13TH IMF STATISTICAL FORUM
MEASURING CROSS-BORDER ECONOMIC and FINANCIAL LINKAGES in a Dynamic World

Understanding supply chains in OECD countries from VAT transaction data

Andrew Green, Christina Palmou, Aviya Tsoref

September 2025

Abstract

Firm-to-firm transaction data offer new possibilities to measure and understand supply chains. Current measures of global supply chains typically use inter-country input-output tables at the sectoral level. However, firms vary widely in terms of size, production processes and linkages with other firms and could therefore be affected differently by shocks because of the variance in the sectors from which they source intermediate inputs, for example. This paper presents first evidence on a new initiative to measure supply chains at a more granular level: using VAT firm-to-firm transaction data. The paper, an output of the OECD/DG GROW LIFT Network, depicts the structure of production networks as seen from these novel datasets. The work shows harmonised, comparable, network statistics providing insights on emerging features of domestic supply chains across different OECD countries. The work aims to not only explore the characteristics of these production networks, but to provide information on these new and underutilised datasets. The paper will conclude by discussing the opportunities and challenges inherent in one of the long-term goals of the network: linking VAT data across countries to complete the picture of granular global value chains.

We are grateful to Dr Leonarda Srdelic and Dr Simona Srdelic from the Institute of Public Finance (Institut za javne financije) for their collaboration on Croatian data as well as to Dr Jaan Masso from Tartu University (Tartu Ülikool) for his support with the Estonian data. We are also grateful to Dr Keith Lai and Joseph Colliass from the UK Office for National Statistics for their insightful discussions on the relationships between firm-to-firm payments data and economic statistics.

Introduction

Supply chain resilience and the strength of global value chains have gained greater salience among policymakers since the pandemic, the ensuing energy crisis and the reconfiguration of trade relationships among large economies. Recently, a new type of data to identify firm-to-firm relationships has become available to researchers to investigate these issues: firm-to-firm transaction data. Transaction data capture the sales and purchases made between firms, most often a byproduct of Value-Added Tax (VAT) records when tax authorities request transaction-level reporting.

Transaction data establish a direct relationship between firms via their sales and purchases to each other allowing for greater understanding of linkages between different economic activities than what can be understood using Input-Output tables (Bacilieri et al., 2023[1]). These datasets can provide an invaluable resource to measure and understand supply chains and open new possibilities for policymakers to not only measure but also to strengthen production networks and their resilience to shocks (Carvalho et al., 2020[2]; Green, Guillouet and Lalanne, 2025[3]). These datasets have been used for research in a growing number of OECD countries, and they are theoretically available in many others but, to date, the use of transaction data has been confined to a few countries over a range of dispersed topics.

To maximise the benefits of these data for policy makers, the OECD, together with DG GROW established the LIFT (Leveraging Inter-Firm Transactions) network. The objective of LIFT is to use this network of stakeholders to pool expertise on the measurement challenges and capabilities of this valuable resource, co-ordinate research using firm-to-firm transaction data and work on common policy questions with a shared methodology. The network also aims, by showcasing the utility of these data to policymakers, to support efforts for greater accessibility and use of VAT for policy research. Finally, the network will also serve as a platform to explore the possibilities of linking VAT data across countries in the future, to move towards a more "complete picture" of interdependencies between OECD economies. This paper is the first output of this endeavor.

The paper shows how VAT data can be used to understand the structure of country production networks. Section 2. discusses the representativeness of the data and how they can be harmonised for cross-country analysis. Section 3. compares summary statistics from production networks across select OECD countries. These stylized facts are important to not only characterise the structure and interconnectedness of individual country economies but highlight emergent features consistent across datasets. The results in this paper are a prototype that includes statistics from Estonia and Croatia. This analysis is being extended to all LIFT network participants currently including Belgium, Greece, Italy, Hungary, Chile, Costa Rica with scope to include other countries in future iterations as the network expands. The work strives to build the largest cross-country comparison of production networks using VAT data to date.

Finally, the work concludes by assessing the options for linking VAT data across countries to understand cross-border supply chains at the firm level. Although national VAT data provide invaluable insights into supply chain resilience and diffusion of industrial policies and economic shocks, the domestic nature of the data, if used in isolation, will fail to give a complete analysis that accounts for foreign suppliers. As this project develops, greater capabilities to link firm-to-firm transactions between countries could open new possibilities to understand these cross-border linkages. This report highlights three potential avenues for further data integration to meet policy needs that transcend borders.

2. Representativeness and cross-country harmonisation of VAT data

VAT transactions can provide a comprehensive representation of the sales and purchases of firms in each country. However, countries have differences in data collection and reporting requirements that can affect coverage of economic activity and comparability across countries. This section outlines differences in VAT data collection and evaluates the representativeness of VAT firm-to-firm transaction data by comparing statistics derived from the VAT data to comparable statistics from National Accounts and Input-Output (I-O) tables. Using aggregates of imported purchases and exported sales by industry from I-O tables, the report evaluates the importance of global value chain flows that are not captured in domestic VAT transactions in each sector. Finally, it discusses the impact of discrepancies in data collection and suggests methods for harmonisation to ensure the comparability of the network statistics produced in section 4.

A. Representativeness of VAT transaction data

VAT transactions can provide a comprehensive representation of the sales and purchases of firms within national borders. However, many countries have thresholds for reporting VAT requiring only firms above a certain size (usually in terms of annual turnover) or transactions above a certain amount to be reported. Table 2.1 reports firm and transaction thresholds in select OECD and OECD accession countries.

Table 2.1. VAT reporting thresholds in select OECD and OECD accession countries

	Years	Firm threshold*	Transaction Threshold
Belgium	2002-	None	EUR 250 / year
Bulgaria“	2016-2017	None	None
Chile	2018	Revenue > EUR 237 500	None
Costa Rica	2008-2019	None	EUR 4500 / year
	2020 – product-level		
Colombia	2006-2012	2006 – EUR 300 000	2006-2007 – EUR 200 (purchases)
	(some product information)	2007-2008 - EUR 100 000	EUR 1 000 (sales)
		2009-2010 – EUR 230 000	2008 – EUR 200
		2011-2012- EUR – 21 000	2009-2012 – EUR 100 (purchases)
			EUR 200 (sales)
Estonia	2015-	Revenue > EUR 40 000**	EUR 1000 / calendar month
Hungary	2015-2018	None	10 000 / year
	2018-2020		1 000 EUR / transaction
	2021-		None
Spain	2008	None	3 000 EUR / year
Türkiye	2006-2020	None	150 EUR / transaction
Brazil“ (One State)	2011-2016	Revenue > EUR 543 000 (2012)	None
Croatia“	2019-2025	2019-2024 – EUR 40 000 2025 – EUR 60 000 (EUR 100 000 for SMEs)	None
Greece	2019-2022	None	None
Italy	2019-	Only limited liability companies	None
Portugal	2010-2022	None	None
Argentina“	2015-2020	Selected large firms	None

Note: *Firms that report VAT are formal firms. Sometimes, thresholds are in effect after being crossed once. **In Estonia, voluntary registration below the threshold is possible and is frequently observed. “Accession country.
Source: OECD LIFT

Given these thresholds, to make inferences about a country's production network, it is important to understand how well VAT data for each country captures total economic activity. As Hötte (2025) discusses, direct comparisons between the level of total firm sales in VAT and Gross Domestic Product (GDP) is not appropriate as the concept of what is considered as "output" from a National Accounts perspective varies substantially to the concept of sales or cash flows, which in VAT sales invoice data. For instance, GDP excludes inventories that would be captured in payment flows between firms but includes government spending or exports and imports that would be excluded from most VAT datasets. How output is measured also varies. For many countries, public services output is assumed to be equal to the cost of inputs, equal to the number of teachers or healthcare workers for instance. In VAT data these sectors would be represented by the sales and purchases they make. Finally, as it will be discussed later in greater detail later in this section, there are differences not only in how output is measured but also how output is allocated among sectors.

Despite these differences, VAT and payments data can capture a real-time value measure of economic activity and as a result, its use of to improve the accuracy and timeliness of GDP has become more prominent in the past decade (ONS, 2018, Statistics Finland, 2023). Table 2.2 reports the correlation of annual GDP and Gross Value Added (GVA) and GDP and GVA growth to total transaction value and transaction growth rate from VAT data for Croatia and Estonia. Total transaction value performs well across all metrics. The performance is slightly better for Croatia than Estonia. While both countries have a firm turnover threshold of EUR 40 000, Croatia has no turnover threshold. But the transaction threshold for Estonia is relatively low and voluntary reporting is allowed so the higher performance of the Croatia VAT data is unlikely to be solely due to better coverage of economic activity. With fewer years of data available for Croatia the impact of the pandemic may have a greater influence on the correlation estimates.

Table 2.2. Correlations of VAT total sales with GDP and GVA

	GDP	GDP growth rate	GVA	GVA growth rate
Croatia (2019-2024)	0.974 (0.001)	0.852 (0.067)	0.978 (<0.001)	0.890 (0.043)
Estonia (2013-2023)	0.460 (0.181)	0.617 (0.077)	0.472 (0.169)	0.657 (0.054)

Note: Pearson correlations (and p-values) between yearly total sales in VAT to yearly GDP and GVA, and between their yearly growth rates.
Source: VAT transactions data, OECD Database (n.d.[4]), Annual GDP and Components - Output Approach, author's calculations.

Next, we evaluate the performance of VAT data against its coverage of different types of economic activity. Transaction and firm thresholds, as well as exemptions of certain products from VAT, will have a different impact on reporting and coverage across sectors. Even more, administrative data are often processed before being made available for research and may therefore not account for redacted or aggregated elements of public sector spending, such as defense, resulting in poorer representation of sectors with large public sector sales or purchases. To evaluate how well different sectors are represented in the VAT data of each country, Large discrepancies between I-O sector output and VAT sales can also be driven by what is counted as a sector's sales compared to what is counted as a sector's output in the National Accounts. For example, because Wholesale and retail acts as an intermediary for the resale of the output of other sectors, a large proportion of its sales aren't counted as Wholesale and retail output in the National Accounts. In VAT data however, where output is measured as cash flow, the resale of goods through a wholesaler is accounted for in the wholesaler's total sales. Differences in these

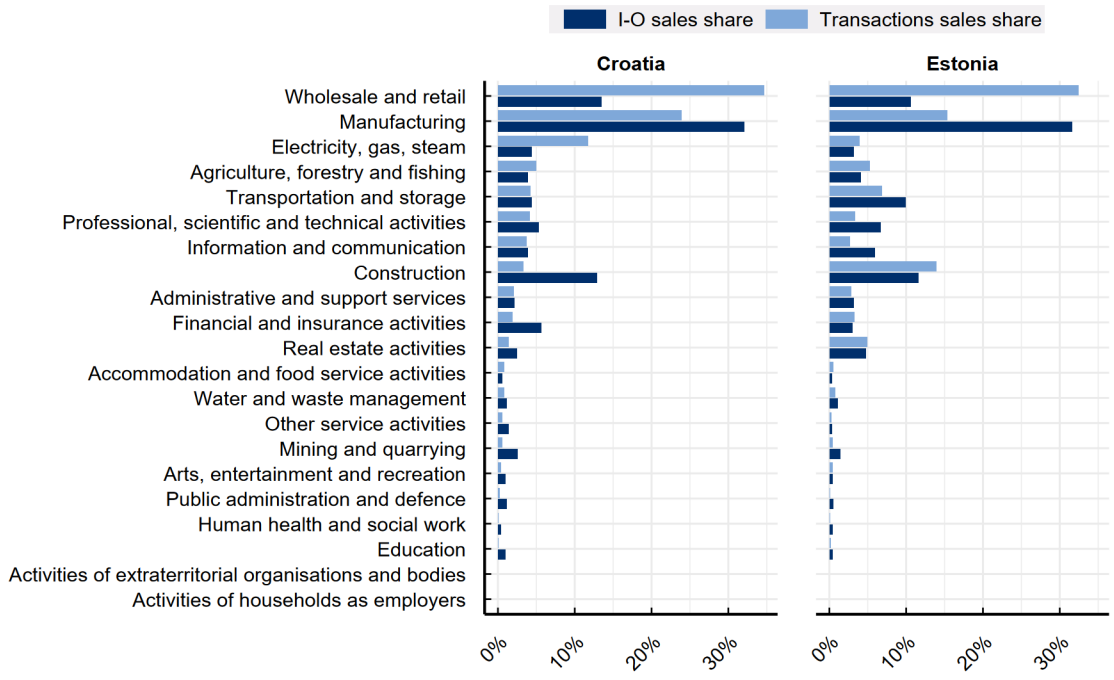
definitions are the drivers of the discrepancies in these sectors. For a further discussion of this issue see Bacilieri et al. (2023[1])2023.

Figure 2.1 reports the percentage of a given industry's sales in VAT data compared to their respective share in the I-O tables for each country.

As expected, sectors such as Education, Health or Public administration that have a large public sector presence are less well represented in VAT data compared to sectors like Accommodation and Food services, Transportation and Storage, Information and Communication technologies (ICT) or Professional Scientific and technical activities.

Large discrepancies between I-O sector output and VAT sales can also be driven by what is counted as a sector's sales compared to what is counted as a sector's output in the National Accounts. For example, because Wholesale and retail acts as an intermediary for the resale of the output of other sectors, a large proportion of its sales aren't counted as Wholesale and retail output in the National Accounts. In VAT data however, where output is measured as cash flow, the resale of goods through a wholesaler is accounted for in the wholesaler's total sales. Differences in these definitions are the drivers of the discrepancies in these sectors. For a further discussion of this issue see Bacilieri et al. (2023[1]).

Figure 2.1. Industry sales shares in VAT and I-O tables



Note: Sectorial composition for Croatia and Estonia in national Input-Output table (blue) and in the VAT transactions data (light blue). Shares are averaged across the years 2019-2020 for Croatia and 2015-2023 for Estonia. Shares do not change significantly in this period. Note that the information for activities of extraterritorial organisations and bodies represents only the transaction sales share, as the I-O do not report on these activities.
Source: OECD National Input-Output Tables (n.d.[5]) and VAT transactions data, author's calculations.

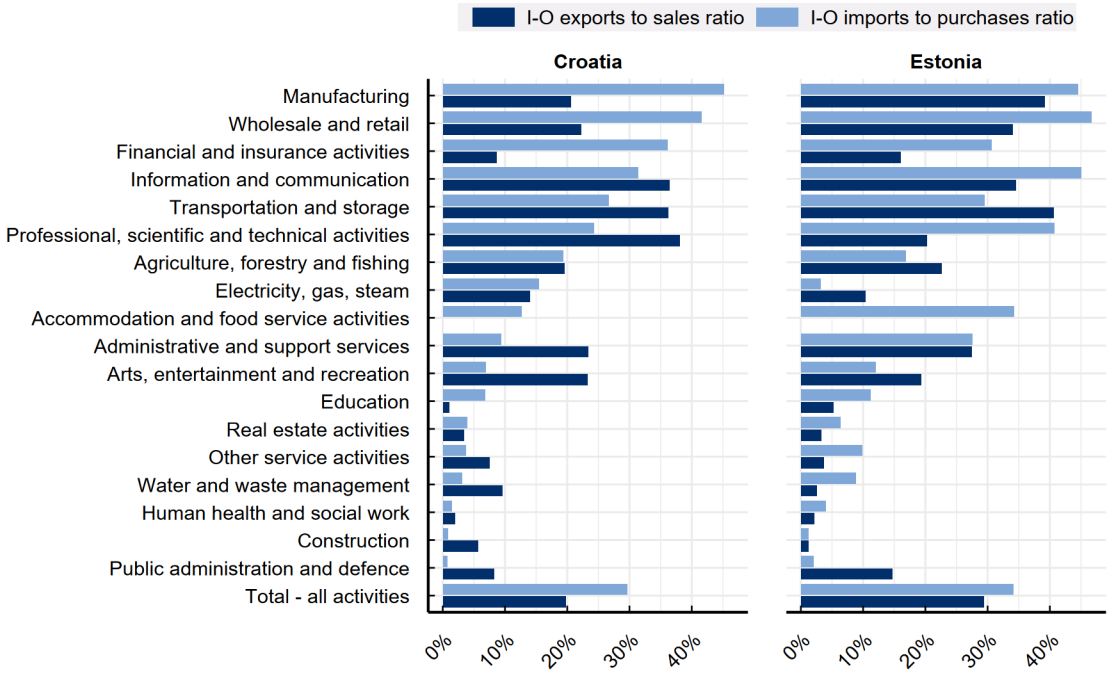
Finally, firm-to-firm transaction data derived from VAT will often identify sales and purchases only between domestic firms. For some countries, interactions with foreign suppliers and customers are only collected for tax purposes as a total amount. In other instances, the VAT identifier of the foreign entity is unknown or can't be linked to the country of origin or to any other

information about the foreign buyer or supplier. Customs data can be a valuable alternative source to fill this gap and understand how embedded a given firm is in global value chains in relation to the domestic production network we observe. However, customs data may not always be available or linkable, if common identifiers for the firm have not been developed or if confidentiality restrictions don't allow linking two such sensitive datasets together. Even when linked, unlike the VAT transaction data, information on trade flows would not be firm-to-firm. To measure the importance of this data gap and the role of global value chains in each sector, proxying for what part of a firm's production network is not captured in domestic VAT transaction data, Figure 2.2 plots the share of output from I-O tables reported for each sector as purchased or sold abroad.

While the integration of each sector in global value chains varies across countries, manufacturing and service industries like ICT, Finance, Wholesale and retail, Transportation and storage and Professional services tend to have a large share of their intermediate consumption and output sourced and sold abroad. Firms in Manufacturing sourced 50% of their intermediate consumption from abroad in Croatia and 45% in Estonia. This suggests that many suppliers of manufacturing firms in these small open economies are likely to be located abroad and estimates of descriptives such as the average number of buyers and suppliers per firm estimated on domestic networks alone may underestimate the resilience of manufacturing supply chains in these countries.

Compared to other sectors, service industry firms in Croatia and Estonia sell a greater share of their output abroad. ICT, Transportation and storage and Professional Scientific and technical activities in Croatia export 35% of their output compared to 20% and 45% respectively in Estonia.

Figure 2.2. Import and export output shares by industry from I-O tables



Note: The share of industry exports out of industry sales (blue), and the share of industry imports out of industry purchases (light blue) in national Input-Output tables for Croatia and Estonia. Shares are averaged across the years for which VAT data is available, these are 2019-2020 for Croatia and 2015-2023 for Estonia. Share values do not experience a significant change in this period.
Source: OECD National Input-Output Tables (n.d.[5]), author's calculations.

B. Harmonisation of transaction data across countries

As shown in Table 2.1, countries have different VAT reporting requirements for firms and transactions so one needs to make sure the data are comparable across countries before computing cross-country stylised facts. When reporting requirements differ, descriptive statistics from transaction data will only capture part of the production network, and differences in the network statistics between countries will reflect, in part, differences in the stringency of these reporting thresholds. For instance, Bacilieri et al. (2023[1]) show that in countries where the entire population of transactions is observed, production networks[1] have similar properties, but some statistics become biased as the reporting threshold for transactions increases. This paper will compare characteristics of production networks across countries. As this work evolves, these estimated descriptive statistics will be compared to statistics estimated on data where the reporting thresholds of the underlying datasets have been harmonised. Below some harmonization methods are briefly discussed.

Simply implementing the most stringent threshold across countries is not a satisfactory method for harmonising the data. A EUR 1 000 transaction threshold, for example, will truncate different shares of a country's network depending on the country's price level and economic development. To compare, in a standardized way, the stringency of reporting thresholds in different datasets, we follow Bacilieri et al. (2023[1]) and adjust transaction thresholds to a country's GDP per capita.[2] Figure 2.3 shows the transaction threshold stringency across countries over time, when normalized in this way.

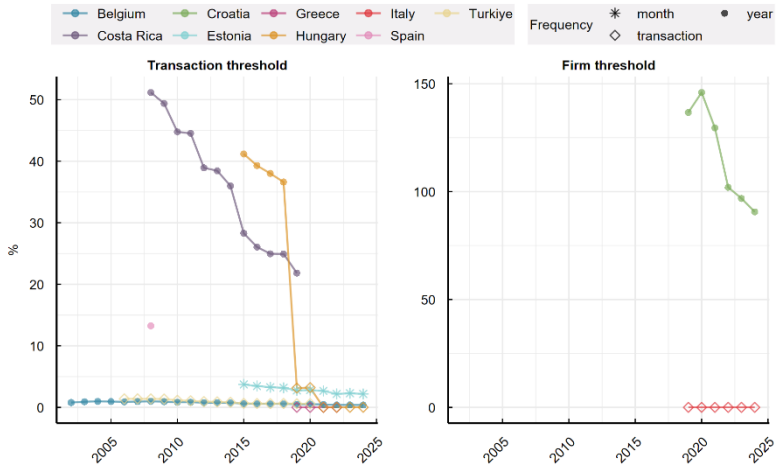
Transaction thresholds range from 51% to 1% of GDP per capita. The 2010 Costa Rica dataset has the most stringent threshold, equivalent to 51% of Costa Rica's GDP per capita. The threshold becomes less stringent over time, as it remains fixed at EUR 4500 while nominal GDP per capita grows, eroding its real value. Estonia and Belgium have the lowest thresholds suggesting that in these countries, close to the entire network of transactions should be observed. Hungary has a relatively high threshold of EUR 10 000 a year, that becomes 1000 EUR per transaction in 2018, equivalent to 5% of GDP per capita. Hungary abolished its transaction threshold in 2021. Bacilieri et al. (2023[1]) find that descriptive network statistics across countries tend to converge when the entire network is observed.

[1] The analysis only does a full harmonised comparison of Hungary and Ecuador and relies on previously published statistics for other countries.

[2] Country thresholds could also be normalised by estimating the most stringent threshold in percentile terms as if the distribution of transactions were not truncated. This will not be explored in this paper but is a method of interest for future analysis.

Figure 2.3. Transaction threshold stringency over time across countries

Transaction threshold as a fraction of GDP per capita



Note: The left-handside panel shows the percentage of GDP per capita that is each country's transaction threshold for reporting VAT while the right handside the percentage of GDP per capita that is each country's firm turnover threshold. Thresholds on monthly transactions have been turned into an annual equivalent.
Source: VAT transactions data, OECD Database (n.d.[6]), Annual GDP and consumption per capita, EUR, current prices, current PPPs, author's calculations.

3. Descriptive statistics from production networks

The structure of a country's production network, the interconnectivity between its firms, the number of interactions and the intensity of its relationships are features that determine how shocks and policy changes ripple through its business population. This section computes and compares such stylised facts on a network's interconnectivity for different countries. To characterise the structure of production networks and understand common features across economies, this section employs a set of statistics commonly used in the literature (Bramoullé, Galeotti and Rogers, 2016[7]; Jackson, 2010[8]). The section below sets out what these statistics are, how they are computed and how they relate to real economic outcomes relevant to policy makers. These stylized facts are grouped into two categories: Statistics capturing a production network's size and structure and descriptives that characterise the strength and frequency of buyer-supplier relationships.

A. Production network size and structure

Table 3.1 reports the total number of firms and connection in a network, the resulting network density, the average number of buyers and suppliers per firm and the average distance (path) between any two firms in the network. The table also reports an estimate measuring how unequally buyers and suppliers are distributed between firms.

Table 3.1. Production network size and structure

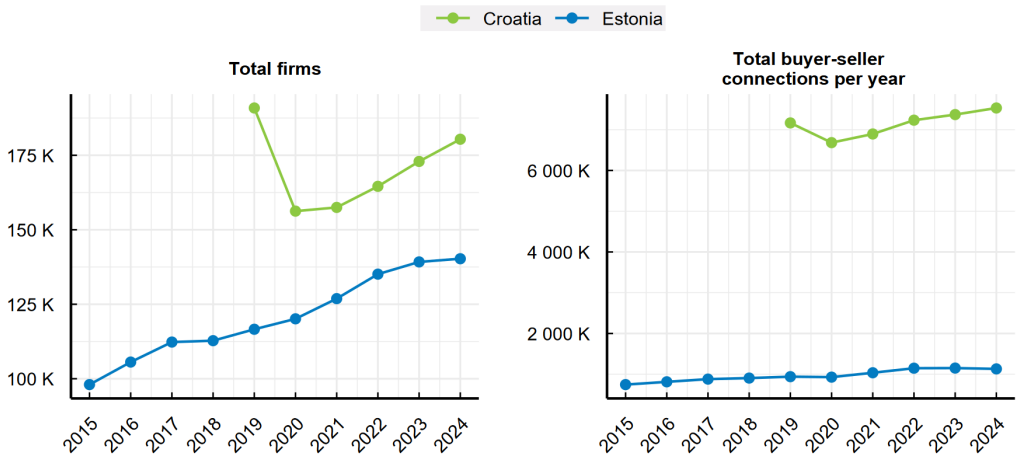
	Number of firms	Total number of yearly transactions	Total transaction value (EUR millions)	Average sellers per firm	Average buyers per firm	Density
Estonia (2015-2023)	116282	941170	30 987	8	8	0.007%
Croatia (2019-2024)	170415	7146809	74 073	42	42	0.02%

Source: VAT transaction data, author's calculations

There is significant variation in the size of production networks among OECD countries. In the countries examined in this work the firm population in VAT datasets is relatively small. For the years of VAT data available Estonia has on average 116 000 firms, while Croatia has 170 000 firms. Figure 3.1 reports network size for these two countries over time. Depending on firm entry and exit reported, a steady and small rise in the number of firms is to be expected. There have been no significant changes in reporting requirements to herald changes in the number of firms over time, as a consequence of changes in the stringency of reporting thresholds or other changes in data collection. It is interesting that the impact of the pandemic in Croatia is quite pronounced in the business population observed in the VAT data.

A greater number of firms doesn't necessarily translate to a proportionately greater number of buyer or supplier relationships. Depending on the country's industry mix, the competitiveness and diversification of its supply chains, the set of relationships may be rich, with many intermediate inputs, sourced from different suppliers that span across sectors or may be sparser. As shown in Figure 3.1, the Croatia production network has 1.5 times the number of firms compared to the Estonian network but has 7.6 times the number of transactions. There are on average 7.1 million buyer-supplier relationships in Croatia and 941 thousand buyer-supplier relationships in Estonia.

Figure 3.1. Number of firms and buyer-seller relationships per year in OECD production networks

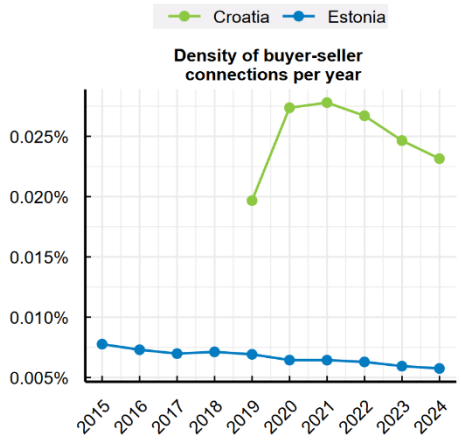


Note: Total number of firms in the network (top left), total number of buyer-seller connections (top right), and density of the network (bottom) across years.
Source: VAT transactions data, author's calculations.

This means the Croatian production network is denser in firm connections. Figure 3.2 reports the density of each country's economy as captured from its VAT data. Density is measured as the percentage of all potential relationships between firms that are present in the data. A completely connected production network, where all firms are buyers and suppliers of all other firms in the economy would have a density of one or 100%. An economy where most firms never interact with most other firms would have a density closer to zero. Indeed, Croatia has a denser network with an average density of 0.02% compared to 0.007% in Estonia. Such low estimates of country-wide densities are common. Because many production processes have a specialised set of intermediate inputs, and small and medium sized firms, that often comprise the majority of a country's business population, tend to have few buyers, production networks tend to be sparse.

Density in buyer supplier relationships matters for the role production networks play in economic growth. Density is often seen as a measure of diversification and variety in supply chains (Acemoglu, Ozdaglar and Tahbaz-Salehi, 2015[9]; Miranda-Pinto, 2021[10]). Economies whose production networks have lower density than anticipated for their size have been found to have lower GDP per capita (Gloria, Miranda-Pinto and Fleming-Muñoz, 2024[11]; Criscuolo et al., 2024[12]). Gloria Miranda-Pinto and Fleming-Muñoz[11] attribute this association between density and GDP per capita to less diversification in intermediate inputs and smaller amplification of positive shocks in sparser networks.

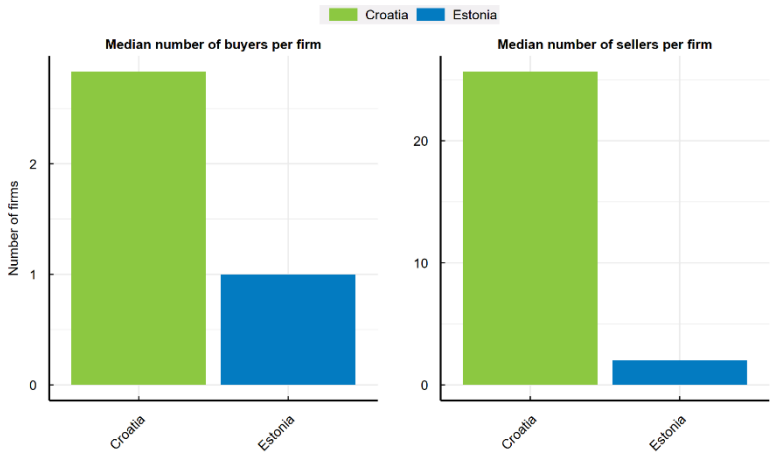
Figure 3.2. Density of buyer-supplier relationships



Note: Density refers to $\frac{\text{number of observed buyer-seller connections}}{\text{number of all potential buyer-seller connections}}$. If N is the total number of firms, the number of all potential connections in a network is calculated as N*(N-1).
Source: VAT transactions data, author's calculations.

Density provides an aggregate and rough measure of the network's ability to amplify economic and policy shocks but to understand how well connected a typical firm is Figure 3.3 reports the median number of buyers and suppliers for each country network. The firm with the median number of buyers, that is, the firm that has more buyers than 50% of other firms, has 3 buyers in Croatia and 1 buyer in Estonia, while the firm with the median number of suppliers has 25 suppliers and 2 respectively.

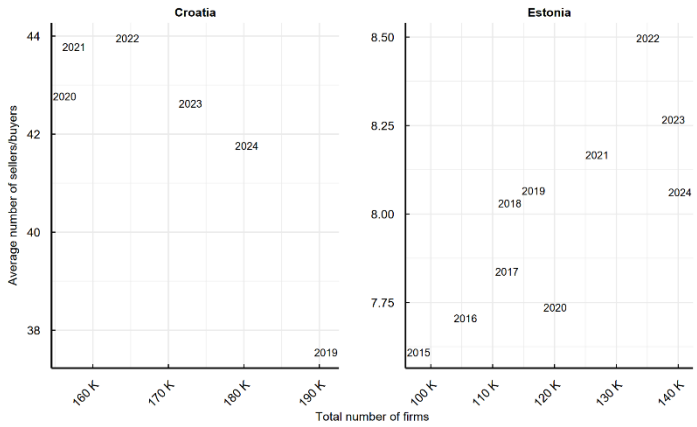
Figure 3.3. Median buyers and sellers per firm



Note: Median buyers per firm (out-degree, left panel) and median sellers per firm (in-degree, right panel), averaged across years 2015-2024 for Estonia, and across 2019-2024 for Croatia.
Source: VAT transactions data, author's calculations.

The average number of buyers and suppliers varies significantly from that of the median. Figure 3.4 plots the average number of firm relationships per year against the size of the production network for each country. The average buyers and suppliers per firm, over the years available, are 42 in Croatia and 8 in Estonia. This disparity between the median and the average suggests there is significant inequality among firm relationships. The average number is broadly stable for Croatia but increases with the size of the network in Estonia following the increase in the number of firms observed earlier.

Figure 3.4. Average number of buyers and number of sellers per firm against total number of firms



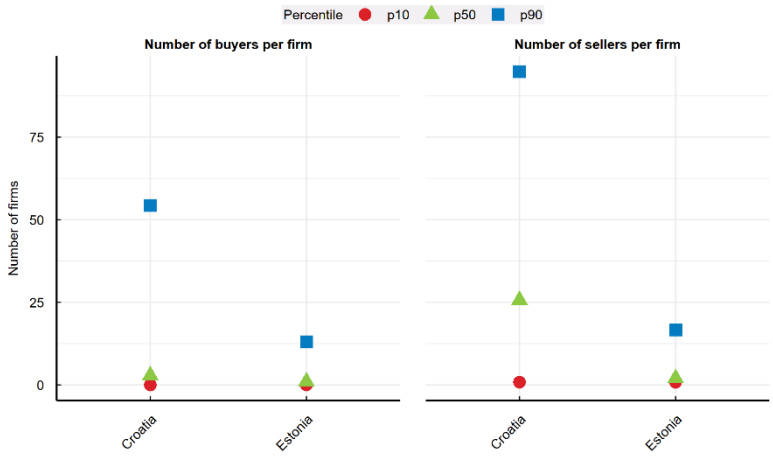
Note: Average number of buyers per firm (out-degree) and average number of sellers per firm (in-degree) across years against the total number of firms (nodes) in the Croatia and Estonia networks. Average number of buyers per firms, which is identical to the average number of sellers per firms, is calculated by first counting for every firms the number of buyers it has in one year, and then taking an average of this quantity across firms.
Source: VAT transactions data, author's calculations.

Measures of the average number of buyers and suppliers capture the immediate influences of the average firm. Inequality in these "immediate influences" among firms matters.

Production networks with large inequalities between firm relationships are thought to be susceptible to greater propagation of economic and policy shocks that affect the few well connected firms in the economy (Acemoglu et al., 2012[13]), sometimes referred to as "key players". In sparce networks with large inequalities, disrupting just a few critical relationships can destabilise supply chains, creating bottlenecks or shortages (Carvalho, Elliott and Spray, 2024[14]). As a result, inequality measures are important for understanding a network's fragility.

To understand the disparity between the most and least embedded firms in their respective production networks Figure 3.4 calculates the number of buyers and suppliers for firms at the 90th and 10th percentiles of the distribution of buyers and suppliers per firm. The firm with more buyers than 90% of other firms has 54 buyers in Croatia and 13 in Estonia, the firm with more suppliers than 90% of other firms has 94 suppliers whereas in Estonia only 17. Firms at the 10th percentile on the other hand have no buyers and 1 supplier in both Croatia and Estonia. In terms of immediate relationships, the outcomes of the most connected firms in Croatia affect almost 100 times more firms in the economy than their least connected counterparts.

Figure 3.5. Number of buyers and sellers per firm percentiles



Note: Percentiles of buyers per firm (out-degree, left panel) and sellers per firm (in-degree, right panel) averaged by year, across 2015-2024 for Estonia, and 2019-2024 for Croatia.
Source: VAT transactions data, author's calculations.

Future research will also explore other measures of inequality in production networks such as estimates of the tail exponent[3] of the distribution of buyers and suppliers which can also be used to summarises the incidence of disproportionally well-connected firms in the network.

B. Strength of buyer supplier relationships

Not all relationships are equal. Relationships between firms that involve large or frequent transactions, or a track record of sales or purchases consistently over the years may be more influential for firms than relationships captured by infrequent transactions that comprise only a small share of a firm's sales or purchases. Amiti et al., (2024[15]) for instance, consider as "serious" and influential relationships only relationships that comprise at least 10% of the sales of the seller.

[3] The tail exponent captures how quickly the probability of observing firms with an unusually large number of buyers or suppliers decreases as those values become more extreme. If the tail exponent is large, then the tail (the far end of the distribution) decays quickly so extreme values are rare, if it is small then extreme values are more common.

Table 3.2 reports the strength of the average relationship as the average annual transaction value between a buyer and a seller, the average transaction frequency, and the average share of a given transaction in a seller's total sales or a buyer's total purchases.

Table 3.2. Strength of buyer supplier relationships in production networks

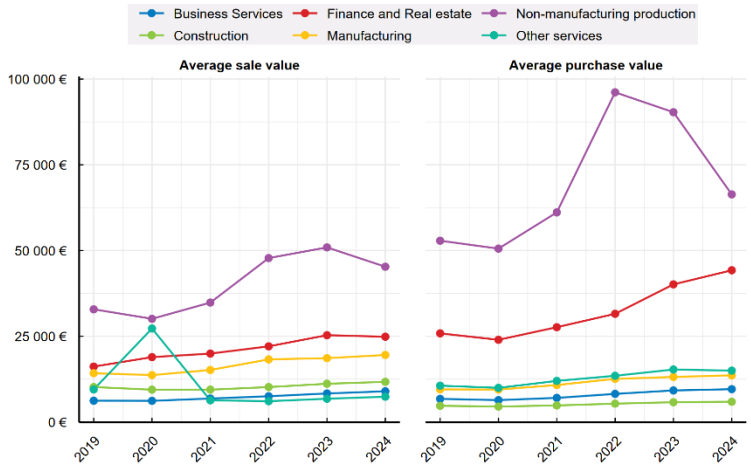
	Average yearly transaction value (EUR)	Average share of transaction value over total firm sales (%)	Average share of transaction value over total firm purchases	Average number of transactions per year between a buyer and a seller
Estonia (2015-2023)	32 045	7%	11%	3
Croatia (2019-2024)	10 300	1.9%	2.1%	11

Source: OECD author calculations using VAT transaction data

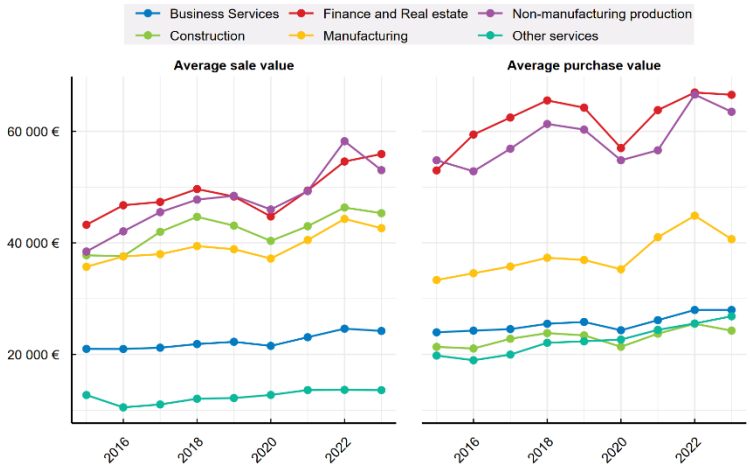
In Croatia, the average business-to-business relationship consists of sales and purchases equivalent to EUR 10 300 roughly whereas in Estonia EUR 32 000. This varies significantly by sector. Figure 3.7 shows the average yearly transaction value of a sale or a purchase by industry category for Croatia and Estonia. Non-manufacturing production and finance stand out in both countries as the sectors with the highest value relationships.

Figure 3.6. Average yearly transaction value between a buyer and a seller in Croatia and Estonia, by industry category

Croatia :



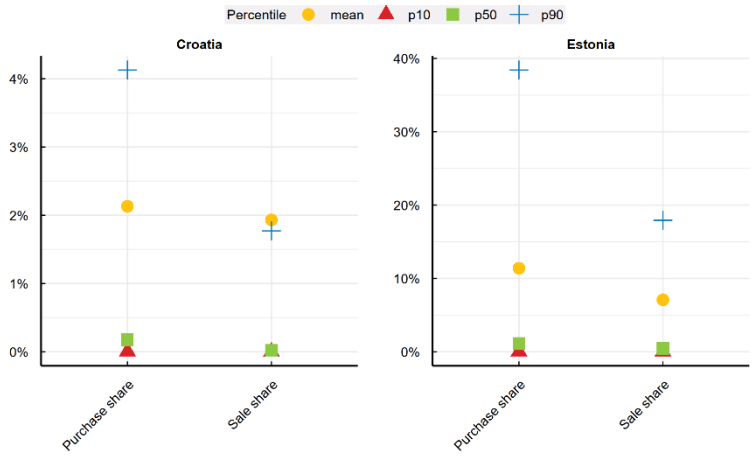
Estonia:



Note: Top: Average yearly sale and purchase transaction value between a buyer and a seller in Croatia, by industry excluding activities of extraterritorial organisations and bodies (U) and electricity, gas, steam (D). Bottom: Average sale and purchase value for Croatia, by industry category, excluding activities of households as employers. Business Services include: wholesale and retail trade; repair of motor vehicles and motorcycles; accommodation and food service activities; transportation and storage; information and communication; professional, scientific and technical activities; administrative and support service activities. Non-manufacturing production includes: agriculture, forestry and fishing; mining and quarrying; electricity, gas, steam and air conditioning supply; water supply; sewerage, waste management and remediation activities. Other services include: public administration and defence; compulsory social security; education; human health and social work activities; arts, entertainment and recreation; other service activities; activities of extraterritorial organisations and bodies.
Source: VAT transactions data, authors' calculations.

Relationship strength can determine how important the influence of a particular buyer-supplier relationship is for a firm's outcomes. Purchase and sales value is a determinant of relationship strength but what may be more relevant is how transaction value relates to firm turnover and intermediate consumption. Figure 3.7 reports the average share of a firm's sales or purchases against its sales and purchase total. The greater a firm's sales share the more concentrated its sales are to a few buyers and suppliers and the more exposed its survival and performance to the survival and performance of these firms. Figure 3.7 suggests that buyer-supplier relationships among Croatian firms are relatively diversified, consistent with the high density estimates found earlier. The average relationship makes up only 2% of the seller's total sales and buyer's purchases. Dispersion is quite small, even for firms whose relationships are most concentrated, making up a greater share of their total sales, they on average depend on any buyer only for 4% of their estimated turnover. The average relationship in Estonia makes up 11% of a buyer's purchases and 7% of a seller's sales. There is however larger dispersion in concentration of transactions from one partner firm. The firms most dependent on another firm for its sales sell 20% to that firm or buy 40% of their intermediate consumption form that supplier. Unfortunately, this excludes the dependencies on foreign buyers and suppliers. The next section discusses ways to integrate cross-border relationships into these statistics in the future.

Figure 3.7. Sale share and purchase share distribution for Croatia and Estonia

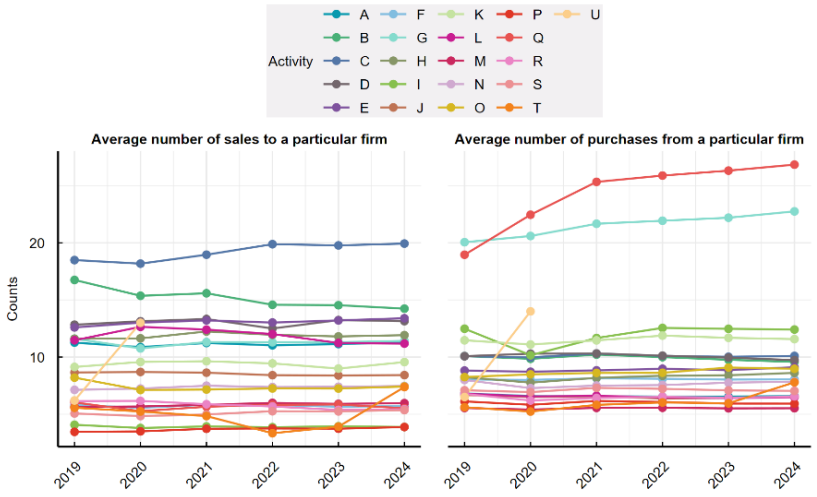


Note: The distribution of shares of a yearly sale to (purchase from) a single buyer (seller) out of the firm's total yearly sales (purchase).
Source: VAT transactions data, author's calculations.

Finally, a buyer-supplier relationship made up of a one-off interaction, even if comprising a large share of purchases in that year may be less influential than one where the two firms interact repeatedly during any given year. Repeated interactions may capture strategic interdependence on the input of that firm for the production process of the buyer, such as leasing costs of essential machinery or a subscription to vital software. In Croatia, the average transaction frequency between a buyer and a seller was 11 transactions a year but the median relationship consists of only 2 transactions.

Figure 3.8 plots the average transaction frequency for different industries. With the exception of an increase in the purchases of firms in the Health sector (Q) following the pandemic, transaction frequency is broadly stable over time consistent with the hypothesis that it captures something fundamental about the production function of a typical firm in that sector. Firms in Manufacturing (C) have the greatest number of interactions with their buyers in a given year, consisting of 20 transactions on average, whereas, aside from Health, firms in Wholesale and retail have the most frequent interactions with their suppliers.

Figure 3.8. Average number of transactions per year between a buyer and a seller in different industries in Croatia



Note: Average number of sales (purchases) per firm from (to) a particular buyer (seller).
Source: VAT transactions data, author's calculations.

4. Options for linking VAT across countries

In this report we have explored some preliminary findings on the structure of supply chains from VAT data from OECD countries. In an increasingly interconnected world, however, firms source their inputs and sell their products both domestically and abroad, and various borders may be crossed for different inputs to be combined into what reaches final demand. Even though these integrated value chains transcend country borders, transaction-level VAT data do not. As a result, the results from this report will always be somewhat limited. As this project develops, greater capabilities to link firm-to-firm transactions between countries will open new possibilities to understand these cross-border linkages between production networks. Engaging with country partners for the analysis presented in this report highlighted three potential avenues for further data integration to meet policy needs that transcend borders.

A. Linking datasets in a trusted secure environment

One option could be to simply link VAT data from two countries within a common, secure, environment. In this secure environment, the data could be linked using unique firm identifiers. While the linking across datasets, subject to the data being accessible in the same environment, is not a constraint, differences in the legal and regulatory frameworks that govern data sharing in different countries, as well as the important coordination efforts required by statistics and tax authorities whose remit and objectives may not be served by such cross-border data sharing, are significant barriers. For instance, for the data to be de-identified and still be possible to link transactions across countries, data owners would need to work together to produce unique firm identifiers corresponding to VAT registration numbers or the original VAT identifiers would need to be available to the linking party, increasing the risks of data sharing for data owners. Despite these difficulties, bilateral efforts by individual statistics authorities to experiment with secure ways of linking firm-to-firm transactions across borders have been made, including a recent pilot using mock data by the Netherlands and Canada statistics authorities (Dasylva et al., 2025[20]). The ambition is that the research produced by the LIFT network, will showcase the value of this data to policymakers and provide a strong use case for such linking efforts to be scaled.

B. Releasing firm-level information in one country to be connected to a second country.

Another option would be for only specific firm level network statistics, such as a firm's centrality index, that cannot be traced back to individual firm-level data, such as a firm's turnover, to be shared for linkage with another country's transaction data. In countries where there are thresholds for reporting VAT, the data would still require co-operation between data owners to be shared in a secure environment as the reporting of information by a firm's VAT identifier would reveal that the turnover of that firm is at least as large as the reporting threshold. Differences in the legal frameworks for sharing data among OECD countries would still be a constraint but lowering the disclosure risk by lowering the requirement to firm-aggregated, and not transaction level information, may offer greater scope for solutions that are consistent with different legal data sharing requirements. In countries where all firms are required to submit VAT information the constraints would not be as strict, although collaboration for secure sharing of information between data owners may still be a requirement in absence of a public record of VAT identifiers.

C. Use machine learning and econometric tools to study what can be inferred about supply chain linkages in the absence of linking.

Finally, the least demanding option in terms of data-sharing would be the use of machine learning and econometric tools to carry out supply chain reconstruction, to estimate links

between firms in absence of firm-to-firm cross border transaction data. The European Statistical System (ESS) is already leading efforts to understand domestic networks in countries where data is absent through its work program: “Applying machine learning methods for estimating firm-level supply chain networks” (Eurostat CROS, 2024[21]). The program is a four-year investment led by the Statistics Netherlands. Depending on the research question, it may not even be necessary to link the VAT data, and/or techniques for network reconstruction may be a suitable substitute.

References

Acemoglu, D. et al. (2012), "The Network Origins of Aggregate Fluctuations", *Econometrica*, Vol. 80/5, pp. 1977-2016, https://doi.org/10.3982/ecta9623. [13]

Acemoglu, D., A. Ozdaglar and A. Tahbaz-Salehi (2015), "Systemic Risk and Stability in Financial Networks", *American Economic Review*, Vol. 105/2, pp. 564-608, https://doi.org/10.1257/aer.20130456. [9]

Amiti, M. et al. (2024), "FDI and superstar spillovers: Evidence from firm-to-firm transactions", *Journal of International Economics*, Vol. 152, p. 103972, https://doi.org/10.1016/j.jinteco.2024.103972. [15]

Andrews, D., C. Criscuolo and P. Gal (2016), "The Best versus the Rest: The Global Productivity Slowdown, Divergence across Firms and the Role of Public Policy", *OECD Productivity Working Papers*, No. 5, OECD Publishing, Paris, https://doi.org/10.1787/63629cc9-en. [43]

Andrews, D., C. Criscuolo and P. Gal (2015), "Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries", *OECD Productivity Working Papers*, No. 2, OECD Publishing, Paris, https://doi.org/10.1787/5jrql2q2jj7b-en. [40]

Bacilieri, A. et al. (2023), "Firm-level production networks: what do we (really) know?", in *INET Oxford Working Paper No. 2023-08*, https://oms-inet.files.svdcdn.com/production/files/Firm-level-production-networks-what-do-we-really-know.pdf. [1]

Balboni, C., J. Boehm and M. Waseem (2024), "Firm Adaptation in Production Networks: Evidence from Extreme Weather Events in Pakistan", *Working Paper*, https://jmboehm.github.io/Pakistan_Floods.pdf. [35]

Banerjee, A. et al. (2013), "The Diffusion of Microfinance", *Science*, Vol. 341/6144, https://doi.org/10.1126/science.1236498. [26]

Baqaee, D. et al. (2025), "Consumer Surplus from Suppliers: How Big is it and Does it Matter for Growth", http://www.econ.ucla.edu/arielb/extensivemargin.pdf. [23]

Barrot, J. and J. Sauvagnat (2016), "Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks *", *The Quarterly Journal of Economics*, Vol. 131/3, pp. 1543-1592, https://doi.org/10.1093/qje/qjw018. [36]

Battiston, S. et al. (2012), "DebtRank: Too Central to Fail? Financial Networks, the FED and Systemic Risk", *Scientific Reports*, Vol. 2/1, https://doi.org/10.1038/srep00541. [28]

Berlingieri, G., P. Blanchenay and C. Criscuolo (2017), "The great divergence(s)", *OECD Science, Technology and Industry Policy Papers*, No. 39, OECD Publishing, Paris, https://doi.org/10.1787/953f3853-en. [41]

Berlingieri, G. et al. (2020), "Laggard firms, technology diffusion and its structural and policy determinants", *OECD Science, Technology and Industry Policy Papers*, No. 86, OECD Publishing, Paris, https://doi.org/10.1787/281bd7a9-en. [42]

Bernard, A. et al. (2022), "The Origins of Firm Heterogeneity: A Production Network Approach", *Journal of Political Economy*, Vol. 130/7, pp. 1765-1804, https://doi.org/10.1086/719759. [34]

Boehm, C., A. Flaaen and N. Pandalai-Nayar (2019), "Input Linkages and the Transmission of Shocks: Firm-Level Evidence from the 2011 Tōhoku Earthquake", *The Review of Economics and Statistics*, Vol. 101/1, pp. 60-75, https://doi.org/10.1162/rest_a_00750. [38]

Borgatti, S. (2005), "Centrality and network flow", *Social Networks*, Vol. 27/1, pp. 55-71, https://doi.org/10.1016/j.socnet.2004.11.008. [25]

Bramoullé, Y., A. Galeotti and B. Rogers (eds.) (2016), *The Oxford Handbook of the Economics of Networks*, Oxford University Press, https://doi.org/10.1093/oxfordhb/9780199948277.001.0001. [7]

Carvalho, M., M. Elliott and J. Spray (2024), . [14]

Carvalho, V. et al. (2020), "Supply Chain Disruptions: Evidence from the Great East Japan Earthquake*", *The Quarterly Journal of Economics*, Vol. 136/2, pp. 1255-1321, https://doi.org/10.1093/qje/qjaa044. [2]

Chacha, P., B. Kirui and V. Wiedemann (2024), "Supply Chains in Times of Crisis: Evidence from Kenya's Production Network", *World Development*, Vol. 173, p. 106363, https://doi.org/10.1016/j.worlddev.2023.106363. [30]

Corrado, C. et al. (2021), "New evidence on intangibles, diffusion and productivity", *OECD Science, Technology and Industry Working Papers*, No. 2021/10, OECD Publishing, Paris, https://doi.org/10.1787/de0378f3-en. [32]

Criscuolo, C. et al. (2024), "Estonia's firm-level production network: Lessons for industrial policy", *OECD Science, Technology and Industry Working Papers*, No. 2024/13, OECD Publishing, Paris, https://doi.org/10.1787/e0f18b9c-en. [12]

Criscuolo, C. et al. (2024), "Estonia's firm-level production network: Lessons for industrial policy", *OECD Science, Technology and Industry Working Papers*, No. 2024/13, OECD Publishing, Paris, https://doi.org/10.1787/e0f18b9c-en. [19]

Dasylva, A. et al. (2025), "Private linkage of international trade microdata in a cloud-based secure enclave", *Statistical Journal of the IAOS*, https://doi.org/10.1177/18747655251355704. [20]

Denbee, E. et al. (2021), "Network risk and key players: A structural analysis of interbank liquidity", *Journal of Financial Economics*, Vol. 141/3, pp. 831-859, https://doi.org/10.1016/j.jfineco.2021.05.010. [29]

Eurostat CROS (2024), *https://cros.ec.europa.eu/book-page/one-stop-shop-artificial-intelligence-and-machine-learning-official-statistics-aiml4os*. [21]

Gelez Alvarez, D. (2023), *An Empirical Study of the Di usion of Foreign Shocks in Production Networks*, Yale Graduate School of Arts and Sciences Dissertations, https://elischolar.library.yale.edu/gsas_dissertations/915/. [37]

Gloria, J., J. Miranda-Pinto and D. Fleming-Muñoz (2024), "Production network diversification and economic development", *Journal of Economic Behavior & Organization*, Vol. 218, pp. 281-295, https://doi.org/10.1016/j.jebo.2023.12.006. [11]

Green, A., L. Guillouet and G. Lalanne (2025), "The transmission of foreign shocks to the Estonian production network", *OECD Science, Technology and Industry Working Papers*, No. 2025/12, OECD Publishing, Paris, https://doi.org/10.1787/7ea2b48e-en. [3]

Hötte K. (2025), "Mapping the disaggregated economy in real-time: Using granular payment network data to complement national accounts, Working Paper: https://arxiv.org/pdf/2407.14776 [8]

Jackson, M. (2010), *Social and Economic Networks*, Princeton University Press, https://doi.org/10.2307/j.ctvcm4gh1.

Khanna, G., N. Morales and N. Pandalai-Nayar (2025), "Supply Chain Resilience: Evidence from Indian Firms", *Federal Reserve Bank of Richmond Working Paper Series* WP 22-11, https://www.richmondfed.org/-/media/RichmondFedOrg/publications/research/working_papers/2022/wp22-11.pdf. [31]

König, M., X. Liu and Y. Zenou (2014), "R&D Networks: Theory, Empirics and Policy Implications", *CEPR Discussion Paper*, No. DP9872, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2444893. [27]

Lafrogne-Joussier, R., J. Martin and I. Mejean (2022), "Supply Shocks in Supply Chains: Evidence from the Early Lockdown in China", *IMF Economic Review*, Vol. 71/1, pp. 170-215, https://doi.org/10.1057/s41308-022-00166-8. [33]

Miranda-Pinto, J. (2021), "Production network structure, service share, and aggregate volatility", *Review of Economic Dynamics*, Vol. 39, pp. 146-173, https://doi.org/10.1016/j.red.2020.07.001. [10]

OECD (2025), "Transaction data for evidence-based industrial policy", *OECD Science, Technology and Industry Policy Papers*, No. 178, OECD Publishing, Paris, https://doi.org/10.1787/46d7c123-en. [22]

OECD (2021), *MultiProd*. [39]

OECD (n.d.), *Annual GDP and Components - Output Approach*, OECD, Paris, https://data-explorer.oecd.org/s/2x3. [4]

OECD (n.d.), *Annual GDP and consumption per capita, US $, current prices, current PPPs*, https://data-explorer.oecd.org/s/2xd. [6]

OECD (n.d.), *National Input-Output Tables (IOTs), 2023 edition*, https://www.oecd.org/sti/ind/input-outputtables.htm. [5]

ONS (2018), "VAT turnover data in National Accounts: background and methodology", Office for National Statistics, https://www.ons.gov.uk/economy/grossdomesticproductgdp/methodologies/vatturnoverdatainnationalaccountsbackgroundandmethodology

Padgett, J. and C. Ansell (1993), "Robust Action and the Rise of the Medici, 1400-1434", *American Journal of Sociology*, Vol. 98/6, pp. 1259-1319, https://doi.org/10.1086/230190. [24]