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DISCUSSION PAPER

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Who Is in the Driver's Seat? Markups, Markdowns, and Profit Sharing in the Car Industry

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Who Is in the Driver's Seat?

Markups, Markdowns, and Profit Sharing in the Car Industry

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Abstract

I develop a general framework for markup and markdown estimation that allows for profit sharing along value chains without making assumptions on conduct between vertically related firms. I derive the conditions under which the markup and markdown estimates relate to the firms' equilibrium bargaining weights. To account for vertical and horizontal product differentiation in the production function estimation, I include plant-level prices and employ car characteristics as demand-based quality controls. Between 2002 and 2018, the European car manufacturers' margins on their input and product markets combined were stable around 10% to 15% on average. The manufacturers' share of the margin on the input market, however, depends on the car segments in which they produce. The suppliers' share depends negatively on the variety of their product portfolio and depends positively on their relationship intensity to car manufacturers. The analysis shows that the manufacturers' bargaining weights decreased during crisis years, such as the financial crisis in 2007 or the dieselgate scandal in 2015.

Keywords: *Market Power, Markups, Markdowns, Production Approach, Car Industry, Vertical Chains.*

JEL Codes: D22, L13, L14, L62

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1 Introduction

In recent years, the concentration of market power and its implications has been heavily debated between economists and policymakers. Researchers found consistent evidence for increasing market power across macro economies and related it for instance to declining labor shares in GDP (De Loecker, Eeckhout, and Unger, 2020; Philippon, 2019) and resource misallocation (Edmond, Midrigan, and Xu, 2023). Industry-specific studies are key for a clear understanding of the drivers of market power at a more disaggregated level. Recent contributions are Miller et al. (2022) for the cement industry, Grieco, Murry, and Yurukoglu (2024) for the car industry, or Döpper et al. (2024) for consumer products.

To measure market power, economists in the field of industrial organization typically rely on the firms' total markups as the ratio of output prices to the marginal cost of production. The common estimation procedures either require assumptions on the underlying demand system and firm conduct (Berry, Levinsohn, and Pakes, 1995), or cost minimization and firm-level production decisions (De Loecker and Warzynski, 2012). These total markups measure the firms' total market power, comprising the firms' margins on both the product and input markets.

In this paper, I provide a general framework for decomposing the firms' total market power into margins on product markets (markups) and input markets (markdowns). The decomposition provides important insights into the concentration of market power along value chains. For instance, a firm's total market power could stay constant in levels and proportionately shift between product and input markets at the same time. In this case, the competitive environments along the value chain change, even though the firm's total market power remains constant. I apply the framework to the European car industry and investigate (i) how the margins are split along the value chain between car manufacturers and their part suppliers, and (ii) the drivers of the margin distribution between vertically related firms.

Because of its distributional implications, the decomposition of the total margins into markups and markdowns is particularly relevant for competition policy. Subsidies that are granted to upstream firms might be extracted by downstream firms if the downstream firms' markdowns are not accounted for. Moreover, merging parties with high markups toward consumers might be subject to different remedies imposed by competition authorities compared to merging parties with the same total margins, but achieved through high markdowns towards suppliers.

The decomposition of the total margins into markups and markdowns is crucial for industries with complex relationships between vertically related firms. This is particularly the case for the automotive industry, which has been subject to an unparalleled restructuring of manufacturer-supplier relationships. Starting in the 1970s, the vertically integrated industry experienced a wave of divestitures by car manufacturers of their input suppliers, leading to frequent power struggles between vertically related firms (MacDuffie and Helper, 2007). A prominent example is the dispute between Volkswagen and its part supplier Prevent. In 2015, a disagreement on price claims escalated and caused Volkswagen a loss of an estimated 100 Million Euro (Handelsblatt, 2018).

I make three contributions to the existing literature. My first contribution relates to the literature on markdown estimation in the spirit of Morlacco (2019) and Rubens (2023). Morlacco (2019) builds on the work of Dobbelaere and Mairesse (2013) and estimates input market power for the French manufacturing sector. Rubens (2023) combines the production and cost approach as in De Loecker et al. (2016) with a model of input supply to separately estimate markups and markdowns for the Chinese tobacco industry. My approach differs from these papers by explicitly allowing for endogenous input prices in a Leontief production framework without making assumptions about the firms' conduct along the value chain or relying on exogenous input prices in other input markets. For instance, the framework allows car manufacturers to set monopsony prices for one car part and to bargain with a supplier over the price of another car part. My measure for the downstream firms' markdown relies on two components, namely (i) the upstream firms' inverse markups, and (ii) the total shared margins between the vertically related firms. The measure can be estimated solely based on financial statements and pricing information and does not require information on contract-specific input quantities.

My second contribution is connecting the production-based measures for markups and markdowns to the firms' relative bargaining weights in a profit-sharing setting. This contribution combines the framework from my paper with insights from the bargaining literature in vertical markets as in Lee, Whinston, and Yurukoglu (2021). I show that, under additional assumptions,[1] variation in the markup-to-markdown ratio between vertically related firms reflects variation in the firms' relative bargaining weights according to the Nash bargaining solution. Theoretically, the framework allows for the estimation of bargaining weights at the contract level.

My third contribution is adding product characteristics as demand-based quality controls to the production function estimation procedure. When firm-level inputs and outputs are not measured in comparable units, the production function might be wrongly estimated as a result of the well-documented price and quality biases (Klette and Griliches, 1996; Katayama, Lu, and Tybout, 2009). Previous contributions constructed comparable input and output units for vertically differentiated products (e.g., Ornaghi, 2006; Pozzi and Schivardi, 2016). De Loecker et al. (2016) control for both vertically and horizontally differentiated products. Building on insights from this paper and the hedonic pricing literature (e.g., Rosen, 1974; Feenstra and Levinsohn, 1995; Triplett, 1969), I include car characteristics in the production function estimation procedure. Intuitively, a plant that produces SUVs requires a different set of inputs and inputs of different quality than a plant that produces Minis. Because input and output quantities between the two plants are not perfectly comparable, the output elasticities might be biased if product characteristics are not accounted for.

[1] That is: (1) before contract negotiations take place, the manufacturer chooses the optimal material input quantity to maximize profits based on a perfectly competitive input price, (2) the resulting profit pins down the manufacturer's outside option, and (3) the supplier has constant marginal cost of production.

A similar notion has been followed by Berry, Kortum, and Pakes (1996), who control for product characteristics in cost function estimation.

The empirical application relies on a dataset of the European car industry. It consists of three parts: (i) plant-level balance sheet information of car manufacturers and suppliers; (ii) contracting data between suppliers and manufacturers, which contains information on the supplied products, names of the contracting parties, and car models the parts are manufactured for; and (iii) sales-weighted product characteristics and prices at the car manufacturing plant-level.

My findings illustrate the importance of accounting for the competitive environment along value chains when analyzing market power in complex industries. Similar to the findings by Grieco, Murry, and Yurukoglu (2024) for U.S. car manufacturers, I find that European car manufacturers' total margins (on the input and output market) stayed stable around 10% to 15% within the time-period 2002 to 2018. However, the steady total margins mask highly volatile compositional effects coming from markups on product markets and markdowns on input markets. The varying distribution of margins between manufacturers and their suppliers is also reflected in the evolution of the car manufacturers' bargaining weights. The bargaining weights towards suppliers strongly decreased during crisis years, such as the financial crisis in 2007 or the famous dieselgate scandal in 2015.

The car manufacturers' markdowns strongly vary within and between manufacturing groups. The variation is correlated with segment composition at the production plant level, where I find a significant difference between markdowns of Mini producers compared to other segments. A possible explanation is that Mini producers exert more pricing pressure on the input market compared to producers of other segments, which would allow them to set more competitive prices downstream. Focusing on the suppliers' markups upstream, I find that markups are negatively correlated with the variety of the suppliers' product portfolios. The more products a supplier offers, the lower is her expertise and bargaining power in any individual category, which translates to lower markups. I find a weak positive correlation between the suppliers' markups and the suppliers' relationship intensity with car manufacturers. I measure relationship intensity as the ratio of a supplier's total amount of active contracts in a given year to the number of manufacturers the contracts are formed with. I show that the more frequent the interactions between a given manufacturer-supplier pair are, the larger the share of the margin that the supplier receives. This indicates a more cooperative contracting environment once manufacturers and suppliers frequently interact.

This paper relates to several strands of literature. It bridges the empirical literatures on bargaining power and markup estimation with imperfect input markets. Recent empirical papers on estimating bargaining power are, for instance, Crawford and Yurukoglu (2012) and Ho and Lee (2017). Recent contributions on markup estimation with imperfect input markets are Avignon and Guigue (2022), Tortarolo and Zarate (2018), Treuren (2022), and Amodio, Medina, and Morlacco (2024). The methodology in this paper allows for the estimation of relative bargaining weights relying on production-based equilibrium outcomes. It requires different assumptions compared to the demand-based literature.[2]

This paper also relates to the empirical literature on the European car industry. Many papers evaluate various aspects of the product market of car manufacturers using demand estimation as in Berry, Levinsohn, and Pakes (1995). These are, for instance, choices of dealer location (Mohapatra, 2021) or scrapping schemes (Grigolon, Leheyda, and Verboven, 2016). I contribute to the literature by evaluating the distribution of market power along the value chain and its driving factors. In contrast to the demand-based literature, approaching the research questions from the production-side allows for the estimation of markups, markdowns, and bargaining weights between manufacturers and suppliers without information on the firms' output or input quantities.

[2]See De Loecker and Scott (2022) for an extensive comparison of the two approaches.

The remainder of the paper is structured as follows. In section 2, I derive measures for manufacturers' markups and markdowns. In section 3, I describe the procurement procedure in the car industry and relate the measures for markups and markdowns from section 2 to the firms' relative bargaining weights according to the Nash bargaining solution. Section 4 presents the empirical framework, while section 5 describes the dataset. I present the results in section 6. Section 7 discusses the main caveats of the model and its application to other industries. I conclude in section 8.

2 Constructing Measures for Markups and Markdowns

In this section, I derive empirical measures for markups and markdowns based on observed equilibrium outcomes. The underlying framework relies on a simplified example where one car manufacturer contracts with one supplier. The car manufacturer and the supplier each are represented by a single production plant, producing a single product.

In subsection 2.1, I derive a measure for the car manufacturer's markup that explicitly allows for markdowns on input markets in the spirit of Rubens (2023) and De Loecker et al. (2016). These papers rely on a monopsony setting, where the measure for markdowns depends on the input supply elasticity of upstream firms. To allow for both the car manufacturer and the supplier to receive a share of the margin on the input market, I derive a measure for markdowns in subsection 2.2 that deviates from the input supply elasticity. In the presented framework, the car manufacturer's markdown depends on the inverse supplier's markup and the shared margin between the car manufacturer and the supplier. The measures for markups and markdowns do not require any assumptions on firm conduct along the value chain.

2.1 Product Market: Equilibrium Markup

The markup μ_{it} of car manufacturer i at time t is defined as the ratio between the output price P_{it} and the marginal cost of production MC_{it}:

$$\mu_{it} = \frac{P_{it}}{MC_{it}}. \tag{1}$$

I assume that the manufacturer uses a Leontief production technology:

$$Q_{it} = min\left\{\kappa_{it}M_{it}, \Omega_{it}F\left(L_{it}, K_{it}; \beta\right)\right\}, \tag{2}$$

where he employs a fixed proportion of material input quantity M_{it} to the combination of labor L_{it} and capital K_{it} to produce one unit of output Q_{it}. For the car manufacturer, κ_{it} represents the inverse of the amount of material inputs required to produce one car.[3]

Intuitively, the manufacturer might substitute between labor and capital, thus replacing workers with machines and vice versa. However, he always requires a fixed proportion κ_{it} of material inputs M_{it} to produce one unit of output. Keeping Ω_{it} constant, it is not possible to hire more workers and buy less material inputs while still producing the same car model. The substitutability of labor and capital is governed by the function $F(.)$, which is parameterized by β. The parameterization could for instance take the Cobb-Douglas or translog form. Ω_{it} represents Hicks-neutral productivity shocks to labor and capital, allowing for factor augmenting productivity shocks to material inputs. This implies that, given the same labor and capital usage, some plants could produce less wastefully in terms of material inputs than others.

Because of the Leontief setting, the manufacturer's marginal cost consists of two parts. I denote

[3] At this point, I abstract from possible unpredicted shocks to production such as machine breakdowns. This only becomes relevant for the production function estimation procedure in section 4.3.1.

the marginal cost from the function $F(L_{it}, K_{it}, \beta)$ as λ_{it}^F and the marginal cost from material inputs as λ_{it}^M:

$$MC_{it} = \lambda_{it}^F + \lambda_{it}^M. \tag{3}$$

I assume that labor and material inputs are variable and can be adjusted statically every period. This implies that the car manufacturer's choice for labor at time t is made in the same period and does not affect the manufacturer's profits at time $t+1$. I assume that the capital input is fixed and dynamic, since capital adjustments require time to be ordered and installed. This implies that the manufacturer's capital choice for time t is pre-determined at time $t-1$.[4]

I construct marginal cost λ_{it}^F following De Loecker and Scott (2022) based on the assumption that the car manufacturer minimizes cost and faces exogenous wages W_{it}. The marginal cost λ_{it}^F depends on the variable input labor and is defined as wages W_{it} multiplied by the marginal number of employees required to produce an additional unit of output:

$$\lambda_{it}^F = W_{it} \frac{\partial L_{it}}{\partial Q_{it}}. \tag{4}$$

I construct marginal cost λ_{it}^M differently from De Loecker and Scott (2022) to allow for the car manufacturer to affect the material input prices. In the authors' setting, material input prices P_{it}^M are exogenous and marginal cost from material inputs enter as $\lambda_{it}^M = P_{it}^M / \kappa_{it}$ in a fixed proportion to marginal cost coming from labor λ_{it}^F. The additional marginal cost from material inputs is simply the exogenous material input price P_{it}^M multiplied by the number of material inputs required to produce one car.

To allow for the car manufacturer to receive margins on the material input market, I extend the marginal cost λ_{it}^M with the markdown γ_{it}^M following Rubens (2023):[5]

[4] See Ackerberg, Caves, and Frazer (2015) for a more detailed explanation on the timing of input choices.

[5] Rubens (2023) specifies λ_{it}^M in a monopsony setting as follows:

$$\lambda_{it}^{M} = \frac{P_{it}^{M}}{\kappa_{it}} \times \gamma_{it}^{M}. \tag{5}$$

Notice that for $\gamma_{it}^{M} = 1$, this measure nests marginal cost of production from material inputs λ_{it}^{M} as defined in the standard setting. In this case, the material input market is exogenous to the manufacturer. For $\gamma_{it}^{M} > 1$, the car manufacturer exerts pressure on material input prices.

I combine λ_{it}^{F} (equation (4)) with λ_{it}^{M} (equation (5)) for the markup equation:

$$\frac{P_{it}}{MC_{it}} = \frac{P_{it}}{\lambda_{it}^{F} + \lambda_{it}^{M}} = \frac{P_{it}}{w_{it}\frac{\partial L_{it}}{\partial Q_{it}} + \frac{P_{it}^{M}}{\kappa_{it}}\gamma_{it}^{M}}. \tag{6}$$

Inserting revenue shares $P_{it}^{X} X_{it}/P_{it} Q_{it} = \alpha_{it}^{X}$ for $(X = L, M)$ and the output elasticity of labor $\theta_{it}^{L} = \frac{\partial Q_{it}}{\partial L_{it}}\frac{L_{it}}{Q_{it}}$ yields the equation for the car manufacturer's markup μ_{it} that allows for shared margins between the car manufacturer and part supplier on the manufacturer's material input market:

$$\mu_{it} = \frac{1}{\frac{\alpha_{it}^{L}}{\theta_{it}^{L}} + \alpha_{it}^{M}\gamma_{it}^{M}}. \tag{7}$$

To provide intuition on the markup equation, I divide it into two parts: (i) $\alpha_{it}^{L}/\theta_{it}^{L}$, which is the ratio of the revenue share of labor to the output elasticity of labor. This part is driven by the inputs from the $F(.)$-function. Only labor without capital enters the markup equation because marginal cost λ_{it}^{F} is driven by the variable input.[6] An increase in the revenue share α_{it}^{L} given a constant output elasticity θ_{it}^{L} leads to a decreasing markup. Conversely, an increase of the output elasticity θ_{it}^{L} given a constant revenue share α_{it}^{L} leads to an increasing markup. (ii) $\alpha_{it}^{M}\gamma_{it}^{M}$, which is the revenue share

$$\lambda_{it}^{M} = P_{it}^{M}/\kappa_{it} \times \gamma_{it}^{M} = P_{it}^{M}/\kappa_{it} \times (1 + \frac{\partial P_{it}^{M}}{\partial M_{it}}\frac{M_{it}}{P_{it}^{M}}).$$

The markdown is defined as one plus the inverse input supply elasticity $\gamma_{it}^{M} = 1 + \frac{\partial P_{it}^{M}}{\partial M_{it}}\frac{M_{it}}{P_{it}^{M}}$. Because my application allows upstream and downstream firms to share the margins on the input market, the observed markdown is not necessarily proportional to the input supply elasticity.

[6]In cases where the production technology is a gross output production function, this part of the equation represents the complete markup equation as in De Loecker and Warzynski (2012).

of material inputs multiplied by the markdown. This part of the markup equation is driven by the complementary input. An increasing revenue share of material inputs α_{it}^M leads to a decreasing markup. For $\gamma_{it}^M = 1$, the car manufacturer's total margin comes from the product market. For $\gamma_{it}^M > 1$, the car manufacturer also receives a share of his margin from the material input market, which rescales the markup μ_{it} on the product market.

2.2 Input Market: Equilibrium Markdown

I define the previously introduced markdown γ_{it}^M as the ratio of the marginal revenue product of the input MRP_{it}^M to the input price P_{it}^M:[7]

$$\gamma_{it}^M = \frac{MRP_{it}^M}{P_{it}^M}. \tag{8}$$

When the manufacturer cannot impact input prices, he sets $MRP_{it}^M = P_{it}^M$. The manufacturer makes positive profits on his input market when $MRP_{it}^M > P_{it}^M$.

I construct the measure for γ_{it}^M based on the supplier's equilibrium markup μ_{st}. At time t, the supplier's markup on her product market is defined as the ratio of the supplier's output price P_{st} to the marginal cost of production MC_{st}:

$$\mu_{st} = \frac{P_{st}}{MC_{st}}. \tag{9}$$

The supplier sells at marginal cost when $P_{st} = MC_{st}$. The supplier makes positive profits on her product market when $P_{st} > MC_{st}$.

In equilibrium, the manufacturer's input price P_{it}^M equals the supplier's output price P_{st}. This allows reformulating (8) for P_{it}^M and inserting the resulting equation into (9) for P_{st}. Reformulating for the markdown γ_{it}^M yields the following equation:

[7] This follows the definition by Rubens (2023). Treuren (2022) labels the same equation as "intermediate input wedge".

$$\gamma_{it}^{M} = \frac{1}{\mu_{st}} \frac{MRP_{it}^{M}}{MC_{st}}. \tag{10}$$

Equation (10) shows that the equilibrium markdown γ_{it}^{M} depends on two components: First, the inverse of the supplier's markup μ_{st}; and second, the shared margin $\frac{MRP_{it}^{M}}{MC_{st}}$ between the supplier and the manufacturer. Varying one component of equation (10) while holding the other constant provides intuition for the composition of γ_{it}^{M}. Assuming that the shared margin $\frac{MRP_{it}^{M}}{MC_{st}}$ stays constant, an increase of the manufacturer's markdown γ_{it}^{M} is reflected by an equally sized decrease of the supplier's markup μ_{st} and vice versa. Assuming that the supplier's markup μ_{st} is constant over time, an increase of the manufacturer's markdown γ_{it}^{M} is reflected by an equally sized increase of the shared margin.

Figure 1 illustrates the intuition of equation (10). At any input quantity M_{it}, the manufacturer and supplier share the margin on the input market, which equals the sum of the blue and orange rectangle. It is the difference between the blue line $(= MRP_{it}^{M})$ and the dashed orange line $(= MC_{st})$ multiplied with the equilibrium quantity M_{it}^{*}. The equilibrium price P_{it}^{M*} at a given quantity M_{it}^{*} (here point B) divides the shared margin into the manufacturer's markdown ($\gamma_{it}^{M} = MRP_{it}^{M}/P_{it}^{M}$) and the supplier's markup ($\mu_{st} = P_{it}^{M}/MC_{st}$) according to the height of the blue and orange rectangles respectively. For the demanded input quantity M_{it}^{*}, the equilibrium price could lie on any point of the red line.

In the standard setting for markup estimation with exogenous input prices as in De Loecker and Warzynski (2012), the markdown equals one ($\gamma_{it}^{M} = 1$). The blue rectangle does not exist in this setting, since the input price P_{it}^{M*} equals its marginal revenue product MRP_{it}^{M}. For $\gamma_{it}^{M} > 1$, the manufacturer's total margin consists partly of his markup μ_{it} towards consumers and the markdown γ_{it}^{M} towards suppliers.[8]

[8] The car manufacturers' markup is not displayed in Fig 1 because it shows only the distribution of the margin on the car manufacturer's input market.

Figure 1 could be replicated for all markets along the value chain. All firms involved in the production process ranging from retailers, car makers and part suppliers up to raw material providers receive a total margin that consists of a margin on their product market with $\mu \geq 1$ (orange rectangle) and a margin on their input market with $\gamma \geq 1$ (blue rectangle). Once a firm faces a perfectly competitive input market, the orange and blue rectangles collapse because the perfectly competitive input market implies that $P_{it}^{*} = MC_{st} = MRP_{it}^{M}$.

In the empirical analysis, I focus on the two main players of the European automotive industry: the car manufacturers and the part suppliers. I thus assume the part suppliers' input market to be perfectly competitive, so that their total margins only consists of the markups $\mu_{st} \geq 1$ with $\gamma_{st}^{M} = 1$.

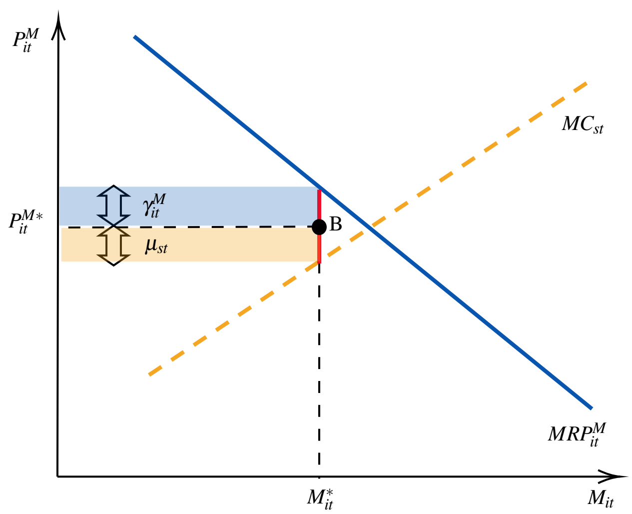


Figure 1: Shared Margins on the Car Manufacturer's Input Market

3 Relating Margins to Bargaining Weights

In this section, I first provide a description of the contracting environment between car manufacturers and suppliers. I then present a profit-sharing framework that relates markups, markdowns, and relative bargaining weights by combining insights from the literature on bargaining in vertical markets (e.g., Lee, Whinston, and Yurukoglu, 2021) with the measures for markups and markdowns as derived in the previous section, accommodating the industry-specific environment.

Relating markups and markdowns to relative bargaining weights requires additional assumptions compared to the measures for markups and markdowns in section 2. These are: (1) before contract negotiations take place, the manufacturer chooses the optimal material input quantity to maximize profits based on perfectly competitive input prices, (2) the resulting profit pins down the manufacturer's outside option, and (3) the supplier has constant marginal cost of production.

3.1 Contracting in the European Automotive Industry

This section is based on Calzolari et al. (2019) and Mueller, Stahl, and Wachtler (2016). I refer to these articles for a detailed description of the automotive industry. As a rule of thumb, each car manufacturer phases out at least one model and replaces it with a new design every year. On average, a model is produced for six to eight years with annual to biannual "facelifts" within the production period. For these facelifts, the manufacturer typically does not change suppliers.

When car manufacturers require a new part, they actively approach suppliers and proceed in a two-stage procurement procedure. In the first stage, the suppliers compete in developing blueprints, which contain information on the investment requirements for the parts (contractible and non-contractible) and the performance specifications of the product. In the second stage, once a supplier wins the blueprint competition, the two firms bargain over contract specifics.[9]

The contract usually determines the production of the part for the entire production period of the car model. Contracting between suppliers and manufacturers is conducted at the part-level and contracts between each manufacturer-supplier pair are formally drafted independently of each other. Mueller, Stahl, and Wachtler (2016) surveyed German part suppliers and car manufacturers. The

[9]As pointed out by Mueller, Stahl, and Wachtler (2016) the contracts typically specify: contract duration, dates and terms of supply, part specifications, and potential adjustments, quantity, the order flow (in terms of logistics), quality and warranty management, payments including cancellation payments, and intellectual property owners.

survey shows that German car manufacturers rarely engage in dual sourcing and never engage in second sourcing. Dual sourcing refers to the practice where a second supplier is selected for the production of a part but in smaller volumes. Second sourcing refers to the practice where a second supplier is selected for the production of a part, but without volumes and only as a backup strategy in case the first supplier cannot produce.

3.2 Theoretical Framework: Profit Sharing

Setting. I assume that the car manufacturer follows a two-step decision process. The timing is as follows: At time t, the manufacturer maximizes profits under the assumption that inputs are procured from perfectly competitive markets. In this step, the manufacturer determines the required material input quantity M_{it}^{*}. At time $t+1$, the manufacturer selects the suppliers from which it purchases the M_{it}^{*} units and bargains over the input prices P_{it}^{M*}. Decisions at time $t+1$ do not affect the production choices time at time t. This implies that possible increases in surplus from procurement are not taken into account when deciding input and output quantities. Intuitively, the car manufacturer will not adjust a fixed output quantity of ten thousand cars and renegotiate existing contracts when achieving the largest surplus in one contract would have required the production of twenty thousand cars.[10]

Step (1): Profit Maximization to Determine Input and Output Quantities. I assume that the car manufacturer maximizes profits given the Leontief production technology:

$$\begin{aligned} \max_{L_{it}, M_{it}} \ & P_{it}(Q_{it})Q_{it} - W_{it}L_{it} - R_{it}K_{it} - \hat{P}_{it}^{M} M_{it} \\ s.t. \ & Q_{it} = min\left\{\kappa_{it}M_{it}, \Omega_{it}F\left(L_{it}, K_{it}; \beta\right)\right\}. \end{aligned} \tag{11}$$

[10]The timing assumptions could be exchanged for assumptions on the decision process within the firm. In this case, the car manufacturer has two relevant divisions for the profit-sharing procedure: (i) a division that determines the target production of cars (output division), and (ii) a division that is responsible for supplier relationships and contracting (procurement division). The output division dictates the required material input quantity M_{it}^{*}. The procurement division then bargains over the price P_{it}^{*} for the given quantity M_{it}^{*} with the suppliers.

Profit maximization requires a predicted material input price $\hat{P}^M_{it}$, which is based on the perfectly competitive input prices of comparable products.[11] Intuitively, the manufacturer expects to pay the highest input prices that they are willing to pay without making a loss. As in the previous section, the prices for labor W_{it} and capital R_{it} are assumed to be exogenous. In the optimum, the manufacturer picks the output quantity Q^*_{it} at which the marginal revenue product of labor MRP^L_{it} equals wages W_{it} and the marginal revenue product of material inputs MRP^M_{it} equals the predicted input price $\hat{P}^M_{it}$. The outcome from profit maximization dictates the material input quantity M^*_{it} in the second step of the procedure.

Step (2): Profit Sharing with Suppliers. I model the second stage of the procurement procedure, assuming that the car manufacturer bargains with one supplier in a profit-sharing framework over a fixed surplus. I define the firms' joint profits without contracting Π_t as follows:

$$\Pi_t = \Pi_{it} + \Pi_{st}. \tag{12}$$

The equation represents the firms' profits without the extra margin generated from the product that they bargain over. Π_{it} and Π_{st} represent the firms' outside options at the bargaining stage. Π_{it} is pinned down by the car manufacturers' profit maximization in the first stage. If bargaining breaks down, the car manufacturer buys a comparable product at the price $P^M_{it} = MRP^M_{it}$. Π_{st} could be interpreted as the part suppliers' profits from already existing contracts.

I define the manufacturer's and supplier's joint profits with contracting as $\widehat{\Pi}_t$. The extra margin that the two firms share is the difference between the product's marginal revenue product and marginal cost of production multiplied by the quantity M^*_{it}[12]:

[11] The equilibrium price P^{M*}_{it} resulting from profit-sharing does not affect the price $\hat{P}^M_{it}$. The optimal output quantity Q^*_{it} is not updated after information on bargaining weights is collected through the profit-sharing procedure.

[12] The assumption of constant marginal cost of the supplier is crucial for the expression $(MRP^M_{it} - MC_{st})M^*_{it}$ to represent the extra margin that the firms share. Alternatively, one could assume that the firms only bargain over the price of the marginal unit of M^*_{it}.

$$\widehat{\Pi}_t = \Pi_t + (MRP_{it}^M - MC_{st})M_{it}^*. \tag{13}$$

I assume that the firms alternate offering contracts $C(P_{it}^M)$ that determine linear prices P_{it}^M for the manufacturer's demanded input quantity M_{it}^*. Any contract $C(P_{it}^M)$ from the contract space $\mathbb{C}$ that results in gains from trade for both parties satisfies the following:

$$\mathbb{C}^+ \equiv \left\{ C \in \mathbb{C} : \widehat{\Pi}_{it}(P_{it}^M) - \Pi_{it} > 0 \;\; and \;\; \widehat{\Pi}_{st}(P_{it}^M) - \Pi_{st} > 0 \right\}. \tag{14}$$

The individual firm's profits from contracting $\widehat{\Pi}_{zt}$ with $z = (i,s)$ are required to be higher than the profits if the firms do not come to an agreement:

$$\widehat{\Pi}_{it}(P_{it}^M) = \Pi_{it} + (MRP_{it}^M - P_{it}^M)M_{it}^*, \tag{15}$$

$$\widehat{\Pi}_{st}(P_{it}^M) = \Pi_{st} + (P_{it}^M - MC_{st})M_{it}^*. \tag{16}$$

Any price P_{it}^M in $\mathbb{C}^+$ divides the profits between the manufacturer and the supplier. The contract is a solution to the Nash bargaining product:

$$\max_{P_{it}^M \in \mathbb{C}^+} \left[\widehat{\Pi}_{it}(P_{it}^M) - \Pi_{it} \right]^b \left[\widehat{\Pi}_{st}(P_{it}^M) - \Pi_{st} \right]^{1-b}. \tag{17}$$

The car manufacturer's bargaining weight is represented by b and the supplier's bargaining weight is represented by $1-b$. Reformulating the FOC of equation (17) results in the following equation:

$$\frac{(\widehat{\Pi}_t - \widehat{\Pi}_{st}(P_{it}^M) - \Pi_{it})}{(\widehat{\Pi}_{st}(P_{it}^M) - \Pi_{st})} = \frac{b}{(1-b)}. \tag{18}$$

Combining equation (18) with (15) and (16) and extending the resulting equation with prices P_{it}^M yields equation (19). It shows that the relative bargaining weights reflect the ratio of the manufacturer's Lerner-type markdown to the supplier's Lerner markup. If the markdown and the markup are equal, both parties have the same bargaining weight ($b = 0.5$). An increase in the manufacturer's markdown implies an increase in the manufacturer's bargaining weight b:

$$\frac{\frac{MRP_{it}^{M} - P_{it}^{M}}{P_{it}^{M}}}{\frac{P_{it}^{M} - MC_{st}}{P_{it}^{M}}} = \frac{b}{(1-b)}. \tag{19}$$

Finally, plugging in γ_{it}^{M} and μ_{st} as defined in equation (1) and (8) yields:

$$\frac{\gamma_{it}^{M} - 1}{1 - \mu_{st}^{-1}} = \frac{b}{(1-b)}. \tag{20}$$

Relating the markup μ_{st} and markdown γ_{it}^{M} to relative bargaining weights rules out the corner cases where either the car manufacturer or the supplier receives the total margins MRP_{it}^{M}/MC_{st}. It allows either the manufacturer's or supplier's bargaining weight to approximate one in the limit only. In scenarios where the supplier's markup or the manufacturer's markdown approximate one in the limit ($\mu_{st} = 1$ or $\gamma_{it}^{M} = 1$), equation (20) is not defined.

4 Empirical Framework

In subsection 4.1, I describe the empirical framework for markdown estimation, including the measure taken to the data and the employed aggregation procedures for the construction of manufacturer plant-level markdowns. In subsection 4.2, I describe the measure for the total margins on the input and output market of the car manufacturers that I take to the data. In subsection 4.3, I describe the structural production function estimation procedure for the output elasticities of labor θ_{it}^{L} and θ_{st}^{L}. I provide a detailed description of the estimation procedure including product characteristics and comparison to other approaches in Hahn (2024).

4.1 Estimating Markdowns

Based on equation (10), the markdown γ_{it}^{M} could be estimated in levels for applications where contract-specific price information between upstream and downstream firms is available. In this case, markdown variation could be decomposed into (i) variation in the distribution of the shared margin between vertically related firms, (ii) variation in the size of the shared margin between vertically related firms, and (iii) variation in both (distribution and size).[13]

Because of data limitations, it is not feasible to estimate the MRP_{it}^{M}/MC_{st}-ratio. It is possible, however, to measure the evolution of markdowns with the additional assumption of either (i) fixing the firms' bargaining weights or (ii) allowing for varying bargaining weights, but fixing the MRP_{it}^{M}/MC_{st}-ratio.

Fixing the bargaining weights implies that variation of the additional margin is proportionately split between the firms. An increasing marginal revenue product or marginal cost shocks to the supplier affect the manufacturer's markdown and the supplier's markup equally. To provide an example, equal bargaining weights of $b = 0.5$ imply that the supplier and manufacturer receive an equal share of the margin. An increase of the supplier's markup is reflected in a proportionate increase of the manufacturer's markdown.[14] To relate this assumption to the illustration in Fig.1, it allows for a varying combined size of the blue and orange rectangles but requires a constant relative size of both rectangles.

Allowing for varying bargaining weights implies that variation in the inverse supplier's markup

[13]In other applications where firms produce with a Gross-Output technology, the markdown could be estimated following the method by Morlacco (2019). In this case, the term $\frac{MRP_{it}^{M}}{MC_{st}}$ can be backed out, because the markdown γ_{it}^{M} and markup μ_{st} are estimated separately.

[14]The assumption of $b = 0.5$ allows for a straightforward application of the presented framework. Because the supplier's markup is equal to the manufacturer's markdown, the suppliers's markup can be directly inserted into equation 7. This allows for a separation of the manufacturer's market power on the product and input markets.

is reflected in variation in the manufacturer's markdown and vice versa:

$$\gamma_{it}^{M} = \frac{1}{\mu_{st}} \frac{MRP_{it}^{M}}{MC_{st}} = \frac{1}{\mu_{st}} X_{is}. \tag{21}$$

This implies that the MRP_{it}^{M}/MC_{st} is constant over time, but may vary between contracts. X_{is} represents the contract specific constant. This assumption rules out shifts in MRP_{it}^{M} that are not reflected in proportional shifts in MC_{st} and vice versa. Variation in the marginal revenue product and marginal cost could for instance occur because of product quality improvements that affect both variables proportionately. To relate this assumption to the illustration in Fig.1, it allows for (i) the relative sizes of the orange and blue rectangles to vary over time, and (ii) the sum of the rectangles to increase and decrease in fixed proportions over time, such that the MRP_{it}^{M}/MC_{st}-ratio stays constant. In this case, car manufacturers could exert more pricing pressure for rather off-the-shelf products compared to elaborate model-specific products. Bargaining weights could also vary over time, because of for instance changes in the firms' product portfolio or macro-economic trends.

Which of these assumptions is most appropriate strongly depends on the industrial environment. I relate fixing the bargaining weights, which allows for both firms to benefit from an increasing marginal revenue product and to make losses because of the supplier's marginal cost shocks, to a cooperative contracting environment. This is the case for Japanese car manufacturers, which have rather paternalistic relationships with their suppliers that usually involve equity ties (Sturgeon et al., 2009). As pointed out by Sturgeon et al. (2009), the car manufacturers' purchasing techniques strongly differ between countries.[15]

I relate fixing MRP_{it}^{M}/MC_{st}-ratio and allowing for flexible bargaining weights to more aggressive bargaining techniques. In this case, marginal cost shocks of suppliers are not necessarily captured by the car manufacturers. European car manufacturers adopted exceptionally exploitative

[15] On page 21, the authors cite managers of US-based suppliers in an interview from the year 2000: *"there is some truth to the idea of that some assemblers are more loyal to their suppliers than others - Japanese assemblers are the most loyal, followed by Europeans, Americans are the least loyal. [...]".*

bargaining techniques from the early 1990s on, which led to an industry crisis concerning trust between car manufacturers and their suppliers see Sturgeon et al., 2009; Calzolari et al., 2019, for more information. The high cost of developing blueprints together with aggressive purchasing practices contributed to an immense increase of bankruptcies among the largest automotive suppliers (Sturgeon et al., 2009).

Therefore, I assume the latter to be the appropriate assumption for the European car market, which allows for varying bargaining weights and a fixed MRP_{it}^{M}/MC_{st}-ratio.

I define the supplier's markup μ_{st} as the standard markup in a Leontief setting following De Loecker and Scott (2022):

$$\gamma_{it}^{M} = \frac{1}{\mu_{st}} X_{is} = \left(\frac{\alpha_{st}^{L}}{\theta_{st}^{L}} + \alpha_{st}^{M} \right) X_{is}. \tag{22}$$

It implies that the input markets of suppliers are exogenous and does not allow for vertical externalities upstream of the part-supplying industry. The car manufacturer's markdown γ_{it}^{M} depends on the part supplier's revenue shares of material inputs α_{st}^{M} and labor α_{st}^{L} and the supplier's output elasticity of labor θ_{st}^{L}.

4.1.1 Aggregating Markdowns to the Manufacturer Plant-Level

Constructing γ_{it}^{M} at the manufacturer plant level requires two weights. First, it requires weighting supplier groups that produce different inputs (such as powertrain components or underbody) to the plant level of the car manufacturer. Second, it requires weighting markups of supplier plants s to construct markups of supplier groups g. The second weights are necessary for this application because contracting information is available between car manufacturing plant i (e.g., Renault plant located in Revoz, Slovenia) with supplier group g (e.g., Bosch, location unknown).

$$\gamma_{it}^M \propto \frac{1}{\sum_{b=1}^{B} \frac{1}{B} \sum_{g=1}^{G} \frac{N_{gbit}}{N_{bit}} \mu_{gt}} \tag{23}$$

I construct γ_{it}^M as in equation (23). Each product category b (e.g., chassis, underbody, or powertrains) receives equal weights. Within product categories, the markups of each supplier group g are weighted by the group g's share of all contracts in product category b with car manufacturing plant i at time t. N represents the total amount of contracts and μ_{gt} is the supplier group-level markup.

I construct the supplier group-level markup μ_{gt} as the sales-weighted plant-level markup of all plants s that belong to the same group g:

$$\mu_{gt} := \sum_{s=1}^{J} \frac{P_{st} Q_{st}}{P_{gt} Q_{gt}} \mu_{st} \; \forall \, s \in g. \tag{24}$$

4.2 Estimating the Manufacturers' Total Margins

Disentangling manufacturer's markups μ_{it} and markdowns γ_{it}^M requires the identification of markdowns in levels. Because I evaluate markdown variation over time, I construct a measure for the total margin of car manufacturers that comprises the manufacturers' markup on the product market μ_{it} and markdown on the input market γ_{it}^M. I denote the measure ψ_{it}.

$$MC_{it} = w_{it} \frac{\partial L_{it}}{\partial Q_{it}} + \frac{P_{it}^M}{\kappa_{it}} \times \gamma_{it}^M \tag{25}$$

$$CMC_{it} = w_{it} \frac{\partial L_{it}}{\partial Q_{it}} + \frac{P_{it}^M}{\kappa_{it}} \tag{26}$$

Similarly to Avignon and Guigue (2022), I differentiate between marginal cost of production MC_{it} that controls for buyer power in equation (25) (as derived in section 2) and marginal cost of production estimated based on the assumption of exogenous input prices with $\gamma_{it}^M = 1$ in equation

(26). I denote the latter counterfactual marginal cost CMC_{it}.[16] The difference between the two measures is that in (25) the car manufacturer internalizes the impact on input prices through γ_{it}^{M}. This measure allows the markdowns on the input market to scale up the marginal cost of production. CMC_{it}, however, relies on exogenous input prices with $\gamma_{it}^{M} = 1$.

Dividing output prices P_{it} by MC_{it} yields the standard markup equation that allows for buyer power. Dividing output prices by CMC_{it}, however, yields a composite measure for total margin which does not differentiate between margins coming from the product or input markets:

$$\psi_{it} = \frac{P_{it}}{CMC_{it}} = \frac{P_{it}}{w_{it}\frac{\partial L_{it}}{\partial Q_{it}} + \frac{P_{it}^{M}}{\kappa_{it}}}. \tag{27}$$

Inserting revenue shares $P_{it}^{X} X_{it} / P_{it} Q_{it} = \alpha_{it}^{X}$ for $(X = L, M)$ and the output elasticity of labor $\theta_{it}^{L} = \frac{\partial Q_{it}}{\partial L_{it}} \frac{L_{it}}{Q_{it}}$ results in the equation for total market power ψ_{it} that I take to the data:

$$\psi_{it} = \frac{1}{\frac{\alpha_{it}^{L}}{\theta_{it}^{L}} + \alpha_{it}^{M}}. \tag{28}$$

The measure ψ_{it} equals the standard markup estimate in a Leontief production setting under the assumption of exogenous input markets as in De Loecker and Scott (2022).

4.3 Production Function Estimation

I structurally estimate the output elasticities of labor θ_{it}^{L} and θ_{st}^{L} with the two-stage control function approach as in Ackerberg, Caves, and Frazer (2015). It controls for unobserved productivity of firms given that productivity determines the firms' input demand and thus affects the estimated output elasticities.

In the following section, I briefly describe the estimation procedure for car manufacturers. I first provide the intuition of the framework relying on comparable input and output quantities

[16] Avignon and Guigue (2022) label CMC_{it} as accounting marginal cost.

and then introduce product characteristics and prices as additional controls to account for product quality variation of cars. Similar to the notion in De Loecker et al. (2016), I employ product dummies, supplier group dummies, and price indices for the production function estimation of part suppliers. The description of the production function estimation procedure for suppliers is provided in Appendix C.

4.3.1 Production Function Specification

Recall that I define the car manufacturers' production function based on a Leontief technology:

$$Q_{it} = min\{\kappa_{it}M_{it}, \Omega_{it}F(L_{it}, K_{it}; \beta)\} exp(\varepsilon_{it}). \tag{29}$$

The output quantities Q_{it}, material input quantities M_{it}, number of employees L_{it}, and capital K_{it} are comparable units in terms of quality. The substitutability between labor and capital is parameterized by the function $F(;\beta)$ and material inputs enter as perfect complements to the combination of labor and capital. The term κ_{it}^{M} represents the inverse of the required per-unit materials inputs, which is plant-specific. It allows for technological and product quality differences between car manufacturing plants.

From the researcher's perspective, there are two unobservables. The first is the productivity term Ω_{it}, which is observed or predictable by the firms when making input decisions. The second is the term ε_{it}, which represents potential measurement error. It could be interpreted as unpredicted shocks to production, such as machine breakdowns.

The car manufacturer chooses the input quantities of labor, capital, and materials according to the following equation:

$$Q_{it} = \kappa_{it}M_{it}exp(\varepsilon_{it}) = \Omega_{it}F(L_{it}, K_{it}; \beta) exp(\varepsilon_{it}). \tag{30}$$

As emphasized in De Loecker and Scott (2022), situations might arise where equation (30) does not hold in practice. These might be situations where materials are the most flexible inputs with labor and capital being quasi-fixed, and material input prices are sufficiently high in comparison to output prices. Under these conditions, it might not be profitable for the firms to produce at all and shut down production with $M_{it} = 0$. However, $M_{it} > 0$ can easily be verified with information on the production locations' financial statements.

4.3.2 Estimation Procedure: Baseline

The goal of the production function estimation procedure is to retrieve the parameters β from the function $F(.)$. Under the assumption that $F(.)$ represents a Cobb-Douglas specification, the production function coefficient on labor β^L is the output elasticity of labor, which is required for the estimation of the car manufacturers' total margins.[17] The following equation represents the production function to be estimated in logarithmic transformation:

$$q_{it} = f(l_{it}, k_{it}, \beta) + \omega_{it} + \varepsilon_{it}. \tag{31}$$

First Stage of the Estimation Procedure. The first stage of the estimation procedure following Ackerberg, Caves, and Frazer (2015) separates unobserved productivity ω_{it} from the measurement error ε_{it}.

As pointed out by De Loecker and Scott (2022), the underlying fixed-proportion rule of the Leontief technology as illustrated in equation (30) allows to construct a control for unobserved productivity without taking a stance on competition in input or product markets.[18] Taking the logarithmic transformation of equation (30) and taking advantage of the fixed-proportion requirement of the Leontief setting allows for the construction of the following equation as control for unobserved

[17] In this case, all firms have a common output elasticity of labor over time, such that $\theta_{it}^L = \beta^L$.

[18] This approach is not bound to the identification problem that arises with gross output production function specifications. See Ackerberg, Caves, and Frazer (2015) and Gandhi, Navarro, and Rivers (2020) for discussions of this issue.

productivity ω_{it}:

$$\omega_{it} = log(\kappa_{it}) + m_{it} - f(l_{it}, k_{it}; \beta). \tag{32}$$

Inserting (32) in (31) yields predicted output Φ_{it} as a function of the plant-specific inverse amount of material inputs required for the construction of cars κ_{it} and material input quantity m_{it} as in (33). This step separates unobserved productivity ω_{it} from the measurement error ε_{it}.

$$\begin{aligned} q_{it} &= f(l_{it}, k_{it}; \beta) + log(\kappa_{it}) + m_{it} - f(l_{it}, k_{it}; \beta) + \varepsilon_{it} \\ &= log(\kappa_{it}) + m_{it} + \varepsilon_{it} \end{aligned} \tag{33}$$

Given a vector of parameters β, productivity $\omega_{it}(\beta)$ is defined as:

$$\omega_{it}(\beta) = \Phi_{it} - f(l_{it}, k_{it}, \beta). \tag{34}$$

Second Stage of the Estimation Procedure. The second stage of the procedure uses the law of motion of productivity and timing assumptions to estimate the production function coefficients. I assume that the law of motion is represented by a non-parametric function $g(.)$, which depends on lagged productivity ω_{it-1} and a dummy variable for lagged acquisitions acq_{it-1}. The dummy for acquisitions accounts for productivity shocks that might occur when a plant changes its owner:[19]

$$\omega_{it} = g_t(\omega_{it-1}, acq_{it-1}) + \xi_{it}. \tag{35}$$

The term ξ_{it} denotes innovation in the productivity process, which is used for the construction of moment conditions for the production function parameters β. Capital is chosen at time t. Labor is subsequently chosen at time $t+1$. The moment conditions in (36) serve for the identification of

[19] See Braguinsky et al. (2015). In this paper, the authors find an impact of acquisitions on plant-level productivity and profitability. De Loecker (2013) points out that the variables included in the productivity process do not necessarily have an impact on productivity. By including acquisitions, I allow the productivity process to depend on this variable and abstract from a process that only depends on ω_{it-1}.

the production function parameters in $f(.)$:

$$E\left(\xi_{it}(\beta)\begin{pmatrix} l_{it-1} \\ k_{it} \end{pmatrix}\right) = 0. \tag{36}$$

4.3.3 Differentiated Products - Leontief Technology

Cars are vertically and horizontally differentiated products with changing product characteristics over time. Even if inputs and outputs were observed in physical quantities, estimating the baseline production function as described in the previous section would result in biased estimates if variation in product characteristics is not fully accounted for. The arising bias, the so-called quality bias, might occur for applications where inputs and outputs are measured in quantities, but products are differentiated. Borrowing insights from the hedonic pricing literature (e.g., Triplett, 1969; Rosen, 1974), I denote comparable input and output quantities in logarithmic transformation as:

$$q_{it} = q^*_{it} + q^H_{it}, \tag{37}$$

and

$$m_{it} = m^*_{it} + m^H_{it}, \tag{38}$$

where I split comparable output quantities q_{it} into two components: first, observed quantity that contains quality variation q^*_{it} and second, a hedonic quantity index q^H_{it} that rescales the observed quantities to comparable units. I apply the same notion to the material input quantity. Based on data availability, I focus on quality variation of material inputs and assume that quality variation of the labor force is covered by including the headcount of employees and the wage bill. However, the same notion could be applied to other inputs.[20] With inputs and outputs observed in expenditures and sales, the production function for differentiated products can be rewritten as the following:

[20] Fox and Smeets (2011) account for quality variation in the labor force, such as education, etc.

$$
\begin{aligned}
q_{it} &= f(l_{it}, k_{it}; \beta) + \omega_{it} + a(p_{it}, q^*_{it}; \alpha) + \varepsilon_{it}, \\
&= log(\kappa_{it}) + m_{it} + h\left(p_{it}, z^M_{it}, q^*_{it}, m^*_{it}; \gamma\right) + \varepsilon_{it}.
\end{aligned} \tag{39}
$$

The functions $a(., \alpha)$ and $h(.; \gamma)$ contain the additional variation that is introduced to the production function because of output price variation p_{it}, output quality variation q^*_{it}, material input price variation z^M_{it} and material input quality variation m^*_{it}. When taking equation (39) to the data without controlling for the functions $a(., \alpha)$ and $h(.; \gamma)$, standard approaches to production function estimation might lead to biased estimates. Both the coefficients in β and unobserved productivity ω_{it} might be correlated with the unobservables in the $a(., \alpha)$ and $h(.; \gamma)$-functions.

4.3.4 Introducing Product Characteristics and Prices

To control for price and quality variation, I introduce sales-weighted plant-level product characteristics and prices to the estimation procedure.

Introducing Characteristics to κ_{it}. Because the required share of material inputs to produce one unit of output is unobserved, I approximate κ_{it} with the following function:

$$
\kappa_{it} = h(\chi_{it}, l_{it}, w_{it}, m_{it}, k_{it}, D_t), \tag{40}
$$

which depends on plant-level sales-weighted car characteristics χ_{it}, the number of employees l_{it}, wages w_{it}, material inputs m_{it}, capital k_{it}, year fixed effects D_t, and respective interactions. The selection of variables is motivated by the optimal input demand in the Leontief production framework as in equation (30). Additionally to the number of employees l_{it}, I include wages w_{it} to account for quality variation in the labor force within and between production locations.[21] Including characteristics to the approximation of κ_{it} allows for variation in the required material input share

[21] De Loecker and Scott (2022) approximate κ_{it} with capital, labor, materials, firm-level wages, year dummies, regional dummies, and interactions.

to depend on the production profiles of the car manufacturers.

Introducing Characteristics to the Production Function. Latent quality variation in inputs and outputs might be correlated with input demand and thus introduces a bias to the production function estimates. To account for unobserved quality variation in inputs and outputs, I introduce product characteristics to both stages of the production function estimation procedure.

For the first stage, I reformulate equation (39) for ω_{it}:

$$\omega_{it} = log(\kappa_{it}) + m_{it} + h(.;\gamma) - f(.;\beta) - a(.;\alpha). \tag{41}$$

and insert (41) into the production function to express predicted output Φ_{it} based on the plant-specific inverse amount of material inputs required for the construction of cars κ_{it}, material input quantity m_{it}, and the function $h(.;\gamma)$. This step separates the two unobserved terms ω_{it} and ε_{it}:

$$\begin{aligned} q_{it} &= \Phi_{it} + \varepsilon_{it}, \\ &= f(.;\beta) + a(.;\alpha) + log(\kappa_{it}) + m_{it} + h(.;\gamma) - f(.;\beta) - a(.;\alpha) + \varepsilon_{it}, \\ &= log(\kappa_{it}) + m_{it} + h(.;\gamma) + \varepsilon_{it}. \end{aligned} \tag{42}$$

To control for $h(.;\gamma)$ in the estimation procedure, I introduce the following quality control function in the spirit of De Loecker et al. (2016):

$$z_{it}^{M} = z_{t}^{M}(\rho_{it}, \chi_{it}, G_i, Y_t). \tag{43}$$

Instead of product-level prices, market shares, product dummies, and geographic dummies as in De Loecker et al. (2016), I employ sales-weighted plant-level prices ρ_{it}, sales-weighted plant-level product characteristics ξ_{it}, country dummies G_i and time dummies Y_t. Including characteristics instead of the product category dummies allows for a higher level of product differentiation and varying product characteristics over time. The notion of adding product characteristics is based on insights from the hedonic pricing literature (e.g., Rosen, 1974; Feenstra and Levinsohn, 1995; Triplett, 1969).

Following the standard control function approach, I specify productivity $\omega_{it}(\beta;\boldsymbol{\alpha})$ based on a vector of parameters $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}$:

$$\omega_{it}(\beta;\boldsymbol{\alpha}) = \Phi_{it} - f(l_{it}, k_{it}, \boldsymbol{\beta}) - a(., \boldsymbol{\alpha}). \tag{44}$$

For the second stage of the estimation procedure, I specify the law of motion of productivity and moment conditions as specified in the baseline approach:

$$\omega_{it} = g_t(\omega_{it-1}, acq_{it-1}) + \xi_{it}, \tag{45}$$

and

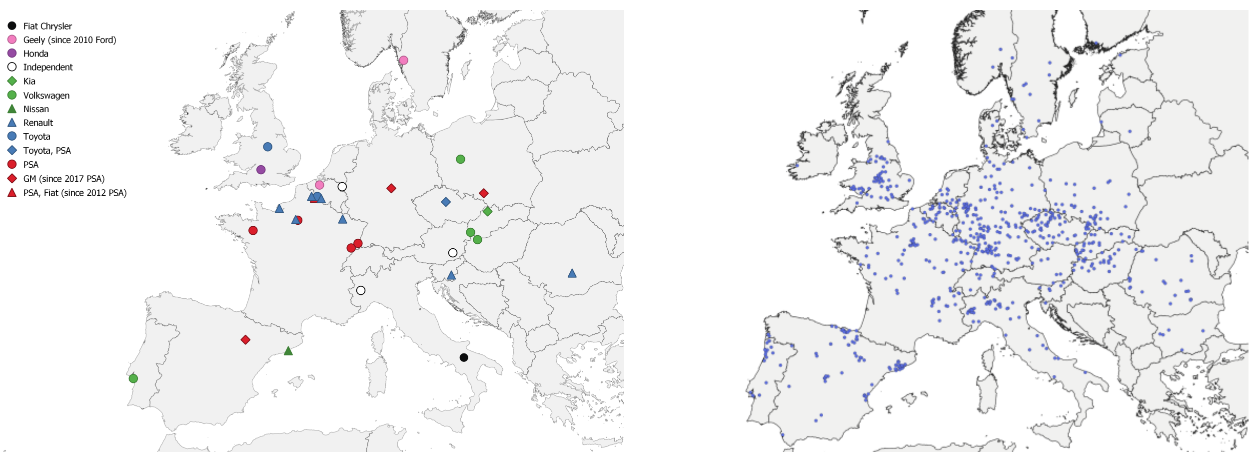
$$E\left(\xi_{it}(\beta;\boldsymbol{\alpha})\begin{pmatrix} l_{it-1} \\ k_{it} \end{pmatrix}\right) = 0. \tag{46}$$

5 Data

I assemble the data from three main sources. I retrieve balance sheet information of suppliers and manufacturers from the Orbis data provided by Bureau van Dijk. The dataset contains plant-level financial statements (e.g., sales, capital, number of employees), product descriptions, and addresses. I retrieve contracting information from the SupplierBusiness data on vertical relationships constructed by IHS Markit. The dataset provides information on the produced parts by suppliers and the car manufacturing plants each supplier contracts with. I construct sales-weighted plant-level characteristics and prices for car manufacturing plants from data provided by JATO and additional production information from the car manufacturers' websites. Additional descriptive statistics on the database are provided in Appendix A.

5.1 Financial Statements

The balance sheet data contains production information for 31 car manufacturing plants within Europe (Fig. 2). There are two main reasons for the small sample size of car manufacturing plants. First, with only 139 plants, the overall number of production locations is relatively small in Europe. Second, most production locations do not report unconsolidated balance sheet information.[22] Using unconsolidated accounts allows the construction of sales-weighted plant-level characteristics and prices because the produced models at a time are available on the individual production locations' websites.



Car Manufacturing Plants   Part Supplier Plants

Notes: The maps show the production plants of car manufacturers and suppliers that report individual financial statements. The analysis of the manufacturers' total margins (markups and markdowns) relies on the subset of manufacturers from the left map. The analysis of the car manufacturers' markdowns requires the suppliers' financial statements (right map) and contracting information between manufacturers and suppliers only. Thus, focusing on markdowns on the input market allows extending the analysis to all car manufacturing plants located in Europe. The analysis of the suppliers' markups relies on the production plants from the right map.

Figure 2: Production Plants

I observe balance sheet data for a total of 253 supplier groups with an average of 14 production

[22]For example, the Audi production location in Wolfsburg (Germany) only reports consolidated accounts for several hundreds of production plants. The consolidated account also contains information on Volkswagen insurance companies and banks. Estimating output elasticities with consolidated accounts creates a measure of markups that cannot be interpreted. It is not transparent how the subsidiaries are weighted within the reported balance sheet data.

locations.[23] The supplier pool also contains unconsolidated balance sheet data only.

	rev_M	exp_M	rev_L	exp_L
2002	0.868	0.557	0.059	0.036
2003	0.862	0.563	0.067	0.036
2004	0.788	0.582	0.094	0.066
2005	0.853	0.592	0.061	0.043
2006	0.879	0.590	0.051	0.033
2007	0.863	0.601	0.068	0.045
2008	0.807	0.613	0.084	0.061
2009	0.829	0.593	0.091	0.053
2010	0.809	0.600	0.106	0.069
2011	0.878	0.619	0.066	0.040
2012	0.856	0.615	0.073	0.059
2013	0.902	0.608	0.055	0.032
2014	0.778	0.612	0.143	0.072
2015	0.869	0.602	0.083	0.050
2016	0.885	0.602	0.045	0.034
2017	0.820	0.603	0.101	0.045
2018	0.800	0.624	0.072	0.045

Manufacturers

	rev_M	exp_M	rev_L	exp_L
2002	0.868	0.557	0.059	0.036
2003	0.862	0.563	0.067	0.036
2004	0.788	0.582	0.094	0.066
2005	0.853	0.592	0.061	0.043
2006	0.879	0.590	0.051	0.033
2007	0.863	0.601	0.068	0.045
2008	0.807	0.613	0.084	0.061
2009	0.829	0.593	0.091	0.053
2010	0.809	0.600	0.106	0.069
2011	0.878	0.619	0.066	0.040
2012	0.856	0.615	0.073	0.059
2013	0.902	0.608	0.055	0.032
2014	0.778	0.612	0.143	0.072
2015	0.869	0.602	0.083	0.050
2016	0.885	0.602	0.045	0.034
2017	0.820	0.603	0.101	0.045
2018	0.800	0.624	0.072	0.045

Suppliers

Table 1: Median Revenue & Expenditure Shares

Table 1 shows median revenue shares and expenditure shares of material inputs and labor at the plant level for car manufacturers and suppliers. Revenue shares are calculated as either labor or material input expenditure divided by sales and expenditure shares are calculated as either labor and material input expenditure divided by total production expenditure.[24] For both car manufacturers and suppliers, the revenue shares of material inputs have been relatively constant during the observed time period. For car manufacturers, however, the revenue shares of labor decreased since 2013. Variation of expenditure shares provides an indication for technology variation between firms and over time under the assumptions of perfectly variable and free adjustable input markets, and constant returns to scale. Variation of expenditure shares of labor and material inputs are relatively stable over time for both manufacturers and suppliers. For this reason, I estimate one production function across years to increase sample size and therefore precision of the estimates.

[23] Appendix A provides additional descriptive statistics. The detailed construction of the supplier pool is described in Appendix D.

[24] Total production expenditure is calculated as the sum of labor expenditure, material input expenditure, and capital (with a depreciation rate of 0.12). Total expenditure could also be defined as the cost of goods sold, which firms sometimes report with their financial statement.

5.2 Prices and Characteristics

To construct plant-level prices and characteristics, I link the JATO database on car characteristics and prices to manufacturing plants.

The JATO database contains prices for car models in seven European countries[25] for the period 1998 to 2018. The construction of plant-level prices faces two challenges: (i) unobserved destination countries of manufactured cars, and (ii) unobserved relative quantities of car models in the product mix of car manufacturers. I solve the first challenge by assuming that each production location sells its cars to European countries. The assumption implies that Volkswagen produces the same models for the Asian or US market in plants that are geographically closer than the European plants. I solve the second challenge of unobserved quantities by weighting plant-level prices and characteristics with sales of the produced models in the respective countries.

Figure 3 presents the correlations of characteristics and prices. The strongest correlation is observed between prices and horsepower (0.961), followed by cylinder and horsepower (0.848). The weakest correlations are observed between height and length (0.187) and width and liter (0.273). I provide more summary statistics on the data in Appendix A.

5.3 Contracting Information

Table 2 provides detailed information on the contracting patterns between European car manufacturing plants and part supplier groups. Between 2002 and 2009, each supplier closed on average 486 contracts with 70 car manufacturing plants for 98 car models. The variance of contracts is high. The lowest quartile of suppliers only closed 94 contracts whereas the highest quartile closed more than seven times as many contracts in the observed time period.

[25] Belgium, France, Germany, Great Britain, Italy, Netherlands, and Spain.

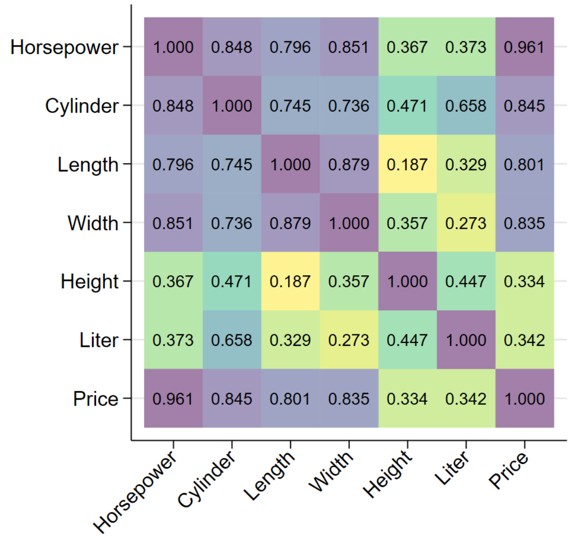


Figure 3: Correlations of Sales-Weighted Plant-Level Characteristics

	mean	p25	p50	p75	count
Observations Supplier Groups:					
Contracts	485.89	94	308	742	29869
Manufacturing Plants	70.48	40	78	103	29869
Car Models	97.96	42	105	152	29869
Products (Wide Category)	3.70	3	4	5	29869
Products (Narrow Category)	13.19	5	11	21	29869
Observations Manufacturing Plants:					
Contracts	405.56	198	355.00	627	29869
Supplier Groups	103.68	69	98.00	140	29869
Car Models	2.81	1	3.00	4	29869
Car Platforms	2.80	1	2.00	4	28196
Peak Production (per Model)	120.52	36	78.15	184	18610
Plants per Model	1.46	1	1.00	2	29869

Notes: The data contains 952 supplier groups and 139 car manufacturing plants that belong to 15 parent companies (Fiat, PSA etc.). Table 14 in Appendix A shows the same table for the subset of plants that reports balance sheet data.

Table 2: Relationships between European Manufacturers and Suppliers

The relationship data contains product categories of different granularity. The wide category contains the five major product groups.[26] The narrow category contains 32 finer-grained product groups (such as suspension system, tires, coatings or battery).[27] On average, suppliers produce in four of the five wide product categories and in 13 of the 32 narrow product categories. Between 2002 and 2009, each car manufacturing plant closed on average 406 contracts with 104 suppliers to produce three car models.

Cars are not only differentiated along the dimensions of car models but also along the dimensions of car platforms. The supplier Magna provides a definition for platforms: *"At its most basic level, an automotive platform can be described as the sum of all non-styling specific parts – functions, components, systems, and sub-assemblies – of a vehicle. This means that an automotive platform is, in essence, the structural underpinnings of a vehicle."*(Magna, 2022b). Some models are more similar to each other, given that they are produced using the same platform as structural underpinning. For this reason, I employ the platform codes as an additional measure of similarity between car models in the subsequent analysis.

On average, a plant's peak production of a model is approximately 120,520 cars. Most models are manufactured within one production plant in Europe. Only plants in the last quartile of the distribution produce models that are manufactured in at least one other European production plant.

6 Results

I take the empirical framework from section 4 and apply it to the data presented in section 5. In the main text, I focus only on the manufacturers' production function estimation, including product characteristics. The suppliers' production function results are provided in Table 16 in Appendix B.

[26]These are chassis/underbody, electrical/electronic, interior, exterior, and powertrain.

[27]Table 10 in Appendix A provides a list of the product categories in which the sampled supplier groups operate in.

6.1 Production Function Estimates

To determine which characteristics to include into the production function estimation procedure, I explore reduced form correlations between characteristics and input demand.

First, I explore whether characteristics and prices explain variations in the input ratios. The relevant ratios in the Leontief setting are the labor-capital ratio, which are the substitutable inputs and the material input-output ratio, which is the complementary input. The coefficients are illustrated in Table 3. Columns (1)-(7) show OLS regression coefficients of the labor-capital ratio on prices and characteristics. They explain little variation in the labor-capital ratio (R^2=0.09). Intuitively, product characteristics do not affect capital and labor usage because car manufacturers conduct the same steps for assembly independent of the model. Some car manufacturers even assemble different car models on the same production line (Magna, 2022a).

Columns (8)-(14) show reduced form regression coefficients of the material input expenditure-output ratio on prices and characteristics. Even though individual characteristics are not significant, together they explain a larger share of the input ratio (R^2=0.29). For this reason, I include characteristics into the approximation of κ_{it} in the first stage of the structural estimation procedure. The notion is that a car manufacturer that assembles SUVs requires a different share of material inputs to produce one car than a manufacturer that assembles Minis.

Second, I explore which characteristics control for remaining quality variation in the output measure that is not captured by variation of prices. Because of the small sample size, it is not feasible to include all characteristics in the estimation procedure. Therefore, I include only the characteristics that explain significant variation in the measure for output quantity once labor and capital are controlled for. Table 15 in Appendix B. shows OLS-regression coefficients of the output quantity on labor, capital, prices, and product characteristics. Of all characteristics and prices,

	(1) l/k	(2) l/k	(3) l/k	(4) l/k	(5) l/k	(6) l/k	(7) l/k	(8) m/q	(9) m/q	(10) m/q	(11) m/q	(12) m/q	(13) m/q	(14) m/q
price	0.359	0.205	0.346	0.989	1.301	1.162	0.902	1.152	3.210	3.742*	4.893*	5.123*	5.138*	4.869*
	(0.492)	(1.403)	(1.079)	(1.229)	(1.237)	(1.238)	(1.235)	(0.616)	(1.763)	(1.598)	(2.142)	(2.148)	(2.133)	(2.126)
cylinder		0.307	-0.0697	0.934	0.0929	-0.286	0.479		-4.139	-5.586*	-3.850*	-4.462*	-4.473*	-4.021*
		(2.099)	(1.781)	(1.952)	(1.914)	(1.952)	(1.696)		(2.622)	(2.581)	(1.612)	(1.736)	(1.732)	(1.523)
height			1.188	0.786	1.705	3.954	5.203			4.235	3.598	4.255	4.184	4.938
			(5.174)	(4.990)	(5.669)	(6.145)	(6.666)			(4.994)	(4.739)	(5.367)	(5.429)	(5.528)
horsepower				-1.688	-2.530	-1.811	-1.210				-3.023	-3.614	-3.643	-3.077
				(1.783)	(2.451)	(2.390)	(2.229)				(2.269)	(2.558)	(2.537)	(2.467)
length					4.262	4.473	9.277					2.992	2.976	5.808
					(5.408)	(5.472)	(6.862)					(4.586)	(4.600)	(5.676)
liter						-1.256**	-1.029*						0.0636	0.0698
						(0.423)	(0.419)						(0.630)	(0.551)
width							-19.55							-11.19
							(9.696)							(6.950)
Observations	296	296	296	296	296	296	296	254	254	254	254	254	254	254
R^2	0.023	0.023	0.024	0.032	0.046	0.070	0.094	0.151	0.227	0.246	0.274	0.283	0.283	0.291
Adjusted R^2	-0.037	-0.041	-0.043	-0.038	-0.027	-0.005	0.017	0.090	0.168	0.184	0.212	0.218	0.215	0.220

Standard errors clustered at the plant-level in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Product Characteristics and Input Ratios

only cylinder has a weakly significant coefficient. The cylinder variable captures the total cylinder capacity of a car, not the number of cylinders. The cylinder capacity of a car is a determining factor for the car's power potential and is highly correlated with other characteristics such as the horsepower, length, and prices.

Table 4 shows the structural production function estimates. Column (1) does not contain any characteristics in the first stage of the procedure. In columns (2)-(7) I subsequently add more characteristics to the first stage. Adding characteristics to the first stage decreases the labor coefficient from 0.976 to 0.882. Adding the last characteristic, which is width, does not have an additional effect on the labor coefficient. The capital and cylinder coefficients are insignificant across specifications. This might driven by small sample size and insufficient variation in the variables. The estimation of the total margin of manufacturers, however, only requires an unbiased estimate of the labor coefficient, which is the output elasticity of labor. For the subsequent analysis, I employ the output elasticity of labor from column (7).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	q	q	q	q	q	q	q
f(.)							
l	0.976**	0.956**	0.976***	0.964***	0.954***	0.882**	0.882**
	(0.324)	(0.303)	(0.259)	(0.275)	(0.284)	(0.273)	(0.290)
k	-0.148	-0.108	-0.129	-0.124	-0.122	0.0406	0.0406
	(0.224)	(0.229)	(0.178)	(0.191)	(0.286)	(0.268)	(0.294)
a(.)							
cylinder	-1.886	-1.925	-1.931	-1.910	-1.909	-2.074	-2.074
	(1.280)	(30.01)	(15.17)	(13.66)	(16.11)	(13.31)	(20.00)
Characteristics in the First Stage:							
cylinder		✓	✓	✓	✓	✓	✓
horsepower			✓	✓	✓	✓	✓
height				✓	✓	✓	✓
liter					✓	✓	✓
width						✓	✓
length							✓
Observations	224	224	224	224	224	224	224

Block-bootstrapped standard errors in parentheses. 10000 replications.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

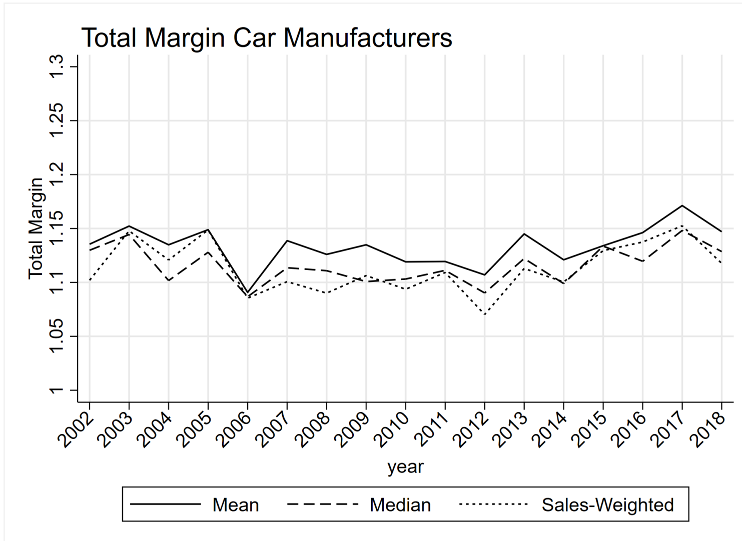
Table 4: Structural Production Function Estimates (ACF)

6.2 Margin Evaluation along the Value Chain

In this section, I analyze the evolution of the manufacturers' total margins, the manufacturers' markdowns, and the suppliers' markups. The estimates rely on the car manufacturers' and suppliers' output elasticities of labor, as well as the respective revenue shares of labor and material inputs as derived in section 2.

6.2.1 Car Manufacturers' Total Margin

Figure 4 shows the evolution of the car manufacturers' total margins. Similarly to the findings of Grieco, Murry, and Yurukoglu (2024) for US car manufacturers, I find that the margins of EU car manufacturers stay relatively constant from 2002 on. For the observed time period, the margins range steadily around 10% to 15%.



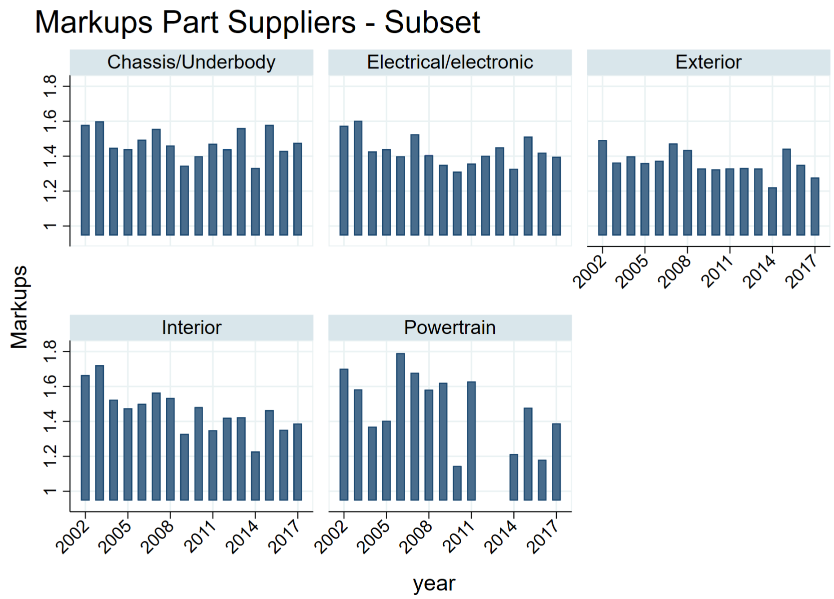
Notes: This graph shows the evolution of the car manufacturers' plant-level margins (markups+markdowns). Independent of the specification (mean, median or sales-weighted), the margins are relatively constant over time, ranging around 10% to 15%.

Figure 4: Car Manufacturers' Total Margins

Figure 5 shows the sales-weighted average of the part suppliers' markups differentiated for product categories.[28] It contains the subset of suppliers that contract with the manufacturers included in the left graphic. Table 15 in Appendix B. shows the same graph for all suppliers. Compared to the manufacturers' total margins, the suppliers' markups are highly volatile across product categories. The markups of interior part suppliers have fallen roughly 40% during the observed time horizon. Sales-weighted markups of powertrain suppliers experience up to 40% year-to-year increases. Chassis, electric and exterior suppliers, set relatively high markups between 25% and 60%.[29]

[28] Since it is unobserved where the supplier groups produce their products, I allocate all plants of a given group to the product category that it closed most contracts in during the observation period.

[29] The number of plants (groups) included for each product category are: Chassis: 356 (81); Electric: 104 (18); Exterior: 37 (10), Interior: 35 (11). Powertrain: 7 (5).



Notes: This graph shows the evolution of the suppliers' sales-weighted markups differentiated for the five major product categories. It contains only the subset of suppliers that contracts with the manufacturing plants contained in Fig. 4. They are allocated to the product categories in which they are most active. The suppliers' markups are highly volatile across product categories. This volatility is not reflected in the margins upstream as depicted in Fig. 4.

Figure 5: Suppliers' Markups

I relate Figure 4 to Figure 5 using the markdown equation $\gamma_{it}^{M} = \mu_{st}^{-1} \frac{MRP_{it}^{M}}{MC_{st}}$. Under the standard assumption of $\gamma_{it}^{M} = 1$, the left graph would represent the car manufacturers' markups μ_{it}. Given that the suppliers' markups are larger than one ($\mu_{st} \neq 1$), this holds only whenever $MRP_{it}^{M} = P_{it}^{M}$. By assumption, the manufacturers would always pay the highest price they are willing to pay without making a loss. Allowing for $P_{it}^{M} \neq MRP_{it}^{M}$ implies that the left graph is a composite measure for the car manufacturers' markups μ_{it} and markdowns γ_{it}^{M}. The markdown γ_{it}^{M} that is latent in the left graph is a function of the inverse markups in the right graph and the total shared margins between the firms.

6.2.2 Bargaining Weights and Shared Margins

Based on the profit sharing framework in section 3, the car manufacturers' bargaining weight can be defined as $b = \frac{\gamma_{it}^M - 1}{\gamma_{it}^M - \mu_{st}^{-1}}$.[30] The estimation of γ_{it}^M requires a measure for MRP_{it}^M / MC_{st}. It relies on contract-specific prices, which are not included in the contracting data available.

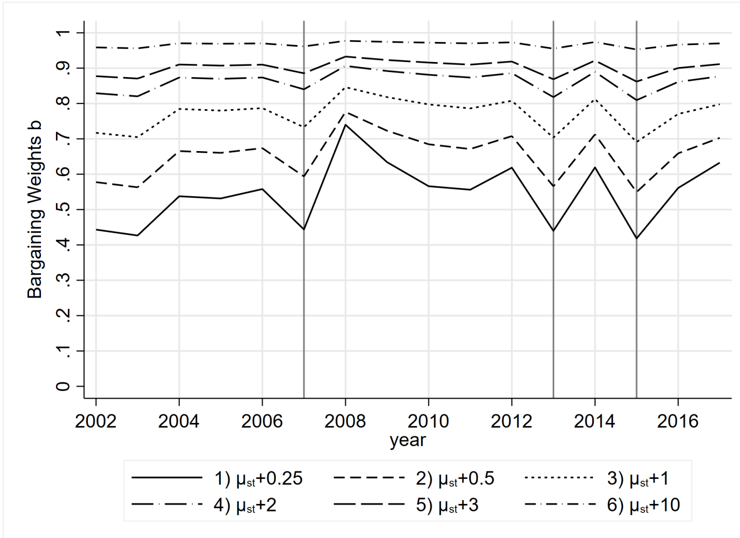
To circumvent the data limitations, I construct the manufacturers' bargaining weight b with different specifications of MRP_{it}^M / MC_{st} and only evaluate the variation of b over time.[31]

Figure 6 and Figure 7 illustrate the results. Figure 6 shows the evolution of the average car manufacturers' bargaining weights b based on different levels of the shared margins MRP_{it}^M / MC_{st}. The shared margins between each manufacturer supplier-pair are required to be at least as high as the suppliers' markups μ_{st}, which are estimated. If the shared margins approach the suppliers' markups in the limit ($MRP_{it}^M / MC_{st} \rightarrow \mu_{st}$), the suppliers receive the total margins and the manufacturers have no margins on the input market ($\gamma_{it}^M = \mu_{st}^{-1}(MRP_{it}^M / MC_{st}) \rightarrow 1$). The graph shows that given the estimated suppliers' markups μ_{st}, an increase in the shared margins leads to an increase of the manufacturers' bargaining weights. The larger the shared margins, the closer the manufacturers' bargaining weights approach one. Evaluating the peaks and troughs of the bargaining weights shows that the manufacturers' bargaining power fell during the financial crisis in 2007, the industry crisis in 2013, or the dieselgate scandal in 2015. The year 2013 was extraordinarily challenging for European car makers. Car sales fell to the lowest level in the last two decades. This was the case for all car makers, specifically for PSA and the Opel brand of General Motors. Volkswagen recorded a 21% loss in operating profits. Industry representatives of BMW attributed the losses

[30] The equation becomes more intuitive when rewriting the markdown and markup in the Lerner format, such that $\gamma_{it}^M = \frac{MRP_{it}^M - P_{it}^M}{P_{it}^M}$ and $\mu_{st} = \frac{P_{it}^M - MC_{st}}{P_{it}^M}$. In this case, $b = \frac{\gamma_{it}^M}{\gamma_{it}^M + \mu_{st}}$. For datasets that allow the estimation of γ_{it}^M and μ_{st} in levels, the bargaining weights could be backed out directly from this equation.

[31] As noted in section 4.1, an alternative approach is to fix the bargaining weights and allow for varying shared margins over time. For Fig. 14 in Appendix B, I construct the shared margin MRP_{it}^M / MC_{st} with different specifications of b.

to strong foreign currency fluctuations and decreasing European demand (New York Times, 2014).[32]

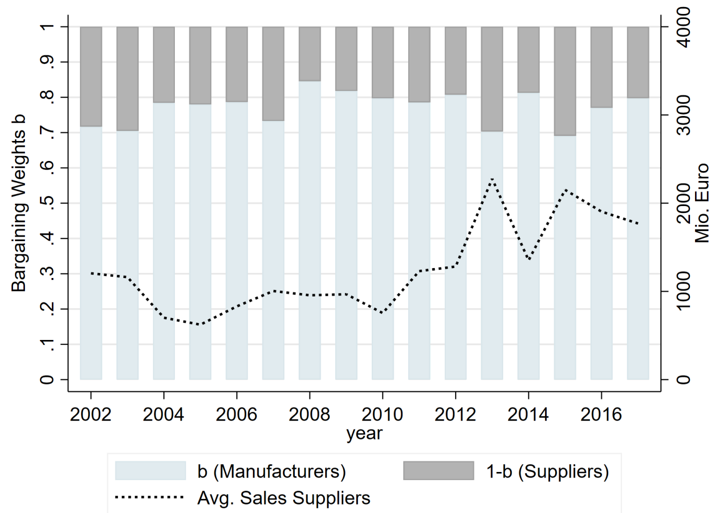


Notes: This graph shows the evolution of the manufacturers' bargaining weighs (b) over time. Due to data limitations, the shared margins between each manufacurer-supplier pair (MRP_{it}^{MM}/MC_{st}) cannot be estimated. Therefore, I construct the manufacturers' bargaining weights with different levels of the shared margin and evaluate changes in bargaining weights. Note that the shared margin between manufacturers and suppliers is required to be at least as high as the estimated suppliers' markups μ_{st}. The manufacturers' bargaining weights decrease with major economic and industry-specific crises, such as the financial crisis in 2007, the major industry crisis in 2013 or the dieselgate scandal in 2015.

Figure 6: Bargaining Weights (1)

Figure 7 shows the third specification from Figure 6 on the left axis and the average suppliers' sales on the right axis. Decreasing bargaining weights of manufacturers are correlated with increasing sales of suppliers. This correlation is particularly pronounced in the years from 2012 to 2017.

[32]Further information on the decline of the European automotive industry in 2013 is provided by the New York Times in New York Times (2013b) and New York Times (2013a).



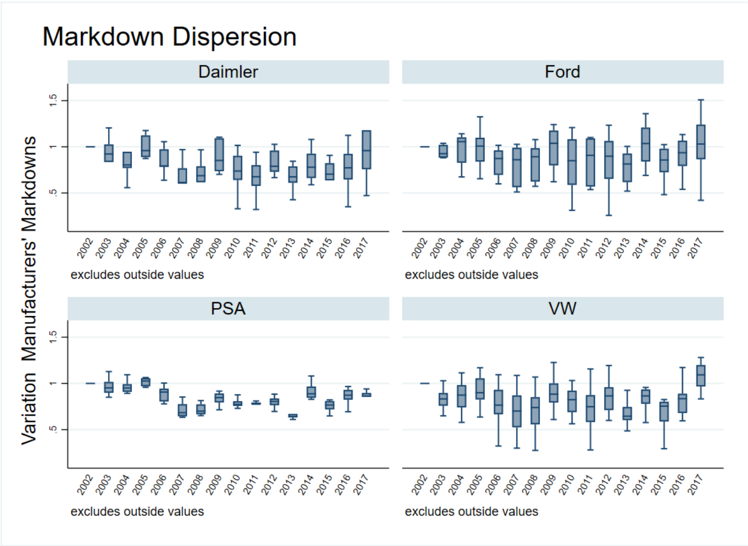
Notes: This graph shows the third specification from Fig. 6 on the left y-axis and the suppliers' average sales on the right y-axis. It indicates an inverse relationship between the suppliers' sales and the manufacturers' bargaining weights.

Figure 7: Bargaining Weights (2)

6.2.3 Car Manufacturers' Markdowns

Constructing variation of manufacturer-level markdowns requires manufacturer-supplier contracting information and suppliers' markup estimates. It does not require balance sheet information of car manufacturers. For this reason, I construct the manufacturer-level markdowns for all European car manufacturing plants that suppliers contract with. This increases the sample size beyond the manufacturers for which balance sheet data is available to a total of 139 European car manufacturing plants.

Figure 8 shows variation of the manufacturer group-level markdowns with the year 2002 chosen as the base year. The underlying manufacturer-supplier relationships are based on the contracting data from 2002 to 2009. The markdowns from 2010 to 2017 rely on the same supplier contracting composition as the year 2009. The graph shows that the markdowns of production locations belonging to different groups are highly dispersed particularly in the case of Daimler (6 plants), Ford (8 plants), and Volkswagen ("VW", 23 plants). For PSA (15 plants), the markdown dispersion is more narrow. A possible explanation for the variation of markdowns within production locations is variation in car segment composition. Car manufacturers specialize in different car segments, which might drive markdown variation.



Notes: This graph shows the dispersion of markdowns within car manufacturer groups. The markdowns are highly dispersed. The year 2002 is chosen as the base year.

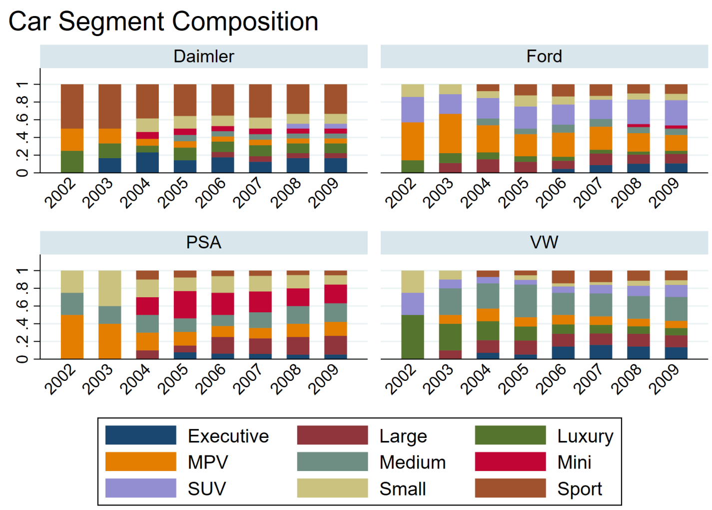
Figure 8: Markdowns at the Manufacturer Group-Level

Figure 9 shows the segment composition of the car manufacturing groups from the left graph.[33] The car manufacturers specialize in different segments. Comparing the manufacturing groups shows that Ford produces the largest share of Sport Utility Vehicles ("SUVs"), Daimler produces most sports cars, and Volkswagen ("VW") specializes in medium-sized cars. All groups produce cars that belong to the segments Multi Purpose Vehicles ("MPVs") and small cars. The same figure with shares weighted by each model's peak production is provided in Appendix B.[34]

To evaluate whether the car manufacturers' production decisions are correlated with markdown variation, I run the following reduced-form regression:

[33]The segment allocation is provided with the contracting data from IHS Markit. Nevertheless, 18 of the 106 models which are assembled in the European manufacturing plants are not allocated to segments. I allocate these 16 models to the respective segments as depicted in Table 13 of Appendix A.

[34]Because the peak production is not provided for all models, weighting by peak production requires dropping some models from the product mix. In Figure 16 in Appendix B I also provide the shares of models at the manufacturer group level for which the yearly peak production is observed.



Notes: This graph shows the car manufacturer groups' yearly car segment composition.

Figure 9: Car Segments at the Manufacturer Group-Level

$$log(\gamma_{it}^{M}) = \beta_0 + \beta_1 X_{it} + \beta_2 FE + \varepsilon_{it}. \tag{47}$$

The dependent variable is the manufacturer plant-level markdown γ_{it}^{M}, and X_{it} contains individual dummy variables for the different car segments as shown in Fig. 9. FE contains country and year fixed effects. To account for possible effects of ongoing and unobserved contracts that were closed before the observed time period, I show the same regression for the subsample 2006 to 2009 in Table 18 of Appendix B. For both the full sample and subsample, I display two specifications with standard errors either clustered at the individual plant level or at the car manufacturer group level. The dummy variable for Executive cars is considered as the outside option.

The regression results show that across specifications, car manufacturers that produce models within the segment Mini set significantly higher markups than manufacturers of executive cars. A possible explanation for this pattern is that manufacturers of Minis receive a larger share of their total margin from their input market and bargain input prices more aggressively. This would allow them to set more competitive prices on the output market towards consumers. A weakly significant but negative correlation is observed for sports car manufacturers, which might receive a larger share of their margin from the output market towards consumers. However, these hypotheses cannot be tested because balance sheet data for car manufacturers is not sufficiently available.

	(1) $\log(\gamma_{it}^M)$	(2) $\log(\gamma_{it}^M)$
Car Segments:		
Large	-0.0313	-0.0313
	(0.0302)	(0.0360)
Luxury	-0.0697	-0.0697
	(0.0518)	(0.0469)
MPV	-0.0230	-0.0230
	(0.0454)	(0.0491)
Medium	0.0437	0.0437
	(0.0287)	(0.0252)
Mini	0.152***	0.152***
	(0.0405)	(0.0275)
SUV	0.00513	0.00513
	(0.0377)	(0.0391)
Small	-0.0657	-0.0657
	(0.0428)	(0.0416)
Sport	-0.0693*	-0.0693*
	(0.0345)	(0.0313)
Clusters Standard Errors:	plant	group
Observations	726	726

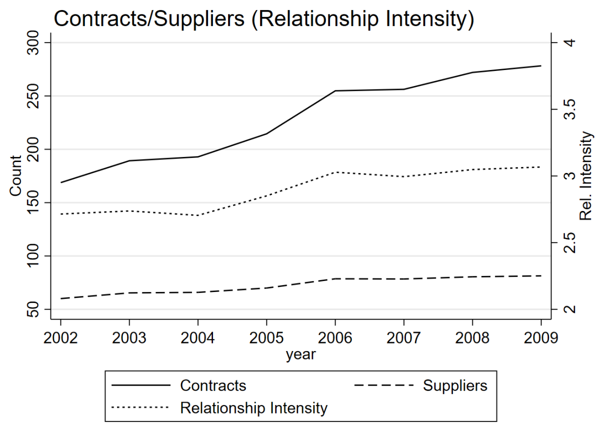
Standard errors in parentheses.
All specifications contain country and year fixed effects.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Manufacturers' Markdowns by Car Segments

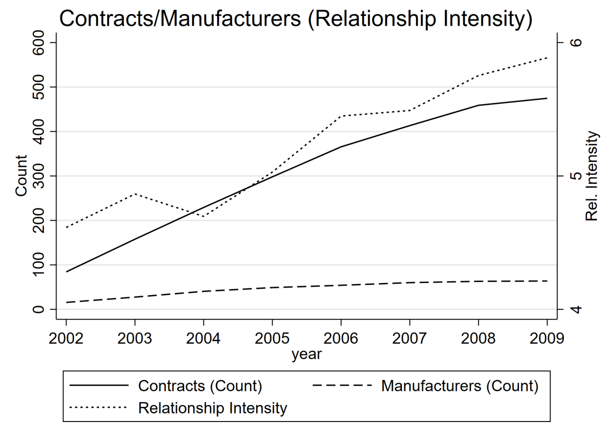
To assess possible drivers of the car manufacturers' markdowns and suppliers' markups beyond the car manufacturers' product portfolio, I explore the manufacturers' and suppliers' contracting patterns in Figure 10 and Figure 11. Figure 10 shows the car manufacturers' and suppliers' total number of active contracts in a given year, their respective number of contracting partners, and both quantities divided by each other as a measure of the firms' relationship intensity. Active contracts and manufacturer-supplier connections are counted according to the start and end production year of car models.[35] The left graph in Figure 10 shows a slight increase in relationship intensity between

[35]As a hypothetical example: A contract that is closed between Volkswagen Wolfsburg and Bosch regarding a specific sensor for the model Volkswagen Polo with production period 2002 to 2006 counts as active for all five years. Every manufacturer plant and supplier group link counts as one connection (Volkswagen Wolfsburg and Bosch, and Volkswagen Wolfsburg and Thyssenkrupp are counted as two supplier connections of Volkswagen Wolfsburg).

manufacturers and their suppliers, as well as the number of contracts from 2004 on. The right graph shows that the part suppliers' relationship intensity with manufacturers significantly increased during the observed time horizon. The increase in relationship intensity occurs as a result of an increasing number of contracts with a relatively steady number of manufacturers.



Car Manufacturers



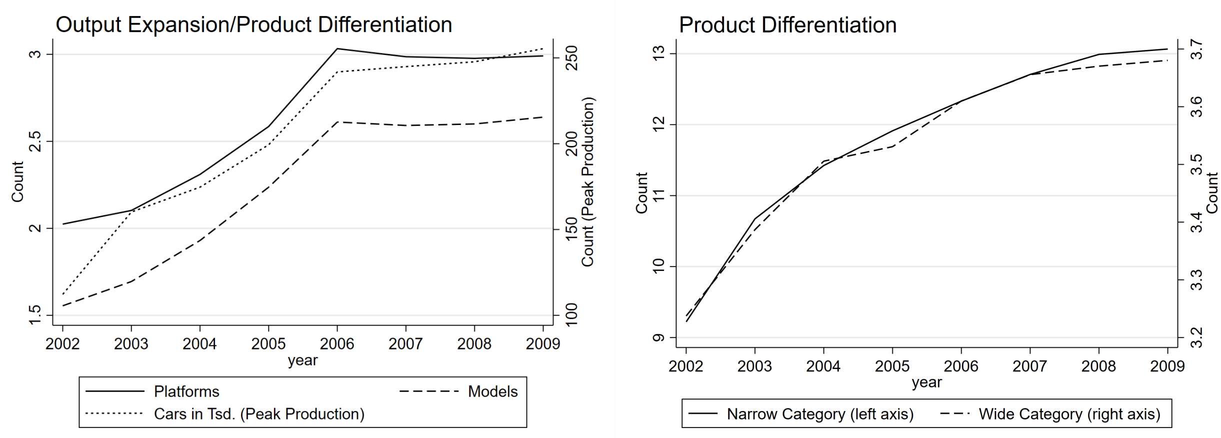
Part Suppliers

Notes: The left graph shows the car manufacturers' number of currently active contracts, the number of active contracting partners (both left y-axes), and the manufacturers' relationship intensity (right y-axis). The relationship intensity is measured as the number of active contracts divided by the number of contracting partners. The right graph shows the same measures for the part suppliers.

Figure 10: Car Manufacturers' and Suppliers' Relationship Intensity

The left graph in Figure 11 shows the number of platforms, car models and total peak production of cars assembled at a manufacturing plant in a given year. It shows a strong increase until the year 2006. From 2006 on, all variables stay relatively constant. The reason for the increase until 2006 is closed contracts between manufacturers and suppliers from the years before 2002, which subsequently ran out until 2006. From 2006 on, the observed contracts fill the whole production capacity of the manufacturing plants. For this reason, I provide reduced-form regression results which might be driven by unobserved contracts for the subset 2006 to 2009. The right graph of Figure 11 shows that suppliers differentiated their product portfolio mostly between narrow but also wide product categories.

To assess whether variation in contracting patterns and production decisions of suppliers are



Car Manufacturers Part Suppliers

Notes: The left graph shows the car manufacturers' average peak production (right y-axis) and average number of platforms and car models (left y-axis). Until 2006, models with contracts that are closed before 2002 run out. From 2006 on, the observed contracts account for the whole production capacity of the manufacturing plants. The right graph shows the average number of product categories of suppliers, differentiated for the narrow category (left y-axis) and wide category (right y-axis).

Figure 11: Car Manufacturers' and Suppliers' Product Portfolio

significantly correlated with the variation in suppliers' markups, I run the following reduced form regressions:

$$log(\mu_{st}) = \beta_0 + \beta_1 X_{gt} + \beta_2 FE + \beta_3 \text{Controls}_{st} + \varepsilon_{st}. \tag{48}$$

The dependent variable is supplier plant-level markups. The independent variables are collected in X_{gt}, which are the relationship intensity with manufacturers and the number of product categories a supplier operates in. FE represents year and country fixed effects. Controls_{it} represents plant-level controls that might affect the variation of markups and would otherwise bias the coefficients in β_1. All continuous independent variables are in logarithmic transformations.

Table 6 contains the results. The suppliers' markups are significantly and positively correlated with relationship intensity. The closer the relationships with manufacturers are, the larger the share that suppliers receive from the margin between the manufacturers and suppliers. The diversity of the suppliers' product portfolio, is significantly and negatively correlated with the suppliers' markups across specifications. The more differentiated the suppliers are, the lower their expertise in a given product category and the lower the suppliers' markups.[36]

	(1) log(μ_{st})	(2) log(μ_{st})	(3) log(μ_{st})	(4) log(μ_{st})
Rel. Intensity	0.0499***	0.0586***	0.0496***	0.0496*
	(0.0129)	(0.0126)	(0.0111)	(0.0204)
Narrow Category	-0.0530***	-0.0421***	-0.0382***	-0.0382*
	(0.0127)	(0.0121)	(0.0111)	(0.0155)
Controls:		sales	sales employees	sales employees
Clusters Standard Errors:	plant	plant	plant	group
Observations	1650	1650	1650	1650

Notes: Standard errors in parentheses. All specifications contain country and year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6: Correlations: Suppliers' Markups

7 Caveats

Ideally, the application is based on a dataset that contains plant-level characteristics, prices, and balance sheet information for all suppliers and manufacturers and the product each supplier plant delivers to each manufacturing plant. Because of data limitations, the previous results face two caveats.

First, it is not feasible to control for product characteristics in the production function estimation of part suppliers. Suppliers like Bosch or Thyssenkrupp report neither where they produce their products, nor the individual quantities or prices. To control for product quality variation of part suppliers, I construct a measure for plant-level output quantities from sales using country-level price deflators and employing plant-level product fixed effects. Moreover, I evaluate only results that are based on the suppliers' production function estimates as variation over time, not in levels. Assuming that the possible biases in the production function estimation affect markup estimates

[36]Table 6 is provided for the subsample of 2006 to 2009 in Table 19 of Appendix B. Restricting the sample to the years after 2005 (because of unobserved contracts from before 2002 that might drive the results) leads to insignificant coefficients for relationship intensity. However, the coefficient on the product portfolio stays significant.

linearly, evaluating variation of markups over time allows for an interpretation of the results that is not affected by possible biases in the estimation procedure. For this application, it is crucial to control for product characteristics in the estimation procedure of the European car manufacturers, because they employ highly differentiated inputs and produce vertically and horizontally differentiated outputs. This caveat becomes less problematic for industries where (i) the input markets are homogenous; thus, for industries that are located closer to the origin of their value chain; and (ii) for industries that produce only horizontally differentiated products. In the latter case, output price variation could be used to approximate input price variation in the estimation procedure.

Second, unobserved links between production locations of suppliers and manufacturers require either aggregating markdowns across manufacturers or defining supplying rules, such as suppliers produce in the closest production location to manufacturers. The caveat is not an issue in other settings where input markets are defined regionally or direct links between plants are available.

8 Conclusion

Many business-to-business environments are characterized by complex interactions between vertically related firms. My findings illustrate that decomposing the firms' total margins into product margins (markups) and input margins (markdowns) is crucial for an understanding of the competitive environments along value chains and the distribution of market power between firms.

I show that the total margins of car manufacturers stayed relatively constant around 10% to 15% between 2002 and 2018. This does not, however, imply a stable competitive environment in the car manufacturers' product or input markets. The part suppliers' markups were highly volatile and the car manufacturers' bargaining weights towards suppliers strongly varied according to national and industry-specific crises. For instance, the financial crisis in 2007 and the dieselgate scandal in 2015 coincide with a drop in the manufacturers' bargaining power, which could be explained by a loss in reputation and credibility vis-à-vis their suppliers. The distribution of margins between car manufacturers and part suppliers is significantly correlated with their respective production choices and diversification of product portfolios. I find evidence that the suppliers' markups are positively correlated with their relationship intensity towards car manufacturers.

As production data and input-to-output links between firms become more available across industries, the application of the presented framework becomes feasible for other value chains. The analysis provides crucial insights into margin reallocation and distributional effects between vertically related industries, which is particularly relevant for competition policy.

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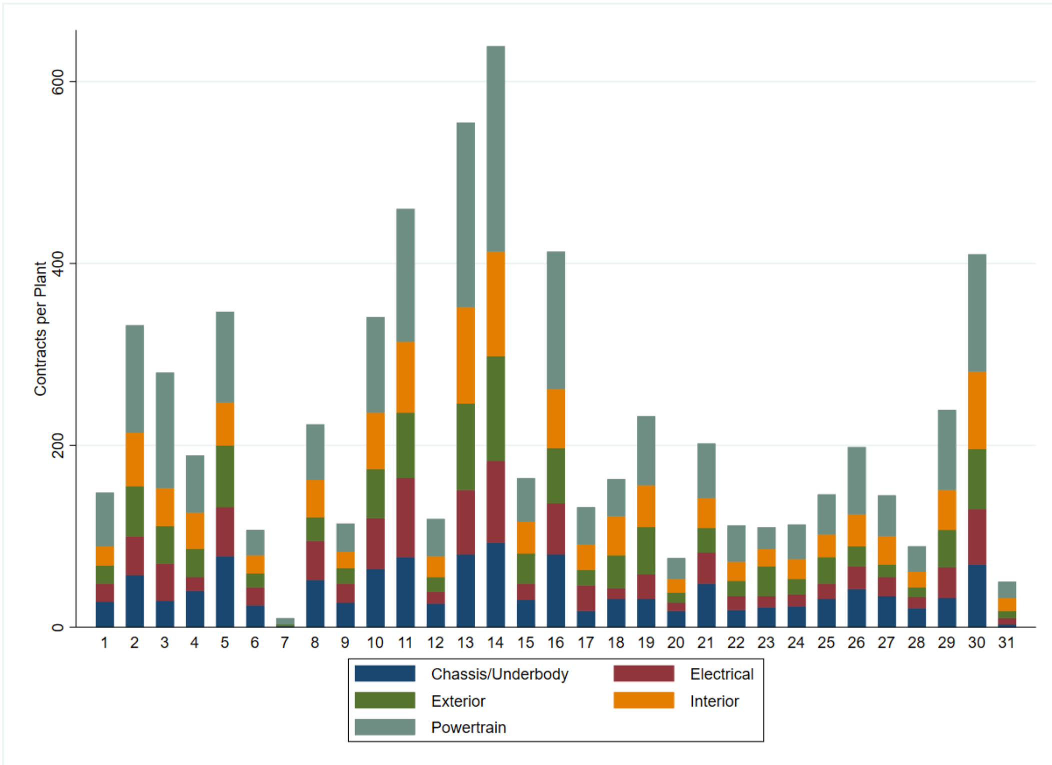
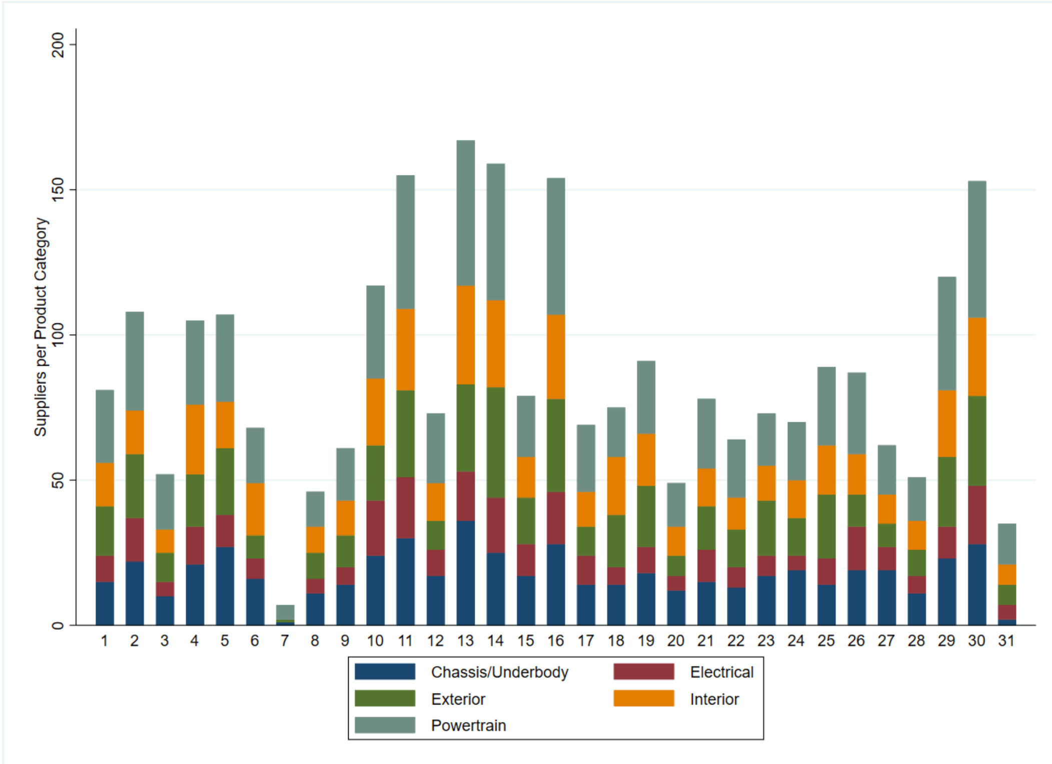
A Additional Descriptive Statistics



Notes: This graph shows the number of observed contracts within each of the five product categories (Chassis/Underbody, Electrical, Exterior, Interior, and Powertrain) for the 31 car manufacturer production locations that report unconsolidated balance sheet information.

Figure 12: Number of Contracts



Notes: This graph shows the number of suppliers within each of the five product categories that the 31 car manufacturing plants contract with.

Figure 13: Number of Suppliers

Group	No. Plants	Group	No. Plants
Same Ownership		Change in Ownership	
Kia	1	PSA (until 2012 Fiat and PSA)	1
Fiat	1	Geely (until 2010 Ford)	2
Nissan	1	PSA (until 2017 GM)	3
Honda	1	SUM	6
Toyota	2		
Independent	3		
Volkswagen	4		
PSA	4		
Renault	7		
PSA, Toyota	1		
SUM	25		

Notes: This table shows the owners of the 31 car manufacturing plants that report financial statements.

Table 7: Ownership Distribution of Car Manufacturing Plants

ISO-Code	Plant	Group	ISO-Code	Plant	Group
AT	9	6	IT	93	60
BE	23	10	LT	3	2
BG	8	7	LU	1	1
CZ	76	43	MT	1	1
DE	130	94	NL	13	6
DK	4	3	NO	6	2
ES	158	54	PL	53	28
FI	2	1	PT	34	15
FR	108	51	RO	39	28
GB	89	50	SE	18	6
HR	1	0	SI	8	6
HU	45	25	SK	43	30
IE	1	0			

Notes: This table shows the number of part suppliers differentiated for their location. I divide between the location of the individual plants (plant column) and the amount of supplier groups that these plants belong to (group column). For instance, in Austria are nine part supplier plants that belong to six distinct groups.

Table 8: Summary Statistics: Suppliers

Supplier	Plants	Supplier	Plants
FAURECIA	47	BENTELER	19
LEAR	34	BOSCH	18
VALEO	33	PLASTIC OMIUM	18
JOHNSON CONTROLS	29	TI AUTOMOTIVE	17
ZF	27	TRW	17
GESTAMP	23	EDSCHA	16
GRUPO ANTOLIN	23	CONTINENTAL	14
MAHLE	22	AUTOLIV	14
FEDERAL-MOGUL	22	DURA	13
BROSE	21	TENNECO	12

Notes: This table shows the number of supplier plants differentiated by groups for which observe financial statements. For instance, the supplier group Faurecia has 47 production plants that report financial statements.

Table 9: Suppliers Groups with the Most Production Plants

Category 1	Category 2	Count Groups 1	Count Plants 1	Count Groups 2	Count Plants 2
Chassis/Underbody	Suspension System	34	116	8	50
Chassis/Underbody	Steering System	34	116	4	25
Chassis/Underbody	Brakes	34	116	10	45
Chassis/Underbody	Pedal Assembly	34	116	4	6
Chassis/Underbody	Chassis Components	34	116	3	4
Chassis/Underbody	Wheels	34	116	5	9
Chassis/Underbody	Tires	34	116	4	8
Chassis/Underbody	Pressed/Stamped and Metal Parts	34	116	8	27
Chassis/Underbody	Axles	34	116	2	5
Electrical/electronic	Electronic Distribution System	25	98	3	15
Electrical/electronic	Fuel System	25	98	4	30
Electrical/electronic	Thermal System	25	98	14	61
Electrical/electronic	Switches	25	98	4	5
Electrical/electronic	Fuse/Relay/Junction Box	25	98	2	6
Electrical/electronic	Battery and Components	25	98	3	28
Electrical/electronic	Motors	25	98	1	2
Electrical/electronic	Infotainment System	25	98	4	4
Electrical/electronic	-	25	98	4	11
Electrical/electronic	Horns	25	98	1	1
Electrical/electronic	Driver Assistance System	25	98	1	1
Exterior	Doors/Tailgate	47	154	15	56
Exterior	Bumper and Components	47	154	3	19
Exterior	Mirrors	47	154	2	4
Exterior	Lighting	47	154	5	15
Exterior	Transmission	47	154	15	32
Exterior	Body Parts	47	154	10	21
Exterior	Noise vibration and Harshness	47	154	4	9
Exterior	Seals	47	154	5	7
Exterior	Glass	47	154	1	1
Exterior	Bonding/Adhesives	47	154	1	1
Exterior	Coatings	47	154	1	1
Interior	Seating	46	203	8	72
Interior	Interior Trim	46	203	17	44
Interior	Airbags	46	203	3	17
Interior	Center Console/Dashboard	46	203	1	1
Powertrain	Engine	67	178	32	96
Powertrain	Exhaust System	67	178	7	14
Powertrain	Heat Shielding	67	178	1	1

Notes: This table shows the number of supplier groups and their observed production locations that report balance sheet information differentiated for the suppliers' product categories. I provide the numbers in two levels of aggregation. First, the wider product category (category 1) and the allocation of supplier groups/plants to this category (Count Group 1, Count Plant 1. Second, the narrow product category (category 2) and the allocation of supplier groups/plants to this category (Count Group 2, Count Plant 2).

Table 10: Allocation of Supplier Groups/Plants to Product Categories

	Mean	p25	p50	p75	p90
Chassis/Underbody					
Category Intensity	0.82	0.66	0.94	1.00	1.00
Contracts in Category	49.47	8.00	16.50	32.00	58.00
Electrical/Electronic					
Category Intensity	0.76	0.57	0.87	1.00	1.00
Contracts in Category	52.45	3.00	14.50	78.50	117.50
Exterior					
Category Intensity	0.74	0.51	0.80	0.99	1.00
Contracts in Category	28.72	2.00	16.00	50.00	83.00
Interior					
Category Intensity	0.82	0.67	0.87	1.00	1.00
Contracts in Category	36.47	3.00	7.00	40.00	117.00
Powertrain					
Category Intensity	0.83	0.67	0.90	1.00	1.00
Contracts in Category	52.42	5.00	19.50	41.00	151.00
Total					
Category Intensity	0.80	0.62	0.87	1.00	1.00
Contracts in Category	43.14	3.00	15.00	41.00	97.00

Notes: This table shows the product differentiation of suppliers within the five main product categories. I allocate suppliers to the product categories in which they produce most products in. For instance, suppliers allocated to the category "Chassis/Underbody" produce on average 82% of all products within this category, which is a total amount of approximately 50 contracts on average.

Table 11: Supplier's Main Product Categories

	mean	p25	p50	p75	count
Horsepower	82.97	61.14	85.36	98.39	480
Cylinder	1618.80	1332.45	1604.11	1823.17	480
Length	423.86	398.06	426.18	449.59	480
Width	175.28	169.69	176.35	181.06	480
Height	150.52	145.33	148.55	152.97	480
Liter	5.41	4.69	5.33	6.03	480
Price	22244.11	14245.66	21394.96	28754.42	480

Notes: This table shows the summary statistics for the sales-weighted plant-level product characteristics and prices of car manufacturers.

Table 12: Summary Statistics: Characteristics

Parent	Model	Segment
Volkswagen	Azure	Executive
Daimler	ForTwo	Mini
Daimler	SLK	Sport
Volkswagen	Rabbit	Medium
Ford	Fiesta	Small
Volkswagen	R8	Sport
Volkswagen	A8	Luxury
Volkswagen	Golf	Medium
Volkswagen	A5 CoupÃ©	Executive
Ford	Range Rover	SUV
Volkswagen	Octavia Scout	Executive
Volkswagen	T5/Transporter	Large
Daimler	SLR McLaren	Sport
Ford	XJ	Luxury
Daimler	V-Class	Executive
Ford	StreetKa	Small
Daimler	SL	Sport
PSA	C4 Picasso	Large

Notes: This table shows the conducted manual allocation of cars to car segments.

Table 13: Allocation of Models to Segments

	mean	p25	p50	p75	count
Observations Suppliers - Subset:					
Contracts	553.13	122	344	786	23233
Manufacturer Plants	72.32	36	84	105	23233
Car Models	102.02	39	111	159	23233
Products (Wide Category)	3.78	3	4	5	23233
Products (Narrow Category)	13.63	5	12	21	23233
Observations Manufacturers - Subset:					
Contracts	352.99	201	288	554	9943
Supplier Groups	94.69	61	84	131	9943
Car Models	2.50	1	3	3	9943
Car Platforms	2.28	1	2	3	9571
Peak Production (per Model)	101.74	30	97	155	4984
Plants per Model	1.58	1	1	2	9943

Notes: This table contains only the contracting information of manufacturers and suppliers that report balance sheet information. It contains 648 supplier groups and 31 assembly locations that belong to 15 parent companies.

Table 14: Relationships between European Manufacturers and Suppliers

B Additional Results

Characteristics and Unobserved Quality Variation in Output.

To determine the variables that explain quality variation in the output measure that is not captured by output prices, I add characteristics and prices to the $a(.)$-function of the production function. Table 10 shows OLS regression coefficients. The labor coefficient ranges steadily between 0.844 and 0.888 independent of the characteristics. Of all characteristics and prices, only cylinder has a weakly significant coefficient.[37] To capture quality variation in the output measure that is driven by cylinder, I include cylinder to the second stage of the structural production function estimation.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	q	q	q	q	q	q	q	q
f(.)								
l	0.844**	0.888***	0.872**	0.870***	0.848**	0.847**	0.847**	0.837**
	(0.247)	(0.227)	(0.234)	(0.230)	(0.230)	(0.229)	(0.231)	(0.234)
k	0.0711	0.0675	0.0268	0.0253	0.0112	0.0136	0.0145	0.0149
	(0.257)	(0.211)	(0.220)	(0.219)	(0.215)	(0.210)	(0.215)	(0.216)
a(.)								
price		-0.963*	0.651	0.760	1.579	1.598	1.594	1.563
		(0.405)	(0.883)	(0.834)	(1.214)	(1.205)	(1.201)	(1.176)
cylinder			-3.181*	-3.467*	-2.429*	-2.489*	-2.500*	-2.316*
			(1.257)	(1.261)	(0.974)	(1.035)	(1.041)	(1.031)
height				0.871	0.505	0.573	0.639	0.979
				(1.961)	(1.975)	(2.066)	(1.864)	(1.634)
horsepower					-1.959	-2.018	-1.998	-1.885
					(1.526)	(1.528)	(1.567)	(1.590)
length						0.325	0.335	1.525
						(2.226)	(2.193)	(3.169)
liter							-0.0368	0.0143
							(0.258)	(0.287)
width								-4.872
								(10.68)
Observations	296	296	296	296	296	296	296	296
R^2	0.630	0.693	0.721	0.721	0.729	0.730	0.730	0.731
Adjusted R^2	0.606	0.672	0.700	0.700	0.708	0.707	0.706	0.706

Notes: Robust standard errors in parentheses, clustered at the plant-level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

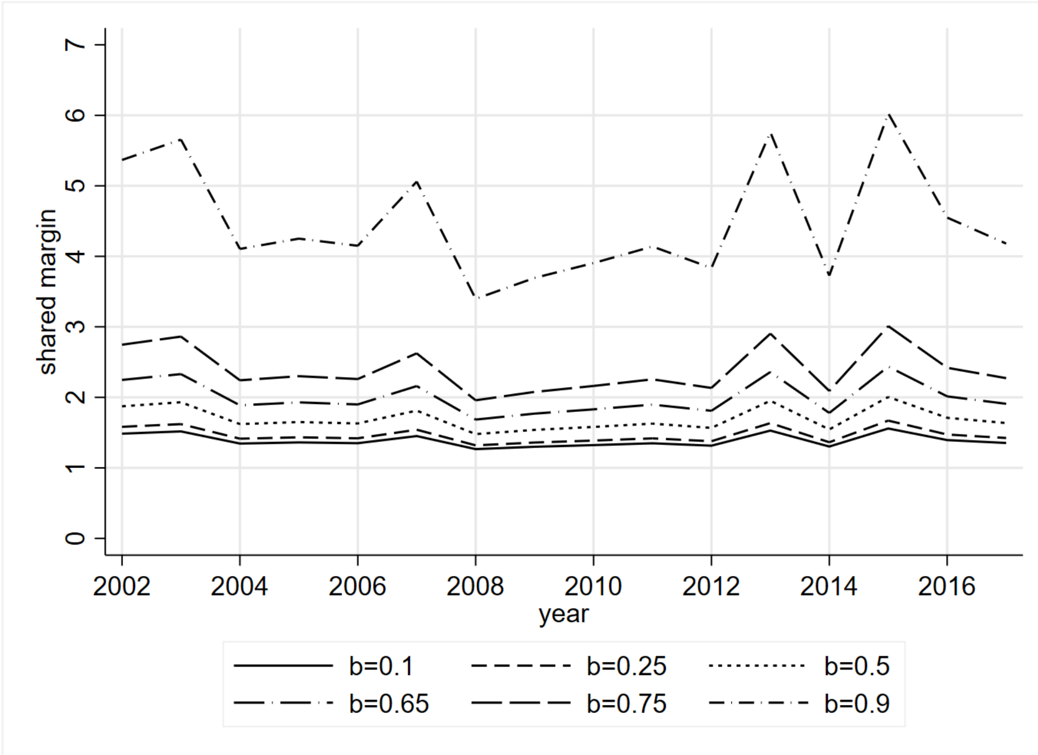
Table 15: OLS-Regressions

[37] The cylinder variable captures the total cylinder capacity of a car, not the number of cylinders. It is a determining factor for the car's power potential.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	OLS	ACF	ACF	ACF	ACF
	sales	sales	sales	sales	sales	sales	sales	sales
l	0.763***	0.703***	0.646***	0.703***	0.589***	0.602***	0.612***	0.624***
	(0.0559)	(0.0629)	(0.0618)	(0.0629)	(0.110)	(0.0990)	(0.101)	(0.0978)
k	0.132**	0.117*	0.204***	0.117*	0.234***	0.225***	0.222***	0.214***
	(0.0493)	(0.0547)	(0.0562)	(0.0547)	(0.0376)	(0.0332)	(0.0342)	(0.0332)
OLS:								
Fixed Effects:								
Country	✓							
Year	✓	✓	✓	✓				
Product Category			✓	✓				
Supplier Group		✓		✓				
First Stage ACF:								
Fixed Effects:								
Year					✓	✓	✓	✓
Product Category					✓	✓	✓	✓
Supplier Group					✓	✓	✓	✓
Productivity Evolution:								
$\omega_{it} = g(.)$					ω_{it-1}	$\omega_{it-1}^{1,2}$	$\omega_{it-1}^{1,2,3}$	$\omega_{it-1}^{1,2,3,4}$
Observations	5609	5609	5609	5609	5609	5609	5609	5609

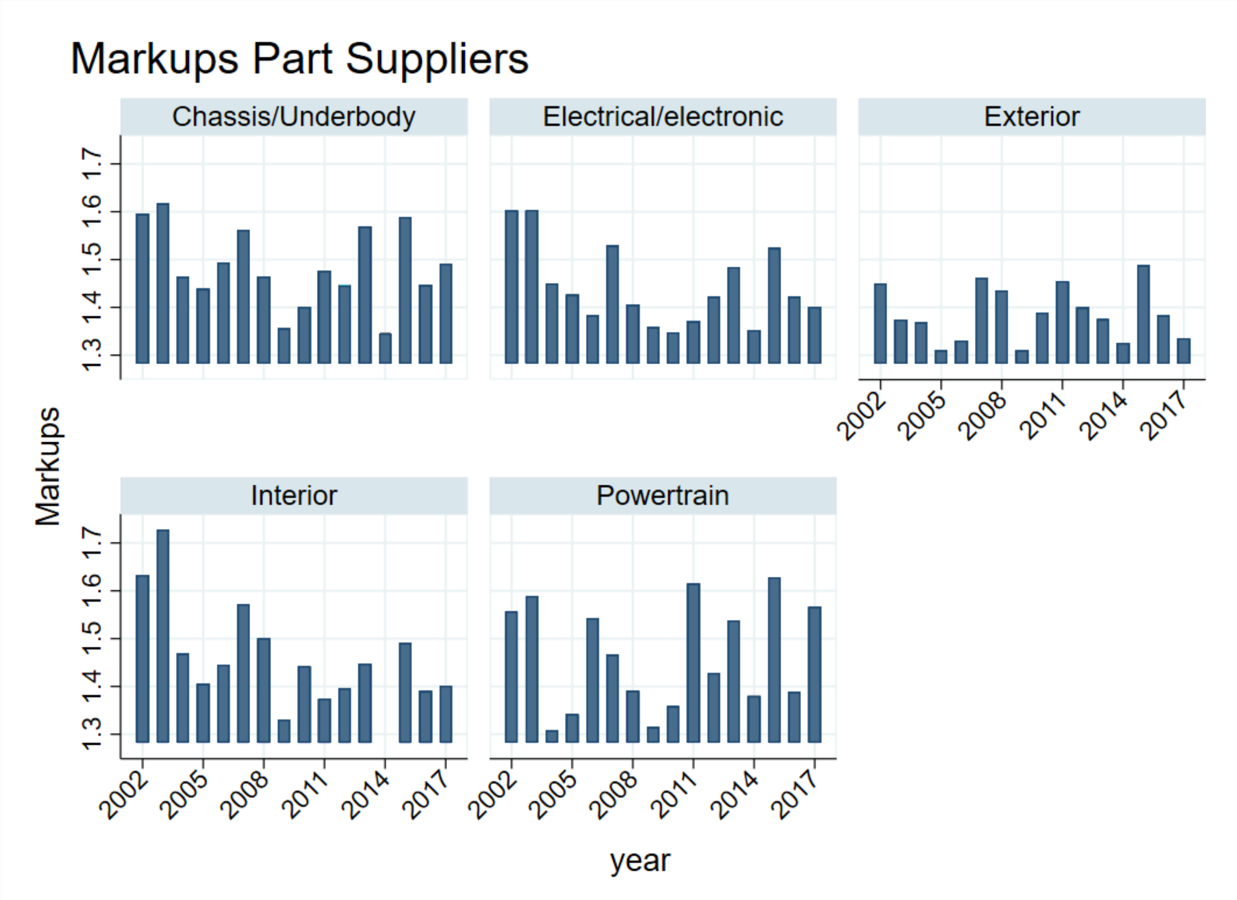
Notes: Block-bootstrapped standard errors in parentheses (clustered at the plant-level, 1000 replications). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ *This table shows the production function estimates for part suppliers. Columns (1)-(4) include OLS-regression specifications with different sets of fixed effects. Across specifications, the labor and capital coefficients are relatively stable. A similar pattern occurs for the ACF-specifications in columns (5)-(8). All ACF specifications include year, product category and supplier group fixed effects and varying specifications of the productivity evolution. Independent of the productivity evolution, production function estimates for labor and capital are relatively stable. I employ the labor coefficient of column (8) for the production function estimates. This specification allows for the most flexible productivity evolution.*

Table 16: Suppliers' Production Function Estimates



Notes: This graph shows the variation in the shared margin when holding the bargaining weights between car manufacturers and suppliers fixed. The different lines represent different levels of bargaining weights. The y-axis indicates the shared margins between the firms and the x-axis indicates the years. This graph shows the results based on the opposite assumptions (holding bargaining weights fixed and allowing for variation in shared margins) compared to the specification employed in the main text (allowing for varying bargaining weights and holding fixed the shared margins) and as illustrated in Fig. 6.

Figure 14: Varying Shared Margins



Notes: This graph shows the variation of the part suppliers markups including all plants in the sample. The same graph in the main text contains the subset of part supplier plants that deliver their products to the car manufacturers which are also included in the database.

Figure 15: Suppliers' Markups: All Plants

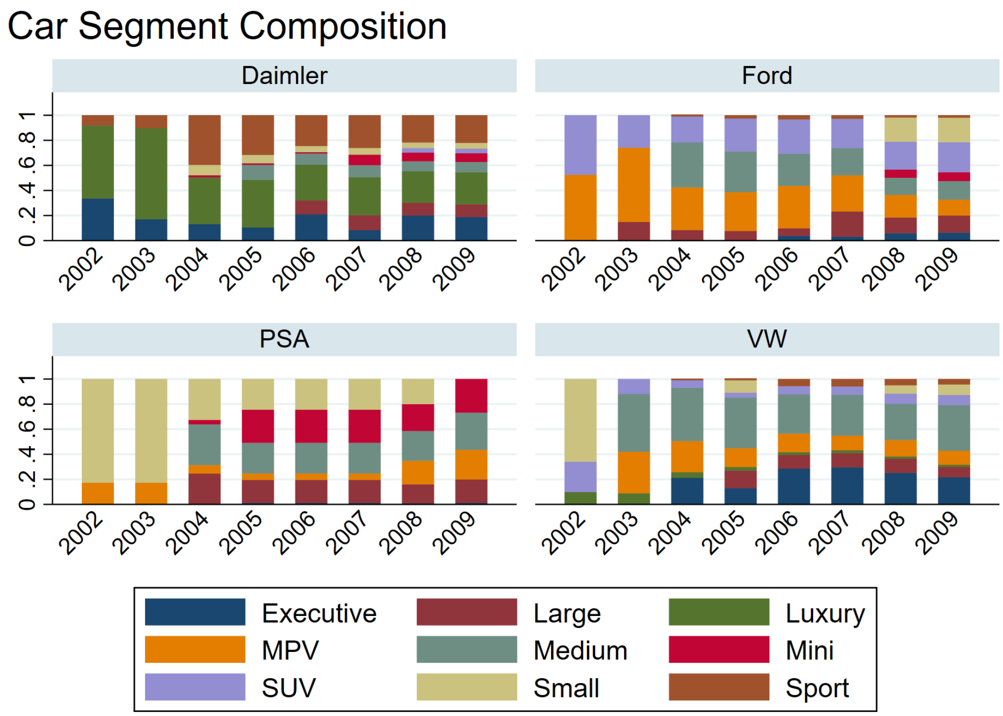
	Mean	p25	p50	p75
2002	0.061	0.024	0.040	0.071
2003	0.053	0.021	0.035	0.067
2004	0.050	0.019	0.032	0.067
2005	0.050	0.018	0.032	0.067
2006	0.043	0.015	0.027	0.056
2007	0.043	0.016	0.028	0.056
2008	0.043	0.015	0.027	0.056
2009	0.042	0.015	0.027	0.056

Product Category 1

	Mean	p25	p50	p75
2002	0.194	0.059	0.100	0.250
2003	0.194	0.050	0.111	0.250
2004	0.182	0.040	0.100	0.211
2005	0.210	0.053	0.111	0.278
2006	0.186	0.050	0.111	0.250
2007	0.173	0.048	0.111	0.200
2008	0.186	0.050	0.111	0.250
2009	0.187	0.051	0.114	0.222

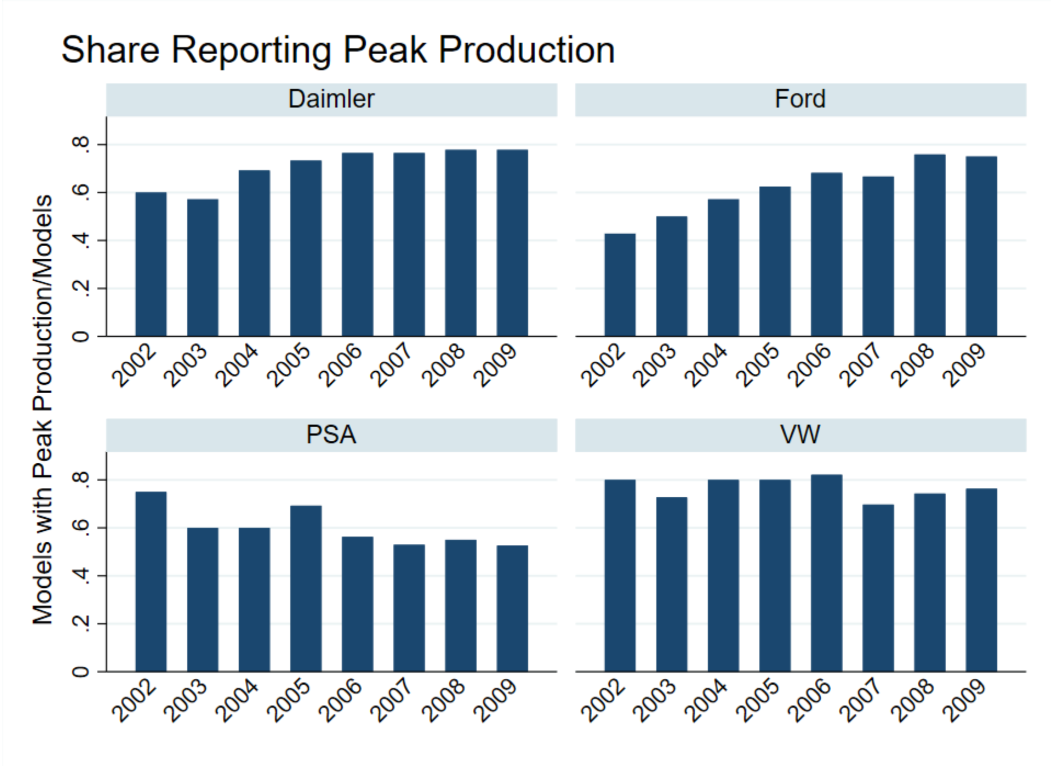
Product Category 2

Table 17: Aggregation Weights



Notes: This graph represents the same illustration as Fig. 9 in the main text, but weighted by plant-level peak production quantity rather than plant-level sales.

Figure 16: Segment Composition Weighted by Peak Production



Notes: This graph shows the share of models at the production location-level that reports the number of peak production differentiated by year. For instance, I observe the peak production quantity of roughly 80% of all produced models in 2009.

Figure 17: Production Locations with Peak Production

	(1) $\log(\gamma_{it}^{M})$	(2) $\log(\gamma_{it}^{M})$	(3) $\log(\gamma_{it}^{M})$	(4) $\log(\gamma_{it}^{M})$
Car Segments:				
Large	-0.0313	-0.0313	-0.0100	-0.0100
	(0.0302)	(0.0360)	(0.0328)	(0.0428)
Luxury	-0.0697	-0.0697	-0.0408	-0.0408
	(0.0518)	(0.0469)	(0.0617)	(0.0512)
MPV	-0.0230	-0.0230	-0.0364	-0.0364
	(0.0454)	(0.0491)	(0.0463)	(0.0600)
Medium	0.0437	0.0437	0.0576	0.0576
	(0.0287)	(0.0252)	(0.0351)	(0.0273)
Mini	0.152***	0.152***	0.144**	0.144***
	(0.0405)	(0.0275)	(0.0472)	(0.0340)
SUV	0.00513	0.00513	0.0126	0.0126
	(0.0377)	(0.0391)	(0.0449)	(0.0366)
Small	-0.0657	-0.0657	-0.0771	-0.0771
	(0.0428)	(0.0416)	(0.0456)	(0.0469)
Sport	-0.0693*	-0.0693*	-0.0683	-0.0683
	(0.0345)	(0.0313)	(0.0417)	(0.0386)
Clusters Standard Errors:	plant	group	plant	group
Subset Years:	all	all	>2005	>2005
Observations	726	726	403	403

Notes: Standard errors in parentheses. All specifications contain country and year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 18: Manufacturers' Markdowns by Car Segments

	(1) $\log(\mu_{st})$	(2) $\log(\mu_{st})$	(3) $\log(\mu_{st})$	(4) $\log(\mu_{st})$	(5) $\log(\mu_{st})$	(6) $\log(\mu_{st})$	(7) $\log(\mu_{st})$	(8) $\log(\mu_{st})$
Rel. Intensity	0.0499***	0.0586***	0.0496***	0.0496*	0.0255	0.0277	0.0188	0.0188
	(0.0129)	(0.0126)	(0.0111)	(0.0204)	(0.0296)	(0.0276)	(0.0263)	(0.0397)
Narrow Category	-0.0530***	-0.0421***	-0.0382***	-0.0382*	-0.0630***	-0.0548**	-0.0510**	-0.0510*
	(0.0127)	(0.0121)	(0.0111)	(0.0155)	(0.0177)	(0.0174)	(0.0168)	(0.0202)
Controls:		sales	sales employees	sales employees		sales	sales employees	sales employees
Clusters Standard Errors:	plant	plant	plant	group	plant	plant	plant	group
Subset Years:	all	all	all	all	>2005	>2005	>2005	>2005
Observations	1650	1650	1650	1650	902	902	902	902

Notes: Standard errors in parentheses. All specifications contain country and year fixed effects.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 19: Correlations: Suppliers' Markups

C Supplier's Production Function Estimation

I assume that suppliers produce with a Leontief production technology similar to car manufacturers:

$$\hat{q}_{st} = f^T\left(l_{st}, k_{st}; \beta^T\right) + \omega_{st} + \varepsilon_{st} = \kappa_{st} + m_{st} + \varepsilon_{st}. \tag{49}$$

$\hat{q}_{st}$ denotes the suppliers' output measure, which is sales deflated by country-level deflators.

The suppliers' production function is different to the manufacturers' production function in two ways. I specify Φ_{st} in the first stage using labor, materials, capital, the respective interactions, product category fixed effects F_p and supplier-group fixed effects F_g.

$$\hat{q}_{st} = \Phi_{st}\left(l_{st}, k_{st}, m_{st}, F_p, F_g\right) \tag{50}$$

I define the productivity evolution of suppliers as in (51):

$$\omega_{st} = g_t\left(\omega_{st-1}\right) + \xi_{st}. \tag{51}$$

Equation (52) represents the moment conditions for suppliers:

$$E\left(\xi_{st}\left(\beta\right) \begin{array}{c} l_{st-1} \\ k_{st} \end{array}\right) = 0. \tag{52}$$

D Construction of the Supplier Pool

Table. 14 illustrates the structure of the SupplierBusiness data. The supplier Polytec for instance produces engine covers for the Volkswagen Polo and delivers these covers to the Volkswagen assemblies in Pamplona (ES) and Bratislava (SK). Polytec also produces belts/tensioners for the Audi A4, which are delivered to the Volkswagen production plants in Ingolstadt (DE) and Neckarsulm (DE).

The SupplierBusiness database only provides the exact location only for car assemblies. For this reason, the provided information allows a linkage to financial accounts for car assembly plants only. Taking Polytec as an example, ORBIS contains 233 entries for companies with the word *Polytec* in the company name that are located within the EU-27.

In the following section, I describe how I construct a pool of part suppliers using information from the ORBIS database and SupplierBusiness.

Supplier	Product	Model	Brand	Assembly	Assembly Location
Polytec	Engine Covers	Polo	Volkswagen	VW	Pamplona, ES; Bratislava, SK;
Hirschmann Automotive	Connectors	CLS-Class	Mercedes-Benz	Daimler	Sindelfingen, DE;
Polytec	Belts/Tensioners	A4	Audi	VW	Ingolstadt, DE; Neckarsulm, DE;

Notes: Number of firms that operate in the 8 most common NACE-codes.

Table 20: Extraction of the SupplierBusiness Database

The initial sample consists of all entries in ORBIS that contain the same names as the suppliers in the SupplierBusiness database and which are located in the EU-28, as well as Switzerland and Norway. This results in an initial pool of 384 suppliers with an average of 6283 production plants. The large number of production plants is explained by the fact that some suppliers have generic names that are also used by firms that operate in other sectors (e.g., Norma or Maier). For this reason, it is necessary to create a subsample of these supplier plants.

Step 1: Selecting Suppliers Based on NACE-Codes First, I select the suppliers that own production plants in car-related nace codes (Table 25). Because some of these production locations might be the headquarters or holdings of a firm, I drop all production plants with a product description that is related to the management or holding of the company. This steps creates a subsample of 210 suppliers with an average of 35 production plants per supplier.

NACE-Code	Description
2910	Manufacture of motor vehicles
2920	Manufacture of bodies (coachwork) for motor vehicles
2931	Manufacture of electrical and electronic equipment for motor vehicles
2932	Manufacture of other parts and accessories for motor vehicles

Table 21: List of NACE-Codes Related to Car Manufacturing

Additionally, I include plants of the 201 suppliers that do not operate within car-related nace codes but produce car related products. To do so, I employ the ORBIS product description and check whether the 210 suppliers own plants that have car related product descriptions, but do not operate within car related nace codes. These are 57 of the 210 suppliers with an average of 1.5 plants.

Supplier	Location	Product Description
Pirelli	Warsaw (PO)	Motor vehicle parts and accessories
Pirelli	Vienna (AU)	Motor vehicle parts and accessories
Pirelli	Miraflores (PT)	Motor vehicle parts and supplies
P. Muhlhoff	Uedem (DE)	Body parts, engine and gearbox, and assembly parts for the automobile industry
Oiles	Kadan (CZ)	Self-lubricating parts for the automotive industry
NKG	Kronberg (DE)	Motor vehicle parts and accessories
NKG	Ratingen (DE)	Automotive parts and accessories [...]

Table 22: Example Product Descriptions (1)

Step 2: Selecting Suppliers based on the Product Description In the second step, I evaluate the remaining 174 suppliers. Therefore, I use the product description provided by ORBIS as guideline to select the production plants. First, I select the production plants with a product description that contains the key words: *Vehicle*, *Automotive*, or *Trunck*. Table 26 provides examples for these product descriptions. Some descriptions contain the mentioned key words but in a different context. This occurs to explicitly indicate that the respective production location does not produce car related products, e.g.*"[...] Household appliance housings and parts; cooking and kitchen utensils; and other non-automotive job stampings [source: Bureau van Dijk]"* or to refer to the agricultural sector, e.g. *"Generators, lawn mowers, pumps, snowblowers, tillers, trimmers, agricultural tractors, [...], rustler utility vehicles, [...] [source: Bureau van Dijk]"*. Additionally, I drop all plants that operate in NACE-Codes that are not related to the supplier's activity (e.g., codes related to business consulting). After dropping these observations, the second step provides a subdataset of 44 suppliers with 1.8 production plants on average.

Supplier	Location	Product Description
Dexter	Crolles (FR)	Wearing apparel and clothing accessories [...]
Corus	Bruxelles (BE)	Management and consultancy services [...]
ABC Group	RÃ¼sselsheim (DE)	Management and administration of its subsidiaries and affiliates [...]
Keiper	Kaiserslautern (DE)	Financial intermediation [...]

Table 23: Example Product Descriptions (2)

Step 3: Selecting Remaining Production Plants I follow two approaches in the third step: First, I evaluate the product descriptions of the remaining firms and drop all plants with product descriptions that clearly are not related to supplying car assemblies. A selection of these product descriptions is provided in Table 20. Additionally, I drop all product descriptions containing the words "Consult" "Account" "Housing" or "Management" and unrelated nace codes (e.g. activities of head offices or computer consultancy activities).

Second, I compare the plant level product descriptions provided by ORBIS with the products that are delivered as indicated by the SupplierBusiness database. The supplier Honsel for example delivers subframe/cylinder heads, blocks for the engines/parts for transmission. Therefore, the Honsel production plants that produce "lighting products" or "professional lighting equipment for industrial and commercial application" drop out. Another example is the supplier Schneider Electric, which produces electric motors for Renault. Schneider electric only produces electric motors in one of its production plants. Therefore, only this plant is considered as a possible production location for the electric motors of Renault. Following these steps results in a subdataset of 48 suppliers with one production plant each.

Combining the steps 1 through 3 results in a supplier pool that contains 301 supplier with an average of 33 production plants per supplier.

Not all of the supplier plants report unconsolidated balance sheet information. Nevertheless, I construct the supplier pool including all possible plants, because the matching procedure between suppliers and manufacturers would be biased otherwise. The closest supplier plant to an assembly location might be a consolidated account that does not report balance sheet information. Thus, dropping out these firms before the geomatching procedure creates a bias in the supplier-assembly allocation.

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