Hence, the ZIP model classifies and removes 'the type' and 'the brand' of trucks that are always zeroes (not sold) against the non-zeroes (trucks sold), which are then fitted in a Poisson regression. The count model coefficients that follow a Poisson distribution are  $x_i(\text{constant} + interfin_i + origin_i + emissions_i)$  and the interaction terms *origin-nonEU*; *erate<sub>i</sub>*, *origin-EU*; *erate<sub>i</sub>*, with price excluded as some prices are not listed for the trucks that are not sold.

## 4.2 Design for the second set of hypotheses: time series models for Case 2

The second set of hypotheses pertains to an uncertainty assessment of the Chilean market that interferes with the importation of trucks. The second dataset as a time series was compiled from ANAC 2004–2017 (Elías, 2015, 2016, 2017), Central Bank of Chile (Banco Central de Chile), Global Rates (2017), the World Bank database (2017), and Chilean Institute of Rational Business Administration

(ICARE 2017–2018). For this time series-based uncertainty analysis, the sequence of the annualized total sales of heavy-duty trucks is estimated in USD millions with value-added tax (VAT) ( $avustotalsales_t$ ) as the dependent variable, which theoretically embodies the firms' boundaries. Hence, its conversion is as follows:

$$\bar{s}_t = (avustotalsalest) = \frac{\text{Sales in CLP (millions) with VAT included}_t}{\text{Annual Average Exchange Rate of CLP and USD}_t} \forall t = 2004, \dots, 2017, \quad (7)$$

where the factor, annualized total sales in CLP millions, is converted to USD millions—given that CLP floats with USD—in order to retain cohesion and simplification of the model's interpretation. Based on insights of cyclical sales in the transportation sector, the annualized variables and currency conversion adjust for seasonality (Lahiri and Yao 2006; Miron and Zeldes 1988). Corbae and Ouliaris (1986) determined that foreign exchange rates follow a random walk. Correspondingly, the selected variables share strong comovements (Appendix E, Figure E-1), indicating an expected correlation among residuals (Enders 2015, 314, Nelson and Plosser 1982, Ling, et al. 2013, De Long and Summers 1991, Fuentes 2011). The observed upward trend in Fig. 1 illustrates nonstationarity, by integrated order one,  $I(1)$ , which implies a unit root and possible cointegration between annual copper price and annualized, estimated total sales. Differencing the series achieves integrated order zero,  $I(0)$  (Appendix E, Figure E-2); and thus, these differenced exogenous variables of this study's uncertainty analysis are as follows: transportation and equipment (capital goods) investments ( $\Delta traninv_t$ ), annualized PIB (GDP) per capita of Chile measured in USD ( $\Delta pib_t$ ), tax revenue from the automotive sector in Chile measured in USD millions ( $\Delta taxrev_t$ ), price of copper in USD/lb ( $\Delta copprice_t$ ), and confidence index ( $\Delta conindex_t$ ). (See Appendix C, Table C-1 for summary statistics of the dataset for the second case.) With the common issue of overparameterization (Lack 2006; Koop and Korobilis 2010) while testing for omitted exogenous variables, the Akaike information criterion (AIC) suggested that the percent annual average of the interest rate in Chile, that is the monetary policy rate ( $\Delta irate_t$ ), and PIB ( $\Delta pib_t$ ) needed to be removed from the linear OLS and bivariate VAR(1) models.

Under this uncertainty analysis, the *time series OLS model (model 5)* addresses *unidirectional causality* among determinants. Model selection criteria recognizes the bias-variance tradeoff in a traditional regression. In essence, adding more lags reduces the sum of squared estimated residuals and increases additional coefficient estimation, at the expense of losing degrees of freedom; thus, highlighting the importance of Box and Jenkins (1970, 1976) approach (Hansen 2017; Stock and Watson 1988). The necessity of stationarity with a times series as noted by Nelson and Plosser (1982) can be observed by inspecting the correlograms while providing insights on model selection. Hence, the plotted autocorrelation function (ACF) may be used to detect a nonstationary series. The partial autocorrelation function (PACF) may uncover geometric decaying and thereby assist lag selection (Udom and Phumchusri 2014). For unit-root test, the Augmented Dickey-Fuller's (ADF) (1981) tests are used (Kleiber and Zeileis 2008, 164–6). (See Appendix E,

Table E-1). In Eq. (8), the linear OLS time series (*model 5*) depicts environmental uncertainty with respect to manufacturers' boundaries:

$$\Delta \bar{s}_t = c_1 + \Delta \mathbf{x}_t \boldsymbol{\beta} + \varepsilon_t \forall t = 2004, \dots 2017, \quad (8)$$

where  $\Delta avustotalsales_t$  as  $\Delta \bar{s}_t = \bar{s}_t - \bar{s}_{t-1}$  denotes the first difference of dependent variable, and exogenous regressors,  $\mathbf{x}_{tk}$ , are  $\Delta traninv_p$ ,  $\Delta taxrev_p$ ,  $\Delta copprice_p$ , and  $\Delta conindex_p$ . Given  $\varepsilon_t = \rho \varepsilon_{t-1} + v_t$  such that  $|\rho| < 1$  denotes stationarity, the term  $v_t$  is the idiosyncratic part of the error component and refers to the coefficient autocorrelation at lag one with an independent and identically distributed disturbance term,  $\varepsilon_t \sim iidN(0, \sigma^2)$ . The constant is represented as  $c_1$ .

To forecast the *multicausality* of commodity market price of copper for sales and PIB, a VAR model (*model 6*) is evaluated. Sims' (1986, 1989) VAR multivariate, especially bivariate, model possesses unique characteristics suitable for estimating more than one dependent variable, requires less restrictions (unrestricted), is data-oriented, and encompasses correlation of observed data. In addition, each variable can be explained by its own lag as well as past lags of other variables, and the explanatory variables can describe dynamic behavior, just to name a few functions (Enders 2015, 314). The functionality of using a multivariate, or multi-equation model, enhances the applicability of truly explanatory variables with economic theory, such as the *reverse* or *multi-causality* of vertical integration with sales performance and spatial competition theories for copper prices and exchange rates (Enders 2015, 345, Kaiser and Obermaier 2020). With a bivariate model, Blanchard and Quah (1989) demonstrated the decomposition of real GNP (Enders 2015, 325). Instead of gross national product (GNP), PIB (GDP per capita) becomes this case's second dependent variable (Kenneth 1988). By specifying a VAR model that includes relevant variables of interest (Clements and Mizon 1991), *hypotheses 2.1* and *2.2* become adequate means to empirically test for potential suggestions and recommendations regarding the boundaries of manufacturers' environmental uncertainty in Chile. Therefore, the second case advances the implementation of bivariate VAR models by Medina (2016) and Roch (2017) to assess uncertainty in the Chilean market. Unlike the time series OLS model, the VAR model is suitably equipped with three tools, namely, impulse response functions, variance decomposition, and Engle and Granger (1987) causality conducted via ADF tests, all of which yield similar results (Wooldridge 2013, 657, Enders 2015, 310, 346). To observe if reverse causation exists with respect to sales as manufacturers' boundaries and GDP (PIB) in Chile, consider the bivariate VAR(1) model (*model 6*) demonstrated in Eqs. (9) and (10):

$$\Delta \bar{s}_t = c_1 + \Delta \bar{s}_{t-1} + \Delta z_{t-1} + \Delta \boldsymbol{\beta}_k \mathbf{x}_{tk} + \varepsilon_{1t} \forall t = 2004, \dots 2017, \quad (9)$$

$$\Delta z_t = c_2 + \Delta \bar{s}_{t-1} + \Delta z_{t-1} + \Delta \boldsymbol{\beta}_k \mathbf{x}_{tk} + \varepsilon_{2t}, \quad (10)$$

such that  $\{\bar{s}_t\}$  and  $\{z_t\}$  are endogenous, and the term  $\Delta z_t$  signifies  $\Delta pib_t$ . Given stationarity, the exogenous regressors,  $\mathbf{x}_{tk}$ , are  $\Delta traninv_p$ ,  $\Delta taxrev_p$ ,  $\Delta copprice_t$ ,  $\Delta conindex_p$ . Sequences  $\{\bar{s}_t\}$  and  $\{z_t\}$  derive the impulse response functions. The constant components,  $c_1$  and  $c_2$ , account for the average growth, affecting the accuracy of

any estimated cointegrated vectors (Watson 1994, 2894). Lin and Tsay (1996) determined the lag order with AIC, in like manner, the lags of Eq. (9) are selected with lower AIC values. (See Appendix E, Table E-1). In similar approach by Anam and Hossain (2012), the restriction of additional lags of both the exogenous and endogenous are attested by correlograms, ACF and PACF. (See Appendix E, Figure E-3). The coefficients on a lag order of one (corresponds to one year) for sales and PIB are  $\Delta \bar{s}_{t-1}$  and  $\Delta z_{t-1}$ , respectively. Given a shortened time series, further lags contribute towards autocorrelation, i.e., serial correlation. Such lags may adversely reduce the explanatory power of the regressors. Cointegration Engle and Granger (1987) test is conducted to demonstrate that no cointegration is present; that is, no long-term co-movement relationship among the variables (Appendix E, Table E-5).

## 5 Results

### 5.1 Empirical results for Case 1: transaction cost analysis

To strengthen the empirical conclusions of TCA, diagnostic checks of the assumptions were performed, which resulted in the selection of the NB model (Breslow 1996). (See Appendix D for diagnostic checks.) Despite the QMLE regression being outperformed by the ZIP (*model 4*) diagnostics, the presence of possible model misspecification may have led to the weak estimations and hyper-inflated Type 1 errors (Perumean-Chaney, et al. 2013). As Perumean-Chaney et al. (2013) inferred, the Vuong test (Appendix D, Table D-4) indicated an improper mean and sample size that consequently fostered the result to favor a non-inflated Poisson regression (*model 1*) (Zeileis et al. 2008). Nevertheless, with Poisson (*model 1*) and QMLE (*model 2*) yielding similar results, the AIC of the NB model is smaller in contrast, implying that the NB model has higher parsimony given the adequate estimation of its covariates (Abdulkabir, et al. 2015). (See Appendix D, Figure D-3 for further diagnostics between QMLE and NB models.) The dispersion parameter did change and was significantly reduced below the value of 1, as captured by  $\theta^9$  with a value of 0.712 (Table 1). Unobserved heterogeneity appears to be the root cause of concern, which the NB model most appropriately addresses via the gamma distribution (Appendix D, Figure D-4). NB model (*model 3*) yields the most accurate coefficient estimates.

Table 1, as exemplified by *model 3*, indicates that the competitors in the Chilean market operate under immediate adaptation from price signaling. *Ceteris paribus*, an increase of *price* per unit, namely an increase of one thousand USD, infers an expected decrease of 0.996 truck units per contractual order (almost one truck unit). An annual anticipation of price inflation of around one thousand USD per vehicle reveals that dealers (buyers) are not willing to forgo a heavy-duty truck over this price increase. However, with all other variables remaining unchanged, a substantial

<sup>9</sup> In the results,  $\theta$  is the precision of the multiplicative random effect and corresponds to  $\frac{1}{\{\sigma^2\}}$  in literature.

**Table 1** Importance of TC determinants for truck manufacturers' boundaries

<i>Predictors</i>	Poisson <i>Model 1</i>	Quasi-Poisson <i>Model 2</i>	NB <i>Model 3</i>	ZIP <i>Model 4</i>
constant	0.151 (0.149)	0.151 (0.763)	0.273 (0.712)	1.327*** (0.089)
price	-0.002*** (0.0003)	-0.002* (0.001)	-0.004*** (0.001)	
interfin	1.853*** (0.067)	1.853*** (0.341)	1.904*** (0.286)	0.730*** (0.023)
origin-nonEU*erate	1.833*** (0.098)	1.833*** (0.501)	1.688*** (0.520)	0.961*** (0.072)
origin-EU*erate	-0.183* (0.106)	-0.183 (0.542)	-0.680 (0.474)	0.724*** (0.071)
emissions*EPA2010	-0.311*** (0.060)	-0.311 (0.307)	-0.274 (0.286)	-0.432*** (0.059)
emissions*EPA98	-0.576*** (0.050)	-0.576** (0.254)	-0.682*** (0.222)	0.129*** (0.048)
emissions*EURO3	-2.132*** (0.120)	-2.132*** (0.613)	-1.965*** (0.375)	-0.950*** (0.106)
emissions*EURO4	-0.269*** (0.070)	-0.269 (0.358)	-0.277 (0.298)	-0.227*** (0.023)
emissions*EURO5	-0.289*** (0.067)	-0.289 (0.345)	-0.292 (0.288)	-0.026 (0.021)
emissions*EURO6	-0.345*** (0.125)	-0.345 (0.640)	0.043 (0.505)	-0.287*** (0.106)
type*Faena	0.112*** (0.035)	0.112 (0.179)	0.285* (0.157)	
type*Forestal	0.606*** (0.036)	0.606*** (0.187)	0.861*** (0.211)	
type*Mixer	0.155*** (0.060)	0.155 (0.306)	0.428 (0.279)	
type*Other	-0.726*** (0.066)	-0.726** (0.339)	-0.336 (0.224)	
type*Reparto	-1.762*** (0.383)	-1.762 (1.958)	-1.705** (0.742)	
type*Rigids	-2.698*** (0.185)	-2.698*** (0.947)	-2.549*** (0.343)	
type*Tolva	0.061** (0.028)	0.061 (0.145)	0.292** (0.127)	
type*Tolva6X4	-0.864 (1.007)	-0.864 (5.155)	-0.771 (1.578)	
type*Tractor	0.093*** (0.021)	0.093 (0.107)	0.282*** (0.094)	

**Table 1** (continued)

<i>Predictors</i>	Poisson <i>Model 1</i>	Quasi-Poisson <i>Model 2</i>	NB <i>Model 3</i>	ZIP <i>Model 4</i>
brand*DAF	2.917*** (0.189)	2.917*** (0.965)	3.467*** (0.870)	
brand*Dongfeng	0.327*** (0.096)	0.327 (0.492)	0.532 (0.332)	
brand*FAW	0.005 (0.096)	0.005 (0.492)	-0.003 (0.290)	
brand*Ford	0.075 (0.048)	0.075 (0.244)	0.192 (0.333)	
brand*Foton	0.558*** (0.090)	0.558 (0.459)	0.622* (0.343)	
brand*Freightliner	-0.779*** (0.082)	-0.779* (0.419)	-0.655 (0.415)	
brand*HINO	-1.142*** (0.073)	-1.142*** (0.372)	-1.073*** (0.381)	
brand*HyundiaVC	-2.076*** (0.097)	-2.076*** (0.496)	-1.989*** (0.373)	
brand*International	-0.935*** (0.079)	-0.935** (0.402)	-0.903** (0.398)	
brand*Iveco	2.854*** (0.183)	2.854*** (0.937)	3.442*** (0.851)	
brand*JAC	0.756*** (0.077)	0.756* (0.395)	0.805*** (0.306)	
brand*Kenworth	0.191** (0.097)	0.191 (0.497)	0.351 (0.362)	
brand*Mack	-0.979*** (0.056)	-0.979*** (0.288)	-0.905*** (0.326)	
brand*MAN	0.290 (0.179)	0.290 (0.915)	0.814 (0.873)	
brand*Mercedes-Benz	1.728*** (0.174)	1.728* (0.893)	2.270*** (0.866)	
brand*Renault	1.183*** (0.188)	1.183 (0.964)	1.650* (0.917)	
brand*Scania	1.231*** (0.177)	1.231 (0.907)	1.697* (0.876)	
brand*Shacman	-1.046*** (0.132)	-1.046 (0.677)	-1.093*** (0.337)	
brand*Volvo	1.821*** (0.179)	1.821** (0.918)	2.378*** (0.887)	
Observations	1,481	1,481	1,481	1,481
Log-likelihood	-15,900.980		-5,154.727	-16,499.450
theta			0.712*** (0.027)	



**Table 1** (continued)

	Poisson	Quasi-Poisson	NB	ZIP
<i>Predictors</i>	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>
AIC	31,879.960		10,387.450	

Significance at less than 1 percent level is “\*\*\*”, less than 5 percent level is transcribed as “\*\*”, 10 percent level as “\*”. Estimated coefficients and standard errors (in parentheses) are from Eqs. (3) through (6). Given the number of iterations, the omitted outputs, being those not applicable, are undetermined coefficients of Sinotruk brand. Their cargo types of units are neither non-EU in origin, being Chinese, nor regulated under EPA2004 emission standards (such as adhering only to EURO emissions standards) and does not provide international financing for their dealers

and unanticipated rate of change in price by ten thousand USD per truck is expected to decrease each contractual transaction by almost four trucks. Hence, dealers are unwilling to agree on a contractual order of trucks when its negotiated change in the offer price is equivalent to the loss in value of one truck unit per order. Moreover, the transaction cost efficiency of the non-European based manufacturer and their internal structural operations, as indicated by *origin-nonEU\*erate*, economizes on shipping and delivery costs given a rise in the exchange rate of EUR to USD. With all else fixed, a unit increase in the EUR-USD exchange rate is anticipated to provide higher competitive performance for non-European preference over European. In this case, the change of factor in exchange rate indicates that five more non-European trucks are sold per contractual order. However, according to *origin-EU\*erate*, the exchange rate fluctuations do not significantly impact European-based manufacturers' boundaries for several reasons. First, *coordination adaptation* by offering international financing to dealers positively increases the boundaries and unit sales per order, regardless of the fleet size. And second, the decision of the dealers to place a contractual order of types of trucks are not only based on price and the exchange rate but rely on brand image and asset specificity, which involves providing services, offering warranties, and retaining the residual value of each truck. Except for the Chinese brands, Foton and JAC, the European brand reputation of DAF, Mercedes-Benz, Renault, Scania, Volvo, and Iveco positively impact their boundaries. Non-European brands of HINO, HyundaiVC, International and Shaman, with the exception of the European brand MAN, retain higher transaction costs. When interpreting *model 3*, the coefficient estimate (-2.549) for the category ‘rigid’ on predictor ‘type’ embodies the difference value of -2.398 in higher asset specificity with respect to ‘cargo’ (baseline truck). Thus, when calculating the exponential value of -2.398, an expected 90% decrease in sales difference results for a *rigid* truck being ordered over a *cargo* truck.

## 5.2 Empirical results for Case 2: uncertainty analysis

As part of the uncertainty analysis, Table 2 depicts the results of *model 5* for environmental uncertainty regarding boundaries. Table 3 presents the results of *model 6* for reverse causation with respect to sales as manufacturers' boundaries and PIB in Chile.

**Table 2** Model 5: Unidirectional causality of transportation investments

Equation (8) dependent variable: $\Delta \text{avustotalsales} (\Delta \bar{s})$					
<i>Predictors</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-ratio</i>	<i>p-value</i>	
Constant	66.0856	172.622	0.3828	0.7118	
$\Delta \text{traninv}_t$	956.802	232.241	4.120	0.0033	***
$\Delta \text{copprice}_t$	707.673	395.591	1.789	0.1114	
$\Delta \text{taxrev}_t$	895.796	587.494	1.525	0.1658	
$\Delta \text{conindex}_t$	-13.9677	24.6008	-0.5678	0.5858	

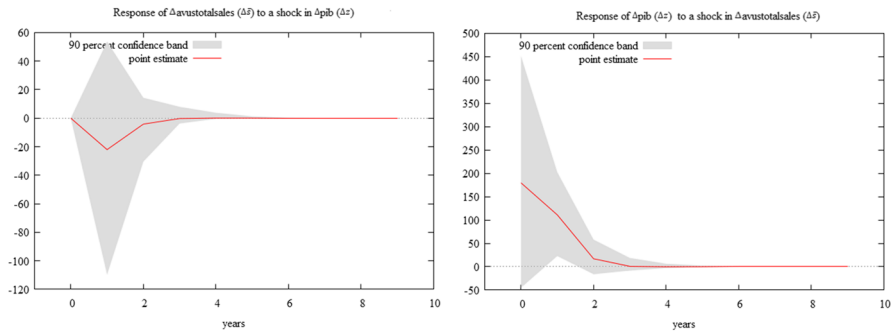
**TABLE 3** Model 6: Multidirectional causality of commodity market prices for sales & PIB

Equation (9) dependent variable: $\Delta \text{avustotalsales} (\Delta \bar{s})$					
<i>Predictors</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-ratio</i>	<i>p-value</i>	
Constant	271.602	263.788	1.030	0.3504	
$\Delta \text{avustotalsales}_{t-1} (\Delta \bar{s}_{t-1})$	0.130658	0.174015	0.7508	0.4866	
$\Delta \text{pib}_{t-1} (\Delta z_{t-1})$	-0.0588456	0.223121	-0.2637	0.8025	
$\Delta \text{traninv}_t$	1277.35	258.137	4.948	0.0043	***
$\Delta \text{copprice}_t$	1188.54	379.213	3.134	0.0258	**
$\Delta \text{irate}_t$	-23.1767	120.000	-0.1931	0.8545	
$\Delta \text{conindex}_t$	5.15002	30.5336	0.1687	0.8727	
Equation (10) dependent variable: $\Delta \text{pib} (\Delta z)$					
<i>Predictors</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-ratio</i>	<i>p-value</i>	
Constant	787.361	297.313	2.648	0.0455	**
$\Delta \text{avustotalsales}_{t-1} (\Delta \bar{s}_{t-1})$	0.271216	0.196130	1.383	0.2253	
$\Delta \text{pib}_{t-1} (\Delta z_{t-1})$	0.0601254	0.251478	0.2391	0.8205	
$\Delta \text{traninv}_t$	-160.686	290.944	-0.5523	0.6045	
$\Delta \text{copprice}_t$	1257.65	427.407	2.943	0.0322	**
$\Delta \text{irate}_t$	-50.6775	135.251	-0.3747	0.7233	
$\Delta \text{conindex}_t$	39.7116	34.4142	1.154	0.3007	

In Appendix E, Table E-2, the Portmanteau test, that is the Ljung-Box (LB) test, fails to reject the null hypothesis, such that the data are independently distributed as achieved through randomness of sampling. The F-score suggests that transportation investments cause seasonally adjusted sales to increase, and likewise, copper prices drive Chilean GDP (PIB)

In Table 2 and Table 3, higher transportation investment significantly diminished environmental uncertainty and improved the demand for trucks in Chile. Table 3 shows that the demand for copper contributed to the rise in PIB per capita and to demand for trucks. The dynamics of truck sales are best indicated by the positive demand for copper, Chile's main export commodity, rather than the industry's strict reliance on PIB (GDP).

Despite the common applications of the use of VARs with differenced data as noted in empirical literature, the need for restrictions as identified by Faust and Leeper's bivariate models (1997), as well as limitations of VAR forecasting; for example, sensitivity in Cholesky ordering of variables, are well documented



**Fig. 2** Impulse Response Analysis

**Table 4** Structural break tests

(a) Chow test for structural break at observation 2007—Null hypothesis: no structural break
Test statistic: $F(2, 6) = 1.30507$ [0.3384]
(b) Chow test for structural break at observation 2010—Null hypothesis: no structural break
Test statistic: $F(5, 3) = 0.391373$ [0.8312]
(c) Test for normality of residual—Null hypothesis: Error is normally distributed
Test statistic: $\text{Chi-square}(2) = 0.495$ [0.7806]

[In brackets] are the p-values. See Appendix E for further modeling specifications on augmented regression for Chow test (b). Chow test (a) displayed collinearity among some variables, which were omitted

(Keating 2002; Heiden 2015). As depicted by the wide 90 percent confidence bootstrap band in Fig. 2, the reliability of structural shocks interpretations ties directly with business cycle theories. More relevant dynamic variables as sources of shocks, such as labor supply with respect to PIB, should be reconsidered and may more accurately explain the changes of PIB than those parameters estimated in *model 6* (Shapiro and Watson 1988). Nevertheless, an annual change in copper price may be viewed as the forecasting indicator for a change of sales for truck imports and PIB.

### 5.3 Robustness checks

As cited by various critiques, Nelson and Plosser (1982) tests, as exemplified by the Dickey and Fuller (1979) unit roots test, posed a vital weakness regarding the presence of structural breaks; that is, an unanticipated shift within the series (Charles and Darné 2012; Luitel and Mahar 2015). This study's empirical linear OLS regression applied a unit root test, specifically the ADF (1984) test (Said and Dickey 1984) without structural breaks, a potential misspecification (Koo and Seo 2015). (See Appendix E, Table E-5). Zivot and Andrews (1992) and their extension by Lumsdaine and Papell (1997) endogenous structural break tests indicate break points (Ling, et al. 2013). Yet, these data were checked using the classical Chow (1960) test by splitting the OLS sample (*model 5*) to determine if any structural breaks were

present (Luitel and Mahar 2015; Ogbonnaya and Ota 2018; Hansen 2001). As displayed below in Table 4, two Chow tests were conducted, one was a priori break date for year 2007 for the financial recession, and the second was a posteriori observation for the economic downturn in 2010.

## 6 Discussion and limitations

The choice of the ‘type of units sold’ as ‘complexity of the asset’ appears to be a reasonable option of measurement for transaction costs among manufacturers. The number of truck type ordered is used as an evaluative unit of frequency of transactions as defined by its asset specificity. The empirical results of Table 1 may have been regarded as invalid, if and only if, the increased organization costs would have lowered asset specificity (Masten et al. 1991). This prospect does not appear to be evident because rising asset specificity as with higher truck specialization, is marked by a higher burden of transaction costs. Thus, *hypothesis 1.1 (Type of Units Sold as Firm Performance and Complexity Indicator)* is accepted.

TCE empirical research has centered its attention on relationship-specific investments as it pertains to vertical integration (Macher and Richman 2008; Klein et al. 1978). From Holmström and Roberts’ (1998) view of governance structures of the firm and to ensure unenforceable contracts of external market transactions, offering international finance becomes an alternative, even indispensable, tool for handling holdup dilemmas and market imperfections (B. Klein 1980; Kim 2019). This finding, which parallels Anderson et al. (2000) study of U.S. automotive firms’ internalization of suppliers, accentuates that a loss of high-powered incentives may exceed transaction costs of external suppliers. This occurrence pertains to complex systems of interactions, which require a reduction of transaction costs. Hence, TCE describes selecting the most ‘efficient’ internal organization features as a tradeoff between incentive intensity and cooperative adaptation. By concentrating the decision-making authority in a hierarchy, the manufacturers’ *cooperative adaptation* improves (Argyres 2009). Likewise when considering the decision to internalize dealers into the manufacturers’ sales force, the *resource capabilities* to offer financing to their dealers improve manufacturers’ boundaries. To smooth the price system’s rigidity, despite the degree of heterogeneous assets among types of trucks, asset price motivates and steers behaviors, particularly when incentivization through offering international financing distorts dealers’ willingness-to-pay (Zenger et al. 2011; Argyres and Zenger 2012). Specialized exchange and dependence among manufacturers and their dealers become enveloped by theories of integration through incentives (Bresnahan and Levin 2012). Given globalization, several studies have emphasized the asymmetric dependence structures among industrial relationships as held among manufacturers (Heide and John 1988, 1990; Joshi and Stump 1999). In addition, vertical control regulates environmental uncertainty (Macher and Richman 2008; Helfat and Teece 1987). Hence, price discrimination generates market forces to promote vertical integration, causing their downstream dealers to become vulnerable to increase price sensitivity. Regardless of the longevity of the manufacturer, theories of vertical integration begin with these market imperfections, while neoclassical

theories stress that vertical integration is a solution to the market power problems with up and down streaming (Kim 2019; Lieberman 1991). *Coordinated adaptation* and *opportunism* by manufacturers as exemplified by offering international financing may be viewed as a supply relationship among manufacturers (upstream parties) with their respective dealers in the market (downstream parties). This finance offering economizes and functions as a convenient solution to alleviate an extensive holdup problem with vertical integration (Holmström and Roberts 1998, 74). *Hypothesis 1.2 (Resource Endowment Capabilities)* is therefore accepted.

The most palpable organizational structure of manufacturers in an international market is the integration of a channel and centralization. Undertaking a TCA, Klein et al. (1990) accentuated a positive association between the probability of establishing a foreign sales subsidiary, i.e., an integration channel, and the volatility of the external environment. Williamson (1993) inferred that motivation of firms to form relationships was rooted in their desired reduction of transaction costs. Integration, namely the conceptual leap of drawing within-firm transactions by including their dealers, or as in practice with their suppliers, inside the firm, would theoretically eliminate market incentive and retain strategic inefficacy for manufacturers (Baker et al. 2001). John and Weitz's (1988) concluded that higher uncertainty warrants higher level of channel integration. In view of Anderson's (1985) findings, his study suggested that higher asset specificity aligns with increased uncertainty (Klein et al. 1990). In this TC study, with copper being Chile's main export commodity, the external environmental uncertainty increased twofold: (1) by volatility of copper prices and (2) by diversity of competitors (Appendix A, Figure A-1), both of which drive centralization of manufacturers (Klein et al. 1990; Alonso et al. 2015). Figure 2 showed impersistent shocks of PIB in the short run, which depend on copper prices that positively influence trucks sales, as indicated in Table 3. Although copper prices contribute to the manufacturers' boundaries as defined by truck sales, evidence supports the rejection of *hypothesis 2.1 (External Uncertainty on Demand)* as shown on Table 2 and Table 3. The tables highlighted the contingent significance of copper prices to be undermined by tax policy (higher contributions) on the truck sales sector in Chile.

As Table 2 and Table 3 imply, irrespective of GDP (PIB) tendencies, transportation investments stimulated the transaction-based expansion of the boundaries of the import-truck producers; and according to Lian et al. (2019), increase trade integration. As a result of coordinated adaptation processes of manufacturers, investments act as a stabilizer and counterweight to commodity trade and policy shocks (tax revenues) in Chile; which tend to increase their boundaries, while retaining hierarchical centralization. *Hypothesis 2.2 (Facilitation of Transaction Cost Efficiency of Firms)* is accepted. Perhaps, as regarded by Williamson (1975), further endeavors in this topic of investments can advance the efficiency of resource allocation in the governance context of multidivisional manufacturers, as opposed to those of external capital markets (Ketokivi and Mahoney 2017).

In contrast to expected price inflation, an *unexpected* surge in price for a contract hampers the bargaining process with their dealers, which is evidence supporting the producers' immediate adaptation to reconsider a dealer's counteroffer on a bid for fewer vehicles. Thus, *hypothesis 1.3 (Autonomous Adaptation of Price Setting*

*Capabilities*) is accepted. Furthermore, higher market share of non-European manufacturers is attributed to a higher EUR-USD exchange rate. The evolution of non-European manufacturers' boundaries coincides with higher imports of their vehicles into Chile, resulting from an uncompetitive euro. Nevertheless, the strengthening of the euro does not necessarily imply transaction inefficiency among European importers. Hence, *hypothesis 1.4 (Coordinated Adaptation, Transaction-based Efficiency and Evolution of Manufacturers Under Uncertainty)* is rejected. In fact, with pricing stagnate in a competitive market, the exchange rate generates cyclical truck sales, which violates the long-run equilibrium of purchasing power parity, meaning that the opportunity for arbitrage among non-European manufacturers exists when the euro strengthens against the dollar (Corbae and Ouliaris 1988).

Social identity has shaped the boundaries of the firm (e.g., Pratt 1998; Ashforth and Mael 1989; Zenger et al. 2011) by promoting integration through coordinated activities. The social identity, which distinguishes manufacturers by their unique services, warranties, and quality of trucks, develops brand equity formation. Summarized in Table 1, brand culture might imply a direct positive relationship with respect to manufacturers' market share (Appendix A, Figure A-3 and Figure A-4), external transactions, and boundaries. The findings demonstrate that the narrow scope of brand among some Asian producers, such as providing limited warranties and other services, compounds the difficulty to secure a contractual order, which translates into smaller boundaries when compared to other diverse brand cultures. The results reinforce the premise that lower performing producers are optimal at a lower degree of vertical integration, based on cost efficiency, as compared to more vertically integrated structures of European producers (Kaiser and Obermaier 2020; Williamson 1991). Given that TCE and international marketing seldom interact with regards to brand affecting transactions (e.g., Seggie 2012; Williamson and Ghani 2011; Chen 2010; John and Reve 2010), brand recognition demonstrates a competitive advantage for the long-run survival and evolution of the firm, which becomes a hallmark contribution of this study. Perspectives of brand value, particularly by dealers and end-users, affect the decision-making processes and behaviors within the manufacturer. *Hypothesis 1.5 (Brand Culture)* is accepted.

Furthermore, emissions standards increase asset specificity of heavy-duty truck manufacturers, which in turn decreases the redeployability of the units of trucks produced to other markets but increases bilateral dependency. However, emission standards bear several negative externalities such as: (1) political imposition of standards may lead to contracting hazards and maladaptations; (2) higher asset specificity forces higher integration, known as commitment to specification, which may generate holdup problems through more integrated governance structures; (3) imposition of regulations may lead to market competition failures; (4) increased bureaucratic costs may be counteracted by bilateral dependency and the expansion of firm boundaries; and (5) increased asset specificity may artificially foster a reliance on adaptations of hierarchy governance structures as opposed to immediate market adaptations (David and Han 2004; Ketokivi and Mahoney 2017; Joskow 1988). Table 1 presents evidence of market competition failure, a negative externality. The announcement and imposition of higher emissions standards created a significant downward pressure on vehicles of lower emissions

such as EPA98 and EURO 3. This effect of environmentally-driven evolution of manufacturers concerning the importation of trucks offer a prospective benefit for an industry split of new versus old technologies, which is to establish a competitive trade barrier known as emission trade scheming (Pechancova 2017; Isley, et al. 2013; Coria and Kyriakopoulou 2018; OECD 2008). Moreover, the availability of types of trucks produced and offered are the evolutionary result of the *ex post* practices to reduce costs. Luiz da Silva and Saes (2007) indicated that assets with indistinguishable specificity, which operate within the same production line, may be the result of evolutionary convergence towards efficient governance structures. This observed evolutionary effect on the production process is manifested by the small variations among all Class 8 trucks, which led to the lack of distinguishable transaction cost measurability among ‘conventional truck types’. As evidenced in Table 1, the types *tolva*, being necessary for mining and construction projects, and *tractor*, used for long haul or distribution, possess lower asset specificity, yet positively impact boundaries through the demand of vocational trucks in Chile. However, types *other*, *reparto* and *rigids* with comparably higher asset specificity generate transaction friction for their manufacturers by requiring variations of specialization tailored for the vehicles’ applications. For example, the categorized ‘*other type*’ of trucks represents little more than 1% of the sample and are attributed with transaction costs as being complex, specialized, hand-man, and off-assembly-line trucks. The announcement of stricter regulations on emissions for imported trucks as a demand for higher specificity failed to render further transaction costs as can be observed by the demand for higher specificity of truck types. *Hypothesis 1.6 (Asset Specificity and the Firm Specific Factors of Emissions Standards and Types of Trucks)* is rejected.

The general organizational trend facing manufacturers remains decentralization (Mourtzis and Doukas 2012). With this development, aside from vertical restrictions, transportation investments and *ex post* effects of the maladaptation or hazards of emission standards appear to become reliable instruments for the retention of centralization among manufacturers. Applying Lafontaine and Slade’s (2007) suggestions to this study, heavy-duty truck manufacturers’ decision to pursue forward integration appears to be deterred by investments and financing, namely operating under the guise of private dealings as found among franchises instead of common agency. With a microanalytical approach to vertical integration, the empirical evidence substantiates TCE, such that vertical integration is the sought-after governance structure with its selection increasing with the frequency of the type of units sold and the reduction of trading partners, namely dealers (Lajili et al. 2007). The most profound limitation of TCE when considering boundary choice is the manufacturers’ decision-making processes of *value creation*, specifically knowing that sustainable advantage of specific investments falls short without strategic foresight of managers and asset combinations (Argyres and Zenger 2012, Lippman and Rumelt 2003). Creating value as defined by Zenger et al. (2011) would entail managers of these producers to assess if the operations of their dealers are best incorporated into their hierarchy. Moreover, the empirical approach to transaction cost theory appears to come short of fully explaining and



gauging the learning and cognitive nuisances that heavy-duty truck manufacturers encounter (Kogut and Zander 1992).

## 7 Conclusions

Pertaining to firm organization, the interpretation of TCE through empirical assessment remains an ongoing endeavor (David and Han 2004). Masten (1993) expressed concern for the lack of explanatory power with regards to governance choice and performance. The evaluation of the results to be successfully applied to theories on firm boundaries depend heavily upon their contextual conditions and surroundings, as well as their origins of market form of governance, namely the establishing of institutions that foster the exchange or transaction (Zenger et al. 2011). Overall, this study identified that transaction costs of foreign manufacturers or original equipment manufacturers tend to increase with specialized off-assembly line trucks, unexpected price spikes, and uncertainty of commodity and policy shocks in Chile. Brand recognition becomes a strategic competitive advantage for the long-term survival and evolution of the firms in competitive markets. As for non-European based manufacturers, the evolution of their boundaries coincides largely with immediate market adaptations of price and the high-powered incentive to offer financing as a form of coordinated adaptation, which remains tied to their resource capability. The uncertainty induced by a high EUR-USD exchange rate steers the opportunistic Chilean dealer to avoid weaker marginal gains by seeking the acquisition of a fleet from non-European producers. Given this uncertainty, TCE would predict a greater degree of integration and coordinated transactions to occur between non-European producers and Chilean dealers. Thus, adaptations towards minimizing transaction cost determinants drive the evolutionary implication for higher degree of integration in this industry. Among the environmental uncertainty determinants in the Chilean market as measured by industry experts in the second case, copper prices and transportation investments played a leading role in transaction frequency of trucks. Higher uncertainty may also cause the Chilean automotive industry to conform into vertical integration as prevalent among efficient manufacturers (Anderson 1988b). Hence, policy makers and in-field practitioners should consider the following prospect: A departure from emissions standards in favor of new technologies—as in the production of electric trucks—may add more *technological uncertainty*. In the context of Kulatilaka and Perotti's (1998) findings, such technological uncertainty surrounding the feasibility of electric trucks presents itself as a possible “growth option” to maintain long-run performance by restricting competitors and generating benefits with brand reputation. In TCE, a “specific asset” innately draws value by being a specialized exchange (Klein et al. 1978). In many respects, a TCE perspective of vehicles with specific emission standards (as a specific asset) would satisfy the criteria that defines a “strategic asset” as noted by Crook et al. (2013) and Barney (1991). The competitive benefit of this strategic asset, which developed the boundaries of these manufacturers, would be swept away by the importation of electric vehicles. Maintaining emissions regulations for truck

imports means retaining the ongoing strategic value that enhances the integrated exchange partnership between Chilean dealers and manufacturers. Consequently, managers should consider that unforeseen market conditions and technological uncertainty devalue the manufacturer's committed investments, such as financing, which delineate integration with their dealers. With the truck manufacturing industry dominated by multinational enterprises and rather than pursuing an integration channel with their dealers, an alternative organizational hierarchy that increases domestic presence or 'factory stores' becomes the suitable evolutionary response. These 'factory stores' would enhance manufacturing effectiveness through the absorption of costs by reconciling manufacturing, sales, parts, and service costs while competing in global markets.

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**Data availability statement** The datasets collected and analyzed within this study are available from the corresponding author upon request.

**Code availability statement** The code that derived the findings of this study is available from the corresponding author upon request.

## Declarations

**Disclosure of potential conflicts of interests** The author declares no conflicts of interests pertaining to this study.

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