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Intellectual Property Rights and the Efficiency of International Production Networks: Evidence from the Automotive Industry[*]

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Abstract

This paper investigates the potential benefits of intellectual property rights (IPR) institutions for international production networks. Using unique data on manufacturer-supplier linkages in the automotive industry, we establish a positive empirical relationship between the productivity and efficiency of manufacturing firms and IPR protection in their suppliers' locations. Notably, IPRs do not have the same impact on ownership networks, and protection of physical property rights does not generate any improvement in performance. We confirm that the results are not driven by other firm-level characteristics and address potential endogeneity concerns by employing a novel gravity-based IV approach, followed by a GMM analysis.

Keywords: International production networks, Intellectual property rights, Ownership, Internalization, Automotive industry, Knowledge dissipation, Firm efficiency

JEL classification: F21, F23, L14, L25, L62, O34, G32

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1 Introduction

The past decade has witnessed a notable rise in the formation of international production networks in various industries. They play a key role in the operation of the world economy today, linking firms globally and accounting for about 80% of international trade flows (UNCTAD, 2013). In recent years, economists have increasingly emphasized the importance of these networks for firms performance, i.e., at micro level (e.g., Bernard et al. 2019), but also as a source of aggregate fluctuations, i.e., at macro level (e.g., Acemoglu et al. 2012), since interconnections between firms may act as a propagation mechanism of idiosyncratic shocks, determining variations in aggregate output. Networks can also act as systems for the transmission of information (e.g., Chaney 2014) among connected traders. The flow of information, however, faces frictions in international trade networks (Allen, 2014), which could in turn translate into systemic risk.

An important determinant of the performance of international production networks, especially in technology-intensive sectors, is given by the degree of protection granted to firms' intellectual property rights (IPRs) by supplier country institutions (see, e.g., Alsamawi et al. 2020).[1] Since the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement of the WTO in 1995, the protection of patents and other forms of IPRs has been advancing towards a minimum required level of global standards. However, while a certain level of convergence has been achieved worldwide, the perception of firms and the effective enforcement remain varied across regions and countries. A crucial factor that influences the efficient running of production networks is therefore the location of the potential trading partners.[2]

In this paper we investigate the empirical relationship between the efficiency of an international production network and IPR protection at the location of its nodes, using unique disaggregated data on the automotive industry. The automotive industry is particularly interesting as centrally designed vehicles are manufactured globally in multiple plants, leading

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[1] Also, a recent wave of more bilateral and regional deep trade agreements that include strict intellectual property provisions has emerged to support and reinforce protection as a tool to promote trade and foster innovation (Orefice and Rocha, 2014; Jinji et al., 2021; Santacreu, 2023).

[2] Lai et al. (2020) demonstrate how even within a country, namely China, heterogeneous provincial-level enforcement of IPRs impacts firm productivity.

buyer-supplier relationships to stretch across multiple production regions Sturgeon et al. (2008). We adopt an econometric framework that takes into account both supplier-customer and firm ownership relationships. The analysis employs annual data on 85 vehicle producers (VP) with a network of auto component suppliers in 56 countries. The evidence suggests that international production networks can benefit in terms of productivity or efficiency from strong IPR institutions in supplier locations. The risk of knowledge dissipation is a matter of concern and can cause disruptions in the secure flow of information within the network, thereby reducing efficiency when suppliers are concentrated in weak-IPR countries.[3]

A potential explanation of why a production network located in countries with better IPR institutions can lead to better performance comes from a reverse causality argument, namely that more productive firms self-select into procuring from suppliers in countries with a better legal environment. We assess the invalidity of this argument by providing a battery of robustness checks.

First, we perform the same exercise for subsidiaries owned by the VPs under study, and find no effect on the productivity or efficiency of the production network. Once again, this shows that better firms are not necessarily attracted to locate their operations in countries with stronger IPR institutions. Alternatively, one can deduce from the results that the channel of knowledge dissipation risk can be internalized through a vertical integration strategy by firms. It is likely that firms choose to own their suppliers in countries with weak IPR institutions to reduce the risk of knowledge dissipation, making IPRs less relevant for the efficiency of the network. Examining the impact of IPRs on efficiency in the absence and in presence of ownership in international production networks, this can be considered a test of the transaction cost theory in light of Klein et al. (1978) and Williamson (1979), showing how integration can be used to eliminate inefficiencies caused in contractual relations and facilitate exchange.[4]

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[3] Dissipation can be thought of as a supplier starting a rival firm on the basis of the appropriated knowledge, or simply technology leaking outside the network.

[4] Note however that we do not study the integration decision of firms, which is introduced in the knowledge dissipation model of Ethier and Markusen (1996) as a choice in the mode of serving a foreign market based on locational factors when knowledge-based capital is involved. It predicts more integration than outsourcing or licensing as more secure means of transfer to reduce the threat of knowledge dissipation in countries with inferior IPRs, particularly for knowledge-intensive firms (Barba Navaretti and Venables, 2004; Ivus et al., 2017;

Regardless of whether firms instead establish subsidiaries in high-IPR countries due to other country characteristics or because they are highly capable firms to begin with, the positive effect of IPR protection on efficiency is not present for ownership network structures. Importantly, there is always a strong and statistically significant effect of IPR protection for a firm's supplier network, identifying the importance of IPRs for the efficient operation of international production networks.

Second, after an initial assessment of the impact of the general International Property Rights Index (IPRI), we distinguish between the protection of intellectual assets and tangible property rights, and isolate the impact of safeguarding the former on firm performance. Physical property rights protection does not convey the same outcome, suggesting that the supplier network of more efficient firms are not located in countries with more advanced legal systems.

Third, taking the portfolio of firms' supplier network as fixed and applying firm fixed effects, we mitigate concerns about the endogenous location decisions based on improvements in the supplier country IPR regime during the period of study. In this case, if a firm chooses suppliers from better IPR countries due to better management or any other firm-specific characteristic, the effect is captured in firm fixed effects. The residual change is all in the IPR protection level of countries, which cannot be caused by the efficiency of VPs at the core of the international production network.

Fourth, we make use of a novel instrumental variable (IV) to directly confront the question of potential endogeneity of our key independent variable. Recall that IPR protection faced by each firm is an average of the level of IPR in all countries where it deals with suppliers, weighted by the intensity of its operations in that country. A potential IV strategy could be to use gravity to weigh the average IPR measure of all countries based on the distance of each country from the VP. In this case, the IV is geographical and depends on the location of the VP, but it is unrelated to the actual location of the suppliers in its network. This instrument can affect the productivity or efficiency of the VP only through its relationships with suppliers operating in those countries, which necessitate IPR protection. Thus, it satisfies the exclusion

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Kukharskyy, 2020).

restriction as well as the relevance assumption.

Fifth, we extend the time span of our analysis to provide some additional results. We start by estimating a dynamic panel model using the Generalized Method of Moments (GMM) estimator and the IPRI index to check whether the main results are confirmed over a longer sample using our baseline static model. Next, we focus once again on the IPR sub-index, and use GMM as an additional approach for dealing with potential endogeneity of suppliers' networks. Here we also consider firms' innovation capacity, controlling for relevant firm-level measures such as their initial stock of patents and the amount of R&D expenditures each year.

The rest of the paper is organized as follows. Section 2 places our contribution within the state of the art literature. Section 3 introduces our data on IPRI and the location of suppliers and subsidiaries, as well the sources of our firm-level and country-level information. Section 4 sketches the empirical framework and methodology. Section 5 reports our empirical results and the corresponding discussion. Section 6 concludes.

2 Related Literature

While the IPR literature has established that stronger IPRs accelerate international technology transfer between firms, there has been surprisingly little empirical research on the effect of IPR protection on the performance of international networks of production (Branstetter et al., 2006). Atalay et al. (2014) shows clear evidence of the importance of the transfer of intangible rather than tangible inputs along the production chain and argues that this flow primarily consists of knowledge inputs, see also Altomonte et al. (2021). We argue that an efficient transfer of technology transfer within a network is essential for its success and can be guaranteed by high-quality IPR institutions in the location of suppliers involved in the network.

Lack of adequate IPR protection can reduce efficiency of international production networks as losses from the dissipation of intellectual assets at any node can propagate across the entire network. Supply chains can therefore be a source of vulnerability as a firm's failure may spread to other parts of the production network (Acemoglu and Tahbaz-Salehi, 2020). The literature has mainly focused on tangible assets and relationship specific inputs, finding that affected suppliers of specific inputs within networks cause losses in firms' output and market value (Barrot and Sauvagnat, 2016) and that in industries relying heavily on such inputs weak enforcement distorts production and sourcing decisions (Boehm and Oberfield, 2020). In our study, firms may suffer from the misappropriation of their intellectual property somewhere along the network and this can have a detrimental effect for the performance of the headquarter and the entire network.

On the role of ownership as an internalization strategy to protect knowledge the evidence is vast. Branstetter (2006) highlights the crucial role of FDI in mediating the flow of knowledge spillovers within Japanese firms. Yeaple (2006) shows that if property rights are not enforceable, firms are induced to internalize activities for which proprietary knowledge asset plays a key role through ownership of their foreign affiliates.[5] Our findings work in parallel to this notion of knowledge protection, with ownership breaking the link between IPR protection in subsidiary host countries and firm efficiency within international production networks. We provide suggestive evidence that ownership takes away the need for IPR institutions for securing knowledge transfer and assuring the efficient functioning of firm networks.

This links our work to Atalay et al. (2014) also from a different perspective, according to which vertical integration increases the flow of intangible inputs within the network as owning each end of the link in a production chain facilitates efficient transfer of marketing know-how, intellectual property, or R&D across its units, see also Ramondo et al. (2016). Taking this paradigm as a baseline, our study confirms these findings by adding IPR institutions as an external source of correction to increase efficiency of the network when units are *not* owned by the headquarter firm. On a similar note, Kukharskyy (2020) reveals that knowledge intensity in firms encourages integration to reduce the threat of dissipation. In other words, knowledge intensity increases the relative attractiveness of ownership, but the magnitude of the effect diminishes with strong IPR protection in the affiliate country. In our context, IPR protection

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[5] Alfaro and Charlton (2009) and Antràs and Yeaple (2014) further emphasize the importance of R&D or skill intensity of inputs for the ownership decision of multinational firms regarding different stages of production.

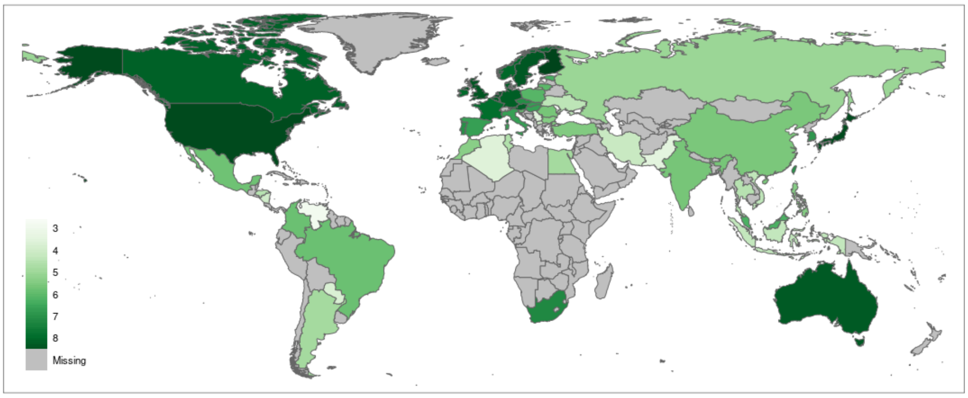
has a positive effect on firm efficiency only when the production network is less integrated. This can be interpreted as IPRs being more pivotal with non-integrated affiliates, and less so when knowledge dissipation risks are internalized.

Overall, our paper contributes to the literature on trade, IPRs and production networks in several directions. First, using a multiple-matrix econometric setup that can account for detailed information on network connections in the global automotive supply chain, we provide evidence that that the protection of IPRs at the location of auto part suppliers has a positive and significant effect on the efficiency of car manufacturers in terms of operating revenues per employee (productivity) and asset turnover ratio (efficiency). We then show that IPRs become a less relevant factor for the efficiency of firms when they own subsidiaries abroad. In other words, ownership internalizes potential inefficiencies brought by dissipation of knowledge and works as a substitute mechanism to protect IPRs. An advantage of our study is that it zooms into one of the most prominent global value chains in terms of length and fragmentation, namely the automotive industry (De Backer and Miroudot, 2013), for which intangible assets are of particular relevance. In addition, our approach makes it possible to look at the entire international production (and ownership) networks of car manufactures as opposed to a mere bilateral analysis of supplier relationships and foreign direct investment.

3 Data

For our empirical analysis, we use unique data on supplier-customer relationships between VPs and their suppliers provided by IHS Markit for over 80 car components. According to IHS, the data covers 97% of the market in the automotive industry. The information includes the identity of the car manufacturer and that of its suppliers, including their location. In addition, the component volume and the respective vehicle volume for each relationship has been provided. The VPs from the IHS database have been matched to the Bureau van Dijk's Orbis data to obtain data on firms' performance. We consider two measures to capture the productivity and the efficiency of a network (y): (log) operating revenues per employee ($OpRev/empl$) and the

Figure 1: Average IPR protection index 2012-2020



Notes: The figure shows the level of IPR protection in all the countries in our sample. The index is expressed on a 0-10 scale and is averaged over the period 2012-2020. The data source is the Property Rights Alliance (`www.propertyrightsalliance.org`).

sales-to-assets ratio or asset turnover ratio ($sales/assets$).[6] Our dataset contains annual data on 85 VPs and 56 countries over the period 2012-2020. The panel is unbalanced.[7]

We consider different measures of property rights protection. We first use the International Property Rights Index (*ipri*) published by the Property Rights Alliance. Next, we focus on the two sub-indices specifically related to intellectual property rights (*ipr*) and physical property rights (*ppr*). All indices are expressed on a 0-10 scale. The International Property Rights Index comes out annually and is a combination of three indices: Legal and Political Environment (LP), Physical Property Rights (PPR), and Intellectual Property Rights (IPR). LP provides information of the strength of a country's institutions and consists of judicial independence, rule of law, political stability, and control of corruption. PPR has the three elements of protection of physical property rights, registering property, and ease of access to loans. Finally, our main explanatory variable of interest IPR comes from the protection of IPRs (Global Competitive Index of the World Economic Forum: https://www.weforum.org), patent protection (Park index from Park (2008)), and Copyright Piracy (the compliance gap measured in the BSA

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[6] To have a longer sample, we divide sales over a year by assets at the end of the year, however almost identical results are obtained when dividing sales by the average of the firm's assets at the start and end of the year.

[7] We include in the sample all VPs for which we have information on suppliers and at least one observation (year) of balance-sheet data on operating revenues, total assets, intangible assets and leverage, allowing us to estimate the smallest model considered in the paper.

Global Software Survey: https://www.bsa.org).[8] Figure 1 shows the average level of IPR protection in all the countries in our sample. Table 1 reports the list of countries and their average IPR protection levels (0-10 scale) over the period 2012-2020.

Table 1: List of countries and average IPR protection index 2012-2020

country	avg. IPR	country	avg. IPR	country	avg. IPR
Algeria	3.58	Ireland	7.95	Romania	5.66
Argentina	4.84	Italy	6.64	Russia	5.05
Australia	8.22	Japan	8.52	Serbia	3.48
Austria	8.20	Lithuania	5.97	Singapore	8.01
Belgium	8.16	Luxembourg	7.98	Slovakia	6.65
Brazil	5.76	Macedonia	4.03	Slovenia	5.81
Bulgaria	5.41	Mainland China	5.60	South Africa	7.19
Canada	8.13	Malaysia	6.26	South Korea	6.85
Czech Republic	7.10	Mexico	5.71	Spain	6.65
Egypt	4.82	Moldova	2.63	Sweden	8.29
Estonia	6.30	Morocco	5.35	Taiwan	6.98
Finland	8.69	Netherlands	8.40	Thailand	4.45
France	7.89	Nicaragua	3.94	Tunisia	4.57
Germany	8.21	Norway	8.02	Turkey	5.47
Honduras	4.47	Pakistan	3.43	Ukraine	4.35
Hungary	6.67	Paraguay	3.66	United Kingdom	8.34
India	5.66	Philippines	5.38	United States	8.55
Indonesia	4.22	Poland	6.06	Vietnam	4.29
Iran	4.08	Portugal	7.01		

Notes: For each country, the table reports the average value of the intellectual property rights (IPR) sub-index of the International Property Rights Index (IPRI), over the period 2012-2020. The index is expressed on a 0-10 scale. The data source is the Property Rights Alliance (`www.propertyrightsalliance.org`).

To measure supplier-based network linkages, we use the IHS Markit data.We quantify the total amount of inputs supplied to by each VPs by each country. To this aim, we cannot simply compare purchased volumes of different components, since the volumes needed to produce a vehicle vary across inputs. Thus, for each supplier-customer relationship involving a specific component, we take the number of vehicles that are manufactured by the customer using the purchased lot of that component. Then, we sum this number across components for each firm-country pair and use the results to calculate the weight of each country in the supplier-based network of each firm.[9] In total, we have data on 56,791 component specific supplier-customer relationships. As an example, Figure 2a-2b displays the global maps of suppliers of Volkswagen

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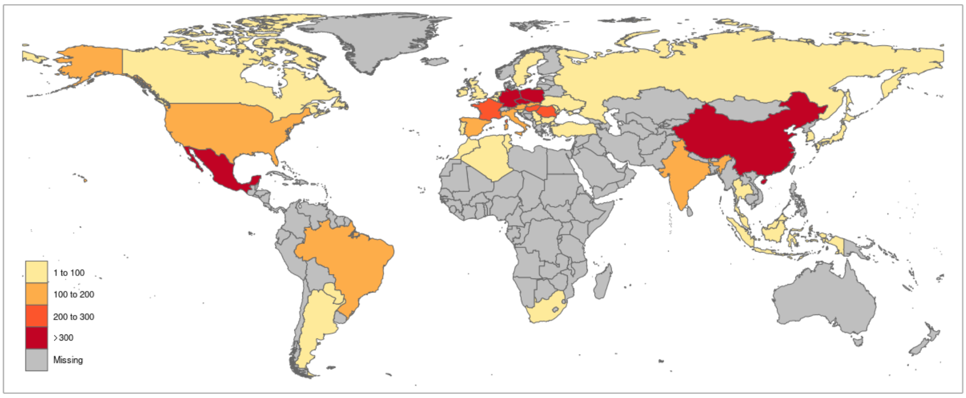
[8] See Alliance (2020) for the detailed methodology on the calculation of the indices.

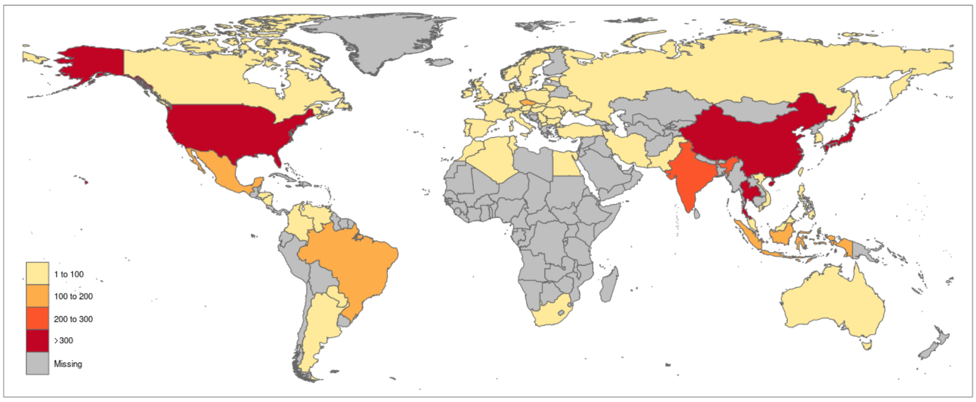
[9] Similar results are obtained if we construct weights using the number of suppliers in each country.

Figure 2: Volkswagen versus Toyota

(a) Suppliers Volkswagen



(b) Suppliers Toyota



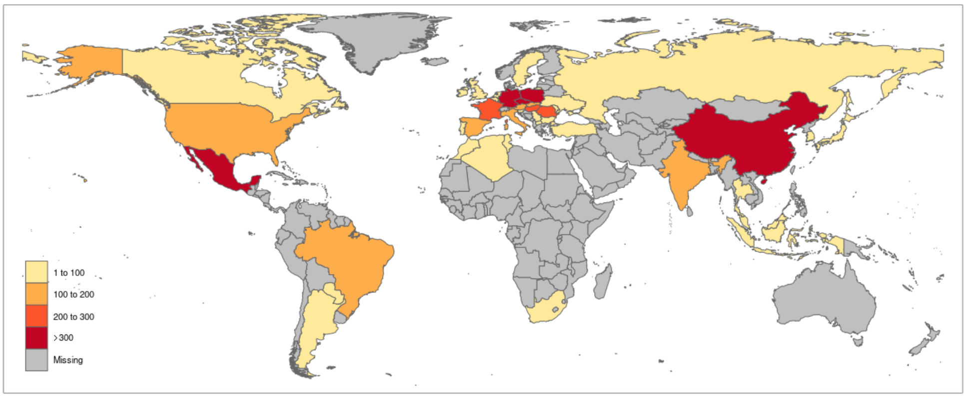
Notes: The figure compares the geographical distribution of suppliers of Volkswagen (a) and Toyota (b) in 2019. The data source is IHS Markit.

and Toyota. We can see how their global network strategy is heterogeneous among firms as their distribution and concentration of suppliers across countries varies substantially.

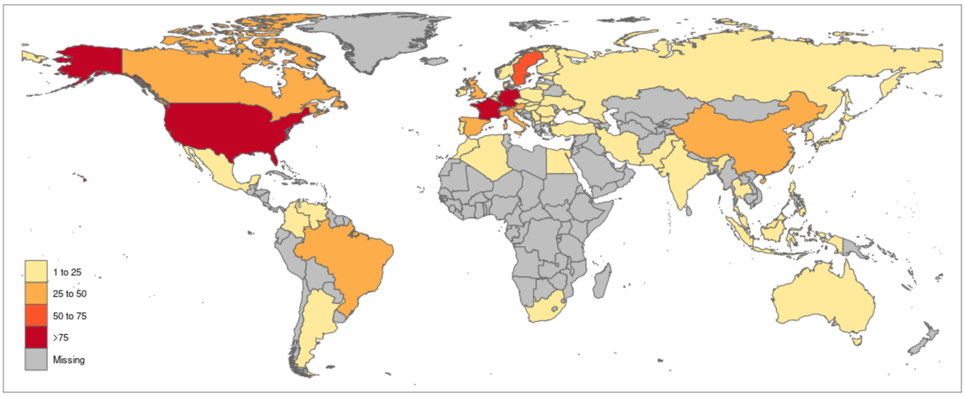
For the ownership network, we use data on cross-shareholdings provided by Orbis. We may consider weighting ownership linkages by the size of subsidiaries. Two problems arise, however: (i) data on total assets or equity are available for just a fraction of subsidiaries of VPs, and (ii) size does not necessarily reflect the importance or specificity of car parts manufactured by subsidiaries (or other business activities carried out by subsidiaries). As shown by Barrot and Sauvagnat (2016), the propagation of firm-level shocks in production networks is mainly

Figure 3: Networks of Volkswagen

(a) Suppliers



(b) Subsidiaries



Notes: The figure compares the geographical distribution of suppliers (a) and subsidiaries (b) of Volkswagen in 2019. The data source for suppliers is IHS Markit, the source for subsidiaries is Bureau van Dijk's Orbis.

determined by suppliers of specific (i.e., research-intensive and difficult to substitute) inputs. As an approximation, we therefore choose to calculate the weight of a country within the ownership-based network of a VP using the number of firms owned by the VP that are located in that country. To construct these weights, we consider two approaches: (i) including only firms in which a VP owns more than 50% of the shares, (ii) including all firms in which a VP owns shares, regardless of the fraction of capital they represent. The main results are similar, and we report results for the second approach, which allows us to exploit a much larger sample of subsidiaries.

We do not have a time series of ownership relationships, but only a snapshot as of December 2020. For supplier-customer relationships, we have data on volumes exchanged in 2019 and 2020. We extrapolate network weights back in time by assuming that they are roughly constant over a small number of years. However, we limit our baseline estimation sample to the period 2018-2020, thus minimizing the impact of this assumption. Moreover, as will be explained in the next section, we assume that network-weighted international IPR levels affect firm efficiency only with a lag (in line with the time frame required by the car production process), so we actually use data on suppliers' network as of 2019 (this also allows us to avoid dealing with the disruptive effects of COVID-19 on supplier-customer relationships in 2020). Figure 3a-3b displays the global maps of suppliers and subsidiaries of Volkswagen. We can deduce from the figure that not only suppliers and subsidiaries of Volkswagen are spread differently worldwide, the ownership network tends to lean towards countries with stronger IPR protection. This can for instance be because firms choose to locate their subsidiaries in countries with more advanced institutions. Low-IPR countries may instead be risky to invest in due to other country characteristics such as political or legal security. This may make it less costly for firms to instead procure from unrelated suppliers in low-IPR countries.

The complete list of VPs and the respective home countries are reported in the Appendix. All other firm-level data are provided by Orbis, except for the initial stock of patents, which is retrieved from the European Patent Office's PATSTAT global database. Data on nominal GDP per capita (current dollars) are from the IMF, data on stock market capitalization are from the World Bank, and data on geographical distances are from the CEPII GeoDist database (Mayer and Zignago 2011). The average distance of suppliers is calculated using supplier-customer weights in 2019.

4 Empirical Framework

We consider an empirical framework where N firms (vehicle producers) have economic linkages with M countries. Let us define $y = (y_1, y_2, \ldots, y_N)'$, where y_i denotes an indicator of efficiency for firm i, with $i = 1, 2, \ldots, N$, and $ipr = (ipr_1, ipr_2, \ldots, ipr_M)'$, with ipr_j denoting the degree of IPR protection in country j, for $j = 1, 2, \ldots, M$. We consider two measures of "connectedness" between firm i and country j. The first reflects the international supplier-customer network and is expressed by the following $N \times m$ matrix of weights $W^{(S)}$:

$$W^{(S)} = \begin{bmatrix} w_{1,1}^{(S)} & w_{1,2}^{(S)} & \cdots & w_{1,M}^{(S)} \\ w_{2,1}^{(S)} & w_{2,2}^{(S)} & \cdots & w_{2,M}^{(S)} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N,1}^{(S)} & w_{N,2}^{(S)} & \cdots & w_{N,M}^{(S)} \end{bmatrix} \tag{1}$$

where the (ij)-th element $w_{i,j}^{(S)}$ denotes the share of firm i's inputs that are supplied by firms located in country j. Each row of $W^{(S)}$ sums to one. The second measure reflects the ownership network, which is expressed by a different weight matrix $W^{(O)}$:

$$W^{(O)} = \begin{bmatrix} w_{1,1}^{(O)} & w_{1,2}^{(O)} & \cdots & w_{1,M}^{(O)} \\ w_{2,1}^{(O)} & w_{2,2}^{(O)} & \cdots & w_{2,M}^{(O)} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N,1}^{(O)} & w_{N,2}^{(S)} & \cdots & w_{N,M}^{(O)} \end{bmatrix} \tag{2}$$

where the (i, j)-th element $w_{i,j}^{(O)}$ denotes the share of firm i's subsidiaries that are located in country j. Again, each row of $W^{(O)}$ sums to one.

We estimate the following model:

$$y = c + \beta_1 W^{(S)} ipr + \beta_2 W^{(O)} ipr + X\gamma + \varepsilon \tag{3}$$

where c is a constant, X is a $N \times k$ matrix that contains k control variables, γ is a $k \times 1$ vector of parameters, and ε is a $N \times 1$ vector of error terms. The parameters β_1 and β_2 capture the effects of IPR protection on firm efficiency operating through supplier-customer and ownership networks, respectively. We rewrite the model in panel form as:

$$y_{it} = c + \beta_1 ipr^{(S)}_{i,t-1} + \beta_1 ipr^{(O)}_{i,t-1} + \gamma' x_{i,t-1} + \varepsilon_{it} \tag{4}$$

where $ipr^{(S)}_{it} = w^{(S)\prime}_{it} ipr_t$, with $w^{(S)\prime}_{it}$ denoting the i-th row of matrix $W^{(S)}_{it}$, $ipr^{(O)}_{it}$ is defined analogously, and x_{it} is a $k \times 1$ vector containing the control variables for firm i at time t. Thus, $ipr^{(S)}_{it}$ and $ipr^{(O)}_{it}$ are the supplier-weighted and ownership-weighted international property rights protection levels, respectively, for firm i. We use lagged regressors for two reasons. First, it is reasonable to assume that changes in IPR affect firm performance with some delay (see, e.g., Alsamawi et al. 2020). Second, and more generally, using lagged regressors alleviates endogeneity problems.

For each firm (VP), we consider a variety of control variables. To begin with, we include other potential determinants of efficiency at the firm level, using balance sheet data. First, we control for firm size, using (log) total assets (*tot_assets*). Second, we control for the composition of the asset side, using the ratio of intangible assets to total assets (*intangible*). Intangible assets represent the stock of R&D-intensive investments, which are in principle more sensitive to IPR protection. Third, we control for composition of the liability side, or capital structure, by including the level of financial leverage, calculated as the ratio of non-current liabilities plus loans to equity (*leverage*). In our robustness checks, we also control for the possibility that firms forming supply chains in high IPR countries are more efficient simply because they are more innovative. We do this by including the stock of patents (*patents*) of each VPs. In particular, we construct our control variable by assigning each VP a value from 1 to 3 based on terciles of the patent stock distribution. To measure the stock of patents, we use the total number of patents granted over the 20 years prior to the first year of the estimation sample. In addition, in our robustness checks we also consider the annual flow of (log) R&D expenditures per employee (*rde*). To control for geographical factors affecting international trade, we include the log average distance between each VP and its suppliers ($distance^{(S)}$), approximated by the distance between the respective countries[10]. It is particularly important to account for these factors in light of the disruptions caused by the COVID-19 pandemic to international supply chains. As additional robustness checks, we also consider the total number of suppliers and the total number of subsidiaries as controls, taking account of efficiency effects associated with the degree fragmentation of supply-chains affects efficiency.

Importantly, we want to distinguish the effects operating specifically through IPR protection from those operating through other channels related to the quality of economic and financial institutions in firms' host countries. To this aim, we also include a variety of country-level and country-firm pair-level variables capturing other institutional factors. First, we control for the overall level of development of each country, which is likely to be a common factor underlying both IPR protection and firms' efficiency. In particular, we include the (log) nominal GDP per capita (*gdp_pc*) and the ratio of stock market capitalization to GDP (*mkt_cap*) of the country where the VP's headquarters are located, with market capitalization acting as a proxy for financial development.We also consider network-weighted average international GDP levels and market capitalization ratios to take account of the quality of institutions in the host countries of suppliers and subsidiaries. Finally, we look at other factors more specifically related to the rule of law. In particular, we control for physical property rights protection (*ppr*).

We first estimate the model over the short sample 2018-2020 adopting a quasi cross-section approach, and later expand the sample back to 2012 for a dynamic panel model. The information on supplier-customer relationships is not available prior to 2018 and is only a recent addition to the IHS database. We thus keep the network weights fixed, also considering that the duration of VPs' contracts with suppliers are likely to span over several years, typically covering the production cycle of a car model from SOP (Start of Production) to EOP (End of Production). Importantly, assuming networks to be approximately fixed over a not too long time span also helps mitigate concerns about their endogeneity.

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[10] We use geodesic distances, calculated following the great circle formula, which considers latitudes and longitudes of the most important cities/agglomerations (in terms of population). This is the variable labeled as *dist* in the CEPII database (Mayer and Zignago 2011).

5 Results

5.1 Baseline results

Given the availability issues for data on supplier-customer networks (see Section 3), we first report regressions over our baseline period $2018 - 2020$. We initially use the IPRI to calculate network-based levels of protection faced by each VM. This index is a broad measure and does not distinguish between the protection of physical and intellectual property rights. Tables 2-3 report the results for our two proxies of efficiency/productivity y. In particular, Table 2 shows the results obtained using log operating revenues per employee as the dependent variable, whereas table 3 show the results for the sales-to-assets ratio. Year dummies (time fixed effects) are included in all regressions. In each regression, we omit outliers defined as observations lying more than 2 standard deviations away from the mean of (log) operating revenues per employee over the period 2012-2020. We do this to avoid concerns about a few abnormal values in the dataset (in particular, the Chinese VPs CNHTC and Zhengzhou Yutong show abnormally high values of operating revenues in some years). However, our findings are confirmed when we include outliers or consider a 3-standard-deviation threshold.

Before commenting on the results, it worth mentioning that, for inference purposes, we perform diagnostic tests on the residuals of the models in Tables 2-3. The Breusch–Pagan/ Cook–Weisberg test for heteroskedasticity rejects the null of homoskedasticity for all regressions except the one with firm fixed effects for operating revenues per employee. Conversely, the Wooldridge test for autocorrelation in panel data does not reject the null hypothesis of no autocorrelation in the residuals for any model at any conventional level of significance, which suggests that correcting standard errors for autocorrelation is not required. However, for greater robustness and for internal coherence throughout the paper, we choose to use clustered standard errors in all the tables, i.e., standard errors that are robust to both heteroskedasticity and within-firm autocorrelation.

We start by considering a basic OLS regression in which the log of operating revenues per

Table 2: Baseline results: operating revenues per employee

	Dependent variable: $OpRev/empl$				
	(1)	(2)	(3)	(4)	(5)
$ipri^{(S)}$	0.517***	0.479**	0.387*	0.486*	1.536***
	(0.161)	(0.216)	(0.210)	(0.246)	(0.550)
$ipri^{(O)}$	-0.032	0.208	-0.011	-0.013	-0.785
	(0.174)	(0.415)	(0.365)	(0.170)	(0.515)
tot_assets	0.211***	0.189***	0.239***	0.216***	0.362
	(0.046)	(0.069)	(0.066)	(0.053)	(0.292)
$intangible$	0.359	-0.391	-0.011	0.133	1.346
	(0.510)	(1.294)	(1.095)	(0.535)	(1.521)
$leverage$er	0.015	0.010	0.043	0.005	0.043**
	(0.050)	(0.075)	(0.071)	(0.050)	(0.019)
$ipri$		-0.229			
		(0.473)			
gdp_pc		0.072			
		(0.271)			
mkt_cap		0.010			
		(0.321)			
$gdp\_pc^{(S)}$				0.088	
				(0.182)	
$mkt\_cap^{(S)}$				-0.307	
				(0.476)	
$distance^{(S)}$				-0.088	
				(0.114)	
year FE	x	x	x	x	x
country FE			x		
firm FE					x
obs.	180	150	180	180	180
N	70	61	70	70	70
adj. R^2	0.417	0.357	0.462	0.416	0.084

Notes: The table reports OLS estimates on annual data over the sample 2018-2020. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported for the fixed-effect regression of column (5) is the within R^2. The significance levels are: *** 0.01 ** 0.05, * 0.1.

employee depends on the supplier-weighted and ownership-weighted IPRI. This is reported in column (1) of Table 2, which only controls for key firm-level characteristics that we include as baseline in all our regressions, namely the VP's size(total assets), composition of its assets (intangible assets intensity), and its capital structure (financial leverage). We find that the coefficient on supplier-weighted (SW) IPRI is around 0.5 and strongly significant, while the coefficient on ownership-weighted (OW) IPRI is negative and not significant. All else being equal, this implies that an increase in the average IPRI of the location of suppliers in a production network by 1 notch is associated with a 50% increase in operating revenues per employee, approximately. The lack of significance for OW IPRI is not simply a result of the simultaneous inclusion of SW IPRI (the correlation between the two is 0.64) but is also found if the latter is excluded. As expected, firm size is also a strong indicator of its operating revenues.

In column (2) we consider controls for the VP's home country. First, supplier-weighted average IPRI may just capture the effect of domestic property rights protection in the VP's home country, if a VP mostly trades with countries at a similar level of development. Thus, we include the IPRI for the country where the VP headquarters are located (*ipri*). Second, we control for nominal GDP per capita of the VP's home country. Third, higher efficiency of VPs may be associated with a higher level of financial market development in their home countries. To control for this, we include the domestic stock market capitalization-to-GDP ratio. Then, to control for all sorts of country-specific characteristics, in column (3) we include country fixed effects. Our key results on the significance of IPRI in supplier countries and its irrelevance in the location of a VP's owned subsidiaries are broadly confirmed.[11]

In column (4) we perform an additional robustness check by considering supplier country characteristics faced by each VP. Namely, we check that the effect we have found is specifically related to property rights protection in suppliers' countries and does not simply reflect the level of economic and financial development of those countries. To this aim, we include the supplier-weighted average nominal GDP per capita ($gdp\_pc^{(S)}$) and the market capitalization ratio ($mkt\_cap^{(S)}$) (note that these variables are firm specific, as they depend on firms' network structures). Furthermore, we consider the average distance of each VP from its suppliers. This captures geographical patterns of international trade and may be an important determinant of firm efficiency. This could include the disruption of international trade during the COVID-19 crisis, though the impact of COVID-19 on efficiency levels is already accounted for by year fixed effects. To calculate average distance we use the same weights as for $ipri^{(S)}$ (number of vehicles

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[11] Note that, given the very short time span of the regressions, the simultaneous inclusion of country controls and country fixed effects would raise collinearity issues, so we include them alternately.

Table 3: Baseline results: sales-to-assets ratio (turnover ratio)

	Dependent variable: $Sales/assets$				
	(1)	(2)	(3)	(4)	(5)
$ipri^{(S)}$	0.368***	0.350***	0.283**	0.527***	0.765**
	(0.103)	(0.130)	(0.121)	(0.141)	(0.372)
$ipri^{(O)}$	-0.109	-0.153	-0.332**	-0.106	-0.396
	(0.104)	(0.312)	(0.160)	(0.096)	(0.273)
tot_assets	0.001	0.002	0.051**	0.006	0.095
	(0.030)	(0.038)	(0.024)	(0.030)	(0.152)
$intangible$	-0.801***	-1.277**	-0.571	-1.023***	0.316
	(0.281)	(0.532)	(0.395)	(0.364)	(0.421)
$leverage$er	-0.031	-0.046	-0.074***	-0.040	-0.013
	(0.028)	(0.032)	(0.027)	(0.026)	(0.011)
$ipri$		0.133			
		(0.239)			
gdp_pc		-0.108			
		(0.147)			
mkt_cap		-0.202			
		(0.238)			
$gdp\_pc^{(S)}$				-0.109	
				(0.106)	
$mkt\_cap^{(S)}$				-0.612**	
				(0.261)	
$distance^{(S)}$				0.029	
				(0.060)	
year FE	x	x	x	x	x
country FE			x		
firm FE					x
obs	172	145	172	172	172
N	67	59	67	67	67
adj. R^2	0.172	0.183	0.568	0.202	0.349

Notes: The table reports OLS estimates on annual data over the sample 2018-2020. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported for the fixed-effect regression of column (5) is the within R^2. The significance levels are: *** 0.01 ** 0.05, * 0.1.

produced using purchased components). Note that the 10% significance of the coefficient in columns (3) and (4) (with a p-value only slightly larger than 5% in both cases) is the result of our precautionary approach of using clustered standard errors even though they are not strictly necessary: if we simply correct standard errors for heteroskedasticity, in line with diagnostic tests, the coefficient is statistically significant at the 5% level for column (3) and at the 1% for column (4).

Finally, to control for any sort of firm-specific characteristics, in column (5) we include firm fixed-effects to the specification from column (1) (which hereafter is referred to as our baseline specification). Of course, in column (5) country fixed-effects cannot be included because of perfect collinearity with firm fixed effects. In both regressions, the coefficient on supplier-weighted property rights protection remains significant. All in all, a coefficient generally close to 0.5 implies a unit decrease in the IPRI reduces the productivity of a supplier network by approximately 50%. The results are also robust to the inclusion of the total number of suppliers of each VP and the total number of subsidiaries (not reported).

In Table 3 we replicate the same regressions for the VPs' sales-to-assets ratio. As before, we obtain a positive and strongly significant coefficient on $ipri_i^{(S)}$ and a non-significant coefficient on $ipri_i^{(O)}$. In this case, the estimated coefficient on $ipri_i^{(S)}$ ranges from 0.28 to 0.76. The coefficient is robust to the similar set of controls and specifications also for the sales-to-assets ratio. The protection of property rights therefore seems to be a relevant factor for efficiency of supplier networks, but no so for ownership networks. Overall, these results suggest that higher property rights protection in countries where suppliers are located is associated with higher efficiency of VPs. Conversely, higher IPR protection in the locations of foreign affiliates does not appear to be significantly related to efficiency.

Also, the results indicate that country controls and supplier-network controls are in general non-significant, while firms' balance-sheet indicators exhibit some explanatory power (in particular, total assets for the operating revenues-to-employee ratio and intangible assets for the sales-to-assets ratio). Thus, in the following sections we keep including the latter as regressors, and use fixed effects to control for any other characteristics that may affect firm performance.

5.2 Intellectual versus Physical Property Rights

Next, in Table 4 we go a step further and break down the IPRI measure to single out the impact of the protection of *intellectual* property rights (*ipr*) as opposed to *physical* property rights (*ppr*). To do so, we make use of the two sub-indices included in IPRI and repeat our baseline specification. Columns (1) and (2) do not include firm fixed effects but only our main

Table 4: IPR and PPR

	(1)	(2)	(3)	(4)
Dep. variable:	*OpRev/empl*	*sales/assets*	*OpRev/empl*	*sales/assets*
$ipr^{(S)}$	0.697**	0.496**	1.165**	0.564***
	(0.264)	(0.222)	(0.493)	(0.172)
$ppr^{(S)}$	-0.472	-0.423	1.370*	0.132
	(0.338)	(0.316)	(0.812)	(0.270)
$ipr^{(O)}$	-0.319	-0.185	-0.715	-0.212
	(0.276)	(0.176)	(0.458)	(0.173)
$ppr^{(O)}$	0.445	0.126	-0.505	-0.189
	(0.333)	(0.182)	(0.346)	(0.169)
tot_assets	0.213***	0.006	0.357	0.116
	(0.048)	(0.030)	(0.297)	(0.155)
intangible	0.136	-0.953***	1.583	0.313
	(0.554)	(0.306)	(1.578)	(0.429)
*leverage*er	-0.005	-0.063*	0.036*	-0.013
	(0.046)	(0.036)	(0.021)	(0.012)
year FE	x	x	x	x
firm FE			x	x
obs.	180	172	180	172
N	70	67	70	67
adj. R^2	0.456	0.259	0.138	0.394

Notes: The table reports OLS estimates on annual data over the sample 2018-2020. Robust standard errors clustered at the firm level are reported in parentheses. The significance levels are: *** 0.01 ** 0.05, * 0.1.

firm-level controls, and show that, for both operating revenues per employee and the sales-to-assets ratio, supplier-weighted IPR protection is significant at the 5% level, while physical property right protection is negative and non-significant. Columns (3) and (4) report the same estimates with firm fixed effects, accounting for any firm-specific characteristics, and clearly confirm that the results are mainly driven by protection of *ipr* rather than *ppr*. Also, the protection of property rights at the location of VPs' subsidiaries is again non-significant for both dependent variables, suggesting that the effect of institutional quality is absent when subsidiaries are integrated within the VP.

5.3 Gravity-Based Instrumental Variable Approach

Network econometric models often take the network structure as exogenous (e.g., see de Paula 2016). However, in our context networks may be endogenous, being the result of firms' integration and outsourcing decisions. To deal with the endogeneity of networks, we use an instrumental variable (IV) regression, estimated by two-stage least squares (2SLS). In particular, we first note that our variable of interest, the average level of IPR protection at the location of suppliers ($ipr^{(S)}$), is calculated using network weights ($W^{(S)}$) that may be endogenous from the perspective of VPs, at least to the extent that they are not simply dictated by differences in input costs across countries. To address this issue, we instrument the network-weighted variable $ipr^{(S)}$ using an alternative measure of international IPR protection, calculated as a cross-country weighted average using exogenous weights, namely weights that depend on geographical distances between countries. We try different transformations of distance to construct our instrument, however we find that the best results are obtained when we consider the inverse of the squared distance. Specifically, for each VP, we calculate an average international IPR level weighting each country by the inverse of the squared distance between that country and the VP's headquarter country. Denoting with $w_{ij}^{(dist)} = 1/distance_{ij}^2$ the distance-based weight of country j for VP i, our instrument is calculated as:

$$ipr_{it}^{(dist)} = \frac{1}{\sum_{j=1}^{N} w_{ij}^{(dist)}} \sum_{j=1}^{N} w_{ij}^{(dist)} ipr_{jt} \tag{5}$$

Our IV first-stage equation is:

$$ipr_{it}^{(S)} = \tilde{c} + \tilde{\beta}_i ipr_{it}^{(dist)} + \tilde{\gamma}' x_{it} + \varepsilon_{it} \tag{6}$$

where $\tilde{c}$ denotes a constant, $\tilde{\beta}_i$ is a slope coefficient, x_{it} is the set of regressors used in the second-stage regression, $\tilde{\gamma}$ is the vector of associated coefficients, and ε_{it} is an error term. As before, we also consider firm and time fixed effects. The coefficient β_i is assumed to be homogeneous for VPs that are based in the same country, but is allowed to vary between VPs that are based in different countries. In other words, the effect of our instrument is allowed to depend on the country where firm i has its headquarters. This assumption is supported by the estimation results, which indicate that this coefficient is heterogeneous across countries. By using the distance-weighted IPR as an instrument in the first-stage regression for supplier-weighted $ipr^{(S)}$, instead of including it as an explanatory variable in the second-stage regression, we impose the exclusion restriction that international IPR protection affects firms' performance only through their production networks, i.e., a country's IPR does not affect VPs if they do not have suppliers there.

Table 5 reports the results. The estimates confirm our main findings on the effect of IPR protection at the suppliers' locations: the coefficient on $ipr^{(S)}$ is always positive and strongly significant. The table also shows the first stage results in the upper part, In particular, the average coefficient on $ipr_{it}^{(dist)}$ across countries and the F-test for instrument relevance are reported. The large values of the F-test (much larger than the conventional threshold of 10 used as a rule of thumb) indicate high relevance of our instrument.[12]

5.4 Extended sample and GMM

In this section, we consider the longer sample $2012 - 2020$, assuming constant network structures, and use it to provide additional results of interest. First, we consider a dynamic panel model, estimated by GMM. The GMM estimator is consistent in the presence of dynamic effects in the dependent variable (Arellano and Bond 1991; Blundell and Bond 1998). In particular, we use the system GMM estimator, which augments the difference GMM and guarantees greater precision with small T and persistent time series (Blundell and Bond 1998). By estimating a dynamic model, we are able to check that our main results are not affected by the inclusion of an autoregressive component. Next, since the GMM estimator allows to deal with endogeneity of regressors using lagged variables as instruments, we use it as an additional approach for addressing the potential endogeneity of network-weighted IPR protection. Finally, we exploit

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[12] Note that, in order to allow β_i to vary with the "home country of the VP, we interact $ipr_{it}^{(dist)}$ with home-country dummies in the first stage regression. Given that the number of home countries in this regression is 21, we effectively exploit 21 instruments instead of one.

Table 5: IV regressions

	First stage			
	Dependent variable: $ipr^{(S)}$			
	(1)	(2)	(3)	(4)
$ipr^{(dist)}$ (avg.)	0.123	0.355	0.319	0.264
F test stat.	32.60	28.73	24.39	24.22
	Second stage			
Dep. variable:	$OpRev/empl$	$sales/assets$	$OpRev/empl$	$sales/assets$
$ipr^{(S)}$	0.452***	0.259***	0.583**	0.362***
	(0.100)	(0.074)	(0.282)	(0.124)
tot_assets	0.186***	-0.023	0.381	0.114
	(0.031)	(0.022)	(0.286)	(0.143)
$intangible$	0.121	-0.835***	1.275	0.302
	(0.458)	(0.300)	(1.471)	(0.390)
$leverage$	0.005	-0.053*	0.051***	-0.009
	(0.048)	(0.030)	(0.020)	(0.011)
year FE	x	x	x	x
firm FE			x	x
obs	191	177	191	177
N	75	70	75	70
adj. R^2	0.407	0.139	0.089	0.372

Notes: The table reports 2SLS and 2SLS within (FE) estimates on annual data over the sample 2018-2020. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported for the fixed-effect regressions is the within R^2. For the first-stage regression, we report the cross-country average coefficient of the instrument. The significance levels are: *** 0.01 ** 0.05, * 0.1.

the longer time dimension of the panel to account for firm-level characteristics related to their innovation capacity, on which we have data only for a subset of firms. In particular, we consider the initial stock of patents and the log R&D expenditures per employee (the two are jointly available only for a subset of 39 companies).

We start by extending the sample in Table 6, using the IPRI index of property rights protection as a regressor. In columns (1) and (2), we report the GMM estimates of a dynamic panel model for operating revenues per employee and the sales-to-assets ratio, respectively.[13] For

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[13] In more detail, the table reports estimates of a one-step system GMM using as instruments (i) for the first differences equation: the lagged levels of the dependent variable at time $t-2$ and earlier, and the first differences of the predictors at time $t-1$; (ii) for the levels equation: the first difference of the dependent variable at time $t-1$ and the lagged levels of the other predictors. Based on the results of Monte Carlo simulations, Judson and Owen (1999) recommend using the one-step GMM estimator in the case of unbalanced panels with small T (in particular, $T \leq 10$). A source of concern for estimation may be the potential non-stationarity of the dependent variables, in particular operating revenues per employee. However, our data cover a short time span, and panel

Table 6: Extended sample (2012-2020): GMM and FE estimates (IPRI)

	(1) GMM *OpRev/empl*	(2) GMM *sales/assets*	(3) FE *OpRev/empl*	(4) FE *sales/assets*
$ipri^{(S)}$	0.203**	0.242***	0.651**	0.402**
	(0.098)	(0.085)	(0.300)	(0.195)
$ipri^{(O)}$	0.039	-0.120	-0.277	-0.261
	(0.101)	(0.079)	(0.223)	(0.157)
tot_assets	0.104***	-0.002	0.055	0.002
	(0.024)	(0.021)	(0.123)	(0.044)
intangible	0.156	-0.631**	1.822*	-0.078
	(0.355)	(0.273)	(0.967)	(0.308)
leverage	0.010	-0.005	0.003	0.013
	(0.020)	(0.024)	(0.017)	(0.014)
lag dep. var.	0.366***	0.155		
	(0.049)	(0.169)		
year FE	x	x	x	x
firm FE			x	x
obs.	440	444	462	445
N	79	77	82	77

Notes: The table reports one-step system GMM (columns 1-2) and FE (columns 3-4) estimates obtained on annual data over the sample 2012-2020. Robust standard errors clustered at the firm level are reported in parentheses. The significance levels are *** 0.01 ** 0.05, * 0.1.

comparison, we also report fixed effects (least-squares dummy variables) estimates in columns (3)-(4). In this case, we simply extend the sample of our baseline (static) panel model, excluding the lagged dependent variable to avoid issues related to the bias of FE estimates of dynamic models (Nickell 1981). Again, all regressions include year fixed effects. As the table shows, the estimated effect of average property rights protection in suppliers' countries ($ipri^{(S)}$) remains strongly significant regardless of the estimation approach. Institutional quality in the location of VP's owned subsidiaries ($ipri^{(O)}$) continues to have no significant effect on productivity or efficiency, and tends to have a negative coefficient in point estimates.

Next, in Table 7 we narrow down institutional quality by focusing on the IPR sub-index, to emphasize the importance of intellectual property, and we use GMM to address the potential

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unit root tests indicate stationarity. The Sargan-Hansen test of exogeneity of instruments does not reject the null hypothesis of instrument validity. The total number of instruments is 48 (as GMM uses separate instruments for each time period, see Roodman 2009). The Arellano-Bond test of autocorrelation does not reject the null hypothesis of no autocorrelation in GMM residuals.

Table 7: GMM and IPR: accounting for endogeneity and innovativeness

	(1) $OpRev/empl$	(2) $OpRev/empl$	(3) $OpRev/empl$	(4) $sales/assets$	(5) $sales/assets$	(6) $sales/assets$
$ipr^{(S)}$	0.342***	0.467***	0.456***	0.150**	0.220***	0.118*
	(0.106)	(0.127)	(0.116)	(0.073)	(0.085)	(0.068)
tot_assets	0.171***	0.203***	0.141***	-0.024	-0.008	-0.010
	(0.026)	(0.039)	(0.050)	(0.018)	(0.027)	(0.028)
$intangible$	0.250	0.068	0.099	-0.706**	-0.850**	-0.021
	(0.509)	(0.641)	(0.617)	(0.279)	(0.335)	(0.281)
$leverage$	-0.001	-0.009	-0.000	-0.024	-0.032	-0.066***
	(0.025)	(0.028)	(0.034)	(0.026)	(0.026)	(0.020)
$patents$		-0.226**	-0.012		-0.141	0.026
		(0.104)	(0.103)		(0.095)	(0.056)
rde			0.110			0.032
			(0.075)			(0.034)
year FE	x	x	x	x	x	x
obs	485	397	285	458	397	285
N	85	64	39	85	64	39

Notes: The table reports one-step system GMM estimates obtained on annual data over the sample 2012-2020. Robust standard errors clustered at the firm level are reported in parentheses. Significance levels: *** 0.01 ** 0.05, * 0.1.

endogeneity of the suppliers' network. In particular, in all regressions of Table 7, we treat the supplier-weighted IPR level ($ipr^{(S)}$) as endogenous (in analogy with section 5.3), and instrument it using a standard GMM instrumenting strategy (see Roodman 2009). Specifically, we use as GMM-type instruments (i) for the first differences equation: the lagged levels of $ipr^{(S)}$ at time $t-2$ and earlier; (ii) for the levels equation: the lagged first difference of $ipr^{(S)}$ at time $t-1$.[14]

Finally, in Table 7 we also control for innovation factors that can influence firms' productivity or efficiency. In particular, we investigate the impact of firms' innovation capacity, as measured by the number of patents they have successfully filed in the 20 years up to the beginning of the sample period (we consider a 20-year period as this is the standard term of patent), or by their R&D expenditure per employee throughout the years under study. We aim to check whether the productivity effect of IPR protection in supplier-customer networks

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[14] The first-stage F-tests for the relevance of instruments indicate that instruments are relevant, both in the first differences equation and in the levels equation. As usual, we also include the other second-stage regressors as instruments in the first stage. Moreover, the Sargan-Hansen test does not reject the hypothesis of exogeneity of instruments. The total number of instruments is 46-48, depending on the specification (column) considered in the table (recall that GMM uses separate instruments for each time period, see Roodman 2009). The Arellano-Bond test does not reject the hypothesis of no autocorrelation in GMM residuals.

is overshadowed by firms' levels of innovativeness.

Columns (1)-(3) of Table 7 report GMM estimates for operating revenues per employee, while in columns (4)-(6) the dependent variable is the sales to asset ratio. Columns (1) and (4) report the baseline regressions for our two dependent variables, and show that our findings are confirmed, with IPRs in suppliers' locations exerting a strongly significant effect on VPs' productivity. Columns (2) and (5) report regressions in which we include the terciles of the initial stock of granted patents (*patents*), i.e., the total number of patents granted between 1992 and 2011. Supplier-weighted IPR continues to be strongly significant. Columns (3) and (6) incrementally adds the lagged annual level of R&D expenditures per employee (*rde*, in logs). Again, our main results are confirmed.

In summary, allowing for endogeneity by means of GMM and controlling for key firm-level variables that represent a firm's innovation capacity does no affect our argument. Hence, these additional estimates support our conjecture that the results are IP-related, yet the higher productivity or efficiency experienced by VPs is not driven by more innovative firms self-selecting into high-IPR countries. Overall, our results emphasize the idea that intellectual property and its protection along the supply chain is critical for the performance of the production network.

6 Conclusions

This study aims to shed light on some basic relationships between institutional quality and the performance of international production networks. Given the growing importance of such networks at the global level and the increasing technological content of international trade, the protection of property rights can play a central role in determining the efficiency of networks. The leak of knowledge at any node of the network can have undesirable effects for the network as a whole. Exploiting detailed data on buyer-supplier relationships in the automotive industry, with information about location on both sides, we are able to evaluate the impact of IPR protection on the productivity and efficiency of manufacturers in an industry for which the international dimension of the supply chain and the reliance on intangible assets are both of utmost relevance.

Our analysis finds a robust relationship between the performance of VPs and the protection of IPRs in supplier countries. We employ a wide battery of controls and estimation strategies to mitigate concerns about omitted variables and endogeneity. Importantly, our interpretation of the results is also tested by splitting the IPRI into two components specifically measuring intellectual property rights and physical property rights, respectively. Our hypothesis is confirmed by discovering that the findings are only valid for *intellectual* property rights.

We also consider the ownership networks of VPs and find that IPRs only increase productivity and efficiency in production networks when they involve suppliers as opposed to subsidiaries. This finding supports our hypothesis that inefficiencies caused by the lack of IPR protection could stem from transactions costs due to the risk of knowledge dissipation along the supply chain. Instead, IPRs do not appear to impact efficiency in the case of ownership, which is likely to be due to the internalization of knowledge transfers, making networks less vulnerable to dissipation risks. In other words, ownership may substitute weak IPR protection in subsidiaries' host countries, mitigating the effect of IPRs on firm performance within international production networks.

To address the possibility that our results derive from better firms choosing suppliers from countries with high-quality institutions, we include firm fixed effects. We then build an exogenous instrumental variable to weight the IPR protection faced by a VP based on distance. In other words, instead of taking the average IPR of its actual suppliers' locations, we take the average IPR index of all countries with the weight diminishing as we move further away from the VP country. We also use a GMM estimator, both to estimate a dynamic panel model (by extending the period of our analysis back to 2012) and as an additional tool to address endogeneity concerns. Finally, we check whether more innovative firms place their nodes, or choose their suppliers, in countries with more advanced quality of institutions by controlling for firm's initial stock of patents and R&D expenditure.

While this is an early attempt to explore the link between IPRs and international production networks, recently-made available data on buyer-supplier relationships makes it possible to deepen the analysis and expand it in several dimensions. An interesting direction would be to consider global supply chains in all industries and assess the gains from IPR protection in the location of the networks. Another avenue of research could be to consider the placement of the network nodes within the supply chain and quantify the potential gains based on their level of upstreamness. Finally, an analysis with a longer time span would allow us to study the trends and restructuring of global supply chains in terms of innovation, resilience, and environmental sustainability.

References

Acemoglu, Daron and Alireza Tahbaz-Salehi, "Firms, Failures, and Fluctuations: The Macroeconomics of Supply Chain Disruptions," NBER Working Paper Series 27565, NBER 2020.

_ , Vasco M. Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-Salehi, "The Network Origins of Aggregate Fluctuations," *Econometrica*, 2012, *80* (5), 1977–2016.

Alfaro, Laura and Andrew Charlton, "Intra-industry Foreign Direct Investment," *American Economic Review*, December 2009, *99* (5), 2096–2119.

Allen, Treb, "Information Frictions in Trade," *Econometrica*, 2014, *82* (6), 2014–2083.

Alliance, Property Rights, "International Property Rights Index," Full Report 2020.

Alsamawi, Ali, Charles Cadestin, Alexander Jaax, Joaquim Guilhoto, Sebastien Miroudot, and Carmen Zuercher, "Returns to intangible capital in global value chains: New evidence on trends and policy determinants," 2020. OECD Trade Policy Papers, No. 240, OECD Publishing, Paris.

Altomonte, Carlo, Gianmarco Ottaviano, Armando Rungi, and Tommaso Sonno, "Business Groups as Knowledge-Based Hierarchies of Firms," CEPR Discussion Paper Series 16677, CEPR 2021.

Antràs, Pol and Stephen R. Yeaple, "Chapter 2 - Multinational Firms and the Structure of International Trade," in Gita Gopinath, Elhanan Helpman, and Kenneth Rogoff, eds., *Handbook of International Economics*, Vol. 4 of *Handbook of International Economics*, Elsevier, 2014, pp. 55–130.

Arellano, Manuel and Stephen Bond, "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *The Review of Economic Studies*, 04 1991, *58* (2), 277–297.

Atalay, Enghin, Ali Hortaçsu, and Chad Syverson, "Vertical Integration and Input Flows," *American Economic Review*, 2014, *104* (4), 1120–48.

Backer, Koen De and Sébastien Miroudot, "Mapping Global Value Chains," Trade Policy Papers 159, OECD 2013.

Barba Navaretti, Giorgio and Anthony Venables, *Multinational Firms in the World Economy*, Princeton University Press, 2004.

Barrot, Jean-Noel and Julien Sauvagnat, " Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks," *The Quarterly Journal of Economics*, 2016, *131* (3), 1543–1592.

Bernard, Andrew B., Andreas Moxnes, and Yukiko U. Saito, "Production Networks, Geography, and Firm Performance," *Journal of Political Economy*, 2019, *127* (2), 639–688.

Blundell, Richard and Stephen Bond, "Initial conditions and moment restrictions in dynamic panel data models," *Journal of Econometrics*, 1998, *87* (1), 115–143.

Boehm, Johannes and Ezra Oberfield, "Misallocation in the Market for Inputs: Enforcement and the Organization of Production," *The Quarterly Journal of Economics*, 2020, *135* (4), 2007–2058.

Branstetter, Lee, "Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the United States," *Journal of International Economics*, 2006, *68* (2), 325–344.

Branstetter, Lee G, Raymond Fisman, and C Fritz Foley, "Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from US Firm-Level Panel Data," *Quarterly Journal of Economics*, 2006, *121* (1), 321–349.

Chaney, Thomas, "The network structure of international trade," *American Economic Review*, 2014, *104* (11), 3600–3634.

de Paula, Aureo, "Econometrics of network models," CeMMAP working papers 06/16, Institute for Fiscal Studies January 2016.

Ethier, Wilfred J. and James R. Markusen, "Multinational firms, technology diffusion and trade," *Journal of International Economics*, 1996, *41*, 1–28.

Ivus, Olena, Kamal Saggi, and Walter Park, "Patent protection and the composition of multinational activity: evidence from US multinational firms," *Journal of International Business Studies*, 2017, *48* (7), 808–836.

Jinji, Naoto, Sawada Yukiko, Zhang Xingyuan, and Haruna Shoji), "Gravity for Cross-border Licensing and the Impact of Deep Trade Agreements: Theory and Evidence," Discussion Paper E-20-008, Kyoto University Graduate School of Economics 2021.

Judson, Ruth A and Ann L Owen, "Estimating dynamic panel data models: a guide for macroeconomists," *Economics Letters*, 1999, *65* (1), 9–15.

Klein, Benjamin, Robert G. Crawford, and Armen A. Alchian, "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process," *Journal of Law and Economics*, 1978, *21* (2), 297–326.

Kukharskyy, Bohdan, "A tale of two property rights: Knowledge, physical assets, and multinational firm boundaries," *Journal of International Economics*, 2020, *122*, 103262.

Lai, Huiwen, Keith E. Maskus, and Lei Yang, "Intellectual property enforcement, exports and productivity of heterogeneous firms in developing countries: Evidence from China," *European Economic Review*, 2020, *123*, 103373.

Mayer, Thierry and Soledad Zignago, "Notes on CEPII's distances measures: The GeoDist database," Working Papers 2011-25, CEPII research center December 2011.

Nickell, Stephen, "Biases in Dynamic Models with Fixed Effects," *Econometrica*, 1981, *49* (6), 1417–1426.

Orefice, Gianluca and Nadia Rocha, "Deep Integration and Production Networks: An Empirical Analysis," *World Economy*, 2014, *37* (1), 106–136.

Park, Walter, "International Patent Protection: 1960-2005," *Research Policy*, 2008, *37* (4), 761–766.

Ramondo, Natalia, Veronica Rappoport, and Kim J. Ruhl, "Intrafirm trade and vertical fragmentation in U.S. multinational corporations," *Journal of International Economics*, 2016, *98*, 51–59.

Roodman, David, "How to do xtabond2: An introduction to difference and system GMM in Stata," *Stata Journal*, March 2009, *9* (1), 86–136.

Santacreu, Ana Maria, "Dynamic Gains from Trade Agreements with Intellectual Property Provisions," 2023. mimeo, Federal Reserve Bank of Saint Louis.

Sturgeon, Timothy, Johannes Van Biesebroeck, and Gary Gereffi, "Value chains, networks and clusters: reframing the global automotive industry," *Journal of Economic Geography*, 2008, *8* (3), 297–321.

UNCTAD, "Global value chains: Investment and trade for development," World investment report, UNCTAD 2013.

Williamson, Oliver E., "The Governance of Contractual Relations," *Journal of Law and Economics*, 1979, *22* (2), 233–261.

Yeaple, Stephen R., "Offshoring, Foreign Direct Investment, and the Structure of U.S. Trade," *Journal of the European Economic Association*, 2006, *4* (2-3), 602–611.

Appendix

In this appendix, we report the list of vehicle producers (VPs) comprised in our sample, along with information on the countries where their headquarters are located (Table 6). For four companies, namely CNH Industrial, Ferrari, Fiat-Chrysler (FCA) and Geely, the countries hosting the legal headquarters (the United Kingdom for CNH Industrial, the Netherlands for Fiat-Chrysler and Ferrari, the Cayman Islands for Geely) do not represent the centers of the companies' economic activities and corporate control. For these firms, we consider the "effective" home countries, namely China for Geely and Italy for CNH Indutrial, Ferrari and Fiat-Chrysler. However, this choice is inconsequential for our main results. IHS provides information on suppliers for the Renault–Nissan–Mitsubishi Alliance as a whole, not for the individual companies composing the partnership. Accordingly, we aggregate firm-specific balance-sheet data provided by Orbis across the three companies. Among the world's biggest car producers, the only one which is not included in our sample is Hyundai, due to unavailability of data on the company's number of employees. However, we check that including Hyundai in the regressions for the sales-to-assets ratio does not affect the main results.

Table 8: List of vehicle producers (VP)

n.	IHS Markit company name	Orbis company name	country
1	Agrale	AGRALE SOCIEDADE ANONIMA	BR
2	Ashok Leyland	ASHOK LEYLAND LIMITED	IN
3	Asia Avto	JSC AZIA AVTO	KZ
4	Aston Martin	ASTON MARTIN LAGONDA GLOBAL HOLDINGS PLC	GB
5	Avtotor	AKTSIONERNOE OBSHCHESTVO AVTOTOR	RU
6	Bahman Group	BAHMAN GROUP COMPANY PUBLIC JOINT STOCK COMPANY	IR
7	BAIC	BAIC MOTOR CORPORATION LIMITED	CN
8	BMW	BAYERISCHE MOTOREN WERKE AG	DE
9	Brilliance Auto	BRILLIANCE AUTO GROUP HOLDINGS CO., LTD.	CN
10	Brilliance-Renault	RENAULT BRILLIANCE JINBEI AUTOMOTIVE CO., LTD.	CN
11	BYD	BYD AUTO INDUSTRY COMPANY LIMITED	CN
12	Caterham	CATERHAM CARS LTD.	GB
13	Changan	CHONGQING CHANGAN AUTOMOBILE COMPANY LIMITED	CN
14	CH-AUTO	CH AUTO TECHNOLOGY CORPORATION LTD.	CN
15	Chery	CHERY AUTOMOBILE CO., LTD.	CN
16	China First Tractor	YTO GROUP CORPORATION	CN
17	CNH Industrial	CNH INDUSTRIAL N.V.	IT
18	CNHTC	CHINA NATIONAL HEAVY DUTY TRUCK GROUP CO., LTD.	CN
19	CRRC	CRRC CORPORATION LIMITED	CN
20	Daimler	DAIMLER AG	DE
21	Dandong Huanghai	DANDONG HUANGHAI AUTOMOTIVE COMPANY LIMITED	CN
22	Dongfeng	DONGFENG MOTOR GROUP COMPANY LIMITED	CN
23	Dorcen	DORCEN AUTOMOBILE GROUP CO., LTD.	CN
24	Eicher Motor	EICHER MOTORS LIMITED	IN
25	Eurocar	EUROCAR IPRIVATE JSC AT	UA
26	FAW-Toyota	CHINA FAW GROUP CORPORATION	CN
27	FCA	STELLANTIS N.V.	IT
28	Ferrari	FERRARI N.V.	IT
29	Force Motors	FORCE MOTORS LIMITED	IN
30	Ford	FORD MOTOR CO	US
31	GAC	GAC MOTOR CO., LTD.	CN
32	GAC-Honda	GAC HONDA AUTOMOBILE CO., LTD.	CN
33	GAMC	GUANGZHOU AUTOMOBILE GROUP CO.,LTD.	CN
34	GAZ	GAZ JSC	RU
35	Geely	GEELY AUTOMOBILE HOLDINGS LIMITED	CN
36	General Motors	GENERAL MOTORS COMPANY	US
37	Ghabbour Auto	G.B. AUTO S.A.E.	EG

Table 8: List of vehicle producers (VP)

n.	IHS Markit company name	Orbis company name	country
38	Ghandara Nissan	GHANDHARA NISSAN LIMITED	PK
39	Great Wall	GREAT WALL MOTOR COMPANY LIMITED	CN
40	Honda	HONDA MOTOR CO., LTD.	JP
41	Hozon EV	HOZON NEW ENERGY AUTOMOBILE CO., LTD.	CN
42	Ineos	INEOS AUTOMOTIVE SAS	FR
43	Isuzu	ISUZU MOTORS LIMITED	JP
44	Jianghuai	ANHUI JIANGHUAI AUTOMOBILE GROUP CORP.,LTD.	CN
45	Jiangling	JIANGLING MOTORS CORPORATION LIMITED	CN
46	Jiangnan	HUNAN JIANGNAN AUTOMOBILE MANUFACTURE CO., LTD.	CN
47	King Long	XIAMEN KING LONG MOTOR GROUP CO.,LTD.	CN
48	Lifan	LIFAN TECHNOLOGY (GROUP) CO.,LTD.	CN
49	Magna-Steyr	MAGNA STEYR FAHRZEUGTECHNIK AG & CO KG	AT
50	Mahindra & Mahindra	MAHINDRA & MAHINDRA LIMITED	IN
51	Mazda	MAZDA MOTOR CORPORATION	JP
52	McLaren	MCLAREN AUTOMOTIVE LIMITED	GB
53	Naza	NAZA AUTOMOTIVE MANUFACTURING SDN BHD	MY
54	Piaggio	PIAGGIO & C. S.P.A.	IT
55	Pininfarina	PININFARINA SPA	IT
56	PSA	PSA AUTOMOBILES SA	FR
57	Qingling Motors	QINGLING MOTORS COMPANY LIMITED	CN
58	Qoros	QOROS AUTOMOTIVE CO., LTD.	CN
59	Renault-Nissan-Mitsubishi	RENAULT/NISSAN MOTOR CO., LTD./MITSUBISHI MOTORS CORPORATION	JP
60	SAIC	SAIC MOTOR CORPORATION LIMITED	CN
61	SAIC-General Motors-Wuling	SAIC GM WULING AUTOMOBILE COMPANY LIMITED	CN
62	SAIPA	SAIPA AUTOMOTIVE MANUFACTURING GROUP PUBLIC JOINT STOCK COMPANY	IR
63	Salvador Caetano	TOYOTA CAETANO PORTUGAL S.A.	PT
64	Shandong Wuzheng	SHANDONG WUZHENG GROUP CO., LTD.	CN
65	Shanxi Victory	SHANXI VICTORY AUTOMOBILE MANUFACTURING CO., LTD.	CN
66	Sichuan Yema	SICHUAN YEMA AUTOMOBILE CO., LTD.	CN
67	Soueast	SOUTH EAST (FUJIAN) MOTOR CORP., LTD.	CN
68	Subaru	SUBARU CORPORATION	JP
69	Suda	SANMENXIA SUDA TRANSPORTATION ENERGY SAVING TECHNOLOGY CO.,LTD.	CN
70	Sunlong Bus	SHANGHAI SHENLONG BUS CO., LTD.	CN
71	Suzuki	SUZUKI MOTOR CORPORATION	JP
72	Tata	TATA MOTORS LIMITED	IN
73	Tesla	TESLA, INC.	US
74	Toyota	TOYOTA MOTOR CORPORATION	JP

Table 8: List of vehicle producers (VP)

n.	IHS Markit company name	Orbis company name	country
75	Valmet	VALMET AUTOMOTIVE OY	FI
76	VinFast	VINFAST TRADING AND PRODUCTION LIMITED LIABILITY COMPANY	VN
77	Volkswagen	VOLKSWAGEN AG	DE
78	Volvo	AB VOLVO	SE
79	Wanxiang Auto	WANXIANG QIANCHAO CO.,LTD.	CN
80	Weichai Power	WEICHAI POWER CO., LTD.	CN
81	WM Motor	WM MOTOR MANUFACTURING WENZHOU CO., LTD.	CN
82	Yudo Auto	YUDO AUTO CO., LTD.	CN
83	Zhengzhou Yutong	ZHENGZHOU YUTONG GROUP CO., LTD.	CN
84	Zhongxing	HEBEI ZHONGXING AUTOMOBILE CO., LTD.	CN
85	Zotye	ZOTYE AUTOMOBILE CO.,LTD.	CN