SUERF
The European Money and Finance Forum

SUERF Policy Brief
No 803, February 2024

The need for a better map of the global supply network*

By Anton Pichler (Vienna University of Economics and Business & Complexity Science Hub Vienna—CSH), Christian Diem (CSH), Alexandra Brintrup (University of Cambridge), François Lafond (University of Oxford), Glenn Magerman (Université Libre de Bruxelles & CEPR), Gert Buiten (Centraal Bureau voor de Statistiek), Thomas Choi (Arizona State University & Complex Adaptive Supply Networks Research Accelerator), Vasco Carvalho (University of Cambridge, CEPR, Alan Turing Institute & European Economic Association), J. Doyne Farmer (University of Oxford & Santa Fe Institute), and Stefan Thurner (Medical University of Vienna, Santa Fe Institute & CSH)

Keywords: production networks, supply chains, inflation, emission accounting, supply disruptions.
JEL codes: C80, D57, L14.

In recent years, the availability of detailed supply network data has revolutionized economic analysis. These granular maps of the economy promise immense potential for addressing pivotal policy objectives such as mitigating inflation, accurately measuring indirect greenhouse gas emissions, and securing the provision of critical goods. Until now, supply networks have been predominantly mapped at the national level, highlighting the necessity for coordinated international efforts to more effectively reconstruct supply linkages crossing country borders. With the anticipated enhancement of global supply network maps in the near future, it is essential to engage in a dialogue about the responsible management and effective use of these data for the greater global benefit.

*This Policy Brief is based on Pichler et al (2023), "Building an alliance to map global supply networks", Science, 382 (6668), 270-272. Acknowledgments: Figures have been created with the help of L. Yang.

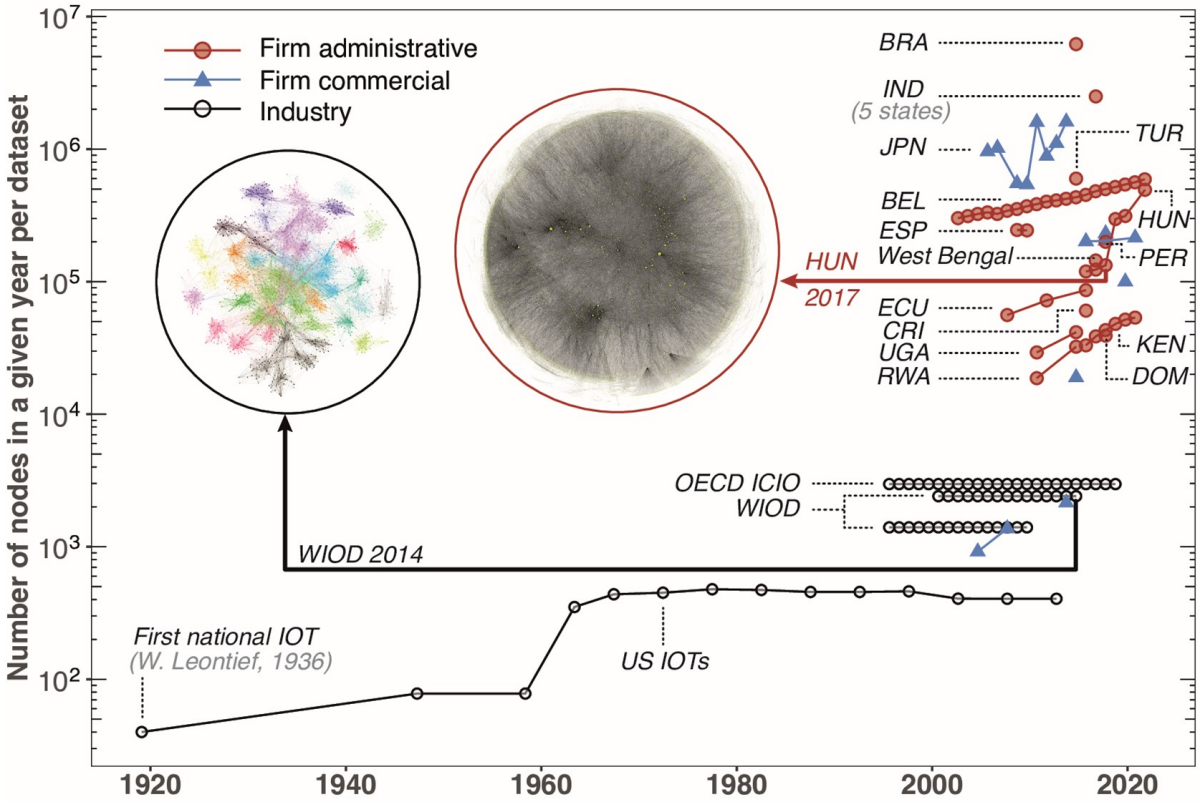
Globally, over 300 million firms are connected through a complex network of an estimated 13 billion supply links[1]. These connections are critical for the production, processing, and delivery of everyday items, such as food, medical supplies, as well as technologies and services that are crucial for maintaining critical infrastructures and national security. Despite their importance in ensuring the smooth functioning of the economy, our understanding of the interdependencies in these supply chains remains surprisingly limited.

In our recent publication in Science, we highlight that this knowledge gap has left us ill-prepared to respond quickly and effectively to economic challenges, as evidenced by the prolonged shortages in raw materials and critical medical supplies during the COVID-19 pandemic. For example, supply disruptions in 2021 led to an estimated 2% loss of global GDP (roughly USD 1.9 trillion), and substantially contributed to the recent surge in inflation[2]. To better manage and mitigate such adverse economic impact, a more detailed understanding of domestic and international supply dependencies at a granular level is essential.

The rise of supply network data

Until very recently, supply network data had been limited to a few hundred firms or industries (traditional input-output tables). In the past decade, a supply network data revolution has begun, enabled by progress in several dimensions, including payment data, value-added tax (VAT) data, and methods for reconstructing missing data[3]. Through these efforts, the scope of supply chain data has increased by several orders of magnitude, allowing for a better picture of the real economy with unprecedented granularity. This process is still ongoing, as illustrated in Fig. 1.

Figure 1: The revolution in supply network data availability



Notes: The size of supply network data sets expanded rapidly in the last decade. For firm (industry)-level datasets, size is measured by the number of nodes, i.e., firms (economic sectors or sector-country pairs). For much of the twentieth century, national input-output tables containing up to a few hundred sectors were the most granular representation of supply networks. Recently firm-level supply network data sets have become available, containing hundreds of thousands and millions of nodes.

[1] See Pichler et al. (2023).

[2] See Celasun et al. (2022).

[3] See Bacilieri et al. (2023).

An important enabler of the recent surge in supply network data are country-wide administrative VAT datasets. In some countries, VAT is reported at the level of individual transactions, allowing the recovery of virtually all domestic business-to-business trades.

The potential of large-scale firm-level supply network data to boost the development of a new generation of firm-level economic models has been demonstrated in recent research. For example, based on detailed Japanese supply network data of several million firm-level supply links, it has been possible to model the indirect countrywide economic impacts of the 2011 Great East Japan Earthquake in unprecedented detail[4]. VAT-based firm-level supply network data has been leveraged to quantify the macroeconomic impact of *individual* firms in case of failure[5], to detect tax fraud[6] or to understand the widespread - but indirect - reliance of firms on international supply chains and imported inputs, even when the typical firm itself does not directly import[7]. Moreover, predictions of economic models that are based on firm-level VAT data can differ substantially from the predictions of the same models based on industry-level data.[8]

As recent events have shown, supply networks play a crucial role as a potential driver of inflation. Cost shocks to individual firms directly affect consumption prices as suppliers to final demand and indirectly as suppliers to firms that ultimately supply final demand. The exact impact on consumption prices and inflation depends on the production network structure and the amount of cost-price pass-through[9]. Firm networks define the micro origins of aggregate price fluctuations. Without detailed information on these networks, the impact of cost shocks or optimal monetary policy simply remains ephemeral.

Mapping the supply network of the European Union

While high-resolution maps of firm-level supply networks have recently been charted for individual economies, the international image remains highly fragmented. In our publication, we provide a blueprint of how a granular supply network map beyond country borders could be achieved within the European Union (EU).

As a first step, it is necessary to collect national firm-to-firm trades through granular VAT records, as is already done in countries like Spain, Belgium, Hungary, and Bulgaria. The next step requires connecting different countries based on trade data. The EU already integrates data on the trade of goods between member countries. Reconstructing the EU supply network at the firm level would require an extension of this data to all goods and services and to merge them with the domestic VAT data. The EU Commission's proposal on *VAT in the Digital Age* (ViDA) could serve as the underlying legal framework. Doing this would result in the first comprehensive multi-country firm-level supply network, representing nearly 20% of world GDP.

The EU could further enlarge its map of supply-chain dependencies to partially include non-member countries by merging its supply network data with customs data. Customs data feature excellent coverage and detail on international firm-level trade and have already been linked with domestic VAT-based supply networks[7]. The supply network of EU firms and their linkages to non-EU trading partners would yield a granular view into supply chain dependencies that cover almost 40% of global trade. Missing information in these maps can be augmented by modern AI techniques[10,11].

[4] See Carvalho et al. (2021).

[5] See Diem et al. (2022).

[6] See Alexopoulos et al. (2020).

[7] See Dhyne et al. (2021).

[8] See Diem et al. (2024).

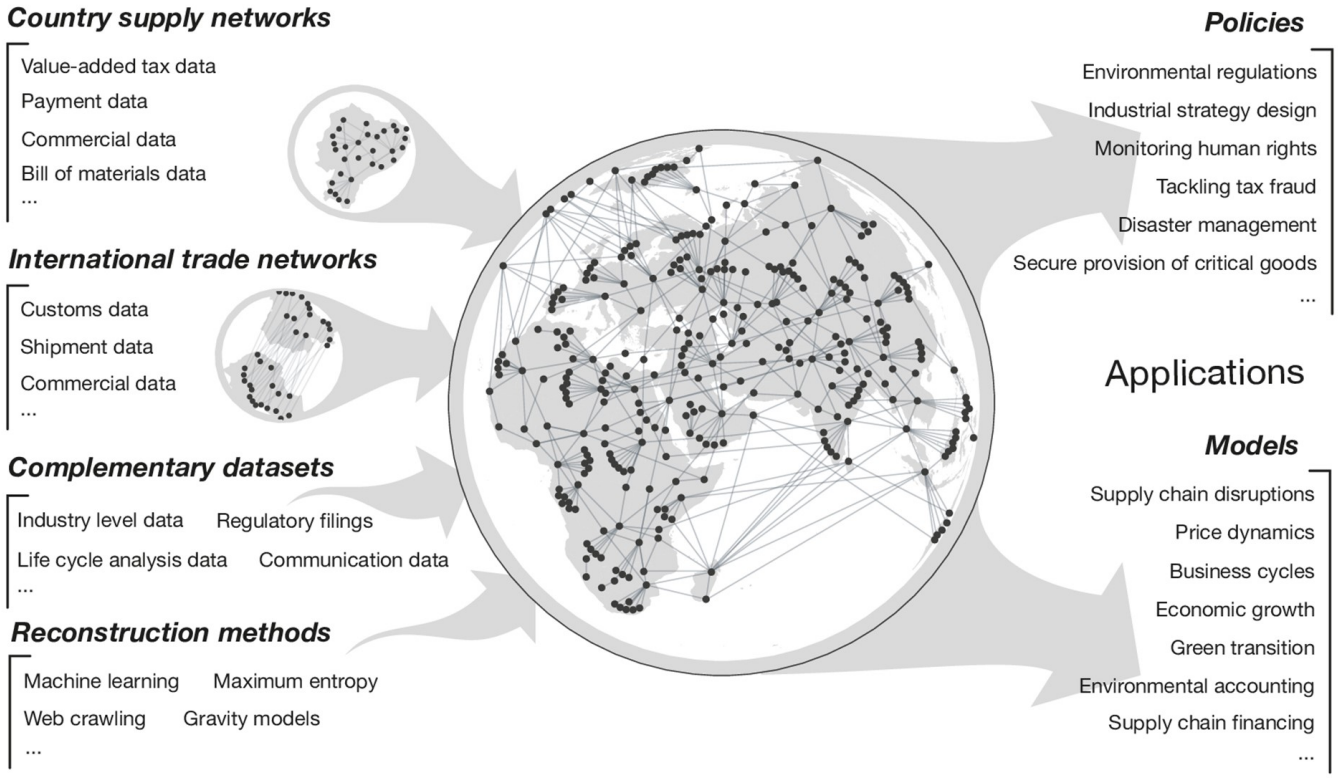
[9] See Duprez & Magerman (2018).

[10] See Brintrup et al. (2018).

[11] See Mungo et el. (2023).

If other economic regions adopted a blueprint similar to the one outlined for the EU, these independent supply networks could be connected through customs and trade data. To achieve a coherent database of international supply linkages, harmonized standards on data collection and formatting should be developed, similar to what happened for the development of national accounts.

Figure 2: Creating and utilizing a map of the global supply network



Notes: To the left: necessary data and methodological inputs to reconstruct the global supply network. To the right: policy applications and areas of economic modeling that would improve with large-scale firm-level supply network data.

Leveraging supply network maps for policy

Supply networks play a key role in the propagation of economic shocks through industries, regions, and countries but are equally important for a variety of further relevant use cases (Fig. 2). For example, current approaches to assess the carbon intensity of products or indirect (Scope 3) emissions of firms build on aggregate industry data or detailed but highly incomplete data from life-cycle analysis. A granular map of underlying supply networks could substantially improve the measurement and monitoring of CO_2 emissions in the economy.[12]

Such maps would be similarly important for effectively implementing and executing policies such as the EU Supply Chain Act, which is targeted at obliging companies to monitor environmental and social standards along their entire supply chain. However, as supply chains are intricate networks, it is almost impossible to comprehensively oversee them without granular data.

Governments could benefit substantially from an improved collection of detailed supply network data. Besides benefitting from enhanced tax compliance, such data will help identify indirect exposures to natural disasters or upstream supply chain bottlenecks for critical goods such as medical supplies. Governments could then take resilience-enhancing measures, such as incentivizing companies to diversify their suppliers.

[12] See Stangl et al (2024).

Central banks could similarly benefit because extensive firm-level supply network data will considerably improve our understanding of inflation dynamics and how the propagation of economic shocks affects financial stability[13]. Central banks are already at the forefront of working with and making these data accessible for scientific economic analysis. As data availability and methodological development progress, they could integrate this knowledge into monetary policy, macro-prudential policy, and financial market supervision.

Currently, there are several independent efforts at both the national and supranational levels to chart specific parts of the global supply network. Notable examples include the EU proposal for a Directive on corporate sustainability due diligence, the U.S. Supply Chain Disruptions Task Force, and the U.K. Department of International Trade supply chains resilience framework, .

However, these maps will remain fragmented and inadequate for addressing critical societal challenges without a concerted approach. International organizations, including the International Monetary Fund, the World Bank, the OECD, the United Nations Statistics Division and Eurostat, have considerable expertise in harmonizing international datasets and should play a key role in scaling up these efforts to the international level.

Building this alliance would result in a comprehensive map of international firm-level supply connections. This map could serve as a new foundation for economic analyses and policies at both the national and international levels.

References

Pichler, A., Diem, C., Brintrup, A., Lafond, F., Magerman, G., Buiten, G., Choi, T.Y., Carvalho, V.M., Farmer, J.D., & Thurner, S. (2023). Building an alliance to map global supply networks. *Science, 382*(6668), 270-272.

O. Celasun, N.-J. H. Hansen, A. Mineshima, M. Spector, J. Zhou, Supply bottlenecks: Where, why, how much, and what next? Working Paper WP/22/31, International Monetary Fund, 17 February 2022.

A. Bacilieri, A. Borsos, P. Astudillo-Estevez, F. Lafond, Firm-level production networks: What do we (really) know? Working paper 2023-08, Institute for New Economic Thinking, University of Oxford, Oxford, May 2023.

Carvalho, V. M., Nirei, M., Saito, Y. U., & Tahbaz-Salehi, A. (2021). Supply chain disruptions: Evidence from the Great East Japan earthquake. *The Quarterly Journal of Economics, 136*(2), 1255-1321.

Diem, C., Borsos, A., Reisch, T., Kertész, J., & Thurner, S. (2022). Quantifying firm-level economic systemic risk from nation-wide supply networks. *Scientific reports, 12*(1), 7719.

Diem, C., Borsos, A., Reisch, T., Kerte sz, J., & Thurner, S. (2024). Estimating the loss of economic predictability from aggregating firm-level production networks. *PNAS Nexus, in press*.

Alexopoulos, A., Dellaportas, P., Gyoshev, S., Kotsogiannis, C., & Pavkov, T. (2020). Detecting network anomalies in the Value Added Taxes (VAT) system. *A TARC Policy Analysis Report*.

Dhyne, E., Kikkawa, A. K., Mogstad, M., & Tintelnot, F. (2021). Trade and domestic production networks. *The Review of Economic Studies, 88*(2), 643-668.

Duprez, C., & Magerman, G. (2018). *Price updating in production networks* (No. 352). NBB Working Paper.

Brintrup, A., Wichmann, P., Woodall, P., McFarlane, D., Nicks, E. and Krechel, W., 2018. Predicting hidden links in supply networks. Complexity, 2018, pp.1-12.

Mungo, L., Lafond, F., Astudillo-Estévez, P. and Farmer, J.D., 2023. Reconstructing production networks using machine learning. *Journal of Economic Dynamics and Control, 148*, p.104607.

Stangl, J., Borsos, A., Diem, C., Reisch, T., & Thurner, S. (2024). Reducing employment and economic output loss in rapid decarbonization scenarios using firm-level production networks. *Nature Sustainability, in press*.

Tabachová, Z., Diem, C., Borsos, A., Burger, C., & Thurner, S. (2023). Estimating the impact of supply chain network contagion on financial stability. *arXiv:2305.04865*.

[13] See Tabachová et al. (2023).

About the authors

Anton Pichler *is a James S. McDonnell Foundation postdoctoral fellow at the Complexity Science Hub in Vienna, Austria, and holds a tenure track position in Supply Chain Analytics at the Vienna University of Economics and Business.*

Christian Diem *is a Senior Scientist in the Network Economics, Supply Chains & Financial Markets Group at Complexity Science Hub Vienna, Austria.*

Alexandra Brintrup *is Professor in Digital Manufacturing and head of the Supply Chain Artificial Intelligence Lab at the University of Cambridge. She is head of Digital Manufacturing at the Alan Turing Institute.*

François Lafond *is at the University of Oxford, where he is Deputy Director of the Complexity Economics programme at the Institute for New Economic Thinking, Lead Researcher at the Smith School of Enterprise and the Environment, and Associate member of Nuffield college.*

Glenn Magerman *is Associate Professor of Economics at ECARES, Université Libre de Bruxelles, and Research Affiliate at CEPR.*

Gert Buiten *is project manager and senior statistician and senior researcher at the Centraal Bureau voor de Statistiek in Den Haag, the Netherlands.*

Thomas Choi *is Regents Professor of Arizona State University and AT&T Professor of Business and serves as co-director of the Complex Adaptive Supply Networks Research Accelerator (CASN-RA).*

Vasco M. Carvalho *is Professor of Macroeconomics at the University of Cambridge, UK, and is the current Director of the Janeway Institute. He is also a Research Fellow at CEPR, a Turing Fellow at the Alan Turing Institute and a member of the Council of the European Economic Association.*

J. Doyne Farmer *is Director of the Complexity Economics programme at the Institute for New Economic Thinking at the Oxford Martin School, Baillie Gifford Professor of Complex Systems Science at the Geography Department at the University of Oxford and an External Professor at the Santa Fe Institute.*

Stefan Thurner *is full professor for Science of Complex Systems at the Medical University of Vienna, external professor at the Santa Fe Institute, and president of the Complexity Science Hub Vienna.*