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Stefan Gebauer, Anton Nakov, Galo Nuño,
Chiara Osbat, Alberto Palazzolo,
Gonzalo Paz-Pardo, Alari Paulus,
Javier Quintana, María Teresa Valderrama

The propagation of shocks across the production network and implications for monetary policy

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Challenges for Monetary Policy Transmission in a Changing World (ChaMP) Research Network

This paper is one of five Occasional Papers (OPs; listed further below) summarising the strands of research conducted within the framework of the Challenges for Monetary Policy Transmission in a Changing World (ChaMP) Research Network, which was an initiative of the European System of Central Banks (ESCB) and brought together economists from the European Central Bank (ECB), the national central banks comprising the ESCB, the Bank of England and Norges Bank. Overall, it produced 168 individual papers and four papers on cross-country coordinated research projects.

ChaMP sought to revisit our knowledge of monetary transmission channels in the euro area and other European economies following a series of unprecedented shocks, and amid multiple ongoing structural changes and the extension of the monetary policy toolkit over the last decade and a half, including the 2021-23 inflation episode. The five OPs cover the main priorities of the network's two workstreams (WSs). WS1 focused on monetary transmission via the financial system, with OP No 389 covering transmission mechanisms from banks to non-financial corporations, OP No 390 examining mechanisms to households and OP No 391 looking at transmission via non-bank financial intermediation. Meanwhile, WS2 was dedicated to monetary transmission via the real economy, with OP No 392 summarising the network's research on transmission through input-output linkages among non-financial corporations and production sectors and OP No 393 examining how various structural changes interact with monetary policy transmission.

ChaMP was coordinated by a team chaired by Philipp Hartmann (ECB) and consisting of Diana Bonfim (Banco de Portugal), Margherita Bottero (Banca d'Italia), Emmanuel Dhyne (Nationale Bank van België/Banque Nationale de Belgique) and Maria T. Valderrama (Oesterreichische Nationalbank). This core team was supported by Melina Papoutsi, Gonzalo Paz-Pardo, Jean-David Sigaux, Raquel Gil-Antona, Clara Dolci and Simone de Luca (all ECB), along with seven central bank advisers and eight academic consultants. More information can be found on the ChaMP website.

Occasional Papers related to the ECB's ChaMP Research Network

No 389, "Monetary policy transmission via banks to firms"

No 390, "Monetary policy transmission through the financial system to households"

No 391, "Monetary policy transmission and non-bank financial intermediation"

No 392, "The propagation of shocks across the production network and implications for monetary policy"

No 393, "Monetary policy transmission and structural changes"

Contents

Abstract

The repeated occurrence of supply-chain disruptions since the COVID-19 pandemic reveals the need to complement traditional macroeconomic frameworks with approaches that better capture the complexity of modern economic production structures. This paper synthesises the findings of the ChaMP Research Network, highlighting how production network models and heterogeneity across firms, sectors and countries enrich our understanding of monetary policy transmission. By capturing input-output relationships between firms and economic sectors, these approaches show how the propagation and persistence of shocks depend on network structure, the position of sectors within the network – where central sectors exert disproportionate influence – and differences and variations in price and wage flexibility. The inflationary effects of supply shocks tend to be amplified, while the effects of demand shocks, including monetary policy shocks, are dampened. In addition, large shocks can give rise to nonlinearities, such as a steepening of the Phillips curve. This aligns with the conclusions of the ECB's most recent strategy assessment, which emphasise the need to analyse the risks surrounding the inflation outlook. The findings also point to the emergence of trade-offs between inflation and output gap stabilisation, as production networks and heterogeneity weaken the alignment between price and output dynamics. As a result, stabilising inflation and output simultaneously calls for astute fiscal policy. Overall, incorporating production networks provides a more nuanced and policy-relevant framework for designing state-contingent and data-informed monetary policy.

JEL codes: E52, E58, D57, E32

Keywords: monetary policy transmission; production networks; supply chains; sectoral structure; supply shocks; Phillips curve

Non-technical summary

Since the COVID-19 pandemic, the euro area and the EU have endured repeated supply shocks and value chain disruptions, most notably the sharp rise in inflation following Russia's invasion of Ukraine, though also the 2026 war in the Middle East. Many observers expect such disruptions to become more frequent moving forward. This underscores the need for the macroeconomic analysis supporting the conduct of monetary policy to focus more on the production structure of the economy. While traditional economic models remain valuable for capturing broad trends, recent research shows that additional insights can be gained by looking more closely at the input-output linkages between firms and sectors, as well as at differences across firms, sectors and countries. This aligns with the conclusions of the ECB's most recent strategy assessment, which emphasise the need to analyse the risks surrounding the inflation outlook.

A key contribution of this research is the use of "production networks" to describe how firms and industries are connected through supply chains. In this view, the production side of the economy is not a single, representative firm or sector but a whole web of interdependent relationships between heterogeneous firms and sectors. These interconnections play a crucial role in determining how shocks, including monetary policy shocks, supply disruptions and shifts in demand, spread and persist across the economy.

A key insight is that the position of a sector within this network matters greatly. Some sectors are highly connected or occupy central positions because they supply many other industries. When these sectors are affected by a shock, the effects can spread widely across the economy. In contrast, shocks to less connected sectors tend to have more limited effects. This helps explain why similar shocks can have very different overall effects, depending on where they originate (e.g. external shocks, productivity shocks affecting upstream or central sectors, or demand shocks affecting downstream sectors).

The research also shows that different types of shocks behave differently, depending on whether production networks are considered. Supply shocks, such as increases in energy prices or disruptions to key inputs, tend to have stronger and more persistent effects on inflation as they propagate along supply chains. This occurs because they trigger repricing decisions among firms, which in turn affect the input prices faced by other firms, prompting them to adjust their prices as well. Demand shocks, including monetary policy shocks, generally have more muted effects when the production network is taken into account. When consumers change their demand, firms that sell directly to them have limited capacity to reduce the prices they pay to their suppliers; instead they reduce the quantities they demand. As a result, price changes take longer to materialise. These patterns arise because firms along the production network interact with one another in complex ways, leading to nonlinear and sometimes asymmetric outcomes.

Another key finding is the importance of differences across firms, sectors and countries. Some firms adjust prices frequently, while others do so only occasionally. Some face significant capacity or financial constraints, while others are more flexible. Similarly, labour markets differ across sectors and countries, affecting how wages and employment respond to economic changes. For example, in a heterogeneous monetary union such as the euro area, countries with more flexible wage structures may experience smaller employment effects in response to a given shock, while contributing more strongly to overall inflation. These differences shape how monetary policy is transmitted and can lead to uneven effects across the economy.

The findings also point to the emergence of trade-offs between inflation and output gap stabilisation, as production networks and heterogeneity weaken the alignment between price and output dynamics, making it difficult to stabilise both simultaneously, even following a demand shock. This means that both monetary and fiscal policies need to be more flexible and responsive to the prevailing circumstances. In particular, policymakers need to consider the source of shocks – whether they are driven by supply or demand – and which sectors are most affected.

To support better decision-making, central banks could benefit from using more detailed indicators, including those showing how connected and large sectors are within the production network ("centrality"), how frequently firms adjust prices, and how exposed they are to cost pressures from upstream suppliers. Such information can help distinguish between different types of inflationary pressures and guide the timing and strength of policy responses. For instance, when large supply shocks lead to more frequent price adjustments, monetary policy may need to act decisively to contain inflation rather than look through the shock.

Finally, the research highlights the importance of having detailed data on transactions between firms. These supply chains provide a richer and more accurate picture of how the supply side of the economy operates. Similarly, information on how often firms adjust wages and prices, and on how their wage- and price-setting behaviour responds to economic shocks, is an essential input when calibrating the models presented in this paper. Expanding access to data on both dimensions is essential for improving economic analysis and supporting effective policymaking in a world characterised by frequent – and potentially large – supply shocks and value chain disruptions.

1 Introduction

Following the sharp rise in inflation during 2021 and 2022, it became clear that the models used to explain inflation dynamics presented significant shortcomings. Focusing solely on aggregate variables overlooked important details about how the economy actually functions. Supply chain disruptions and differences in the way countries and industries responded to shocks laid bare the complex and interconnected nature of production networks and showed how heterogeneity affects the transmission of shocks. Production networks vary in length across countries and, even within the same sector, firms differ widely in their degree of interconnectedness with other firms. Moreover, price rigidities and the frequency of price adjustments are heterogeneous, not only across firms and sectors but also across time, depending on economic conditions. Finally, the composition of final demand between different types of goods and services also affects how quickly shocks are transmitted to prices and consumption.

The ChaMP Research Network was established to gain a clearer understanding of how monetary policy transmission has changed in a rapidly changing world by studying how heterogeneity can be modelled better, including through the use of production networks at the sectoral and firm levels. The research carried out within ChaMP, as summarised in this paper, provides insights into two aspects of monetary policy. The first is how monetary policy shocks propagate through production networks and how various dimensions of heterogeneity across firms, sectors and households influence the strength and speed of monetary policy transmission. The second aspect has to do with the conduct of monetary policy in the face of supply shocks, which tend to be sector-specific.

Research on production networks has deepened our understanding of the 2021-22 inflation surge and led to models that better capture the structure of the economy. The main insight from this body of literature is that many dimensions of heterogeneity within production networks matter for the transmission of monetary policy: for example, wages and prices are more flexible in some sectors and countries; households provide different labour services with different elasticities of supply; and sectors produce with different intensities of labour and capital and with different bundles of intermediate goods. Thus, the impact of shocks, particularly monetary policy shocks, on aggregate outcomes (such as inflation, employment and output) depends on the interaction between these heterogeneous characteristics and the direct and indirect sectoral exposure to shocks.

Incorporating production networks and heterogeneity thus provides a more realistic framework for analysing how shocks spread and how monetary policy is transmitted across the economy. For example, ChaMP studies show that supply and demand shocks propagate differently through production networks. While the inflationary effects of supply shocks tend to be amplified, the effects of demand shocks are typically dampened. Moreover, following a large shock, the frequency of price adjustments increases, which temporarily steepens the Phillips curve. This and other potential nonlinearities are key in understanding how shocks are transmitted. Equipped with these models and disaggregated data, researchers and policymakers can promptly identify the nature of the shocks that take place, which is crucial for designing effective monetary policy.

This area of research has also highlighted which dimensions of firm and sectoral heterogeneity are important for monetary policy transmission and warrant particular attention from policymakers. Firms that face binding capacity constraints raise prices more strongly following a period of monetary policy easing, particularly if they have market power; those that sell to leveraged and financially constrained firms experience larger reductions in demand following a period of monetary policy tightening. The consumption of workers in sectors with rigid labour markets and less flexible pricing declines most sharply following a contractionary shock, and sectors producing discretionary spending items bear the brunt of the adjustment following a negative shock. Hence, factors such as firm financing conditions, supply chain tensions and price-setting rigidities interact with monetary policy transmission, generating state-dependence and potential asymmetries.

Studies using more granular data, such as firm-level transaction data that reveal linkages between firms (B2B data), provide an even clearer picture of how heterogeneous firms are. The rich dynamics and structural complexity observed at the firm level underscore the importance of having access to detailed, micro-level data to better understand the transmission of monetary policy and inflation dynamics.

Thus, production networks and the rich heterogeneity embedded within them provide a more realistic representation of the economy. Ignoring them risks overlooking important interactions between firms and sectors, which are essential for explaining the heterogeneous responses to monetary policy shocks and can ultimately lead to a loss of economic predictability.

Finally, insights from these models carry important normative implications for the optimal design of monetary policy. Several studies carried out within the ChaMP network explicitly analyse optimal policy in the presence of nonlinearities or within networked economies, rather than under aggregate, representative conditions. Their findings indicate that, given the existing heterogeneity across sectors, inputs and demand, as well as differences in price-setting behaviour, the Phillips curve is inherently nonlinear and can, under certain circumstances, become steeper. This implies that the costs of reducing inflation through tighter monetary policy following a large supply shock may be lower than previously thought, since the economy adjusts more quickly when price changes become more frequent.

Modeling the economy as a production network, whether at the country, sectoral or firm level, also reveals that, at each level of disaggregation, the so-called “divine coincidence” breaks down: it is not possible to stabilise both inflation and the output gap simultaneously, even in the presence of demand shocks. This introduces meaningful trade-offs between inflation and output stabilisation, necessitating a revision of traditional approaches to optimal monetary policy. In particular, optimal policy should be state-contingent and sector-sensitive. Indicators such as the frequency of price changes, measures of core or services inflation, and network-based statistics can guide policymakers in distinguishing between demand- and supply-driven pressures and in identifying emerging nonlinear inflationary dynamics. Finally, expectations management becomes critical in networked economies. Firms that set prices within a network have incentives to be attentive to aggregate and sectoral shocks, particularly if they are inflationary in nature, making inflation both more forward-looking and asymmetric. Anchoring expectations effectively is therefore essential for maintaining stability when shocks propagate through complex production structures.

This report, which summarises the main insights obtained from ChaMP research in this area, is structured as follows: Chapter 2 sets the stage for understanding production networks by introducing the concept, describing the main indicators and explaining how they are used to study the transmission of shocks. Chapter 3 summarises the existing body of research, drawing on production networks and disaggregated data to show how the transmission of shocks depends on whether they originate from a supply or demand shock, on where they occur within the network, and on the characteristics of the sectors, such as the degree of market power, capacity or financial constraints. Chapter 4 examines more granular data to explore the characteristics of production networks based on firm-level transaction data, showing that, at this level of disaggregation, considerable heterogeneity exists across firms and that sectoral aggregations are not reliable representations of single firms. Chapter 5 presents the implications of these findings for our understanding of the Phillips curve and for the design of optimal monetary policy. Finally, Chapter 6 presents the conclusions and policy implications.

2 Theoretical foundations: production networks, amplification and propagation

Prepared by Javier Quintana (Banco de España)

2.1 Production networks as economic objects

Production networks capture the relationships between firms that buy products from each other, and allow us to track the effects of shocks as they spread through the economy – whether firm- or sector-specific shocks, such as productivity disruptions, or aggregate shocks, such as monetary policy or demand shocks.

Economies should not be thought of as collections of agents operating in isolation. Firms rely on goods and services produced by other firms as intermediate inputs, and those suppliers in turn depend on their own upstream providers. Therefore, even if households interact directly only with final-good producers, or downstream sectors, they remain indirectly exposed to developments occurring at other stages of the production chain. Because production is organised in stages and economic actors are interdependent, localised disturbances can have macroeconomic consequences not only through their direct effects at the point of impact, but also through propagation along buyer-supplier linkages. A natural way to represent these interdependencies is through an input-output table, where each entry captures the extent to which a buyer uses a supplier's output as an intermediate input.

To better model these processes, researchers rely on production networks, which provide a disciplined way of mapping how shocks – whether originating at a single firm or sector, or at the aggregate level – translate into macroeconomic outcomes. Similarly, aggregate shocks can produce heterogeneous direct effects across firms and sectors, making network interactions essential for understanding both the transmission and the overall impact of such shocks. The key conceptual shift relative to the one-sector benchmark is that heterogeneous input dependencies mean that the macroeconomic impact of a shock depends on where it occurs and how it propagates through buyer-supplier linkages. In network terms, the economy can be depicted as a directed and weighted graph, in which nodes are firms or sectors and edges represent input purchases or sales (see, for example, Acemoglu et al., 2016; Ozdagli and Weber, 2025).

This accounting framework yields two key metrics of each industry's importance for shock propagation to other industries and aggregate output. The first of these is the Domar weight, which measures the size of each sector not as its value added but as its sales relative to total GDP (see Box 1): an upstream sector that sells little directly to end consumers may nonetheless have a substantial Domar weight, because its output is embedded in the costs of many downstream producers, a point formalised by Hulten (1978). The second key metric is network multipliers, which capture how a cost or quantity shock to one node propagates through direct and indirect input-output linkages – raising input demand upstream and affecting marginal costs downstream – even before any equilibrium price adjustment takes place, as shown by Long and Plosser (1983), Acemoglu et al. (2012) and Carvalho (2014).

Beyond their own size, the position of a given firm or sector within the production chain can be equally important for understanding the aggregate effects of shocks that affect them. For example, a disruption to an upstream sector – situated at the beginning of the productive process – will reverberate along the entire value chain. Moreover, input-output matrices can be weighted by various node characteristics to capture different economic mechanisms. For example, they can be weighted by the degree of price rigidity, as in Rubbo (2023) and Pastén et al. (2024), whose stickiness-weighted Leontief inverse captures which sectors are most important for monetary non-neutrality, or by the level of markups (Liu, 2019), allowing for an analysis of the distortions generated by demand shocks propagating through the network. Influence measures derived from the network therefore combine size and position: a node can be small in value added yet highly influential if it sits upstream of many production chains or if it is difficult to substitute away from, as shown by Gabaix (2011), Acemoglu et al. (2012) and Carvalho (2014). For a systematic treatment of these metrics, see Carvalho and Tahbaz-Salehi (2019) and Baqaee and Rubbo (2023).

Empirically, the same logic applies whether the nodes are sectors, measured via national accounts input-output tables, or firms, identified through administrative buyer-supplier transaction records. Magerman et al. (2026) emphasise that firm-level networks are sparse, highly skewed and directional, with only a small number of firms accounting for a disproportionately large share of purchases and sales. Dhyne et al. (2026) show that distance to final demand is an informative organising statistic for the dynamics of firm-level outcomes, a finding that recurs in later sections.

These regularities have important implications for measurement: aggregation can mask concentration, mismeasure distances along the production chain, and compress heterogeneity in exposure – precisely the heterogeneity that later sections use to interpret heterogeneous responses to monetary shocks. Aggregation may also reduce the predictive power of network-based models relative to firm-level approaches, as explored by Diem et al. (2024), although the evidence on this point remains preliminary. Box 1 summarises the main network metrics used to operationalise these concepts.

Box 1
Key metrics for assessing production-network positions and centrality

Prepared by Stefan Gebauer, European Central Bank, and Javier Quintana, Banco de España.

Concepts such as Domar weights, influence vectors, centrality measures and exposure decompositions were formalised and given their modern interpretation in the context of aggregate fluctuations and shock propagation by Acemoglu et al. (2012), Carvalho (2014) and Carvalho and Tahbaz-Salehi (2019). Their application to firm-level networks is even more recent, and the associated toolkit is still being developed (see Baqaee and Rubbo, 2023). The metrics below capture concepts applied in several ChaMP papers and are presented in that spirit: as tools grounded in modern macroeconomic network theory.

- **Domar weights** measure a sector's or firm's share of total GDP based on its sales. An upstream sector may have a negligible direct consumption share – because it sells little or nothing directly to end consumers – yet command a substantial Domar weight, because its output is embedded as an intermediate input in the costs of many downstream producers. This is why Domar weights, rather than value-added or direct consumption shares, are the natural metric for linking sector-level shocks to aggregate fluctuations: they capture both direct and indirect contributions to GDP (see Hulten, 1978; Domar, 1961). As a result, Domar weights sum to more than one across all sectors of an economy.

- **Backward and forward linkages** measure a sector's dependence on upstream inputs and its importance as a supplier to downstream sectors. Backward linkages correspond to column sums of technical coefficients or the Leontief inverse, while forward linkages correspond to row sums of allocation coefficients or Ghosh-based measures.

- **Upstreamness and downstreamness** measure the average distance of a sector's output from final demand (Antràs et al., 2012). Formally, upstreamness captures the expected number of production stages through which an output passes before reaching its final use. Sectors with high upstreamness predominantly supply intermediate inputs, while downstream sectors are closer to final consumption.

- **Network centrality** captures a sector's or firm's overall importance as both a direct and indirect supplier to the rest of the economy. It is measured using indicators such as Katz-Bonacich centrality, which extends the logic of backward linkages to account for the full chain of indirect input relationships, and the Leontief and Ghosh inverses, which summarise the total production requirements associated with changes in final demand or primary inputs respectively (see Pastén et al., 2024; Carvalho and Tahbaz-Salehi, 2019; Acemoglu et al., 2012). Along similar lines, Ghassibe and Nakov (2025) introduce the supplier Herfindahl metric, which captures a sector's systemic importance by combining its average role as an input provider with the concentration of its supply across downstream users, thus revealing its contribution to the sensitivity of aggregate outcomes to sectoral supply shocks.

- **Influence vectors and exposure decompositions** are tools for attributing aggregate fluctuations to individual nodes. Influence vectors summarise how a unit shock originating at a given node propagates through the input-output system, weighting each node by its downstream reach. Exposure decompositions then attribute aggregate volatility to individual sectors or firms, making it possible to identify the main drivers of macroeconomic fluctuations (see Acemoglu et al., 2012; Carvalho, 2014; Baqaee and Rubbo, 2023).

2.2 Why networks amplify: from microeconomic shocks to macroeconomic outcomes

In a production network, a shock that affects a firm or sector influences the pricing and production decisions of all its suppliers and buyers; some firms or sectors are particularly central and thus produce substantial shock amplification effects.

Disturbances tend to wash out quickly in the aggregate, whether considering aggregate shocks in a model with a single representative sector or firm, or idiosyncratic shocks in a multisector environment without input-output linkages. Networks change this benchmark for two related reasons. First, input-output linkages create interdependence: a disruption affecting a supplier raises costs for many buyers, which then feeds into the costs of their buyers, and so on. Second, some firms straddle high-throughput points in the production chain, so shocks to them have disproportionately large macroeconomic effects.

This logic appears already in early multisector real business cycle models, such as the one put forward by Long and Plosser (1983). More recent studies sharpen the conditions under which microeconomic shocks do not average out. Granular, highly skewed firm-size distributions –in other words, economies in which there are few very large firms – imply that such firms alone can generate aggregate volatility even in the absence of strong input-output linkages, as shown by Gabaix (2011). Input-output linkages imply that even small shocks can have meaningful effects if they affect nodes that are important in the network sense, with such importance captured by influence and centrality measures derived from the network itself, as in Acemoglu et al. (2012) and Carvalho (2014); the same metrics discussed in Box 1.

A complementary empirical lesson is that buyer-supplier relationships adjust slowly: it takes time for firms to find new buyers and suppliers when their existing ones face a disruption. Supplier specificity and limited substitutability can therefore make shock propagation sharper and more persistent, because downstream firms cannot easily replace their input sources when a key supplier is affected. Barrot and Sauvagnat (2016) provide an influential example of this mechanism operating in the context of firm networks, documenting how idiosyncratic supplier shocks are transmitted to customer outcomes when inputs are specific.

A second amplification channel operates through nonlinearities and, in dynamic settings, through state dependence and cascades – two related but distinct mechanisms. Baqaee and Farhi (2019) show why the macroeconomic impact of shocks can be nonlinear even when the primitive disturbances appear small at the micro level, because equilibrium reallocation interacts with network structure in ways that are absent from linearised models. This mechanism is static in nature but has clear dynamic extensions: in multisector environments with capital accumulation, the endogenous distribution of resources across upstream and downstream nodes can either dampen or amplify downturns, as shown by Carvalho et al. (2025) in the context of optimal capital allocation towards upstream bottleneck sectors – a result with direct implications for the nonlinear transmission of monetary policy discussed in Section 2.4 and further explored in Section 5. The debate over the macroeconomic consequences of a potential cut-off of German energy imports from Russia illustrates the quantitative relevance of nonlinear network propagation in a policy-relevant setting. Using a multi-sector open-economy model, Bachmann et al. (2024) show that the estimated output loss depends critically on substitution elasticities and reallocation along the production chain, with the results ranging from 0.5% to 3% of GDP depending on those assumptions. Networks also interact with a country's wealth distribution in meaningful ways (Battistini et al., 2026).

2.3 Propagation of monetary policy shocks through networks

Monetary policy affects firm costs and final demand, but production networks alter how these effects are transmitted to aggregate output and inflation: the location of nominal rigidities along the chain and the structure of input-output linkages jointly determine the speed, magnitude and persistence of the response.

Monetary policy enters networked economies through familiar nominal channels – interest rates, discounting and aggregate demand – and its real effects depend on how nominal rigidities and input-output linkages interact. Two mechanisms are particularly important in this regard.

Nominal rigidities and cost propagation along the production chain. When upstream suppliers are slow to adjust their prices, this affects the transmission of monetary shocks into real marginal costs along buyer-supplier chains. Because intermediate inputs travel through many stages of a production chain, with each stage facing price rigidities, the effective nominal rigidity faced by downstream producers is amplified: rigidity upstream is partially inherited downstream. This means that the location of nominal rigidities along the production chain matters, not just the average rigidity. Nakamura and Steinsson (2010) and Pasten, Schoenle and Weber (2020) provide classic multisector pricing frameworks emphasising this channel, while Carvalho, Lee and Park (2021) show quantitatively how input-output linkages help generate slow price responses to aggregate shocks while allowing faster responses to sectoral shocks. A related implication is that large shocks can trigger pricing cascades through the extensive margin of adjustment: under aggregate demand shocks such as monetary policy, networks tend to dampen the pricing response because intermediate input prices rise only gradually. By contrast, under aggregate or sector-specific supply shocks, networks amplify cascading repricing waves, as formalised in Ghassibe and Nakov (2025).

These mechanisms have two foundational implications that underlie much of the subsequent analysis. First, input-output linkages alter the slope of the aggregate Phillips curve: nominal rigidities compound along production chains, meaning that even when individual firms adjust prices relatively frequently, the aggregate inflation-output relationship can be considerably flatter than micro-level estimates would suggest. Second, sectoral productivity or cost shocks generate endogenous cost-push shocks that propagate through the network, creating inflation-output trade-offs even in the absence of aggregate demand fluctuations. Both results are formalised in the benchmark linearised New Keynesian input-output model put forward by Rubbo (2023), and analogous mechanisms appear in the nonlinear and open-economy settings reviewed in later sections of this paper.

Demand reallocation and downstream propagation. Monetary shocks also shift final demand across categories and sectors. Downstream firms that are closer to end consumers respond first, while upstream responses follow with a lag as intermediate demand contracts and propagates backwards through the network. Ozdagli and Weber (2025) provide foundational evidence of this mechanism, showing that between 55% and 85% of the total effect of monetary policy on stock market returns operates through production network linkages rather than through firms' direct exposure to consumer demand. Buda et al. (2025) document the same sequencing in high-frequency data for Spain, finding that real activity responds at surprisingly short horizons, with downstream sectors reacting first and upstream sectors following more slowly but more persistently. A related measurement lesson is that time aggregation conceals these fast network adjustments: quarterly data mechanically shift significant responses to longer lags even when daily and weekly measures reveal economically meaningful short-run dynamics.

Ghassibe (2021) brings these ideas to the data by quantifying how much of the aggregate real response to monetary shocks is attributable to network amplification through input-output linkages, showing that amplification is concentrated in sectors that are both sticky and intermediate-input intensive – precisely the sectors in which the two mechanisms described above interact most strongly. These findings motivate the empirical focus in later sections on heterogeneity across network positions and on measurement at frequencies aligned with the adjustment margins of interest.

2.4 Investment networks as a distinct propagation channel

The inputs used for firm investment are also produced within an investment input-output network, which is typically more concentrated than the intermediate input-output network, implying large aggregate responses to shocks that interact with financing conditions in ways that are absent from models focused solely on intermediate inputs.

A production network built on intermediate inputs provides only half the story in economies where capital accumulation also plays a central role. Investment itself is produced through supply chains involving capital goods, construction, equipment and intangible assets, and is often highly concentrated in specific hub sectors. This gives rise to an investment network that can propagate shocks differently from the intermediate-input network.

The core mechanism is that shocks affecting investment hubs resemble aggregate investment supply disturbances: they alter the price and availability of capital goods across the entire economy, changing capital accumulation and thereby affecting employment and output dynamics more broadly. Vom Lehn and Winberry (2022) emphasise that the investment network is typically more concentrated than the intermediate inputs network, which can generate sizeable aggregate responses even when the initial disturbance is sector-specific. This channel is particularly relevant for monetary policy because interest rates operate directly on the intertemporal margins and financing conditions that in turn govern investment decisions. Once investment is embedded in a network, interest rate changes propagate through the capital-goods supply chain and feed back into intermediate demand.

Beyond the static propagation of shocks, the investment network also matters in dynamic environments where capital allocation across sectors is endogenous. Carvalho et al. (2025) show that optimal capital allocation tilts resources towards upstream bottleneck sectors precisely to reduce the probability and severity of large cascade events, at the cost of lower average consumption. This finding illustrates how the investment network and the intermediate-input network interact over the business cycle: the distribution of capital across upstream and downstream nodes shapes not only the level but also the tail risk of aggregate fluctuations, with direct implications for the nonlinear policy transmission discussed in Section 5.

Covarrubias et al. (2025) advocate modelling investment linkages explicitly rather than treating them as a residual margin. The central message is that mapping who supplies investment goods to whom matters for both propagation and incidence: an interest rate shock can compress investment demand in a way that disproportionately affects a small set of capital goods suppliers, and the resulting effects propagate onwards through the production network. Financial constraints amplify this mechanism, shaping which sectors transmit a monetary policy tightening most strongly – a point developed further in the context of firm-level financial frictions by De Sanctis et al. (2026), who show that the sign and magnitude of financial amplification depend critically on where in the network those constraints are located.

2.5 Open-economy considerations and the role of imported inputs

The cross-country integration of supply chains generates additional propagation mechanisms for monetary policy and supply shocks, and makes the incidence of these shocks dependent on the structure of each economy's production network rather than solely on its aggregate trade exposure.

As many European economies are deeply integrated into cross-border supply chains, the relevant network for monetary transmission often extends beyond national borders. Imported intermediate goods affect domestic marginal costs, foreign demand influences domestic sales through export networks, and exchange rate movements shift relative input prices across countries. Shocks can therefore propagate to the domestic economy not only through aggregate demand, but also through imported input costs, external demand spillovers and cross-border network feedback.

A first set of results, prior to ChaMP, points to the quantitative importance of international input-output linkages for inflation synchronisation. Auer et al. (2019) document, using a multi-country, industry-level dataset, that international input-output linkages account for roughly half of the global component of producer price inflation: cost shocks originating in one country propagate through the global input-output network and generate correlated price dynamics across countries. This finding is immediately relevant for the euro area, where the common monetary policy must respond to inflation that partly reflects global network propagation rather than domestic demand conditions. In a related result focusing specifically on monetary policy transmission, di Giovanni and Hale (2022) show that nearly 70% of the impact of US monetary policy shocks on global stock returns is attributable to the network effect of global production linkages, and that shutting down those linkages would halve the overall global impact of US monetary policy.

A second set of results, developed within ChaMP, addresses the analytical framework needed to study these channels coherently. Aguilar et al. (2026) develop a consistent open-economy New Keynesian input-output (IO) framework – calibrated to the four largest euro area countries, the rest of the euro area and the rest of the world – that keeps network accounting explicit while allowing for the simulation of both monetary and foreign price shocks. Their key analytical finding is that international IO linkages steepen the slope of the Phillips curve relative to a closed economy and introduce novel monetary policy trade-offs through inefficient movements in sectoral terms of trade, which feed into domestic inflation over and above movements in the output gap. Quantitatively, they find that without IO linkages, cumulative headline inflation in response to an energy price shock would be roughly 40% lower, with international linkages alone explaining around half of the total network amplification.

The structure of domestic production chains also matters for how external shocks propagate within a country. Aguilar et al. (2026) show that countries with longer production chains – where intermediate goods pass through more stages before reaching end consumers – exhibit stronger and more persistent pass-through of imported energy price shocks to core inflation. This provides a concrete network-based explanation for the cross-country heterogeneity in inflation dynamics observed during the 2021-2022 energy shock: Spain, with a more downstream and less complex production structure, experienced a sharp but short-lived inflationary spike, while Germany, with longer and more upstream chains, saw a more gradual but persistent increase in core inflation.

3 Heterogeneous monetary policy transmission and networks

Prepared by Stefan Gebauer (European Central Bank)

ChaMP studies provide robust evidence that monetary policy transmission is heterogeneous along production networks. A firm's or sector's position relative to final demand systematically shapes both the timing and persistence of its response to monetary policy shocks, carrying important implications for aggregate inflation and real activity. On the activity side, downstream sectors close to final demand tend to react more quickly, while upstream sectors respond more slowly but often more persistently. Regarding prices, studies confirm the importance of nominal rigidities in the sectoral transmission of monetary policy, but reach somewhat different conclusions about the location of such frictions within the production network. In addition, financial frictions interact with production networks to amplify or dampen these effects.

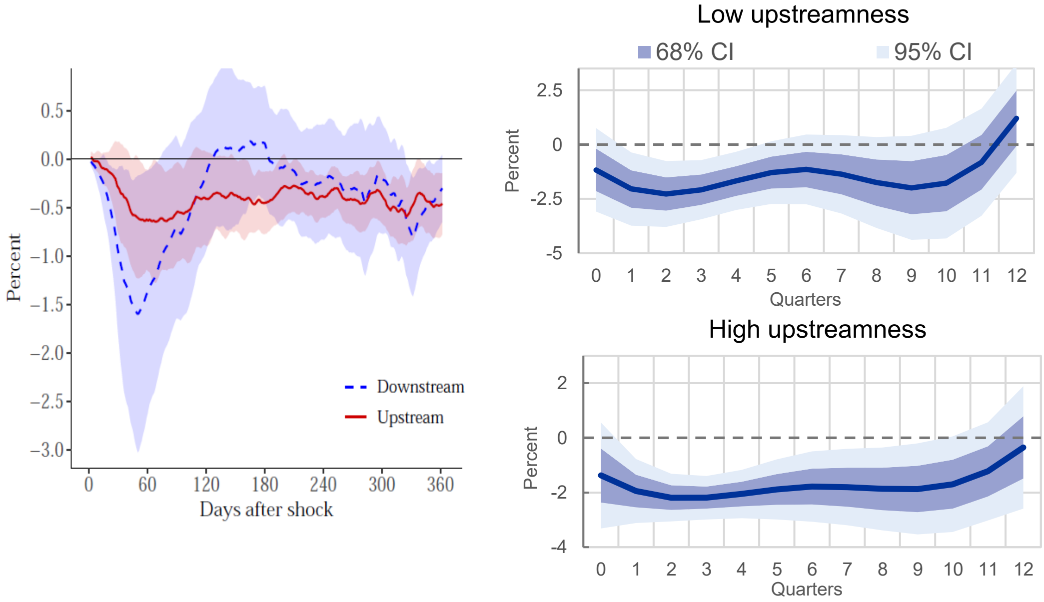
3.1 Transmission to real activity

Following a monetary policy shock, firms located upstream in the production network are slower to adjust their sales and production, but do so in a persistent manner.

Evidence on real activity highlights the importance of proximity to final demand. Using daily administrative and bank transaction data for Spain, Buda et al. (2025) show that sales and consumption in downstream sectors tied to final demand – particularly durable and luxury goods – respond strongly to monetary policy shocks with very short lags (Chart 1). Contractions become visible within weeks, and the magnitude of the response is substantially larger than for upstream sectors. By contrast, upstream sectors supplying intermediate inputs are slower to respond but do so more persistently, consistent with the upstream propagation of weaker final demand through the production network. These findings challenge the conventional view that real variables take a long time to respond to monetary policy shocks. They suggest that consumption and sales can respond at short lags, while delays mainly arise in terms of prices and employment. Similarly, using detailed firm-to-firm transaction data, Dhyne et al. (2026) also document that upstream sectors are associated with particularly persistent responses in sales. Like Buda et al. (2025), they also find that quantity adjustment is typically fastest among downstream firms (see Section 4).

Chart 1

Upstream vs downstream sectoral sales to a monetary policy shock



Notes: LHS: LP impulse response functions to a one-standard-deviation monetary policy shock. The responses are reported in levels. The confidence intervals are computed from heteroskedasticity-robust standard errors. Lighter-shaded areas are the 90% confidence intervals. The sample runs from 1 July, 2018 to 30 October 2023. The standard deviation of the monetary policy shock is 4.1 bp. See Online Appendix D.1 for further details on the sectoral classification of sales upstream (red line and band) and downstream (dashed blue line and blue band). The right-hand panel presents the difference between upstream and downstream sales responses together with the 68% (lighter-shaded areas) and 90% (darker-shaded areas) confidence intervals of this difference. RHS: Horizon expressed in quarters. Impulse responses to a 5-bp monetary policy shock (one standard deviation), estimated via smoothed local projections (see Barnichon and Brownlees, 2019). Upstreamness = 1 (= 5) indicates the most downstream (upstream) sectors.
Source: Buda et al. (2025) and Dhyne et al. (2026)

Discretionary spending items display a higher sensitivity to monetary policy than non-discretionary items, particularly if they are credit-financed.

A complementary perspective is provided by Allayioti et al. (2025), who analyse heterogeneity in monetary policy transmission across consumption items. Although their focus is on prices, their classification of items into discretionary and non-discretionary categories points to underlying heterogeneity in demand responses. Discretionary and credit-financed items – often associated with durable consumption and higher-income households – are much more sensitive to monetary policy shocks than non-discretionary items, such as rent and medical services, which are more often subject to administered prices. These findings suggest that monetary policy primarily affects real activity where consumption can be postponed or financed through credit. More broadly, credit-sensitive consumption categories and investment respond rapidly to interest rate changes, indicating a greater sensitivity of demand patterns to monetary policy changes for these items.

Complementary evidence on the role of credit linkages within production networks is provided by Filep-Mosberger et al. (2021). Using Hungarian firm-level buyer-seller data matched with credit registry information, they show that firms' bank choices are strongly influenced by the banking relationships of their trading partners, reflecting information spillovers within the production network. While the study does not analyse monetary policy shocks directly, its findings imply that the relative position of firms within the network can shape their access to external finance, thereby affecting the strength of monetary policy transmission to real activity. In this sense, production networks not only transmit demand shocks but also shape the distribution of financial constraints across firms.

Similarly, Andreolli et al. (2026) documents pronounced sectoral heterogeneity in monetary policy transmission linked to differences in demand cyclicality across consumption categories. Following a contractionary monetary policy shock, discretionary industries experience significantly larger declines in consumption, employment, profits and asset returns. These heterogeneous responses generate important second-round effects, as discretionary sectors employ a larger share of low-income, hand-to-mouth workers, amplifying the initial demand contraction through income and employment channels. Linking sectoral heterogeneity to labour markets more explicitly, Rubbo et al. (2026) stress that conventional input-output models commonly feature many industries, but a single labour market. This limits their ability to capture the structure of the European Union, where labour markets are segmented within and across countries. Labour market institutions and industry composition differ across countries, which nevertheless trade their goods and services within an integrated market. The authors therefore discuss how these heterogeneities and interconnections affect the way different member countries transmit local shocks and respond to monetary policy.

Taken together, the evidence suggests that monetary policy shocks tend to propagate to real activity primarily through backward, demand-based linkages. Downstream sectors are typically the first and hardest to be hit, while upstream sectors experience more persistent adjustments as reduced final demand propagates through the production network. In addition, activity appears to respond most strongly in sectors producing discretionary items.

3.2 Transmission to prices

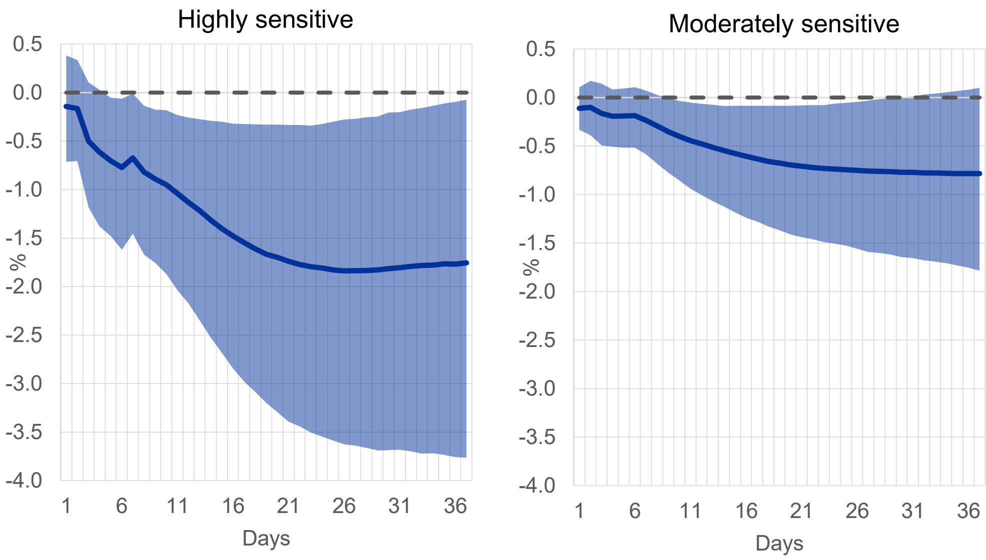
Prices of discretionary consumption items respond more strongly to changes in monetary policy than those of non-discretionary or administered-price items.

Production networks also shape the magnitude and timing of price responses to monetary policy shocks, generating pronounced heterogeneity across sectors and firms. From a consumption perspective, Allayioti et al. (2025) show that only around one-third of core inflation items respond significantly to monetary policy shocks, with sensitive items exhibiting substantially larger cumulative price responses (see Chart 2). Prices of discretionary items, such as durable consumption goods and recreation-related services, respond much more strongly to changes in monetary policy than those of non-discretionary or administered-price items (e.g. health and postal services), which display little or no sensitivity. In contrast, items with administered prices – and thus lower frequencies of price adjustment – respond less strongly. This heterogeneity mirrors the uneven transmission of monetary policy to demand across consumption categories.

Chart 2

Monetary policy pass-through to highly vs moderately sensitive HICPX items

(percent)



Notes: The figure shows the responses of HICPX sub-indices classified as highly (left panel) and moderately (right panel) sensitive to monetary policy shocks, based on the estimation of equation (5). Black lines represent the median of the distribution of weighted average responses based on the items' weights in the HICPX basket. Shaded areas represent the 68% credibility bands of the impulse response functions (IRFs). The IRFs are normalised to a positive monetary policy shock that increases the 1Y German Bund by 25 basis points.
Source: Allayioti et al. (2025).

Firms facing binding capacity constraints raise prices more strongly following a monetary policy easing shock, particularly if they have high market power.

On the production side, ChaMP studies highlight the role of pricing frictions, capacity constraints and market power. The importance of nominal rigidities for monetary policy transmission is broadly confirmed across ChaMP studies, which show how these rigidities affect different parts of the supply chain through several mechanisms. Using product- and firm-level evidence from Sweden, Ahlander et al. (2025) find that monetary policy easing shocks tend to generate delayed and hump-shaped producer price responses. However, this aggregate pattern masks substantial heterogeneity: firms facing binding capacity constraints raise prices more strongly, and among these firms, significant price increases are concentrated in those with high market power. This is consistent with standard network models showing that cost changes at intermediate production stages can propagate to downstream sectors through input-output linkages, and that when firms face binding capacity constraints, shocks are more likely to be transmitted via prices rather than quantities (see Acemoglu et al., 2016; Baqaee and Farhi, 2022). Along similar lines, Ahlander et al. (2025) document larger price rigidities in upstream sectors than in downstream sectors in the micro-data underlying the consumer and producer price indices for Sweden. They also show that the pass-through across products varies substantially with price-change frequencies.

While these studies do not explicitly model production-network positions, these findings may, taken together, suggest that nominal frictions play a stronger role in monetary policy transmission in upstream sectors. This seems consistent with further empirical evidence indicating that upstream industries tend to be associated with higher markups and stronger pricing power than downstream industries (see Colonescu, 2021). Consistent with the view that nominal rigidities dampen monetary policy transmission, Dhyne et al. (2026) find relatively delayed price responses only among upstream firms, indicating that firms in these sectors tend to be associated with a higher degree of nominal rigidity than downstream firms. In contrast, Christoffel et al. (2025) and Monti and van Keirsbilck (2025) find a more pronounced and rapid transmission of monetary policy to prices in upstream sectors, with these sectors, including energy and agriculture, tending to be characterised by relatively more flexible prices.

These differences highlight that the exact unfolding of sector-specific pricing effects depends on the composition of firm-level characteristics, going beyond the location of a sector within the production chain (see Section 4). For instance, Parlapiano (2025) shows that the pass-through of input cost shocks to output prices is incomplete for the average firm, with only very large firms exhibiting systematic pricing power and profit gains, thus underscoring the highly concentrated nature of price adjustment capacity within production networks. Rubbo et al. (2026) further illustrate how factor market segmentation, price and wage rigidities, and ownership structure amplify these effects across countries and sectors.

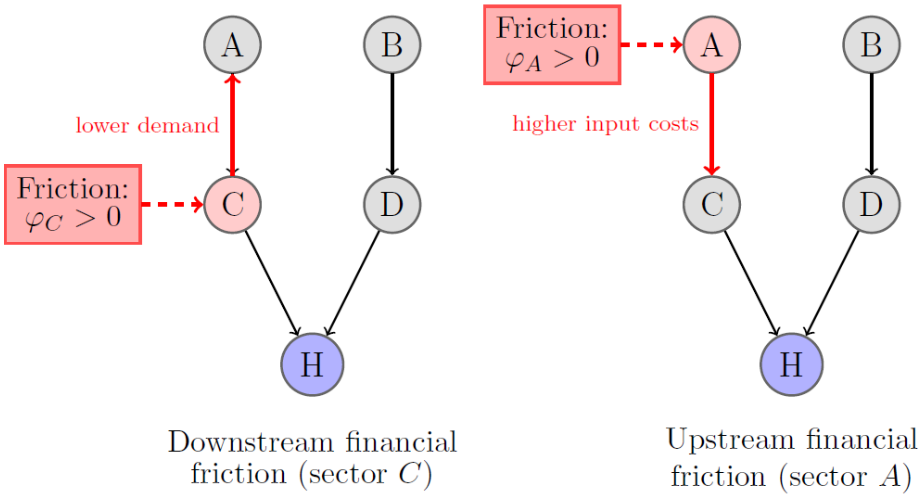
Following a monetary policy tightening episode, financially constrained downstream firms amplify disinflationary effects by further reducing their input demand. Meanwhile, financially constrained upstream firms mitigate disinflationary effects by raising their intermediate input costs.

Beyond pricing rigidities, financial conditions can shape price-setting behaviour along production networks by affecting firms’ marginal costs, liquidity constraints and the speed at which shocks are passed through to prices. Holm-Hadulla and Thürwächter (2026) show that higher corporate leverage strengthens the transmission of monetary policy to prices, even though it does not materially affect the impact of monetary policy on total output. They attribute this pattern to a competitiveness channel: economies experiencing an increase in leverage exhibit a stronger monetary policy-induced contraction in domestic demand than those experiencing a decline. However, in the former case, this is counteracted by a milder drop in exports, facilitated by the competitiveness gains resulting from their stronger price-level response. Given the marked variation in corporate leverage, these findings point to a relevant source of heterogeneity in monetary policy transmission associated with heterogeneous financial positions among firms.

Explicitly embedding financial frictions into production networks, De Sanctis et al. (2026) show that network-induced leverage exposure – capturing indirect financial dependence through supply chains – can either amplify or dampen disinflationary effects following a monetary policy tightening episode. Downstream financial constraints tend to reinforce disinflationary effects by reducing demand, with this contraction propagating upstream (left panel of Chart 3 below). By contrast, tight financing conditions for upstream suppliers mitigate disinflationary effects by raising intermediate input costs that then propagate downstream (right panel of Chart 3). These results underscore that the sign and strength of financial amplification depend critically on where financial frictions are located within the production network.

Chart 3

Financial frictions-induced propagation mechanism following an interest rate increase



Notes: The figure shows the upstream (LHS panel) and downstream (RHS panel) propagation of a tightening episode under sector-specific financial conditions associated with a tighter monetary policy stance in a stylised four-sector economy. Sectors A and B consist of firms acting as strict upstream suppliers of intermediate goods, while firms in sectors C and D are downstream final-goods producers, and thus customers from the production network. Households (H) buy only from downstream final-goods producers in sectors C and D.
Source: De Sanctis et al. (2026).

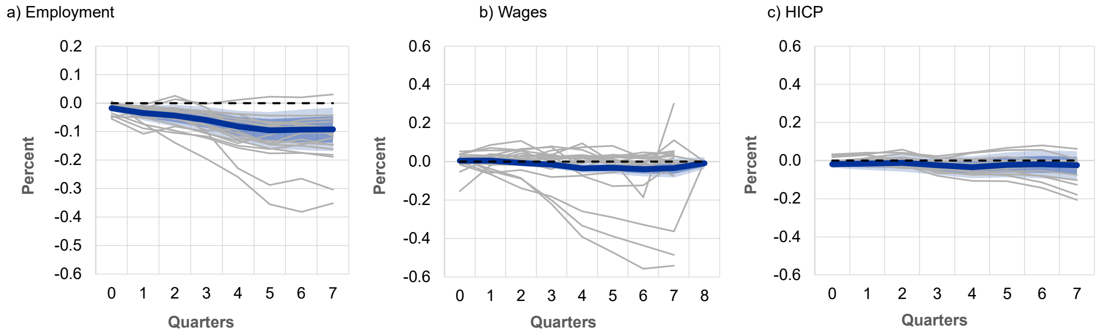
Box 2
Monetary policy in a currency union: aggregate and distributional impacts

Prepared by Chiara Osbat, with input from E. Rubbo, R. Domínguez-Díaz and G. Buss

This box introduces an input-output framework with multiple heterogeneous labour markets, allowing us to describe a currency union in which Member States differ in their industry composition, labour market institutions and trade linkages. The model connects these characteristics with uneven monetary transmission and imperfect stabilisation across member countries. Rubbo et al. (2026) depict the euro area as a network of 20 countries, where each industry in each country uses different types of labour and capital. It is well known (see Galí and Monacelli, 2008) that a single monetary authority is unable to perfectly stabilise country-specific shocks. The richness of our model allows us to take the Galí-Monacelli argument a step further: not only do member countries suffer from imperfect stabilisation, but the resulting employment and income volatilities are different across countries, even if they are subject to common aggregate shocks. This occurs for two reasons. First, imperfect stabilisation of local shocks generates different residual volatilities across countries. Second, even common shocks – including monetary policy itself – have differential effects across countries. Monetary policy transmission and residual volatility depend on country-level characteristics, such as wage and price flexibility and the average labour share. The quantitative results show that countries face very different levels of consumption, employment and output volatility in response to both monetary shocks and idiosyncratic local shocks. These sources of heterogeneity play a fundamental role in shaping the aggregate effects of local demand and supply shocks, and the appropriate monetary response to these shocks.

Chart A

Impulse responses to a monetary policy shock

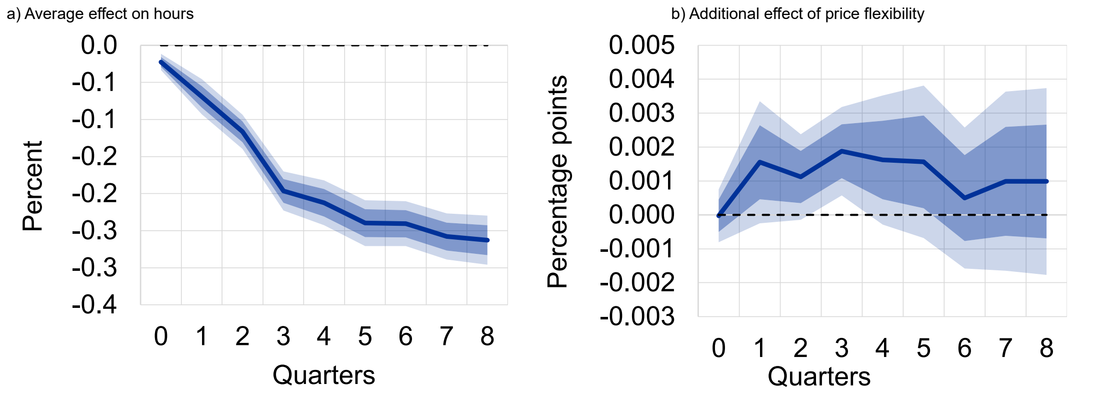


Note: Jarociński-Karadi monetary policy shock.
Source: Rubbo et al. (2026).

When the ECB tightens monetary policy, employment and consumption fall everywhere, but do so unevenly across countries and industries. Model-generated impulse responses reveal substantial dispersion in employment, wage and price responses (see Chart A). This heterogeneity is systematic and persistent, and it is linked to observable structural features of each economy, such as the degree of price flexibility in each industry. For example, the empirical results show that the contraction in hours following a monetary policy shock is smaller in sectors with more flexible prices, as predicted by the model (see Chart B).

Chart B

Impulse response of hours to a monetary policy shock, controlling for country-sector labour share



Note: Jarociński-Karadi monetary policy shock.
Source: Rubbo et al. (2026).

Why does the same interest rate change produce such different outcomes? The model predicts that output in countries with stickier wages, lower labour shares (as is typically the case in countries that specialise in manufacturing), and an industry composition tilted toward price-rigid sectors (such as services) contracts most following a policy tightening episode. The same pattern emerges, this time even more strongly, for the imperfect stabilisation of local TFP and demand shocks, resulting in markedly different residual volatility across Member States (see Chart C).

hen demand falls, firms in sticky-price sectors that cannot cut prices to maintain sales cut quantities instead. Countries whose industry composition is tilted towards more rigid sectors, such as services, therefore experience larger real effects. Wage and price rigidities within a given sector also differ across countries, further amplifying cross-country dispersion.

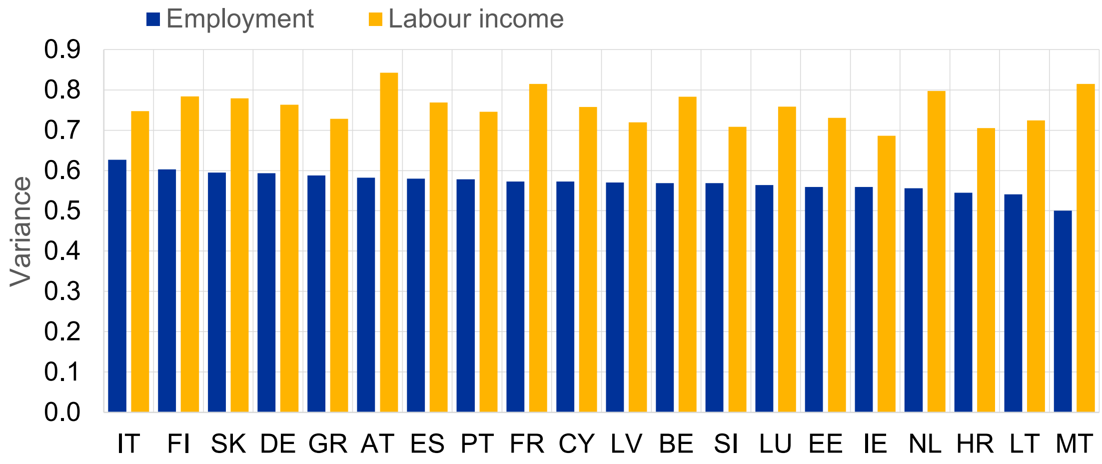
Position in the production network also matters. A country's position within the global supply chain also shapes its exposure to common shocks, as shown, for example, by Ghassibe and Nakov (2025). Countries specialising in upstream sectors tend to experience larger output responses.

Labour market characteristics are also important. In the short run, resources cannot be freely reallocated across countries, or even across industries within a country. If monetary policy dampens aggregate demand, workers in rigid labour markets find it hard to move. Likewise, fixed assets such as land and equipment cannot be easily scaled down. Industries that rely heavily on these assets are more sensitive to local and aggregate macroeconomic conditions. This effect is symmetric in the model with respect to positive and negative shocks.

These micro-level differences are observable in the data, and disaggregated measures can be directly mapped into the model using data from national accounts or the ESCB's PRISMA and Wage Dynamics Network databases (see Gautier et al., 2024, 2026; European Central Bank, 2009; and Izquierdo et al., 2017). The calibrated model tells us how a common aggregate demand shift affects different industries and households, which can in turn be aggregated to country-level data. In other words, this framework allows us to analyse differences in country responses in terms of observable characteristics of their economies and to perform counterfactual and sensitivity analysis based on alternative assumptions about labour market and industry characteristics.

Chart C

Volatility of employment and labour income following a monetary policy shock



Source: Rubbo et al. (2026).

Differences in employment and consumption volatility across countries and the distributional implications of this raise political economy concerns and hinder the smooth transmission of the common monetary policy. Even though countries bearing a greater burden during periods of restrictive policy correspondingly benefit more during periods of monetary easing, it is costly for them to face higher employment and income volatility. The model highlights the national characteristics associated with higher volatility, illustrating which structural reforms have the greatest potential to smooth transmission across countries. Examples include increasing the flexibility of labour and product markets – both within and across countries – and completing a capital markets union. The latter would help mitigate distributional effects, given that part of household income comes from ownership of firms and non-labour assets.

4 The granular view: empirical insights from firm-level production networks

Prepared by Alari Paulus (Eesti Pank) and Alberto Palazzolo (Nationale Bank van België/Banque Nationale de Belgique)

While empirical research using data on sectoral input-output linkages has a long history dating back to Leontief's groundbreaking work in the late 1920s, research using data on firm-level production networks is much more recent and remains fairly limited. However, national business-to-business datasets are becoming more readily available and the resulting increase in data granularity and dimensionality is striking, as we move from a few dozen or a few hundred sectors to hundreds of thousands or even millions of firms (see Box 3).

Data on firm-to-firm transactions allow researchers to build complex representations of the production network at a granular level. In Europe, such data are available for Belgium and, more recently, for several other countries (Estonia, Hungary, Italy and Portugal), whose data development was fostered by the ChaMP network.

Why is the firm dimension important? Highly granular information allows for more accurate mapping of supply chains and the identification of critical firms; it also enables more timely monitoring of supply disruptions (see Pichler et al., 2023). More fundamentally, from the perspective of improving our understanding of how shock propagation operates in production networks, firm-level data are important because they reveal much greater variation than sectoral data. The distribution of firm sizes and between-firm linkages is much more extreme than the distribution of sector sizes and between-sector linkages, carrying critical implications for shock propagation. In a theoretical input-output framework, it may not immediately matter whether the unit of analysis is defined as a sector or a firm (leaving aside the question of whether production technologies at different levels of aggregation can be approximated by the same production function). However, their distributions do matter, and the distributions of firms and sectors are not the same. As demonstrated by Gabaix (2011) and Acemoglu et al. (2012), the shape of the distribution determines how shocks propagate through the production network and whether they average out or decay too slowly for that to happen.

This section discusses what can be learned from firm-level production networks, drawing primarily on contributions from the ChaMP network. The first part presents key stylised facts about firm-level production networks and highlights additional empirical insights that emerge when moving from sectoral- or industry-level data to firm-level data. The remainder of the section examines empirical evidence on shock propagation in firm-level production networks, covering both the macroeconomic implications of firm-level shocks and the transmission of aggregate – specifically monetary policy – shocks through production networks.

Box 3
Business-to-business transaction data

Prepared by Alari Paulus (Eesti Pank) and Alberto Palazzolo (Nationale Bank van België/Banque Nationale de Belgique)

Data on firm-level production networks mainly come from administrative registers collected for value-added tax (VAT) purposes. Such data have been made available for a number of countries in Africa, Asia, Europe and South America. In Europe, Belgium has been at the forefront of research using business-to-business data. Business-to-business (B2B) data typically include information on sales volumes, although in some cases they are limited to binary indicators of links without information on transaction values (e.g. survey-based B2B data for Japan), and only rarely are sales volumes decomposed into prices and quantities.

Administrative data offer three key advantages for studying production networks. First, their near-universal coverage captures all registered firms above minimum reporting thresholds, spanning microenterprises to multinationals. This gives it a critical edge over commercial datasets such as FactSet, which typically cover only large or publicly listed firms and therefore suffer from substantial selection bias, missing the vast majority of small firms that dominate network connectivity (see Bacilieri et al., 2023). Second, arm's-length transactions ensure that reported flows reflect market exchanges between distinct legal entities. Third, pecuniary sanctions for misreporting, together with cross-checks between seller-reported sales and buyer-reported purchases, ensure a high degree of accuracy. The main limitation of administrative records on B2B transactions is that they usually cover only domestic transactions, and it would be a natural goal to extend the mapping of firm networks across country borders and regions (Pichler et al., 2023). VAT declarations are also typically subject to reporting thresholds, albeit with some exceptions (e.g. Hungary and Ecuador).

Magerman et al. (2026) draw on B2B transaction data collected by European tax authorities for fiscal monitoring and enforcement purposes. Across Europe, two principal data collection methods coexist: value-added tax (VAT) declarations and electronic invoicing systems. Under the VAT declaration regime (Belgium, Estonia and Hungary), firms report the aggregate value of their transactions with each trading partner to the tax authorities, with reporting frequencies ranging from monthly (Estonia) to annual (Belgium). When a seller reports its sales to a buyer, the bilateral relationship becomes observable with a high degree of accuracy. Electronic invoicing regimes (Italy and Portugal) require firms to transmit individual invoices to the tax authorities in real time. While e-invoicing generates transaction-level rather than relationship-level data, aggregation to the firm-pair level yields datasets that are structurally comparable to those obtained under VAT declaration systems. In 2019, the datasets for these five countries covered between 100,000 firms (Estonia) and 1.7 million firms (Italy), with the number of observed B2B relationships ranging from more than 800,000 annual bilateral links in Estonia to nearly 60 million in Italy.

4.1 From sectoral to firm-level production networks

Recent empirical studies using business-to-business (B2B) transaction data reveal fundamental properties of production networks that were previously masked by sectoral aggregation. We draw on Magerman et al. (2026), who provide a comparative analysis of firm-level production networks in five European countries (Belgium, Estonia, Hungary, Italy and Portugal), and on Bacilieri et al. (2023), who systematically compare datasets across different economies and reporting regimes to identify which network properties are robust rather than artefacts of data collection. Together, these studies provide the most comprehensive cross-country evidence to date on firm-level production networks.

As documented in Magerman et al. (2026), six robust empirical regularities emerge from comparing firm-level networks across these five European countries. The consistency of these patterns across countries with different economic sizes, industrial compositions and institutional settings provides added confidence that they represent fundamental features rather than country-specific sectoral or institutional structures. Network properties also tend to be relatively stable over time (Bacilieri et al. 2023).

Sales are heavily concentrated across the firm distribution, with the top 10% of firms accounting for 80-90% of sales, although the degree of concentration varies heavily across industries.

Firs, production networks exhibit extreme concentration at both the firm and network relationship levels (Table 1). The top 10% of firms account for 81-89% of total network sales across the five countries, while the top 1% alone captures 45-64%. Estonia displays the lowest concentration (top 1% at 45%), while Belgium shows the highest (64%). Concentration is even more pronounced at the relationship level: the top 10% of B2B links account for 81-96% of total transaction value, while the top 1% of bilateral relationships represents 50-80%. This concentration at both the firm and link levels implies that shocks to the largest firms or most important partnerships can have aggregate consequences, challenging the standard assumption that idiosyncratic firm-level disturbances average out when aggregated across many producers.

Table 1

Concentration of firm-level network sales and buyer-seller relationship values

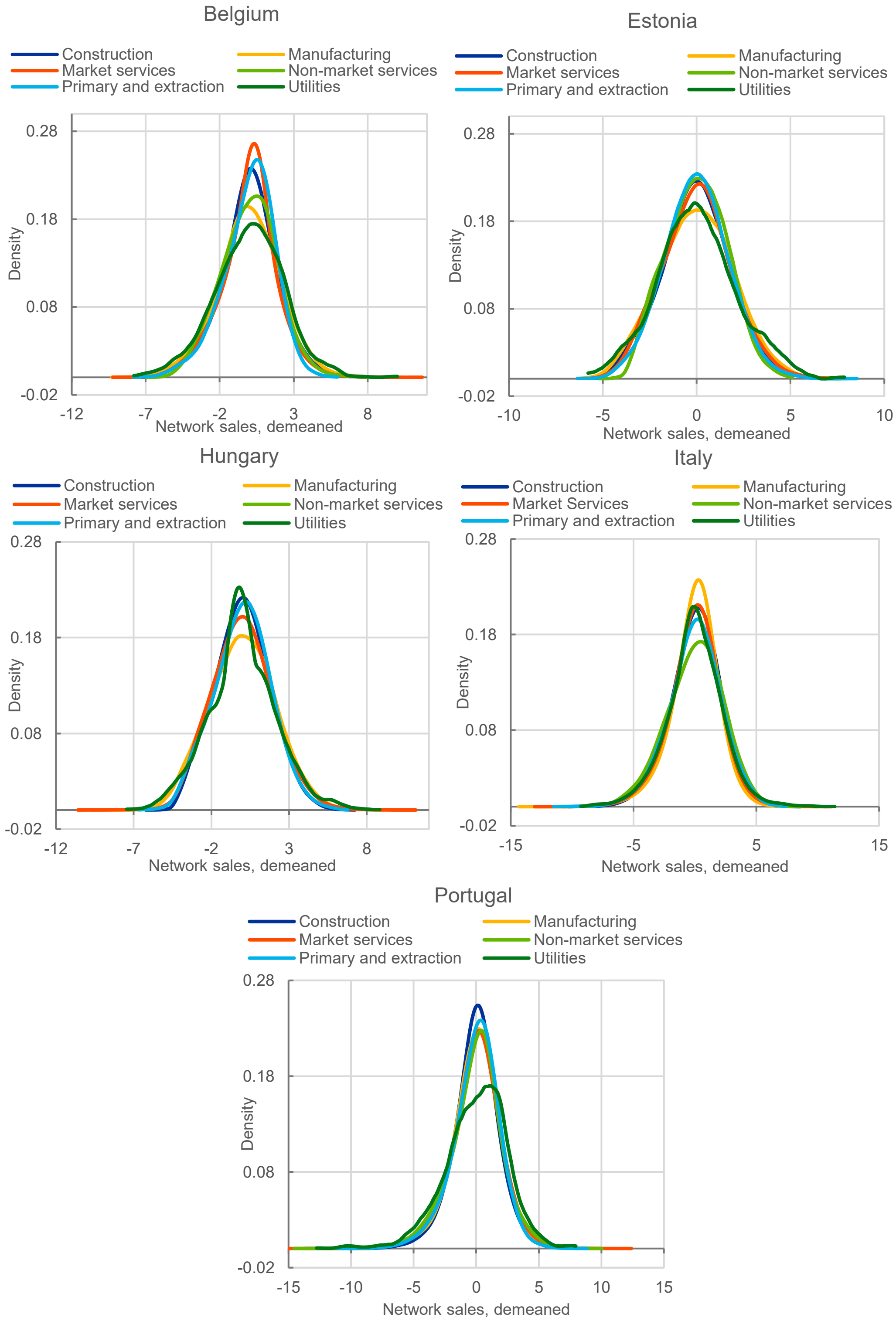
	Panel a): Network sales		Panel b): Bilateral sales	
Country	Top 10%	Top 1%	Top 10%	Top 1%
Belgium	0.89	0.64	0.92	0.72
Estonia	0.81	0.45	0.81	0.5
Hungary	0.86	0.59	0.86	0.61
Italy	0.87	0.61	0.93	0.72
Portugal	0.87	0.63	0.96	0.79

Notes: Panel a) reports the share of total domestic inter-firm sales observed in the network accruing to the top 10% and top 1% of firms by country for the year 2019. Panel b) reports the share of total bilateral sales value accruing to the top 10% and top 1% buyer-seller relationships, ranked by annual transaction value
Source: Magerman et al., 2026.

Second, even after accounting for the characteristics of narrowly defined sectors, firms’ network sales vary by 6-8 orders of magnitude within the same narrowly defined industry. Thus, there is sizeable within-industry heterogeneity. Chart 4 plots industry-demeaned distributions of network sales across all five countries. The distributions overlap substantially across sectors, suggesting that the degree of within-industry heterogeneity is broadly similar regardless of sector affiliation, meaning that firms within an industry tend to differ from one another about as much as firms across different industries do. This pattern holds most clearly for Belgium, Italy and Portugal.

Chart 4

Distribution of firm-level network sales by industry



Notes: The figure reports kernel density estimates of firm-level network sales, demeaned at the NACE 4-digit level and grouped again by high-level industry. The horizontal axis is shown on a logarithmic scale.
Source: Magerman et al. (2026).

In Hungary and Estonia, some sectoral differences remain visible, particularly in the left tail, suggesting that the degree of within-sector dispersion is not entirely uniform across sectors in these countries. The main exception across all countries is utilities, whose distribution tends to stand somewhat apart from the rest. This finding is not surprising given the very limited number of firms in that sector, which makes the estimated distribution more sensitive to individual observations. This pattern is stable across countries despite substantial differences in the size of their economy and industrial structure. Sectoral affiliation explains only a small fraction of the observed heterogeneity: the vast majority of economically relevant variation occurs at the firm level within sectors rather than across sectors. Consequently, models that assume within-industry homogeneity fail to capture most of this variation.

Third, firm-level data show substantial heterogeneity not only in the number of customers (out-degree), as in industry-level networks, but also in the number of suppliers (in-degree). The number of customers per firm follows a power-law distribution with a heavier tail than the number of suppliers. This makes customer networks extremely concentrated: the distribution is so skewed that a small number of firms serve so many more customers relative to the typical firm that the variance is effectively infinite. Supplier networks, while still heavy-tailed, display less extreme dispersion. While firms typically supply and source from a similar number of counterparties, the upper tail tells a different story: the maximum number of customers a single firm can reach far exceeds the maximum number of suppliers a firm sources from, pointing to a fundamental asymmetry between the two sides of the network. This asymmetry is remarkably stable across countries, both in Magerman et al. (2026) and in the comprehensive datasets covering all transactions analysed by Bacilieri et al. (2023). In other words, even when firms grow by expanding their customer base, their supplier base does not grow commensurately.

A variance decomposition of firm sales confirms this pattern: the extensive margin of customers accounts for 42-51% of within-industry firm size variance across countries, while seller-side characteristics (such as productivity, quality or the firm's supplier base) explain 16-22% and customer characteristics contribute 21-26%. Final demand exposure explains only 1-12%. Hence, this evidence suggests that firm growth is associated mainly with acquiring more customers rather than with increasing sales to existing customers or expanding direct exposure to final demand. The dominance of the extensive margin of customers is observed across all sectors, indicating that it represents a pervasive structural feature rather than an industry-specific phenomenon. Similarly, the extensive margin of customers has been found to account for most of the sales variation across merchants based on Visa card transaction data for the United States (see Einav et al., 2021).

At the sectoral level, networks appear denser than they are at the firm level; firm-level data allows us to study transmission through specific supply chains.

Fourth, firm-level production networks (FPNs) are extremely sparse, meaning that the vast majority of potential firm-pair links do not exist. Yet when aggregated to broad sectors, the network appears nearly fully connected, with almost every sector pair recording positive flows in both directions. At the firm level, production chains are well defined, with identifiable upstream-downstream paths. At the sector level, however, networks appear diffuse, with multiple alternative pathways. This "artificial densification" may alter shock propagation: sectoral input-output models suggest broad diffusion across many channels, whereas the firm-level reality frequently involves concentrated transmission through specific supply chains. Despite their sparsity, FPNs still exhibit the small-world property, meaning that all firms are interconnected through relatively few steps (Bacilieri et al., 2023).

Fifth, for any given sector pair, firm-level input shares exhibit enormous dispersion around their sector average. Even among firms operating within the same narrowly defined supplier-customer pair, the variation across firms is several times larger than the average itself, meaning that the sector-level coefficient is a poor summary of the underlying firm-level relationships. A sector-level input-output table might report that automotive manufacturers source 5% of their inputs from the steel sector, yet individual firms range from nearly zero to several multiples of that average. Output shares display similarly large heterogeneity across all countries and levels of aggregation. This substantial within-pair dispersion implies that sector-level technical coefficients are poor proxies for firm-level linkages. Consequently, a shock to the steel sector affects automotive manufacturers very differently, depending on their idiosyncratic exposure: some experience no impact, while others face substantial input cost increases.

Sixth, network influence, measured by Katz-Bonacich centrality (see Box 1), correlates only moderately with firm size. Some medium-sized firms are highly central because they supply many producers who are themselves well-connected, while some large firms are peripheral, selling mainly to final demand. This means that knowing a firm’s size is not enough in itself to predict its influence on aggregate outcomes through the network. Network influence is also only moderately correlated with the number of trading partners, indicating that what matters is not just how many partners a firm has but also who those partners are. Vertical position in production chains represents yet another independent dimension of heterogeneity: how far a firm sits from final demand is essentially unrelated to how large it is, and a firm’s distance to final demand tells us little about its distance from primary inputs. These dimensions of heterogeneity are therefore distinct and cannot be reduced to one another. Large firms are not systematically located upstream or downstream, and upstreamness is only weakly correlated with centrality. This multi-dimensional heterogeneity means that the aggregate impact of firm-level shocks cannot be inferred from firm size or sales share alone. Network centrality and vertical position constitute distinct dimensions of heterogeneity that are masked by sectoral aggregation and have direct implications for monetary transmission.

Collectively, these findings show that production network heterogeneity operates along multiple independent dimensions (size, concentration, centrality, vertical position and customer-supplier asymmetry) that are invisible in sectoral data but critical for understanding how monetary policy shocks propagate through firm-to-firm relationships and generate heterogeneous real effects.

4.2 Macroeconomic implications of firm-level shocks

Firm-level data strengthen the predictive accuracy of sector-level data by accounting for important asymmetries and nonlinearities.

How much does the granularity of production networks matter for modelling the propagation of shocks in the economy? Diem et al. (2024) use Hungarian firm-level data on the production network to investigate how model predictions differ between firm-level and sectoral aggregation, modelling a range of shocks calibrated to the COVID-19 episode. They demonstrate that aggregate industries do not always reflect the features of individual firms, which are highly heterogeneous within sectors in terms of their linkages to other firms, both within and across sectors. They also find that firm-level input-output linkages add substantial predictive accuracy when compared with sectoral level linkages. For the simulated shocks, predictions at the sectoral level typically underestimate aggregate outcomes by about 15-20% because they fail to account for important asymmetries and nonlinearities. The structure of the production network at the firm level is therefore crucial for understanding how shocks propagate and how the economy adapts and evolves in response.

Theoretical work by Gabaix (2011) and Acemoglu et al. (2012) has shown that idiosyncratic productivity shocks at the firm or sectoral level do not average out when the distribution of firms or sectors is highly skewed and network links are highly asymmetric. As a result, such shocks can push up aggregate volatility to a significant degree. Using Belgian B2B data, Magerman et al. (2016) confirm that idiosyncratic firm-level volatility in productivity growth accounts for roughly half of the aggregate volatility of GDP growth. This is similar to what Foerster et al. (2011) found using sectoral level data for the United States, although it is somewhat lower than the 80% estimated by Atalay et al. (2017) for the United States at the industry-level. Magerman et al. (2016) further demonstrate the importance of granular effects by showing that the top 100 most influential firms account for as much as 90% of the total contribution that idiosyncratic shocks make to the aggregate volatility of the economy.

Common input shocks are passed through fully from buyers to sellers, while idiosyncratic shocks are passed through only partially.

Further insights into price setting and pass-through in production networks can be gained by combining B2B data with high-frequency firm-level producer price data. For example, using data from Belgian manufacturing firms, Duprez and Magerman (2018) estimate that the pass-through of input price changes to consumer prices is incomplete and that, on average, only about half of input cost increases are passed on to buyers. They also show that firms respond to the prices charged by other firms and highlight an important distinction regarding the nature of shocks: while common input cost shocks are fully passed through, idiosyncratic shocks are passed through only partially.

4.3 Propagation of monetary policy shocks in firm production networks

Following a monetary policy shock, the sales and prices of firms close to final demand react faster but less persistently, while upstream firms are slower to react, but do so more persistently.

Firm-level production network data can also enhance our understanding of how aggregate (exogenous) shocks propagate through the economy and their heterogeneous effects on the real economy and prices. Dhyne et al. (2026) estimate the effects of monetary policy shocks in the euro area on firm-level sales and producer prices in Belgium. Their main contribution lies in showing how these effects vary with firms' positions in the production network – ranging from upstream to downstream – or, in other words, with their distance from final demand. They find that, following a negative monetary policy shock, firms closer to final demand experience relatively rapid but short-lived declines in sales (lasting up to two quarters), whereas firms that are further upstream face more pronounced and more persistent contractions (lasting up to three years), albeit with a longer lag (nine to ten quarters). Similar dynamics are found to exist for producer prices.

Given that monetary policy shocks operate primarily through the demand channel, this result may seem counterintuitive at first, as one might expect that firms closer to final demand (i.e. more downstream firms) would respond more strongly. Dhyne et al. (2026) investigate this further by separating the direct and indirect effects of monetary policy shocks. They show that the overall response is driven primarily by indirect effects arising from firms' exposure to other firms in the production network as shocks propagate through it, rather than by direct effects on individual firms. More importantly, exposure to downstream customers (backward propagation) is found to have significant effects, while there is insufficient evidence on the effects of exposure to upstream suppliers (forward propagation), highlighting the importance of shock transmission through the indirect demand channel.

The contribution of upstream and downstream firms to the aggregate reaction to monetary policy shocks is heterogeneous across countries, with Italy exhibiting a larger contribution from upstream firms, followed by Belgium and Portugal, while firms towards the middle of the production chain play a more prominent role in Estonia and Hungary.

Magerman et al. (2026) use these results to extrapolate the effects of monetary shocks to other selected European countries (Estonia, Hungary, Italy and Portugal), taking into account the structure of their production networks, in particular firms' upstreamness. Aggregate sales and price responses of the most upstream firms vary considerably across countries (see Table 2).

Table 2

Average contribution of firms with an upstreamness index greater than or equal to 4 to the aggregate sales and price response to a monetary policy shock

Table 9 in Magerman et al. (2026)

	Sales	Prices	Share of firms with upstreamness ≥ 4
Belgium	0.30	0.21	0.34
Estonia	0.03	0.02	0.13
Hungary	0.05	0.04	0.26
Italy	0.46	0.73	0.40
Portugal	0.21	0.46	0.24

Note: The contributions are computed as the ratio of the sales-weighted response of the group to the total sales-weighted aggregate response and are then averaged across years and horizons.

At one extreme is Italy, the largest country in the sample, where the most upstream firms alone account for a large share of the aggregate response to monetary policy shocks. At the other extreme are Estonia and Hungary, where firms in the middle of the upstream-downstream distribution account for the bulk of the aggregate response. Belgium and Portugal are closer to Italy than to the other two countries, with the most upstream firms contributing a large share of the aggregate response (around 20-45%), though the pattern is less extreme than in Italy. The ranking of countries partly reflects the cross-country distribution of firms based on their upstreamness (see the last column). Notably, the same ranking emerges when the response is calculated for the top 10% of the most upstream firms.

5 Implications for the Phillips curve and for monetary policy

Prepared by Anton Nakov (European Central Bank)

The Phillips curve is a core organising device in macroeconomics, linking inflation to measures of real activity such as unemployment or the output gap. In its traditional, linear New Keynesian form, inflation is modelled as a function of expected future inflation and real marginal costs, with a constant slope. This framework underlies much of modern monetary analysis, including optimal monetary policy. The slope of the Phillips curve is critical because it determines the trade-off the central bank faces between stabilising inflation and closing the output gap.

Recent research, however, offers a more nuanced understanding of this relationship. For instance, Gagliardone et al. (2025a) find a steep slope for the cost-based Phillips curve, which contrasts with the low estimates obtained for the conventional output gap-based formulation found in the earlier literature. At the same time, Gagliardone et al. (2025b) and Karadi et al. (2025) show that state-dependent pricing generates nonlinearities in the inflation-activity nexus. The Phillips curve appears to be steeper at the ends and flatter in its central segment, thus yielding a more complex inflation-output gap trade-off.

This chapter discusses how nominal frictions and networks reshape the Phillips curve (Section 5.1), and how these features modify the design of monetary policy (Section 5.2). It draws on ChaMP studies that combine granular production networks, heterogeneous firms, and state-dependent pricing in models of inflation dynamics and monetary policy.

5.1 Nominal rigidities, networks and the Phillips curve

5.1.1 Nonlinearity from state-dependent pricing

Firms adjust prices more frequently when there are large aggregate shocks, and the average size of price changes also increases.

In models with state-dependent pricing, firms adjust prices when the expected gains from doing so exceed the fixed (“menu”) cost. The frequency and size of price changes therefore depend on the state of the economy, including the magnitude and persistence of shocks.

Evidence from recent episodes of large shocks, such as the COVID-19 pandemic and the subsequent energy and supply disruptions, indicates that the Phillips curve is not well approximated by a linear relationship with a constant slope, as documented by Gautier et al. (2026) and Ascari et al. (2025). When aggregate shocks are small, many firms remain in a region where it is not profitable to adjust prices except for idiosyncratic reasons. In this case, price increases and decreases roughly cancel each other out in the aggregate. As a result, the inflation response to changes in slack or marginal costs is more muted, giving rise to a relatively flat Phillips curve in normal times.

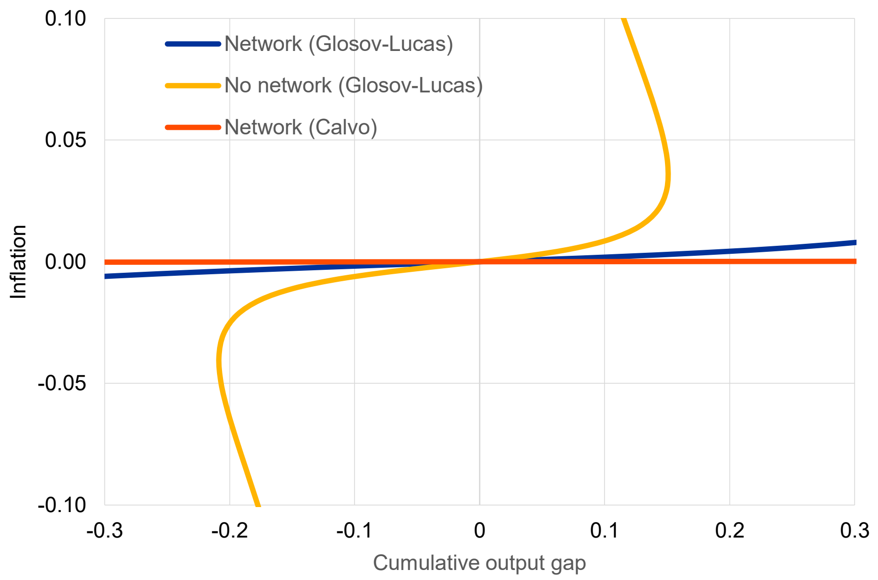
By contrast, during large aggregate shocks, many firms are pushed past their inaction thresholds. The fraction of firms adjusting prices rises sharply and the average size of the price changes increases. Gautier et al. (2026) and Ascari et al. (2025) show that, in such situations, the slope of the Phillips curve steepens. Inflation becomes more responsive to a given change in marginal cost, and the sacrifice ratio falls: for a given desired change in inflation, the necessary change in output or unemployment is smaller.

Phillips curves are nonlinear: they have a flat region for small shocks and normal macroeconomic conditions and a steeper region for larger shocks.

To sum up, the Phillips curve has a flatter region for small shocks and normal macroeconomic conditions, characterised by higher effective price stickiness and a higher sacrifice ratio, and a steeper region for large shocks, where widespread price adjustment yields a stronger mapping from slack to inflation and a lower sacrifice ratio (see the yellow line in Chart 5).

Nonlinearity helps reconcile another related tension: micro-level evidence often supports steep cost-based Phillips curves – firm-level prices respond strongly to marginal costs – whereas macroeconomic data often exhibit flat output-based Phillips curves. Gagliardone et al. (2025a) show that, once one accounts for the low elasticity of aggregate output with respect to marginal costs and for strategic complementarities in pricing, micro-level steepness translates into an aggregate relationship that is weak in normal times but can become much stronger in stressed states.

Chart 5
Phillips curves with and without networks



Source: Ghassibe and Nakov (2025).

5.1.2 Network-driven amplification and dampening

The shape and slope of the Phillips curve are further altered when production takes place within a network of interconnected firms and sectors. In such environments, shocks to a subset of nodes, such as key upstream suppliers or tradable goods sectors, propagate downstream and across sectors through input-output linkages.

Aggregate demand shocks are dampened by the production network because intermediate input prices rise only gradually.

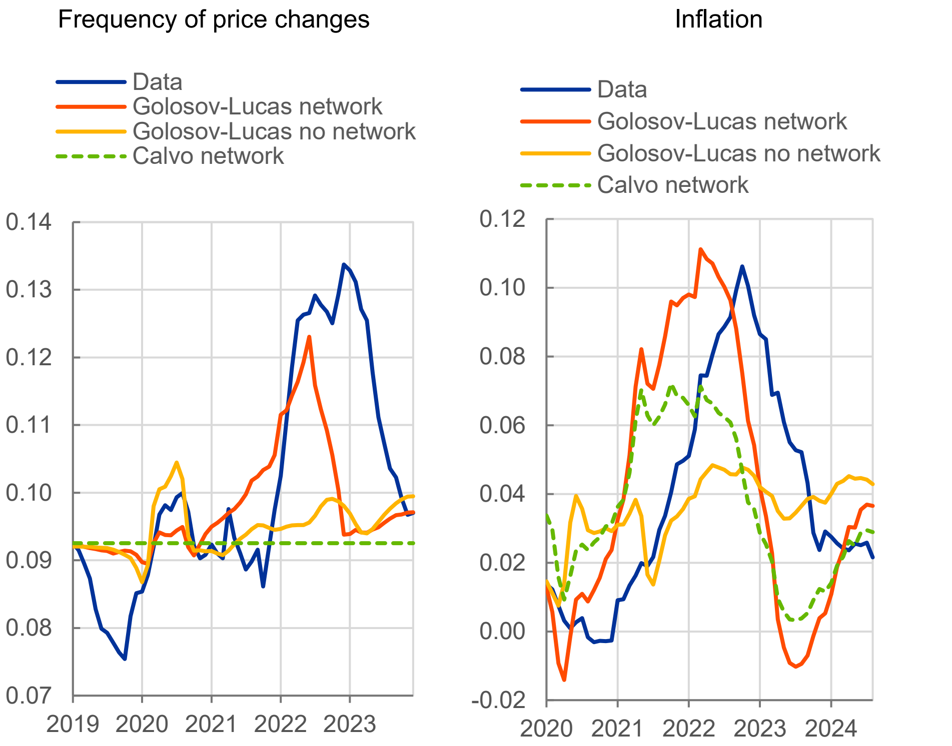
Building on the literature initiated by Nakamura and Steinsson (2010) and Klenow and Willis (2016), Ghassibe and Nakov (2025) show that when aggregate demand rises, such as following a monetary expansion, firms experience higher sales and only moderately higher costs; not enough to trigger widespread repricing. This is because the prices of intermediate inputs, which are also subject to menu costs, rise only gradually when compared with the increase in demand. Since costs rise by less than the increase in demand, so do output prices in any given sector, thus dampening the overall increase in the fraction of firms that reprice. As a result, networks slow price adjustment in response to demand shocks relative to an otherwise identical economy without network linkages. This gives rise to a wider flat central section of the Phillips curve (see Chart 5, blue line).

Supply shocks trigger pricing cascades because many firms in different sectors are incentivised to reprice at the same time.

Aggregate supply shocks tell a different story: assuming constant demand, a substantial increase in the cost of all inputs triggers a “pricing cascade”. Many firms in different sectors are incentivised to reprice at the same time, with prices feeding back as higher input costs for all sectors. This induces firms in all sectors to raise their prices further, leading to a sharp and rapid inflationary surge and a drop in real output. Indeed, the euro area inflation surge of 2021-23 and the associated rise in repricing frequency can be modelled jointly by combining production networks with state-dependent pricing, as in Ghassibe and Nakov (2025) (see Chart 6).

Chart 6

Frequency of price changes and inflation



Notes: Blue solid line: data; red solid line: model with production networks and state-dependent pricing; yellow solid line: model with no production networks; green dashed line: model without state-dependent pricing.
Sources: Gautier et al. (2026) and Ghassibe and Nakov (2025).

The location of the shock within the network also matters. A cost shock affecting an upstream firm raises its output price, which in turn becomes an input cost for downstream firms. Those downstream firms may then adjust their own prices, potentially amplifying the initial shock as it travels along the supply chain. When shocks affect highly central sectors (i.e. those with many customers or suppliers), the impact on aggregate inflation can be disproportionate relative to the sector's share of GDP. As a result, a given sectoral shock may move the aggregate Phillips curve more than would be implied by a representative firm model.

Firms differ in their frequency of price adjustment, menu costs and exposure to shocks. Ghassibe et al. (2025) emphasise that such heterogeneity, combined with network propagation, can amplify the forward-looking component of inflation. Sticky-price firms that are deeply embedded in the network have strong incentives to adjust prices in anticipation of future cost changes that will arrive through their input suppliers, imparting a more forward-looking character to inflation dynamics.

Firms' optimal prices depend not only on their own costs and levels of demand but also on the prices charged by their competitors and suppliers. In networks with strong complementarities, individual price adjustments raise the incentive for others to adjust, creating clusters of adjustments and reinforcing the nonlinear response of inflation to shocks.

Regarding monetary policy, Christoffel et al. (2025) find that production networks tend to dampen the aggregate and sector-specific inflation sensitivities to a monetary policy shock, implying a weaker transmission of monetary policy to inflation in the presence of inter-sectoral linkages.

5.2 Optimal monetary policy with a nonlinear Phillips curve and networked economies

5.2.1 Previous findings on optimal policy with networks

Although production networks add complexity to the central bank's problem, it is still optimal to focus on the aggregate output gap rather than attempting to stabilise relative prices.

La'O and Tahbaz-Salehi (2022) find that once firms are linked through input-output networks, the textbook "divine coincidence" result tends to break down: monetary policy can no longer implement the flexible-price, first-best allocation except under very special conditions. Within a stylised benchmark economy, the optimal monetary policy is characterised as stabilising a specially constructed price index rather than the standard CPI or PPI, with relative weights that rise for sectors that are larger, have stickier prices, are more upstream, and have relatively flexible suppliers but stickier downstream customers. A policy that succeeds in stabilising the aggregate output gap performs close to the optimum when sectors with flexible prices are assigned lower weights and sectors are weighted by their sales shares.

In a similar vein, Rubbo (2023) finds that in a production-network economy the optimal monetary policy trades off closing the aggregate output gap against reducing price misallocation within and across sectors. However, when using aggregate instruments only (such as the policy interest rate, QE or forward guidance), the central bank's ability to improve allocative efficiency across sectors becomes very limited. The welfare gains from distorting the output gap to fix network-induced price gaps are small, and the optimal policy is extremely close to strict output-gap stabilisation in all periods, implementable via a Taylor-type rule targeting a "divine coincidence" inflation index adjusted for network structure.

Network details imply only small optimal deviations from a zero output gap, such as, a bias toward stabilizing upstream prices or wages in vertical production chains, or a modest accommodation of inflationary supply shocks. However, network details do not affect the core prescription that near-complete stabilisation of the aggregate output gap is optimal.

5.2.2 Responses to large cost-push shocks

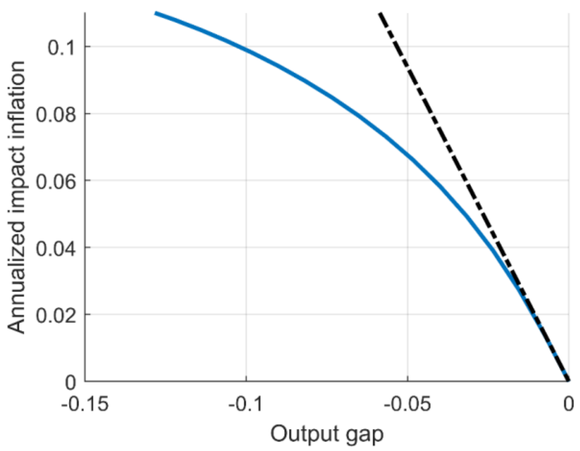
The sacrifice ratio for monetary policy is lower following a large aggregate cost-push shock, implying that aggressive policy reactions can be optimal for bringing inflation back to target.

Much of the existing literature on optimal policy focuses on constant-slope New Keynesian Phillips curves. Moreover, traditional frameworks, such as linear-quadratic approximations around the steady-state, may be misleading in nonlinear networked environments. Optimal policy must be both state contingent and "network-aware".

For instance, Karadi et al. (2025), Gagliardone et al. (2025b), Ascari et al. (2025) and Gautier et al. (2026) all argue that, in models with state-dependent pricing, the Phillips curve steepens when large aggregate cost-push shocks emerge. In this region, the marginal cost of reducing inflation in terms of output loss is lower than in normal times. This implies that more aggressive policy tightening in response to large cost shocks can be optimal, all else being equal. The central bank might want to "strike while the iron is hot," exploiting the steeper Phillips curve to bring inflation down rapidly (see Chart 7). A contrasting argument is presented in Section 5.2.3, which instead prescribes a less aggressive response to purely supply-driven, external inflationary pressures.

Beyond the risk of missing the window of opportunity, delayed or timid responses may allow inflation expectations to drift, ultimately requiring more persistent and costly tightening once the economy has moved back into a flatter region of the Phillips curve. This logic rationalises front-loaded rate hikes in response to large supply shocks (e.g. rising global energy prices or shipping disruptions). In a networked environment, where shocks propagate and may affect central nodes, the gains to be made from early, decisive action may be even larger, as such action prevents network amplification from transforming localised cost pressure into generalised inflation.

Chart 7
Target output – inflation relationship



Notes: Dashed line: traditional Calvo model. Blue solid line: SDP model.
Source: Karadi et al. (2025).

5.2.3 Global value chains and the inflation-output trade-off

In economies that are highly integrated into global supply chains, optimal monetary policy should be less aggressive in response to supply-driven, external inflationary pressures.

Global value chains (GVCs) add another layer of network complexity. When production is fragmented across borders, domestic inflation is influenced by foreign costs, exchange rates and external bottlenecks. Ascari et al. (2024) suggest that the degree of GVC participation modifies the inflation-output trade-off in important ways.

High GVC integration means that foreign and external cost shocks have larger effects on domestic prices via imported intermediate inputs.

Supply chain disruptions, such as port closures, shipping delays and geopolitical tensions, translate more rapidly and strongly into domestic inflation. In such economies, attempting to fully offset supply-driven inflation with domestic demand contraction may lead to larger output losses. In their analysis, the effective slope of the Phillips curve with respect to domestic slack becomes flatter, in the sense that stabilising inflation requires disproportionately large declines in domestic activity.

Therefore, in economies with high GVC integration, optimal monetary policy should be less aggressive in response to purely supply-driven external inflationary pressures. The central bank must disentangle demand-driven from supply-driven inflation and accept some inflation variability when shocks are driven by global cost factors that are costly to offset domestically.

5.2.4 Targeting strategies in a networked economy

Services inflation and underlying core measures are more reliable indicators of the domestic component of inflationary pressures and are therefore useful in calibrating the policy stance.

Network structures and GVCs complicate simple targeting strategies based on headline inflation. When inflation reflects a mixture of network-propagated supply shocks and domestic demand conditions, using aggregate CPI as the sole guide for policy can be misleading. Christoffel et al. (2025) argue that policymakers should prioritise the joint stabilisation of output and inflation while using services inflation as a key policy signal.

Services inflation tends to be less directly affected by global commodity prices and tradable intermediate inputs, and more closely tied to domestic labour market conditions, demand and underlying inflation expectations. In a networked production structure, where goods sectors are heavily exposed to external supply shocks, services inflation is a more reliable measure of the domestic component of inflationary pressure.[1]

This leads to a more nuanced targeting strategy: headline and goods inflation are monitored for signs of network-driven shocks and bottlenecks, while services inflation and underlying core measures are predominantly used to gauge demand conditions and calibrate the policy stance.

Such sectoral or component-based targeting is naturally complemented by network-based indicators, such as measures of sectoral inflation dispersion, the frequency and size of price changes in key upstream sectors, and real-time indicators of supply chain stress and delivery times. These indicators help identify whether the economy is in a regime dominated by network-driven supply shocks or broad-based demand pressures.

[1] Andreolli et al. (2025) argue that central banks may find it desirable to consider inflation and output dynamics separately in essential and non-essential sectors.

5.2.5 Expectations management under heterogeneous stickiness

Expectations management is a key policy instrument for the central bank, particularly when the complexity of the economy makes output-gap stabilisation less predictable.

With heterogeneous price-setting behaviour and network propagation, expectations become even more central to the transmission of monetary policy. Ghassibe et al. (2025) show that heterogeneity in price stickiness makes inflation more forward-looking at the aggregate level: firms that adjust prices infrequently have strong incentives to incorporate expectations of future costs and demand into their current pricing decisions.

In a networked context, this means that expectations about future shocks to central sectors or to global supply chains can significantly influence current inflation, even before such shocks fully materialise. If expectations become unanchored (such as where agents anticipate persistent future inflation owing to repeated network disruptions), inflation becomes more sensitive to beliefs and less sensitive to current slack.

For central banks, the implication is that expectations management is a primary policy instrument, particularly when structural features of the economy (GVCs, complex networks, heterogeneous stickiness, etc.) reduce the efficacy or predictability of conventional output-gap stabilisation. Effective expectations management requires clear, consistent communication about the reaction function and long-term inflation goal; a credible commitment to returning inflation to target over a realistic horizon; and a clear differentiation in policy communication between transient, network-driven supply shocks and persistent demand-driven inflation.

By anchoring expectations, central banks can partially offset the amplification of forward-looking behaviour induced by network structures and heterogeneity, thereby helping to stabilise the economy over the medium term.

5.2.6 Monetary rules for networked economies

Optimal monetary policy should be state-contingent and network-aware, incorporating measures of cost-push and domestic demand pressures.

The combined presence of nonlinear Phillips curves, production networks, and GVCs calls for a rethinking of “simple rules” for monetary policy. Standard Taylor rules, which map deviations of conventional measures of inflation and output from their targets into interest rate changes using constant coefficients, are unlikely to be fully optimal in this environment.

Three types of modifications emerge from recent work:

1. Targeting the right measure of inflation

Rubbo (2023) underscores the importance of targeting the right measure of aggregate inflation (known as the “divine coincidence index”) to account for network linkages, even abstracting from import prices or nonlinearities. Her proposed inflation measure places greater weight on larger and stickier sectors.

2. State-dependent and nonlinear reaction coefficients

Karadi et al. (2025) suggest that policy rules should respond more strongly to inflation and cost-push shocks when these are large and widespread, i.e. when the economy is in the steep region of the Phillips curve. The rule may include explicit indicators of cost-push pressures (e.g. energy prices, wages in key sectors or global input prices) and respond nonlinearly to them.

However, the issue remains unsettled. As argued by Ascari et al. (2025), in economies with high GVC integration, optimal monetary policy may be less aggressive in response to purely supply-driven external inflationary pressures.

3. Network-informed and sector-sensitive rules

Christoffel et al. (2025) show that allowing for sectoral information in the central bank reaction function may be superior, in terms of minimising losses, to relying on aggregate data on output and inflation alone. In particular, including services inflation instead of headline inflation may yield a further reduction in losses, underscoring its potential as a more reliable indicator of underlying inflation trends within a networked economy.

6 Conclusions and policy implications

Research on production networks and economic heterogeneity has fundamentally changed our understanding of how shocks are transmitted to the real economy. By modelling the economy as an interconnected network of firms and sectors, rather than as a single representative agent, we now see that the transmission, amplification and persistence of shocks depend critically on the structure of these linkages. The structure of the production network fundamentally determines the amplification, speed and heterogeneity of monetary policy transmission across firms and sectors. Moreover, the position and centrality of a sector within the production chain often matter more than its size: shocks to upstream or central sectors have economy-wide effects far beyond what aggregate models predict, while shocks to peripheral or downstream sectors remain more localised.

This perspective also reveals that the type of shock and the degree of heterogeneity in price and wage flexibility determine how economic adjustments unfold. The inflationary impact of supply shocks, which tend to be sectoral, tends to be amplified, whereas that of demand shocks tends to be dampened, because interactions across sectors and firms create nonlinear and asymmetric responses. In a monetary union, we observe that while sectors and countries with more flexible wages tend to be insulated from aggregate shocks in terms of employment, their local shocks are transmitted more powerfully into aggregate euro area-wide inflation. Moreover, excess demand in countries with flexible wages or capital-intensive production generates a euro area-wide inflation-output trade-off. As a result, ignoring these linkages and the heterogeneities across sectors and countries risks underestimating the speed and strength of transmission and the existence of nonlinearities. Furthermore, the finding that structurally lower factor supply elasticity and lower wage-price rigidity in some countries in a monetary union generate higher volatility in terms of employment and income raises political economy concerns.

Policymakers must recognise that these interdependencies imply structural trade-offs – the so-called "divine coincidence" between output and price stability no longer holds under CPI targeting when production networks and heterogeneity are taken into account. This shows the importance of comparing the robustness of outcomes across policy scenarios under different policy rules, such as by also including inflation indicators that are robust to the breakdown of the divine coincidence. Policy design should therefore become state-contingent, take into account sector information and be sensitive to the sources of shocks. Central banks should complement traditional macroeconomic indicators with network-based measures such as sectoral centrality, the frequency of price changes and exposure to upstream cost fluctuations. These indicators can help distinguish between supply-driven and demand-driven pressures and guide the timing and intensity of policy action. For example, given the nonlinear nature of the Phillips curve, ChaMP research suggests that when large cost-push shocks occur and the Phillips curve steepens, the optimal policy response may be not to look through these shocks but rather to "strike while the iron is hot". This more aggressive tightening leverages the steepened Phillips curve slope, which is associated with a lower sacrifice ratio (i.e. a lower output cost of reducing inflation), allowing policy to rapidly stabilise inflation expectations and the frequency of price changes. However, when faced with a large supply shock, this rationale for activism may need to be counterbalanced by prudence, given the difficulty of assessing the nature, persistence and magnitude of shocks in real time. The existing research also shows that in economies with high global value chain integration, optimal monetary policy should be less aggressive in response to purely supply-driven external inflationary pressures.

For this reason, further research and effective policymaking in this area will depend heavily on access to granular data. Firm-to-firm transaction (B2B) datasets and detailed input-output information allow researchers to model the real architecture of production and capture the varying degrees of heterogeneity that shape macroeconomic outcomes. These data reveal how a small number of highly connected firms drive aggregate fluctuations, how sectoral rigidities vary and how shocks propagate across borders. Expanding the availability and comparability of such datasets is therefore crucial: granular evidence provides the foundation for credible, policy-relevant modelling of complex modern economies.

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Stefan Gebauer
European Central Bank, Frankfurt am Main, Germany; email: stefan.gebauer@ecb.europa.eu

Anton Nakov
European Central Bank, Frankfurt am Main, Germany; email: anton.nakov@ecb.europa.eu

Galo Nuño
Banco de España, Madrid, Spain; email: galo.nuno@bde.es

Chiara Osbat
European Central Bank, Frankfurt am Main, Germany; email: chiara.osbat@ecb.europa.eu

Alberto Palazzolo
Nationale Bank van België/Banque Nationale de Belgique, Brussels, Belgium; email: alberto.palazzolo@nbb.be

Gonzalo Paz-Pardo
European Central Bank, Frankfurt am Main, Germany; email: gonzalo.paz_pardo@ecb.europa.eu

Alari Paulus
Eesti Pank, Tallin, Estonia; email: alari.paulus@eestipank.ee

Javier Quintana
Banco de España, Madrid, Spain; email: javier.quintana@bde.es

María Teresa Valderrama
Oesterreichische Nationalbank, Vienna, Austria; email: maria.valderrama@oenb.at

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

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