Journal of Economic Geography, 2026, 1–31
https://doi.org/10.1093/jeg/lbag042
Original Article

OXFORD

Intellectual property rights and the efficiency of international production networks: evidence from the automotive industry

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Abstract

This study 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 efficiency of vehicle producers and IPR protection in their suppliers' locations. Notably, IPR do not have the same impact on ownership networks as knowledge is internalized within the boundaries of the firm. We confirm that the results are not driven by other firm- or country-level characteristics, and address potential endogeneity concerns by employing a novel gravity-based IV approach using geographical distance and language proximity.

Keywords: **international production networks; intellectual property rights; ownership; internalization; automotive industry; knowledge dissipation; firm efficiency.**

JEL classifications: **F21, F23, L14, L25, L62, O34, G32.**

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). Networks can also act as systems for the transmission of information among connected traders (Chaney 2014). The flow of knowledge, however, faces frictions in international trade networks, which could in turn translate into

Received: 4 December 2023. **Accepted:** 17 May 2026

systemic risk (Allen 2014). The quality of intellectual property protection helps secure this flow, thereby enhancing returns to intangible assets in global value chains (Alsamawi et al. 2020).[1] A crucial factor that influences the efficient functioning of production networks is therefore the quality of institutions at the location of potential trading partners.[2]

In this study, we investigate the empirical relationship between the efficiency of an international production network and intellectual property rights (IPR) protection at the location of its nodes, using unique disaggregated data on buyer–supplier relationships in the automotive industry obtained from IHS Markit.[3] We provide evidence that the protection of IPR at the location of auto part suppliers, measured using the International Property Rights Index (IPRI), has a positive and significant effect on a vehicle producer (VP)'s efficient use of assets, measured by its sales-to-assets ratio (or asset turnover ratio). We argue that better IPR protection ensures a secure flow of information along the production network, mitigating instances of opportunistic behavior by suppliers or involuntary knowledge dissipation outside the network. The results indicate that if a country's IPRI increases by one point (on a 0 – 10 scale), then a VP procuring 10 per cent of its inputs from suppliers in that country experiences an increase in its sales-to-assets ratio by approximately eight percentage points.[4]

The observed higher efficiency among VPs sourcing from countries with strong IPR institutions may reflect reverse causality, as production networks can be endogenous to firms' location and organizational choices. For example, more efficient car producers may self-select into countries with more effective legal systems, rather than those institutions driving the higher efficiency. We address network endogeneity by constructing a geographical gravity instrument that weights IPR levels by each country's inverse distance from the VP's home (headquarter) country, rather than by the VP's actual supplier distribution. According to the standard role of gravity in trade and transport costs, trade with geographically close firms is likely to be prevalent in supplier networks, reducing the influence of institutions in distant countries (Chaney 2018). We further validate our findings using two additional instruments: one weights IPR protection by the inverse squared distance from the VP, also capturing the decay of knowledge diffusion with distance, and the other by linguistic proximity to the VP. In all cases, we also control for IPR protection in the locations of VPs' customers (sales), to ensure that the impact of IPR on efficiency operates through VP-supplier relationships and is not driven by higher demand for products in nearby or common language markets.

To account for multiple types of network connections in the automotive global supply chain, we complement data on suppliers with information on firm ownership linkages from Orbis Bureau van Dijk. We find that stronger IPR in the locations of subsidiaries owned by car manufacturers do not play a role in determining network efficiency, since the knowledge kept within firm boundaries is less exposed to the risk of dissipation. This is in line with the knowledge-capital model of the multinational enterprise, which suggests that potential inefficiencies arising from knowledge dissipation can be internalized within ownership networks as an alternative mechanism to protect innovation.[5]

To test our conceptual framework, which posits that the prevention of knowledge dissipation is the main driver of the results, we break down the aggregate IPRI into intellectual and physical property rights (*PPR*) protection, and show that what matters for efficiency is intellectual property protection. We

1. Also, a recent wave of 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. 2024; Santacreu 2025).
2. Lai et al. (2020) demonstrate how even within a country, namely China, heterogeneous provincial-level intellectual property enforcement impacts firm productivity.
3. The automotive industry is particularly interesting in terms of international property rights protection, as centrally designed vehicles are manufactured globally in multiple plants, leading buyer–supplier relationships to stretch across different production regions (Sturgeon et al. 2008).
4. As an example, if the IPRI of Spain increases to the level of France (a one-point increase, approximately), then the sales-to-assets ratio of the vehicle producer PSA, which has around 10 per cent of suppliers in Spain (the highest share of Spain, compared to all other VPs) should increase by eight percentage points.
5. Due to knowledge capital, firms favor control of foreign operations to prevent the dissipation of proprietary knowledge to competitors (Markusen 2002).

next show, in line with the transaction cost theory (Klein et al. 1978; Williamson 1979, 1985), that internalizing knowledge within the boundaries of the firm is beneficial for efficiency under weak IPR regimes. In particular, lower IPR protection increases the benefits of ownership when a substantial portion of a firm's subsidiaries is located in weak-IPR countries, whereas better IPR protection in the locations of its unaffiliated suppliers always enhances efficiency. We conduct a variety of robustness checks, which confirm the relationship between efficiency of production networks and IPR protection in suppliers' locations.

The rest of the study is organized as follows. Section 2 places our contribution within the state-of-the-art literature. Section 3 provides a simple conceptual framework to describe our main argument. Section 4 introduces our data on IPRI and the location of suppliers and subsidiaries, as well as the sources of our firm-level and country-level information. Section 5 sketches the empirical framework and methodology. Section 6 reports our empirical results and the corresponding discussion. Section 7 concludes. In the Appendix, we provide further robustness checks, tables, and figures.

2. Related literature

While the literature has established that stronger IPR accelerate international technology transfer between firms (Branstetter et al. 2006), there has been surprisingly little empirical research on the effect of IPR protection on the performance of international networks of production. Atalay et al. (2014) show clear evidence on the importance of the transfer of intangible rather than tangible inputs along the production chain and argue that this flow primarily consists of knowledge inputs (see also Altomonte et al. 2026). Lack of adequate IPR protection can reduce efficiency as losses from the dissipation of intellectual assets at any node can propagate across the entire network. In our study, firms may suffer from the misappropriation of their intellectual property somewhere along the network and this can have a detrimental effect on the performance of the headquarters and the entire network. We argue that efficient 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.

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 assets play a key role through ownership of their foreign affiliates.[6] 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.

This links our work also to Atalay et al. (2014) 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. This can be interpreted as IPR being more pivotal with non-integrated affiliates, and less so when knowledge dissipation risks are internalized.[7]

6. 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.
7. On a similar note, Kukharskyy (2020) reveals that knowledge intensity in firms increases the relative attractiveness of ownership to reduce the threat of dissipation, but less so when IPR are strong in the affiliate country.

3. Conceptual framework

Consider a VP i procuring auto parts from suppliers located in M countries. We denote the quality of IPR institutions in supplier country j by IPR_j, where a lower IPR_j implies higher transaction costs due to the increased risk of imitation. The proportion of VP i's network activities that take place in country j is denoted by $w_{i,j} \in [0,1]$, with $\sum_{j=1}^{M} w_{i,j} = 1$. The efficiency of VP i, denoted with y_i, is a function of the aggregate IPR quality that the firm faces across its international network, weighted by the contribution of each location to production. Measuring the contribution in terms of supplied inputs, the degree of IPR protection specifically faced by VP i can be written as $IPR_i^{(S)} = \sum_{j=1}^{M} w_{i,j}^{(S)} IPR_j$, where superscript S is used to indicate a network of suppliers. Our conjecture is that weaker IPR protection in the location of its suppliers exposes VP i to the risk of imitation, reducing its innovative edge and consequently its market share in the final goods market. We therefore expect to observe a positive relationship between IPR and efficiency, such that $\frac{\partial y_i^{(S)}}{\partial IPR_i^{(S)}} > 0$.

The framework allows us to examine the impact of IPR on efficiency as a test of the transaction cost theory in light of Klein et al. (1978) and Williamson (1979, 1985). Firms with international networks of suppliers face transaction costs that stem from the risk of opportunism and knowledge appropriation when parts of the network are located in environments with weak institutions. Such inefficiencies can be eliminated by integrating suppliers within firm boundaries. The ownership decision of firms is introduced in the knowledge dissipation model of Ethier and Markusen (1996) as a choice on the mode of serving a foreign market when knowledge-based capital is involved. The model predicts more integration as a secure means of transfer in countries with inferior IPR, to reduce the threat of knowledge dissipation.[8] Although we do not study the integration decision of firms, by observing networks of both unrelated and affiliated parties we can check that ownership may act as an alternative protection mechanism to improve efficiency in weak-IPR countries. In our context, the transaction cost theory would predict IPR to be less relevant for the efficiency of ownership networks, as IPR is already protected when the nodes of a production network are integrated, that is, $\frac{\partial y_i^{(O)}}{\partial IPR_i^{(O)}} \approx 0$, where $IPR_i^{(O)} = \sum_{j=1}^{M} w_{i,j}^{(O)} IPR_j$ with superscript O indicating an ownership network, that is, a network of subsidiaries.[9]

4. Data

For our empirical analysis, we use unique data on buyer–supplier relationships between VPs and their suppliers provided by IHS Markit for over eighty car components. According to IHS, the entire dataset covers 97 per cent of the market in the automotive industry. The information includes the identity of the car manufacturer and that of its suppliers, as well as their location. In addition, for each relationship, the dataset provides information on the volume of car components supplied and the volume of vehicles produced using those components. The VPs from the IHS database have been matched to Bureau van Dijk's Orbis data to obtain data on firms' performance.

As an indicator of efficiency (y), we use the sales-to-assets ratio ($sales/assets$) or asset turnover, one of the most widely used indices of efficiency in corporate finance (see, e.g. Brealey et al. 2020) and particularly related to property rights protection. For robustness, we also use the (log) operating revenues per employee ($OpRev/empl$) as an alternative indicator of efficiency; all empirical results based on this

8. See also Barba Navaretti and Venables (2004), Ivus et al. (2017), Kukharskyy (2020).
9. Looking at networks predominantly located in weak-IPR countries, we can even show how ownership is a suitable strategy when facing weaker IPR enforcement as it is associated with higher levels of efficiency, i.e., $\frac{\partial y_i^{(O)}}{\partial IPR_i^{(O)}} < 0$.

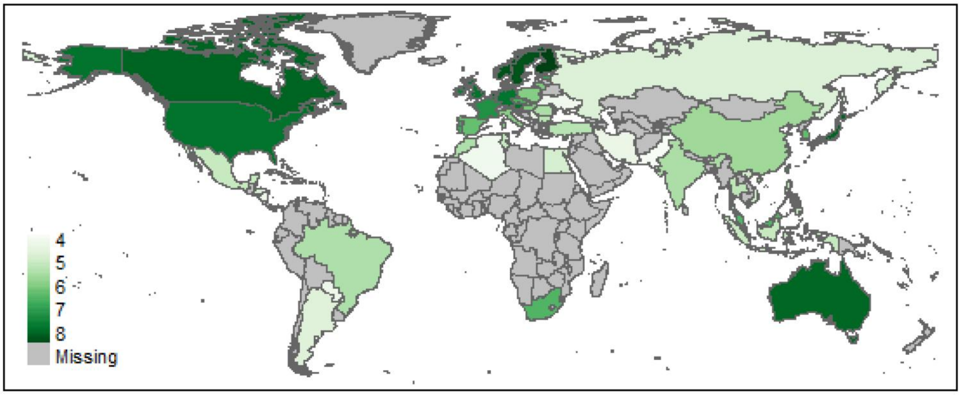

Figure 1. International Property Rights Index (IPRI), average 2012–2020.

Notes: The figure shows the value of the IPRI 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).

indicator are reported in Appendix 1. We consider sales, revenues and employees at the global level, not just in the VP's headquarter country. Overall, our dataset contains annual data on seventy-seven VPs and fifty-six countries over the period 2012–2020. The panel is unbalanced.[10]

We consider different measures of property rights protection. We mainly focus on the aggregate *IPRI* published by the Property Rights Alliance. To provide additional results, we also make use of subindices specifically related to *IPR* and *PPR*. All indices are expressed on a 0–10 scale. The IPRI comes out annually and is a combination of three indices: Legal and political environment (LP), PPR, and IPR. LP provides information on the strength of a country's institutions, taking into account judicial independence, rule of law, political stability, and control of corruption. PPR consists of three elements: protection of PPR, registering property, and ease of access to loans. Finally, IPR measures the protection of IPR (Global Competitiveness 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 Global Software Survey: https://www.bsa.org).[11]

Figure 1 illustrates the average IPRI levels for the countries in our sample over the period 2012–2020, while Table 1 provides the list of countries and their corresponding index values. All countries are comprised in a range of IPRI from 3.9 to 8.6, approximately. The countries with the strongest protection of property rights over this period include Northern European countries, Singapore, Japan, Canada, and Australia, while the lowest average values are observed in Pakistan, Moldova, Ukraine and Algeria.

Figure 2 depicts the time profile of the IPRI index during this period for eight major countries in the sample, as well as the average faced by four selected large firms in their respective suppliers' networks. Most countries have experienced either a mild increase or roughly constant values of IPRI over this period. Among all countries in the sample, Japan is the one characterized by the largest absolute increase (0.66 units, cumulatively), followed by Morocco (0.63) and Czech Republic (0.61), while the largest decreases have been observed in Tunisia (–0.51), South Africa (–0.49), and Poland (–0.43). As an example, the rise in Czech Republic's IPRI index is partly associated with improvements in trademark protection following a major amendment to its Trademark Act in 2019. The deterioration of the IPRI index in

10. The VPs included in the sample are those for which we have data jointly on supplier networks, ownership networks, and the balance-sheet indicators used in the analysis.
11. See Levy-Carciente (2020) for the detailed methodology on the calculation of the indices.

Table 1. List of countries and average IPRI, 2012-2020.

Country	IPRI	Country	IPRI	Country	IPRI
Algeria	4.12	Ireland	7.59	Romania	5.50
Argentina	4.61	Italy	5.97	Russia	4.65
Australia	8.05	Japan	8.06	Serbia	4.36
Austria	7.87	Lithuania	6.14	Singapore	8.26
Belgium	7.58	Luxembourg	8.27	Slovakia	6.23
Brazil	5.45	Macedonia	4.83	Slovenia	5.88
Bulgaria	5.29	Mainland China	5.67	South Africa	6.56
Canada	8.08	Malaysia	6.59	South Korea	6.41
Czech Republic	6.68	Mexico	5.10	Spain	6.32
Egypt	4.81	Moldova	3.90	Sweden	8.31
Estonia	6.94	Morocco	5.45	Taiwan	7.14
Finland	8.57	Netherlands	8.17	Thailand	5.20
France	7.29	Nicaragua	4.21	Tunisia	5.07
Germany	7.78	Norway	8.32	Turkey	5.30
Honduras	4.72	Pakistan	3.89	Ukraine	4.11
Hungary	6.09	Paraguay	4.26	United Kingdom	7.86
India	5.50	Philippines	5.15	United States	7.84
Indonesia	5.10	Poland	6.03	Vietnam	4.84
Iran	4.35	Portugal	6.81		

Notes: For each country, the table reports the average value of the International Property Rights Index (IPRI), over the period 2012–2020. The index is expressed on a 0–10 scale. Luxembourg is only available from 2018. The data source is the Property Rights Alliance (www.propertyrightsalliance.org).

Poland is a consequence of experiencing the steepest decline in judicial independence of any country in the world since 2017.

To measure supplier-based network linkages, we use the IHS Markit data. We quantify the total volume of inputs supplied to each VP by each country. We do not have information on the dollar amounts of transactions between VPs and their suppliers. However, for each buyer-supplier relationship, IHS Markit provides information on the number of vehicles that are manufactured by the buyer using the inputs purchased from the supplier. We can use this number to aggregate the volume of inputs supplied by different suppliers, to calculate the total volume of inputs supplied by each country and assign weights to countries in each VP's network. A simple practical example may be useful to explain how country weights are computed. Suppose that the VP X has only two suppliers, A and B, which are located in country 1 and 2, respectively. The inputs supplied by A are used to produce 100 vehicles, while the inputs supplied by B are used to produce 200 vehicles. Then, the weight assigned to country 1 in the supplier network of X will be $100/(100+200)=1/3$ and the weight of country 2 will be $200/(100+200)=2/3$. We will provide a more formal discussion of network weights in Section 5. Figure 3 displays the global maps of suppliers of Volkswagen and Toyota, as examples. We can see how the global network strategy is heterogeneous among firms, as the distribution and concentration of suppliers across countries vary 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. However, data on total assets or equity are available for just a fraction of subsidiaries of VPs. We therefore choose to calculate the weight of a country within the ownership-based network of a VP using the number of firms the VP owns in that country. To construct these weights, we consider two approaches: (1) including only firms in which a VP owns more than 50 per cent of the shares, (2) 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. Also, it takes into account the

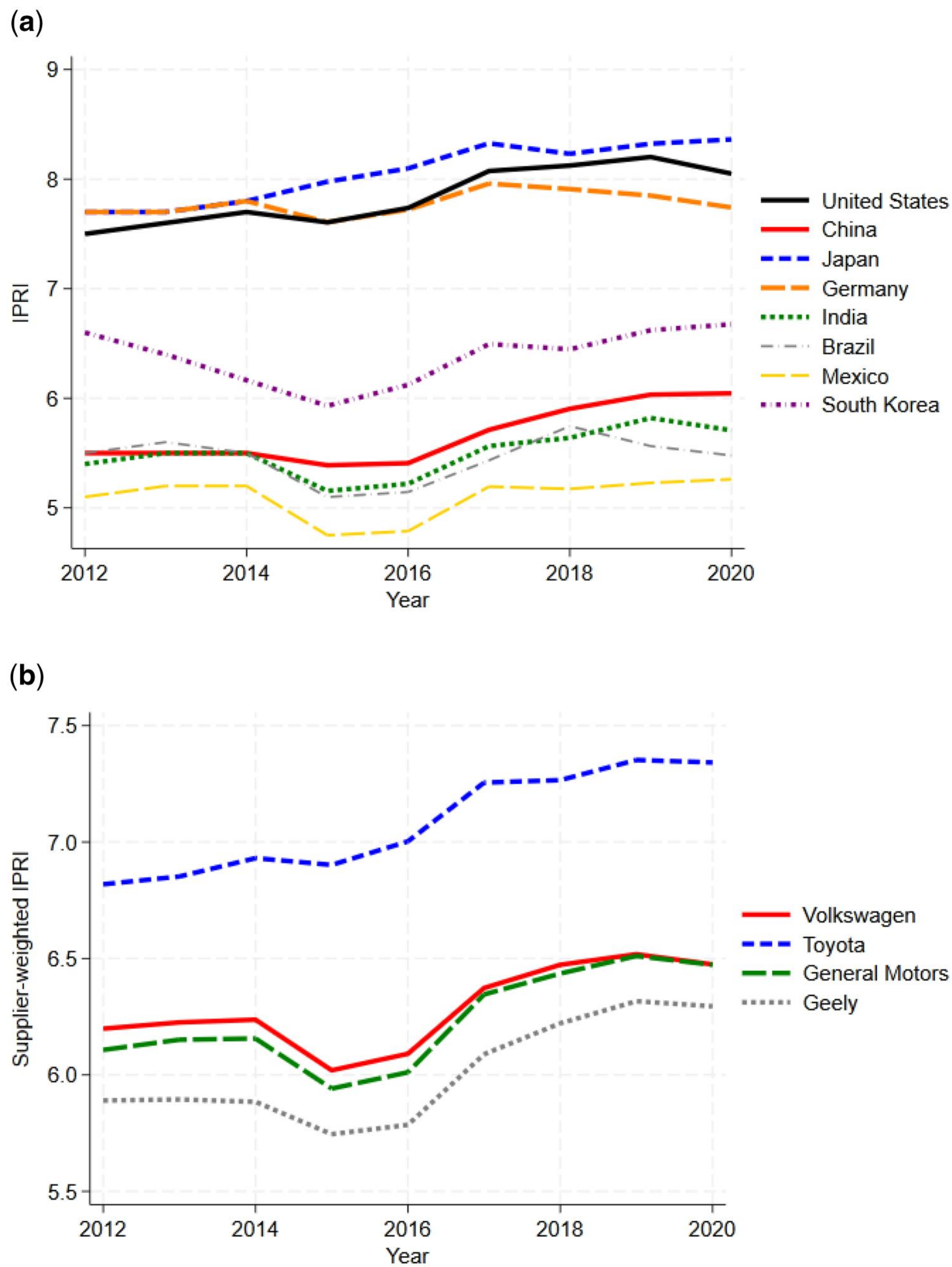

Figure 2. IPRI over time. (a) IPRI levels by country. (b) Supplier-weighted IPRI by vehicle producer.

Notes: The figure displays the time series of the IPRI index for selected countries and supplier-weighted IPRI levels for selected VPs. The data sources are the Property Rights Alliance (www.propertyrightsalliance.org) and IHS Markit.

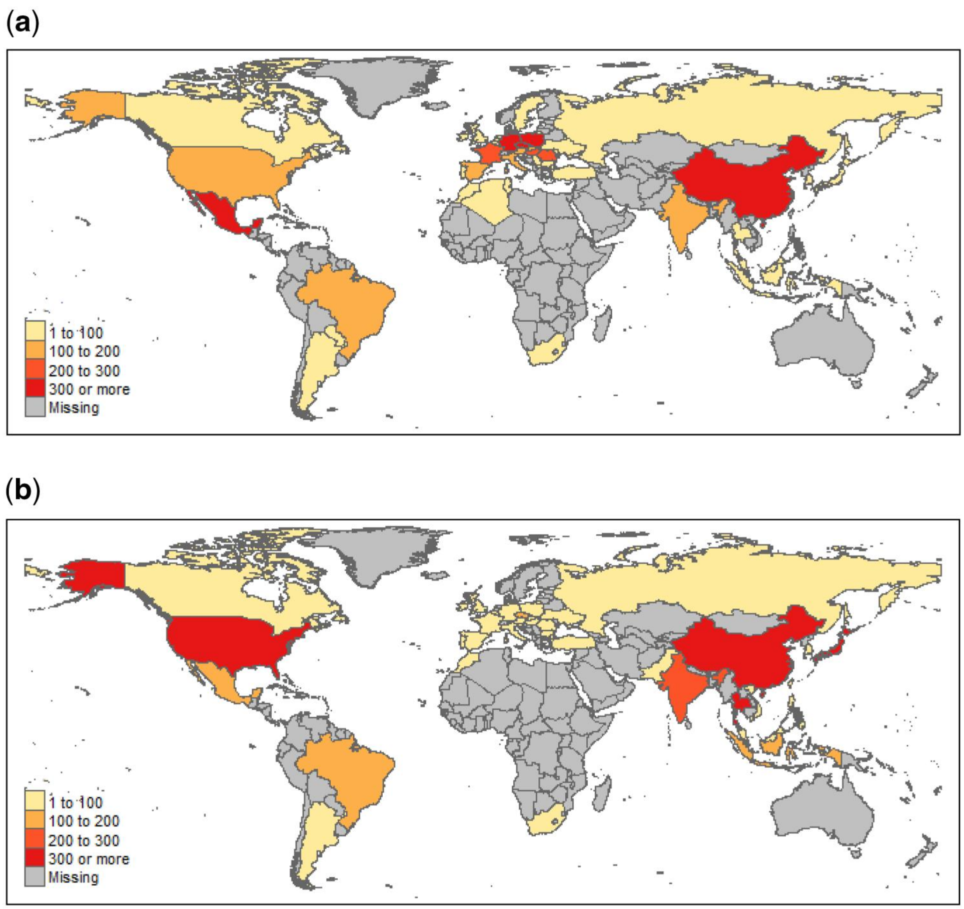

Figure 3. Supplier networks: Volkswagen versus Toyota. (a) Suppliers of Volkswagen. (b) Suppliers of Toyota.
Notes: The figure compares the geographical distribution of suppliers of Volkswagen (a) and Toyota (b) in 2019. The data source is IHS Markit.

fact that corporate control of large firms (especially so-called public companies, in which ownership is widely dispersed) is typically granted by a much smaller share than 50 per cent.

Throughout the analysis, we also control for the geographical distribution of vehicle sales (or consumer network), to ensure that our results are not driven by demand fluctuations that may correlate with variations in IPR levels. Data on VPs' light vehicle sales in all countries has been provided by IHS Markit. Our econometric approach exploits this feature to determine whether variations in efficiency stem from knowledge flows or market-driven factors. Buyer–supplier relationship data are available for 2019–2020, light vehicle sales data for 2019, and a snapshot of ownership information as of December 2020. Earlier periods are constructed by extrapolating network weights, assuming limited variation over short horizons. Figure 4 displays the global maps of suppliers, subsidiaries, and sales (in terms of number of vehicles) of Volkswagen, in panels (a–c), respectively. We can deduce from the figure that a large car producer's suppliers, subsidiaries, and sales are distributed differently across regions.

Table A.5 in Appendix 4 reports summary statistics on efficiency indicators and other balance-sheet variables used in the empirical analysis, as well as network-weighted IPRI levels faced by VPs and other information on supplier and ownership networks. The complete list of VPs and the respective home

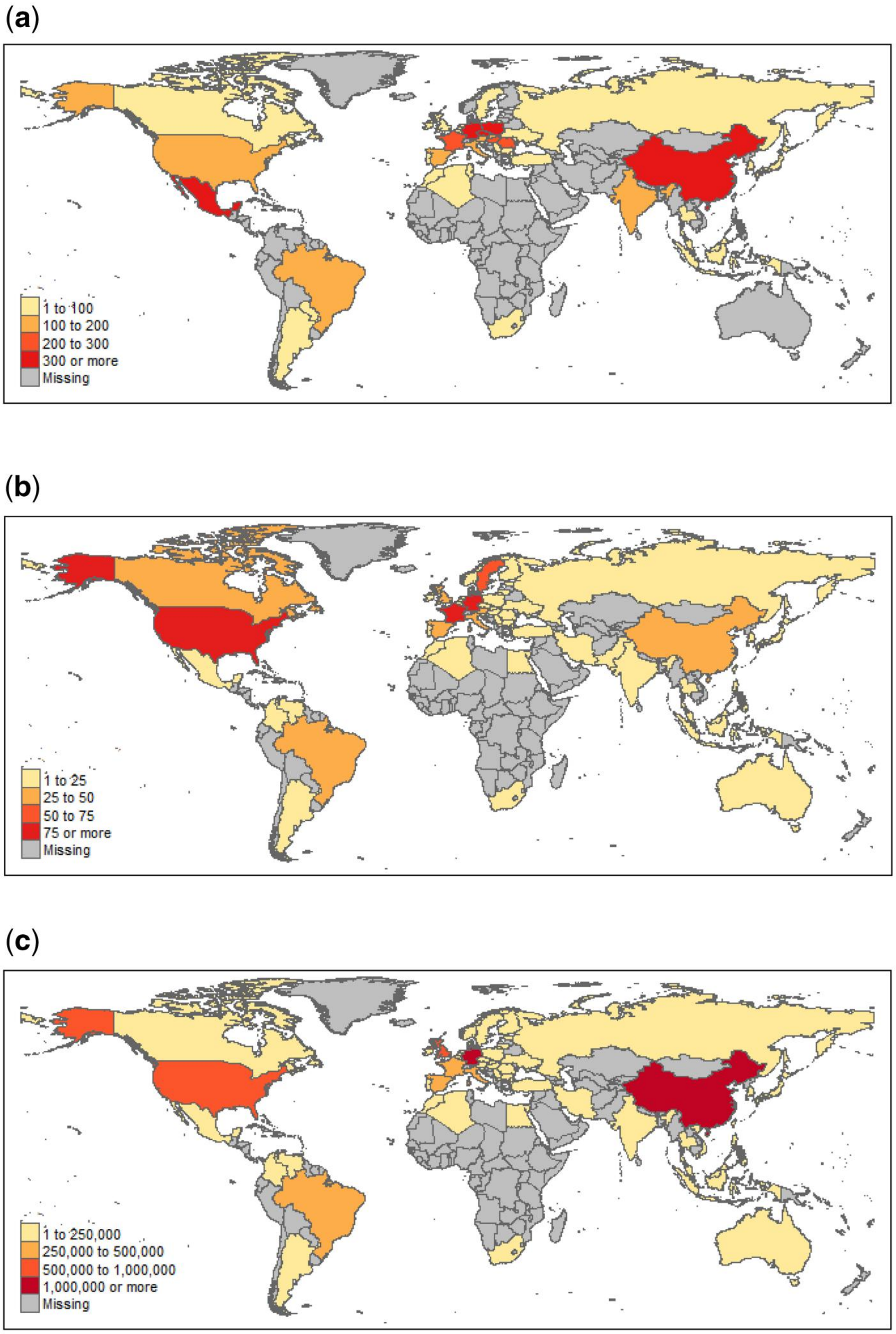

Figure 4. Networks of Volkswagen. (a) Suppliers. (b) Subsidiaries. (c) Sales.

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

countries are reported in Table A.10. All other firm-level data are provided by Orbis, except for the initial stock of patents used in Appendix 2, which has been retrieved from the European Patent Office's PATSTAT global database. Like the efficiency indicators, all other balance-sheet data used in the analysis are also global (consolidated) and do not refer solely to the VP's home country. As for country-level indicators, data on nominal GDP per capita (current dollars) and stock market capitalization are from the IMF and the World Bank, respectively. Data on geographical distances are from the CEPII GeoDist database (Mayer and Zignago 2011), while language proximity data come from Melitz and Toubal (2014).

5. Empirical framework

We consider an empirical framework in which N VPs have economic linkages with M countries. For the moment, let us abstract from the time dimension and define $y = (y_1, y_2, \dots, y_N)'$, where y_i represents an efficiency indicator for VP i ($i = 1, 2, \dots, N$), and $IPRI = (IPRI_1, IPRI_2, \dots, IPRI_M)'$, where $IPRI_j$ denotes the level of property rights protection in country j ($j = 1, 2, \dots, M$). We consider two measures of "connectedness" between VP i and country j. The first reflects the international buyer-supplier network and is expressed by the following $N \times M$ matrix of weights $W^{(S)}$:

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

where the (i,j)-th element $w_{i,j}^{(S)}$ denotes the share of VP i's inputs that are supplied by firms located in country j. Each row of $W^{(S)}$ sums to one. In particular, we calculate $w_{i,j}^{(S)}$ as $w_{i,j}^{(S)} = inputs_{i,j} / \sum_{h=1}^{M} inputs_{i,h}$, where the generic term $inputs_{i,h}$ denotes the volume of inputs supplied by country h to VP i. As explained in Section 4, we quantify the volume of inputs using the number of vehicles produced with the supplied components. The second measure reflects the ownership network, which is expressed by a different weight matrix $W^{(O)}$:

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

where the (i,j)-th element $w_{i,j}^{(O)}$ represents the fraction of VP i's subsidiaries that are located in country j, that is, $w_{i,j}^{(O)} = nsub_{i,j} / \sum_{h=1}^{M} nsub_{i,h}$ with $nsub_{i,h}$ denoting the number of VP i's subsidiaries located in country h. Again, each row of $W^{(O)}$ sums to one. Then, let us define

$$IPRI^{(S)} = W^{(S)} IPRI. \tag{3}$$

Hence, $IPRI^{(S)}$ is a vector of length N whose i-th element represents the average level of the IPRI index faced by VP i in its international network of suppliers. Analogously, let us define

$$IPRI^{(O)} = W^{(O)} IPRI, \tag{4}$$

which indicates a vector whose *i*-th element represents the average level of property rights protection faced by VP *i* in its ownership network.

Introducing now the time dimension, we obtain the following panel model:

$$y_{i,t} = c + \beta_1 IPRI^{(S)}_{i,t-1} + \beta_2 IPRI^{(O)}_{i,t-1} + \gamma' x_{i,t-1} + \varepsilon_{i,t}, \tag{5}$$

where $IPRI^{(S)}_{i,t}$ is the *i*-th element of vector $IPRI^{(S)}$ at time *t*, that is, the supplier-weighted IPRI index for VP *i*, $IPRI^{(O)}_{i,t}$ is the *i*-th element of vector $IPRI^{(O)}$, that is, the ownership-weighted IPRI index for VP *i*, $x_{i,t}$ is a column vector of control variables for VP *i* with corresponding parameter vector γ, *c* is a constant term, and $\varepsilon_{i,t}$ is an error term. We use lagged regressors for two reasons. First, changes in IPR are likely to affect VPs' performance with some delay, given the timespan of a car production process. Second, and more generally, using lagged regressors mitigates endogeneity concerns. The literature suggests that changes in IPR may impact VP performance after 1–2 years.[12] We consider a 1-year lag of the IPRI index, but also report results using a 2-year lag, confirming the main conclusions.

We also use information on each VP's geographical distribution of vehicle sales. In particular, we calculate the average IPRI index at customer locations and use this variable as a control to ensure that our main results are not driven by VP–consumer rather than VP–supplier relationships. Such a sales-weighted (or customer-weighted) IPRI measure, denoted as $IPRI^{(C)}$, is constructed analogously to the other network-weighted IPRI variables, $IPRI^{(S)}$ and $IPRI^{(O)}$, with country weights for each VP based on the number of light vehicles sold in each country.[13]

For each 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*), possibly accounting for economies of scale. 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 the composition of the liability side, or capital structure, by including the level of financial leverage, calculated as the ratio of debt (non-current liabilities plus loans) to equity (*leverage*). 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, based on the supplier network observed in 2019.[14]

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 network-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 per

12. Branch (1974) finds that granted patents typically influence sales growth after a year, while Gerken et al. (2015) show a 1-year lag between patent publication and market launch in the automotive industry. Alsamawi et al. (2020) instead consider a two-year lag between IPR and returns on intangibles.
13. Table A.7 of Appendix 4 exhibits the correlation between the IPRI measures built based on VPs' supplier, ownership, and consumer networks.
14. 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).

capita levels and market capitalization ratios to take account of the quality of institutions in the host countries of suppliers.

6. Results

In this section, we present the results of our empirical analysis. As explained in Section 4, data on buyer-supplier relationships is only available from 2019. Based on information supplied by the data provider (IHS Markit), it is safe to posit that network structures in this industry are practically constant over 2–3 consecutive years, due to the longer duration of contracts, spanning from the start to the end of vehicle production.[15] For this reason, we produce our baseline results considering a 3-year period centered around the year when our network data were observed (2019), hence our primary sample is 2018–2020. In Appendix 3, we show that the main results still hold when we restrict the sample to 2018–2019, excluding 2020.

In Section 6.4, we will present additional results using a longer time span starting in 2012. Since we can only use imputed data on production networks for all the years prior to 2019, we will make the assumption that network weights are constant throughout the period and equal to their observed 2019 values. While we recognize that this assumption is clearly stronger over the longer time span—and for this reason we do not use it as our baseline—it is an approximation which allows us to perform valuable robustness checks that cannot be performed on the short baseline sample. All regressions throughout the study include year dummies (time fixed effects) to account for time-varying macro factors affecting the industry, and use clustered standard errors (robust to both heteroskedasticity and within-firm autocorrelation).

6.1 Baseline results

Table 2 reports our first results on the impact of IPRI on the VP's efficiency, y, measured by its sales-to-assets ratio. In Appendix 1, we also consider our alternative efficiency proxy—log operating revenues per employee—as the dependent variable.[16] We start by considering a basic OLS regression in which efficiency depends on supplier-weighted IPRI and ownership-weighted IPRI. This is reported in column (1) of Table 2, which only controls for key firm-level characteristics included as basic explanatory variables in all our regressions: the VP's size (total assets), asset composition (intangible assets intensity), and capital structure (financial leverage). We find that the coefficient on supplier-weighted IPRI, or $IPRI^{(S)}$, is around 0.37 and strongly significant, while the coefficient on ownership-weighted IPRI, or $IPRI^{(O)}$, is negative and not significant. All else being equal, this implies that a one-point increase in the average IPRI at the locations of suppliers in a production network is associated with an increase of 37 percentage points in the sales-to-assets ratio, approximately.

In column (2), we introduce controls for the VP's home country. First, we note that supplier-weighted average IPRI may capture the effect of domestic property rights protection in the VP's home country, especially if a VP mostly trades with countries of similar development levels. Thus, we include the IPRI for the country where the VP's headquarters are located (*IPRI*). Second, we control for (log) nominal GDP per

15. Our data reveal that network weights were broadly unchanged in 2020 compared to 2019. In particular, for seventy VPs out of seventy-seven included in the analysis, the correlation between the vector of country weights $w_{i,j}^{(S)}$ in 2019 and the corresponding vector in 2020 is above 0.99, and only one VP shows a correlation below 0.90. The few changes observed from the data do not appear in contrast with our narrative, as they mainly consist of a shift from countries experiencing a reduction in their IPRI index towards China, where the index has been steadily rising since 2016, see Fig. 2. The main changes in network weights are reported in Appendix 4, Table A.6.

16. In the dataset, some firms show abnormally high values of operating revenues in some years, probably due to measurement errors (in particular, the Chinese VPs CNHTC and Zhengzhou Yutong). To avoid concerns related to outliers, we exclude from regressions observations that lie more than 2 standard deviations away from the mean of log operating revenues per employee over the period 2012–2020.

Table 2. Baseline results with firm, country, and network controls.

Dependent:	Sales/assets		
	(1)	(2)	(3)
$IPRI^{(S)}$	0.368***	0.350***	0.527***
	(0.103)	(0.130)	(0.141)
$IPRI^{(O)}$	−0.109	−0.153	−0.106
	(0.104)	(0.312)	(0.096)
tot_assets	0.001	0.002	0.006
	(0.030)	(0.038)	(0.030)
intangible	−0.801***	−1.277**	−1.023***
	(0.281)	(0.532)	(0.364)
leverage	−0.031	−0.046	−0.040
	(0.028)	(0.032)	(0.026)
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
Obs.	172	145	172
N	67	59	67
Adj. R^2	0.172	0.183	0.202

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: ***.01, **.05, *.10.

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.

In column (3), we control for supplier-country characteristics faced by each VP as an initial test to ensure that our results are driven by IPRI and not by other development-related covariates. Specifically, we check whether the effect we observed is directly related to property rights protection in suppliers' countries, rather than simply reflecting the level of economic and financial development in those countries. To this aim, we include the log of supplier-weighted average nominal GDP per capita ($gdp\_pc^{(S)}$) and the supplier-weighted market capitalization ratio ($mkt\_cap^{(S)}$).[17] We also consider the log average distance of each VP from its suppliers.[18] This captures geographical patterns of international trade and may be an important determinant of firm efficiency. Finally, time fixed effects allow us to control for any year-specific events affecting the auto industry, such as the COVID-19 outbreak. In Appendix 3, we provide additional results excluding the year 2020 from the sample (Table A.3). The estimates remain very similar, showing that the main results are not affected by COVID-19.

17. Note that these variables are firm specific, as they depend on firms' network structures.
18. To calculate average distance we use the same weights as for $IPRI^{(S)}$ (number of vehicles produced using purchased components).

Table 3. Baseline results with firm fixed effects, 2-year lag of IPRI, and consumer-network-weighted IPRI.

Dependent:	Sales/assets		
	(1)	**(2)**	**(3)**
$IPRI^{(S)}$	0.765**	0.583***	0.983**
	(0.372)	(0.191)	(0.435)
$IPRI^{(O)}$	−0.396	0.090	−0.461
	(0.273)	(0.158)	(0.304)
$IPRI^{(C)}$			−0.103
			(0.065)
Lag IPRI	1	2	1
Firm controls	x	x	x
Year FE	x	x	x
Firm FE	x	x	x
Obs.	172	172	162
N	67	67	63
R^2	0.375	0.401	0.396

Notes: The table reports fixed-effects estimates on annual data over the sample 2018–2020. Firm controls are: *tot_assets*, *intangible*, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported is the within R^2.

The significance levels are: ***.01, **.05, *.10.

In Table 3, we include firm fixed effects to control for any other firm-specific characteristics, like management practices, that can play a role in the selection of suppliers and affect the VP's performance. Column (1) adds firm fixed effects to the specification from column (1) of Table 2 and is referred to hereafter as our baseline specification. The coefficient on supplier-weighted IPRI remains significant. A coefficient of about 0.76 means that a one-point increase in the average IPRI level of suppliers' countries is associated with an increase in the sales-to-assets ratio of approximately 76 percentage points. To get a sense of the magnitude of this effect, note that a one-standard-deviation increase in supplier-weighted IPRI (corresponding to about 0.65 points, as can be seen in Appendix 4, Table A.5) would lead to an increase of about 49 percentage points in the sales-to-assets ratio, which is close to the standard deviation of approximately 0.45 from Appendix 4, Table A.5. As an example, consider China's IPRI, which has grown approximately from 5.5 to 6 over the period from 2012 to 2020 (see Fig. 2). Based on our baseline result, a VP that has all its suppliers in China should have experienced (all else being equal) an increase in its sales-to-assets ratio of $0.5 \cdot 0.76 = 0.38$, that is, 38 percentage points, which is less than one standard deviation of the ratio. Major VPs like Honda and General Motors, which both have a notably high share of suppliers in China (around 30 per cent of supplied components), should have experienced a positive effect of $0.3 \cdot 0.5 \cdot 0.76 = 11$ percentage points. The impact of ownership-weighted IPRI on efficiency continues to be insignificant, implying that potential transaction costs associated with weak property rights protection are internalized in networks already owned by the VP.

In column (2), we check the robustness of our results using a 2-year lag of IPRI, to account for the possibility that the effects of changes in property rights protection on efficiency may necessitate more than 1 year to materialize. In this case, the magnitude of the coefficient on IPRI is slightly reduced, but its statistical significance increases to the 1 per cent level. In column (3), we confirm our results by controlling for IPRI weighted by a VP's consumer network, that is, using sales in different countries to construct network weights. Doing so allows us to determine whether the observed effects can be ascribed to relationships with suppliers or with customers. The statistically insignificant coefficient for consumer networks suggests that common shocks, such as demand fluctuations, that correlate with changes in IPRI can be deemed less relevant than being protected in supplier locations.

All in all, the protection of property rights seems to be a relevant factor for efficiency when it applies to supplier networks, but not so much for ownership networks. These results suggest that higher property rights protection in countries where suppliers are located is associated with higher efficiency of VPs. Conversely, higher protection in the locations of affiliates or final goods markets does not appear to be significantly related to efficiency. In Fig. A.1 of Appendix 4, we provide a graphical representation of the baseline FE regression reported in column (1) of Table 3, using a scatterplot.

6.2 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 potential endogeneity of networks, we estimate instrumental variable (IV) regressions, using two-stage least squares (2SLS). In particular, we first note that our key variable of interest, the average IPRI index at the locations of suppliers, $IPRI^{(S)}$, 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 $IPRI^{(S)}$ using an alternative measure of property rights protection, calculated as a cross-country weighted average with exogenous weights determined by geographical distances between countries. For each VP, we compute an average IPRI level weighting each country by the inverse of its distance from the VP's headquarters, reflecting the fact that countries farther away typically host fewer suppliers and thus contribute less to overall IPR relevance. By using the gravity-weighted IPRI as an instrument in the first-stage regression for supplier-weighted $IPRI^{(S)}$, instead of including it as an explanatory variable in the second-stage regression, we rely on the exclusion restriction that property rights protection affects firms' performance only through their production networks, i.e., a country's IPR institutions do not affect VPs if they do not engage with suppliers there.

Denoting with $w_{i,j}^{(dist)} = 1/distance_{i,j}$ the distance-based weight of country j for VP i,[19] our instrument is calculated as:

$$IPRI_{i,t}^{(dist)} = \frac{1}{\sum_{j=1}^{M} w_{i,j}^{(dist)}} \sum_{j=1}^{M} w_{i,j}^{(dist)} IPRI_{j,t} \tag{6}$$

Our IV first-stage equation is:

$$IPRI_{i,t}^{(S)} = \tilde{c} + \tilde{\beta}_i IPRI_{i,t}^{(dist)} + \tilde{\gamma}' x_{i,t} + \tilde{\varepsilon}_{i,t} \tag{7}$$

where $\tilde{c}$ denotes a constant, $\tilde{\beta}_i$ is a slope coefficient, $x_{i,t}$ is the set of regressors used in the second-stage regression, $\tilde{\gamma}$ is the vector of associated coefficients, and $\tilde{\varepsilon}_{i,t}$ is an error term. As before, we also consider firm and time fixed effects. The coefficient $\tilde{\beta}_i$ is allowed to vary between VPs that are based in different countries, that is, to depend on the country where VP i has its headquarters. This assumption is supported by the estimation results, which indicate that this coefficient is heterogeneous across countries.

Table 4 reports the results for our IV based on geographical distance in columns (1) and (2). The estimates confirm our main findings on the effect of IPRI at the suppliers' locations: the coefficient on $IPRI^{(S)}$ is always positive and significant. The estimated coefficient in column (1) is 0.324, down from the

19. In CEPII data, the distance between a VP and its home country is not zero, but the average distance between different locations within the country, based on its total area (Mayer and Zignago 2011). Accordingly, we include domestic countries when constructing the distance-weighted IPR measure; however, excluding them yields similar results, as reported in Appendix 4, Table A.8.

Table 4. IV regressions using geographical distance and language proximity.

Dependent:	Sales/assets					
	Geographical distance		Squared distance		Language	
	(1)	(2)	(3)	(4)	(5)	(6)
$IPRI^{(S)}$	0.324**	0.538**	0.473**	0.853***	0.349**	0.609**
	(0.165)	(0.240)	(0.209)	(0.331)	(0.168)	(0.246)
$IPRI^{(C)}$		−0.134		−0.261*		−0.163*
		(0.089)		(0.143)		(0.095)
1st-stage *F* stat.	28.74	16.54	21.21	13.92	26.20	14.00
Firm controls	x	x	x	x	x	x
Year FE	x	x	x	x	x	x
Firm FE	x	x	x	x	x	x
Obs.	172	162	172	162	172	162
N	67	63	67	63	67	63
R^2	0.359	0.378	0.358	0.372	0.359	0.378

Notes: The table reports 2SLS estimates on annual data over the sample 2018 – 2020. Firm controls are: *tot_assets*, *intangible*, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported is the within R^2. The significance levels are: ***.01, **.05, *.10.

baseline of 0.765 in Table 3. Based on this lower-bound estimate, a one-unit increase in the average IPRI of suppliers' countries is associated with a 32.4 percentage point increase in a VP's sales-to-assets ratio. Applying this to our previous example, major VPs with a high share of around 30 per cent Chinese suppliers would see an efficiency gain of 4.9 percentage points over the 2012–2020 period as China's IPRI improved.

The assumption of our IV strategy is that IPR protection in nearby countries only affects efficiency through its impact on suppliers. However, VPs may also experience higher demand for their products in nearby markets, which could have an impact on efficiency. To control for this other potential channel related to distance, in column (2) we also include IPRI weighted by the VP's consumer network. This ensures that the impact of institutions on VPs' efficiency operates specifically through their relationships with suppliers and is not due to higher demand in nearby or common-language markets. Our key results for supplier networks hold, while the IPRI weighted by consumer locations exhibits a negative coefficient.[20] In Table A.9 of Appendix 4, we additionally include inverse-distance-weighted log GDP per capita to control for neighboring countries' other characteristics beyond institutions.

Next, we consider an alternative weighting strategy also based on geographical distance. We build on a gravitational approach rationalized using Tobler's first law of geography (Tobler 1970), in which the strength of the distance decay function depends not only on transportation costs, but also on non-material concepts such as knowledge, culture, and ideas. Geographical distance has a negative effect on the reach of knowledge flows (Jaffe et al. 1993; Branstetter 2001; Maurseth and Verspagen 2002; Bottazzi and Peri 2003), diminishing the importance of IPR protection. Motivated by this twofold decay of the institutions' importance with distance, we consider the inverse of the *squared* distance, in place of the simple distance, to construct a second instrument. This allows us to capture the compounding effect of trade/transport costs and the decay of knowledge diffusion.

20. We have further checked and found that our knowledge-embedded measure of distance and linguistic distance are not good predictors of the location of a VP's sales, while they are for the location of suppliers. A potential explanation could be that a car manufacturer keeps suppliers close as they must bear transport costs for importing auto components, but may serve large markets in other continents through its subsidiaries. Results are available upon request.

Specifically, for each VP, we first calculate an average IPRI level weighting each country by the inverse of the squared distance between that country and the VP's headquarter country. Our alternative instrument is now calculated as:

$$IPRI_{i,t}^{(dist2)} = \frac{1}{\sum_{j=1}^{M} w_{i,j}^{(dist2)}} \sum_{j=1}^{M} w_{i,j}^{(dist2)} IPRI_{j,t}, \tag{8}$$

where $w_{i,j}^{(dist2)} = 1/distance_{i,j}^2$. The results are presented in columns (3)–(4) of Table 4 and mirror those obtained using the standard gravity IV based on distance. The *F*-statistics indicate that this instrument is also relevant. Interestingly, higher IPRI in VPs' customer markets is associated with a weak negative effect on their efficiency.

The trade literature has also emphasized the pivotal role of cultural and language differences in explaining geographic frictions. To further validate our IV approach, we build a third IV using data on linguistic proximity from Melitz and Toubal (2014). These calculations are based on the Ethnologue (2009) classification of language trees and take a value between 0 and 1. In this case, we weight the IPRI index of each supplier country with the proximity of its language to the VP's country.

Thus, denoting with $w_{i,j}^{(lang)}$ the Melitz and Toubal (2014) measure of language proximity of country *j* for VP *i*, our alternative instrument is calculated as:

$$IPRI_{i,t}^{(lang)} = \frac{1}{\sum_{j=1}^{M} w_{i,j}^{(lang)}} \sum_{j=1}^{M} w_{i,j}^{(lang)} IPRI_{j,t} \tag{9}$$

As shown in columns (5)–(6) of Table 4, the language-proximity IV also delivers results comparable to those based on geographical distance.

6.3 A test of the transaction cost theory

In Section 3, we argued that integration helps internalize knowledge within firm boundaries, mitigating reliance on institutions to protect intellectual property and their role in the performance of firms. So far, we have observed this through the positive effect of IPRI manifesting itself only in the location of suppliers, but not in the location of owned subsidiaries. We now take a twofold step further to test our conceptual framework. First, we check whether gains from higher-quality institutions are specifically associated with knowledge. Second, we check if ownership can act as a substitute for IPR protection in increasing network efficiency by shielding knowledge. We would expect the impact of ownership to materialize when a significant portion of a firm's subsidiaries reside in countries with sufficiently weak IPR regimes.

For these purposes, we first break down the IPRI measure into two distinct components, 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) of Table 5 show the results without and with firm fixed effects, respectively. We observe that the impact of supplier-weighted IPR protection on efficiency is positive and significant in both cases, whereas PPR protection does not have the same influence. Also, the protection of property rights at the location of VPs' subsidiaries is again non-significant, suggesting (in line with the transaction cost theory) that the effect of institutional quality is absent when connected firms are integrated within the VP.

After confirming that the results are mainly driven by protection of IPR rather than PPR, we focus on IPR and split the sample between firms with above and below 75% of their ownership network in weak-IPR countries (75 per cent is approximately the median observation in our sample). Specifically, we

Table 5. IPR versus PPR and sample split by share of ownership in weak-IPR countries.

	IPR versus PPR		Sample split by ownership	
			$>$75% in weak IPR countries	$\leq$75% in weak IPR countries
Dependent:	(1) Sales/assets	(2) Sales/assets	(3) Sales/assets	(4) Sales/assets
$\boldsymbol{IPR^{(S)}}$	0.496**	0.564***	1.270***	0.548**
	(0.222)	(0.172)	(0.313)	(0.237)
$\boldsymbol{IPR^{(O)}}$	−0.185	−0.212	−0.607***	0.002
	(0.176)	(0.173)	(0.135)	(0.637)
$\boldsymbol{PPR^{(S)}}$	−0.423	0.132		
	(0.316)	(0.270)		
$\boldsymbol{PPR^{(O)}}$	0.126	−0.189		
	(0.182)	(0.169)		
Firm controls	x	x	x	x
Year FE	x	x	x	x
Firm FE		x	x	x
Obs.	172	172	88	84
$\boldsymbol{N}$	67	67	38	29
$\boldsymbol{R^2}$	0.218	0.394	0.336	0.518

Notes: The table reports OLS estimates on annual data over the sample 2018–2020. Firm controls are: *tot_assets*, *intangible*, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported is the adjusted R^2 for column (1) and the within R^2 for columns (2)–(4).
The significance levels are: ***.01, **.05, *.10.

classify countries as low-IPR (high-IPR) countries based on their IPR level being below (above) the cross-country median in the year prior to the sample, that is, 2017. This heterogeneity analysis is displayed in columns (3) and (4) of Table 5. Column (3) presents the results for VPs owning other firms primarily ($>$75%) in weak-IPR countries. We find a negative coefficient on $IPR^{(O)}$, suggesting that ownership is suitable in terms of efficiency at *low* IPR levels. More specifically, our interpretation of the negative coefficient is the following: when VPs primarily operate in weak-IPR countries, stronger IPR protection reduces the efficiency of owning component producers, while, symmetrically, a weaker IPR regime increases the benefits of ownership. This pattern holds for alternative thresholds above 75 per cent. In contrast, in column (4) we observe that when 75 per cent or less of a firm's owned subsidiaries operate in weak-IPR countries, ownership has no relevant impact on efficiency. Notably, our findings on supplier-weighted IPR persist across both sub-samples, consistently indicating positive effects on efficiency.

6.4 Longer sample and the exclusion of domestic suppliers

We next provide results obtained on a longer sample. As previously mentioned, we assume networks to be constant at their 2019 values. In columns (1)–(3) of Table 6, we replicate the baseline FE regressions from Table 3 and show that our key results still hold when the start of the sample is shifted back to 2012.

However, the main value added of using a longer sample is that it also allows us to consider an alternative specification, in which we restrict attention to the foreign part of the international production networks, thus excluding domestic suppliers and subsidiaries from the analysis. Leaving out the domestic nodes of the network allows us to isolate more accurately the specific efficiency gains derived from IPRI in the countries of international suppliers from the general benefits associated with higher domestic levels of IPRI. More specifically, in this case the regression specification becomes:

Table 6. Longer sample (2012–2020).

Dependent:	Sales/assets			
	(1)	**(2)**	**(3)**	**(4) Excluding domestic**
$IPRI^{(S)}$	0.403**	0.477**	0.578***	0.634**
	(0.194)	(0.188)	(0.185)	(0.251)
$IPRI^{(O)}$	−0.260	−0.156	−0.271	−0.523**
	(0.157)	(0.136)	(0.184)	(0.243)
$IPRI^{(C)}$			−0.087	0.156*
			(0.116)	(0.079)
IPRI				0.019
				(0.080)
Lag IPRI	1	2	1	1
Firm controls	x	x	x	x
Year FE	x	x	x	x
Firm FE	x	x	x	x
Obs.	446	397	412	210
N	77	76	71	30
R^2	0.102	0.109	0.120	0.364

Notes: The table reports FE estimates obtained on annual data over the period 2012–2020. Firm controls are: *tot_assets*, *intangible*, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported is the within R^2.
The significance levels are: ***.01, **.05, *.10.

$$y_{i,t} = c + \beta_1 IPRI^{(S)}_{\text{excl\_dom,i,t}-1} + \beta_2 IPRI^{(O)}_{\text{excl\_dom,i,t}-1} + \delta IPRI_{i,t-1} + \gamma' x_{i,t-1} + \varepsilon_{i,t} \tag{10}$$

where $IPRI^{(S)}_{\text{excl\_dom,i,t}}$ denotes the supplier-weighted IPRI level for VP i, excluding from the supplier network of i the suppliers that are located in i's home country, i.e., $IPRI^{(S)}_{\text{excl\_dom,i,t}} = \left(\frac{1}{\sum_{j\neq h} w^{(S)}_{i,j}}\right) \sum_{j\neq h} w^{(S)}_{i,j} IPR_{j,t}$, where h indicates the home country of VP i, and $IPRI^{(O)}_{\text{excl\_dom,i,t}}$ is defined analogously for subsidiaries. As before, $IPRI_{i,t}$ indicates the IPRI level in i's home country. In this case, we focus on the IPRI of foreign suppliers' countries as our predictor of interest. We include the IPRI of the VP's home country as a separate regressor to control for general efficiency benefits deriving from higher domestic IPR protection.

The exclusion of the domestic parts of the networks causes a substantial reduction in the number of VPs and observations available for estimation, and would thus lead to very imprecise estimates over our short baseline sample. In particular, out of seventy-seven VPs included in the analysis, our data indicate that fifty-four have foreign suppliers, forty-three have foreign affiliates, and only thirty-six have both. Moreover, forty-six VPs sell cars to foreign consumers, and only thirty VPs have foreign networks in all three dimensions (suppliers, subsidiaries, and consumers) jointly. For this reason, we introduce this specification only in the long sample.

Column (4) of Table 6 shows that our main finding continues to hold when we restrict attention to the foreign part of the international production networks. This corroborates and extends our previous result that the effect of property rights protection in suppliers' locations is not driven by domestic IPRI (which we already pointed out when controlling for domestic IPRI in Table 2). Although excluding the domestic portion of each automotive production network substantially reduces the number of observations, the impact of IPRI in the foreign locations of the network remains significant at the 5% level, consistent with the results for the entire network in column (1) but with a somewhat larger magnitude. In Appendix 3 (Table A.4), we show again that our results for the long sample remain robust even after excluding the year 2020, thereby addressing potential concerns related to the impact of COVID-19. The longer sample also makes it feasible to estimate a GMM model, allowing us to exploit an additional methodology for dealing with endogeneity concerns. We perform this robustness check in Appendix 2, also using information on VPs' patent profiles and R&D expenditures to control for firms' innovation capacity.

7. 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 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 IPR in supplier countries. We also consider the ownership networks of VPs and find that IPR only increase efficiency in production networks when they involve external suppliers as opposed to subsidiaries. This may suggest that higher-performing firms are not necessarily drawn to establish operations in countries with stronger IPR institutions. An alternative explanation could be that firms choose to own their suppliers in countries with weak IPR institutions to mitigate the risk of knowledge dissipation. In other words, ownership may act as a substitute for IPR protection in subsidiaries' host countries, rendering IPR less relevant for the efficiency of international production networks.

To test this, we differentiate between the protection of intangible and tangible property rights to isolate the effect of safeguarding knowledge on firm efficiency. The lack of a similar outcome for PPR protection suggests that the efficiency gains are primarily linked to knowledge protection. We further split the sample between firms with more or less than 75% of their subsidiaries located in weak-IPR countries. The results reveal that ownership is a suitable strategy for firms primarily operating in weak-IPR countries to internalize the risk of knowledge dissipation through a vertical integration strategy.

We employ a wide battery of controls and estimation strategies to mitigate concerns about omitted variables and endogeneity. To address the possibility that our results may derive from better firms choosing suppliers from countries with high-quality institutions, we include firm fixed effects and build three exogenous IV by assigning different weights to the IPR protection levels faced by a VP. The first two rely on geographical distance (also squared to capture localized knowledge spillovers), while the third is based on language proximity. In other words, rather than averaging the IPR levels of a firm's actual supplier locations, we compute a weighted average of the IPR index across all countries, with weights decreasing in geographical or linguistic distance from the VP's home country.

While this is an early attempt to explore the link between IPR and international production networks, recently released 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 various industries and assess the gains from IPR protection in the location of the networks. Another avenue of research could be the quantification of potential gains based on the location and level of upstreamness of network nodes within a supply chain. 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 the environment.

Acknowledgements

We thank Jorge De la Roca (Editor) for his encouragement and suggestions and are indebted to two anonymous referees for their thorough and very constructive comments on an earlier version of the study. We are also grateful to the participants of the IAAE Conference (Turin), the AISSEC Conference (Pescara) and the International Trade and Intellectual Property Rights workshop (Rimini) for valuable discussions. Part of this research was conducted while Graziano Moramarco was affiliated with the University of Bologna.

Conflicts of interest. None declared.

Funding

We gratefully acknowledge financial support from MIUR, PRIN 2017, Grants 2017TA7TYC (Giuseppe Cavaliere and Graziano Moramarco) and 2017E37YRL (Alireza Naghavi), and GRINS project, CUP J33C22002910001 (Graziano Moramarco).

Appendix

Appendix 1 Alternative proxy for efficiency: operating revenues per employee

Table A.1 reports results based on (log) operating revenues per employee (*OpRev/empl*) as an alternative measure of efficiency. Columns (1)–(3) correspond to the specifications reported in Table 2, while column (4) is the counterpart of the baseline regression in column (1) of Table 3.

Table A.1. Operating revenues per employee: baseline results with firm, country and network controls, and fixed effects.

Dependent:	***OpRev/empl***			
	(1)	**(2)**	**(3)**	**(4)**
IPRI$^{(S)}$	0.505***	0.400**	0.504**	1.883***
	(0.134)	(0.165)	(0.249)	(0.583)
IPRI$^{(O)}$	−0.024	0.223	−0.010	−1.360**
	(0.161)	(0.380)	(0.152)	(0.533)
IPRI		−0.254		
		(0.357)		
gdp_pc		0.176		
		(0.197)		
mkt_cap		−0.059		
		(0.312)		
gdp_pc$^{(S)}$			0.088	
			(0.182)	
mkt_cap$^{(S)}$			−0.440	
			(0.427)	
distance$^{(S)}$			−0.138	
			(0.099)	
Firm controls	x	x	x	x
Firm FE				x
Year FE	x	x	x	x
Obs.	172	145	172	172
N	67	59	67	67
R^2	0.536	0.506	0.551	0.190

Notes: The table reports OLS estimates on annual data over the sample 2018 – 2020. Firm controls are: *tot_assets*, *intangible*, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported is the adjusted R^2 for columns (1)–(3) and the within R^2 for column (4).
The significance levels are: ***.01, **.05, *.10.

Appendix 2 Innovation capacity

In this appendix, we 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 VP. In particular, we construct our control variable by assigning to 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 (long) estimation sample (we consider a 20-year period as this is the standard term of patent). As an additional control, we also include the annual flow of (log) R&D expenditures per employee (*rde*).

Table A.2 reports the results. 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 endogeneity of the suppliers' network. In particular, in all regressions of Table A.2, we treat the supplier-weighted IPR level ($IPR^{(S)}$) as endogenous (in analogy with Section 6.2), and instrument it using a standard system-GMM instrumenting strategy (see Roodman 2009).[21]

Columns (1)–(3) of Table A.2 report GMM estimates for the sales-to-assets ratio, while in columns (4)–(6) the dependent variable is operating revenues per employee (in logs). Columns (1) and (4) report the baseline regressions for our two dependent variables, and show that our findings are confirmed, with IPR in suppliers' locations exerting a strongly significant effect on VPs' efficiency. Columns (2) and (5) report regressions in which we include the terciles of the initial stock of granted patents, that is, the total number of patents granted between 1992 and 2011. Supplier-weighted IPR continues to be strongly significant. Columns (3) and (6) incrementally add the lagged annual level of log R&D expenditures per employee. 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 not affect our argument. Hence, these additional estimates support our conjecture that the results are IP-related, yet the higher efficiency experienced by VPs is not driven by more innovative firms self-selecting into high-IPR countries. Overall, our results

Table A.2. GMM and IPR: accounting for endogeneity and innovativeness.

	(1) Sales/assets	(2) Sales/assets	(3) Sales/assets	(4) $OpRev/empl$	(5) $OpRev/empl$	(6) $OpRev/empl$
$IPR^{(S)}$	0.192***	0.220***	0.118*	0.388***	0.504***	0.416***
	(0.061)	(0.084)	(0.068)	(0.094)	(0.117)	(0.102)
Patents		−0.141	0.026		−0.223**	−0.016
		(0.095)	(0.057)		(0.105)	(0.102)
rde			0.032			0.142**
			(0.035)			(0.066)
Firm controls	x	x	x	x	x	x
Year FE	x	x	x	x	x	x
Obs	446	398	285	446	398	285
N	77	64	39	77	64	39

Notes: The table reports one-step system GMM estimates obtained on annual data over the period 2012–2020. Firm controls are: *tot_assets*, *intangible*, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. The significance levels are: ***.01, **.05, *.10.

21. Specifically, we use as GMM-type instruments (1) for the first differences equation: the lagged levels of $IPR^{(S)}$ at time $t-2$ and earlier; (2) for the levels equation: the lagged first difference of $IPR^{(S)}$ at time $t-1$.

emphasize the idea that the protection of intellectual property along the supply chain is critical for the performance of the production network.

Appendix 3 Excluding 2020

Table A.3 is the counterpart of Tables 2 and A.1 when we exclude 2020 from the baseline sample, and therefore restrict the sample to 2018–2019. In this case, we do not include firm fixed effects, given the quasi-cross-section nature of the sample and insufficient time variability of dependent and explanatory variables, which would result in high collinearity and unreliable inference. Table A.4, in turn, is the counterpart of Table 6 excluding 2020.

Table A.3. Baseline results excluding 2020.

Dependent:	Sales/assets			*OpRev/empl*		
	(1)	(2)	(3)	(4)	(5)	(6)
$IPRI^{(S)}$	0.362***	0.381**	0.523***	0.477***	0.396**	0.457*
	(0.099)	(0.161)	(0.149)	(0.104)	(0.158)	(0.236)
$IPRI^{(O)}$	−0.095	−0.195	−0.098	−0.016	0.124	−0.006
	(0.108)	(0.357)	(0.109)	(0.140)	(0.351)	(0.140)
IPRI		0.153			−0.032	
		(0.258)			(0.337)	
gdp_pc		−0.118			0.034	
		(0.174)			(0.182)	
mkt_cap		−0.171			−0.328	
		(0.376)			(0.387)	
$gdp\_pc^{(S)}$			−0.118			0.099
			(0.127)			(0.179)
$mkt\_cap^{(S)}$			−0.472			−0.263
			(0.303)			(0.460)
$distance^{(S)}$			0.008			−0.160
			(0.073)			(0.101)
Firm controls	x	x	x	x	x	x
Obs.	121	105	121	121	105	121
N	67	59	67	67	59	67
Adj. R^2	0.137	0.139	0.137	0.569	0.537	0.575

Notes: The table reports OLS estimates on annual data over the sample 2018–2019. Firm controls are: *tot_assets*, ***intangible***, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses.
The significance levels are: ***.01, **.05, *.10.

Appendix 4 Additional tables and figures

In Fig. A.1, we provide scatterplots of residualized efficiency indicators against supplier-weighted IPRI levels. Panel (a) plots sales-to-assets ratios against supplier-weighted IPRI levels, both residualized using the controls and fixed effects from the baseline FE regression in Table 3 (column 1). Panel (b) plots log operating revenues per employee against supplier-weighted IPRI levels, both residualized using the controls and fixed effects from the baseline FE regression in Table A.1 (column 4). The slopes of the linear fit lines in the two charts correspond to the coefficients on $IPRI^{(S)}$ in column (1) of Table 3 and column (4) of Table A.1, respectively. The main results continue to hold if we exclude from the sales/assets regression

Table A.4. Longer sample excluding 2020.

Dependent:	Sales/assets			
	(1)	(2)	(3)	(4) Excluding domestic
$IPRI^{(S)}$	0.339*	0.449**	0.509***	0.607**
	(0.186)	(0.188)	(0.174)	(0.238)
$IPRI^{(O)}$	−0.314	−0.350**	−0.326	−0.499**
	(0.192)	(0.163)	(0.221)	(0.239)
$IPRI^{(C)}$			−0.081	0.259***
			(0.210)	(0.080)
$IPRI$				−0.031
				(0.082)
Lag IPRI	1	2	1	1
Firm controls	x	x	x	x
Year FE	x	x	x	x
Firm FE	x	x	x	x
Obs.	395	346	364	183
N	77	76	71	30
R^2	0.054	0.061	0.069	0.231

Notes: The table reports FE estimates obtained on annual data over the period 2012–2019. Firm controls are: ***tot_assets***, *intangible*, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. The R^2 reported is the within R^2.
The significance levels are: ***.01, **.05, *.10.

the VP with the largest residuals, namely Magna–Steyr. The coefficient on $IPRI^{(S)}$ in this latter case is approximately 0.5 and remains statistically significant.

Table A.5 reports descriptive statistics for the main variables used in the analysis as well as additional information on networks, over the baseline period 2018–2020.

Table A.6 reports the main changes in suppliers' network weights from 2019 to 2020.

Table A.7 reports the correlation between the three network-weighted lagged IPRI measures used throughout the study, namely based on suppliers, ownership, and sales, for both the short (2018–2020) and the long (2012–2020) sample.

Table A.8 excludes the home country from the weighting when constructing the distance-based instrument (that is, we set $w_{i,j}^{(dist)} = 0$ in Equation 6 if j is VP i's home country), as a robustness check.

Table A.9 includes inverse-distance-weighted log GDP per capita in our IV regressions as a robustness check to control for nearby countries' characteristics unrelated to institutions.

Table A.10 reports the list of vehicle producers (VPs) comprised in our sample, along with information on the countries where their headquarters are located. For three companies, namely Ferrari, Fiat-Chrysler (FCA), and Geely, the countries hosting the legal headquarters (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 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.

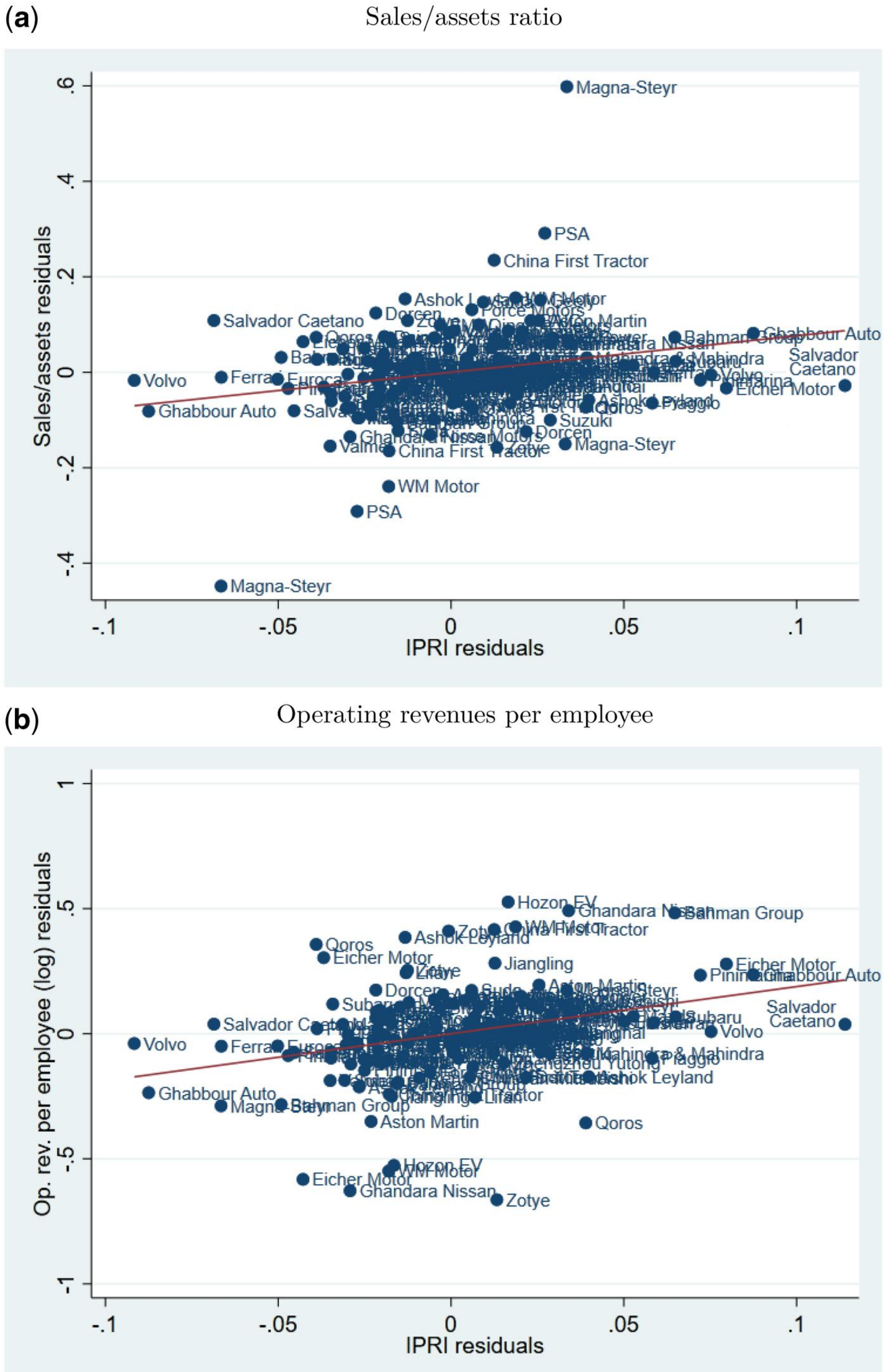

Figure A.1. Scatterplots of residualized efficiency and IPRI.

Notes: The scatterplot in panel (a) plots sales-to-assets ratio against supplier-weighted IPRI levels, both residualized using the controls and fixed effects from the baseline FE regression in Table 3 (column 1). The scatterplot in panel (b) plots log operating revenues per employee against supplier-weighted IPRI levels, both residualized using the controls and fixed effects from the baseline FE regression in Table A.1 (column 4).

Table A.5. Descriptive statistics 2018–2020.

Variable	Mean	Median	Std. Dev.	Min	Max
Sales/assets	0.749	0.651	0.449	0.068	3.158
Oper. revenues/employee (th. USD)	402.139	310.828	305.419	14.247	1,619.603
Sales (USD)	36.8 bln	5.69 bln	65.4 bln	4.17 mln	284 bln
Oper. revenues (USD)	37.2 bln	5.88 bln	66.2 bln	4.17 mln	292 bln
No. employees	69,974	16,270	118,124	158	671,205
Supplier-weighted IPRI	6.283	6.033	0.659	5.100	8.264
Ownership-weighted IPRI	6.470	6.125	0.966	3.474	8.190
Total assets (USD)	57.5 bln	6.56 bln	116 bln	40.1 mln	548 bln
Intangible asset ratio	0.083	0.041	0.112	0	0.570
Leverage ratio	1.229	0.836	1.437	0	8.865
No. suppliers	661.149	115	1,202.424	13	5,634
No. subsidiaries	118.818	31	210.692	2	1,169
No. suppliers' countries	12.045	5	13.895	1	48
No. subsidiaries' countries	10.507	4	13.860	1	53

Notes: The table provides summary statistics calculated over all observations included in the baseline regression on the sample 2018–2020. In line with the regression specification, 1-year lagged values are considered for supplier-weighted and ownership-weighted IPRI, total assets, intangible ratio, and leverage ratio.

Table A.6. Main changes in supplier country weights between 2019 and 2020.

Company	Correlation of weights 2019 versus 2020	Main changes
Agrale	0.194	Weights in 2019: Brazil 82%, United States 18%. Weights in 2020: United States 100% (but very few transactions recorded in 2020)
Tesla	0.907	Largest weights in 2019: United States 64%, Mexico 24%, China 6%. Largest weights in 2020: United States 49%, China 30%, Mexico 16%.
Bahman	0.980	China's weight increased from 46% to 58%, Iran's weight declined from 40% to 34%.
Ghabbour	0.986	China up from 48% to 57%, Egypt down from 28% to 22%.
BMW	0.988	China up from 22% to 27%, Germany down from 25% to 22%.
Honda	0.989	China up from 31% to 38%, US down from 26% to 24%, Thailand down from 6% to 4%.
Daimler	0.989	China up from 23% to 28%, Germany down from 32% to 29%

Table A.7. Correlation of network-weighted IPRI measures.

	$IPRI^{(S)}$	$IPRI^{(O)}$	$IPRI^{(C)}$
2018 – 2020			
$IPRI^{(S)}$	1.00		
$IPRI^{(O)}$	0.75	1.00	
$IPRI^{(C)}$	0.76	0.88	1.00
2012 – 2020			
$IPRI^{(S)}$	1.00		
$IPRI^{(O)}$	0.78	1.00	
$IPRI^{(C)}$	0.81	0.89	1.00

Table A.8. IV regressions excluding home country from instrument.

Dependent:	**Sales/assets**	
	Geographical distance	
	(1)	**(2)**
$\boldsymbol{IPRI}^{(\boldsymbol{S})}$	0.342**	0.613**
	(0.167)	(0.248)
$\boldsymbol{IPRI}^{(\boldsymbol{C})}$		−0.165*
		(0.098)
1st-stage *F* stat.	28.46	14.71
Firm controls	x	x
Year FE	x	x
Firm FE	x	x
Obs.	172	162
N	67	63
$\boldsymbol{R}^2$	0.359	0.378

Notes: The table reports 2SLS estimates on annual data over the sample 2018–2020. Firm controls are: *tot_assets*, ***intangible***, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. For the first-stage regression, we report the cross-country average coefficient of the instrument. The R^2 reported is the within R^2.
The significance levels are: ***.01, **.05, *.10.

Table A.9. IV regressions controlling for inverse-distance-weighted GDP.

Dependent:	**Sales/assets**	
	Geographical distance	
	(1)	**(2)**
$\boldsymbol{IPRI}^{(\boldsymbol{S})}$	0.367*	0.642**
	(0.188)	(0.311)
$\boldsymbol{IPRI}^{(\boldsymbol{C})}$		−0.149
		(0.094)
$\boldsymbol{gdp\_pc}^{(\boldsymbol{dist})}$	−0.159	−0.295
	(0.463)	(0.558)
1st-stage *F* stat.	19.03	11.75
Firm controls	x	x
Year FE	x	x
Firm FE	x	x
Obs	172	162
N	67	63
$\boldsymbol{R}^2$	0.360	0.380

Notes: The table reports 2SLS estimates on annual data over the sample 2018 – 2020. Firm controls are: *tot_assets*, ***intangible***, and *leverage*. Robust standard errors clustered at the firm level are reported in parentheses. For the first-stage regression, we report the cross-country average coefficient of the instrument. The R^2 reported is the within R^2.
The significance levels are: ***.01, **.05, *.10.

Table A.10. List of vehicle producers (VPs).

N.	IHS Markit company name	Orbis company name	Country
1	Agrale	AGRALE SOCIEDADE ANONIMA	BR
2	Ashok Leyland	ASHOK LEYLAND LIMITED	IN
3	Aston Martin	ASTON MARTIN LAGONDA GLOBAL HOLDINGS PLC	GB
4	Bahman Group	BAHMAN GROUP COMPANY PUBLIC JOINT STOCK COMPANY	IR
5	BAIC	BAIC MOTOR CORPORATION LIMITED	CN
6	BMW	BAYERISCHE MOTOREN WERKE AG	DE
7	Brilliance Auto	BRILLIANCE AUTO GROUP HOLDINGS CO., LTD.	CN
8	Brilliance-Renault	RENAULT BRILLIANCE JINBEI AUTOMOTIVE CO., LTD.	CN
9	BYD	BYD AUTO INDUSTRY COMPANY LIMITED	CN
10	Changan	CHONGQING CHANGAN AUTOMOBILE COMPANY LIMITED	CN
11	CH-AUTO	CH AUTO TECHNOLOGY CORPORATION LTD.	CN
12	Chery	CHERY AUTOMOBILE CO., LTD.	CN
13	China First Tractor	YTO GROUP CORPORATION	CN
14	CNHTC	CHINA NATIONAL HEAVY DUTY TRUCK GROUP CO., LTD.	CN
15	CRRC	CRRC CORPORATION LIMITED	CN
16	Daimler	DAIMLER AG	DE
17	Dandong Huanghai	DANDONG HUANGHAI AUTOMOTIVE COMPANY LIMITED	CN
18	Dongfeng	DONGFENG MOTOR GROUP COMPANY LIMITED	CN
19	Dorcen	DORCEN AUTOMOBILE GROUP CO., LTD.	CN
20	Eicher Motor	EICHER MOTORS LIMITED	IN
21	Eurocar	EUROCAR PRIVATE JSC AT	UA
22	FAW-Toyota	CHINA FAW GROUP CORPORATION	CN
23	FCA	STELLANTIS N.V.	IT
24	Ferrari	FERRARI N.V.	IT
25	Force Motors	FORCE MOTORS LIMITED	IN
26	Ford	FORD MOTOR CO	US
27	GAC	GAC MOTOR CO., LTD.	CN
28	GAC-Honda	GAC HONDA AUTOMOBILE CO., LTD.	CN
29	GAMC	GUANGZHOU AUTOMOBILE GROUP CO.,LTD.	CN
30	Geely	GEELY AUTOMOBILE HOLDINGS LIMITED	CN
31	General Motors	GENERAL MOTORS COMPANY	US
32	Ghabbour Auto	G.B. AUTO S.A.E.	EG
33	Ghandara Nissan	GHANDHARA NISSAN LIMITED	PK
34	Great Wall	GREAT WALL MOTOR COMPANY LIMITED	CN
35	Honda	HONDA MOTOR CO., LTD.	JP
36	Hozon EV	HOZON NEW ENERGY AUTOMOBILE CO., LTD.	CN
37	Isuzu	ISUZU MOTORS LIMITED	JP
38	Jianghuai	ANHUI JIANGHUAI AUTOMOBILE GROUP CORP., LTD.	CN
39	Jiangling	JIANGLING MOTORS CORPORATION LIMITED	CN
40	Jiangnan	HUNAN JIANGNAN AUTOMOBILE MANUFACTURE CO., LTD.	CN
41	King Long	XIAMEN KING LONG MOTOR GROUP CO., LTD.	CN
42	Lifan	LIFAN TECHNOLOGY (GROUP) CO.,LTD.	CN
43	Magna-Steyr	MAGNA STEYR FAHRZEUGTECHNIK AG & CO KG	AT
44	Mahindra & Mahindra	MAHINDRA & MAHINDRA LIMITED	IN
45	Mazda	MAZDA MOTOR CORPORATION	JP
46	Piaggio	PIAGGIO & C. S.P.A.	IT

(continued)

Table A.10. (continued)

N.	IHS Markit company name	Orbis company name	Country
47	Pininfarina	PININFARINA SPA	IT
48	PSA	PSA AUTOMOBILES SA	FR
49	Qingling Motors	QINGLING MOTORS COMPANY LIMITED	CN
50	Qoros	QOROS AUTOMOTIVE CO., LTD.	CN
51	Renault-Nissan-Mitsubishi	RENAULT/NISSAN MOTOR CO., LTD./MITSUBISHI MOTORS CORPORATION	JP
52	SAIC	SAIC MOTOR CORPORATION LIMITED	CN
53	SAIC-General Motors-Wuling	SAIC GM WULING AUTOMOBILE COMPANY LIMITED	CN
54	SAIPA	SAIPA AUTOMOTIVE MANUFACTURING GROUP PUBLIC JOINT STOCK COMPANY	IR
55	Salvador Caetano	TOYOTA CAETANO PORTUGAL S.A.	PT
56	Shandong Wuzheng	SHANDONG WUZHENG GROUP CO., LTD.	CN
57	Shanxi Victory	SHANXI VICTORY AUTOMOBILE MANUFACTURING CO., LTD.	CN
58	Sichuan Yema	SICHUAN YEMA AUTOMOBILE CO., LTD.	CN
59	Soueast	SOUTH EAST (FUJIAN) MOTOR CORP., LTD.	CN
60	Subaru	SUBARU CORPORATION	JP
61	Suda	SANMENXIA SUDA TRANSPORTATION ENERGY SAVING TECHNOLOGY CO.,LTD.	CN
62	Sunlong Bus	SHANGHAI SHENLONG BUS CO., LTD.	CN
63	Suzuki	SUZUKI MOTOR CORPORATION	JP
64	Tata	TATA MOTORS LIMITED	IN
65	Tesla	TESLA, INC.	US
66	Toyota	TOYOTA MOTOR CORPORATION	JP
67	Valmet	VALMET AUTOMOTIVE OY	FI
68	VinFast	VINFAST TRADING AND PRODUCTION LIMITED LIABILITY COMPANY	VN
69	Volkswagen	VOLKSWAGEN AG	DE
70	Volvo	AB VOLVO	SE
71	Wanxiang Auto	WANXIANG QIANCHAO CO.,LTD.	CN
72	Weichai Power	WEICHAI POWER CO., LTD.	CN
73	WM Motor	WM MOTOR MANUFACTURING WENZHOU CO., LTD.	CN
74	Yudo Auto	YUDO AUTO CO., LTD.	CN
75	Zhengzhou Yutong	ZHENGZHOU YUTONG GROUP CO., LTD.	CN
76	Zhongxing	HEBEI ZHONGXING AUTOMOBILE CO., LTD.	CN
77	Zotye	ZOTYE AUTOMOBILE CO.,LTD.	CN

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Journal of Economic Geography, 2026, 00, 1–31
https://doi.org/10.1093/jeg/lbag042
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