

# Production Networks, Transmission, and Policy

Sean Callahan

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## Abstract

How far do fiscal shocks travel through a production network? I answer this question for the euro area by applying the network granular instrumental variable (N-GIV) approach of [Chodorow-Reich et al. \(2026\)](#) to FIGARO inter-country input-output tables covering 1,178 country-sectors over the period 2010–2019. The method identifies two reduced-form propagation parameters: the share of a shock transmitted upstream from customers to suppliers (the demand channel) and the share transmitted downstream from suppliers to customers (the supply channel). I develop a static production network model with monopolistic competition and constant returns, that predicts an asymmetric response: quantities respond to demand shocks only through the demand channel, while prices respond to cost shocks only through the supply channel. I then test the model empirically, confirming these results. Each link in the network passes on 41 percent of a demand shock to employment and 32 percent to gross output, while 40 percent of a cost shock passes through to relative prices; the cross-channel parameters are statistically indistinguishable from zero. The implied propagation multipliers show that 17 percent of the employment response and 12 percent of the gross output response to government spending arise from network transmission beyond the sector where the spending lands first. Intuitively, sectors that are further away through the network see almost no effect from the shock, implying that the sectoral composition of fiscal policy matters for its aggregate effects.

# 1 Introduction

Most macroeconomists concern themselves with the consequences of macroeconomic shocks, while a growing number of these economists are turning their attention toward the propagation of microeconomic shocks across productively linked sectors or firms that aggregate into macroeconomic fluctuations (e.g., [Acemoglu et al., 2012, 2016](#); [Carvalho and Tahbaz-Salehi, 2019](#); [Huneus, 2020](#); [Gabaix, 2011](#)). Yet, causal identification is a persistent challenge in applied macroeconomics as there are a dearth of instruments available to macroeconomists. This paper applies a novel method developed by [Chodorow-Reich et al. \(2026\)](#) to construct instruments to identify the propagation of economic shocks through European Production Networks.

[Gabaix \(2011\)](#) makes the observation that large firms or sectors, when shocked, do not wash out in the aggregate but generate macroeconomic fluctuations. [Gabaix and Koijen \(2023\)](#) later takes this observation and developed the granular instrumental variable (GIV) approach. The GIV, which is built from observed outcomes, built from idiosyncratic shocks, uncorrelated with common shocks and with one another, to estimate elasticities and multipliers. However, large firms (sectors) are linked to other firms (sectors) via chains of input-output linkages. A shock to a large firm (sector) in one corner of the economy will *echo* through a chain of interlinked producers and customers and may reach a firm (sector) that has no direct link with the source of the initial shock. As the initial shock echoes through the economy, it reverberates back to the source through other linkages, meaning the source’s idiosyncratic shock is correlated with the echo. The portion of the echo that *returns to the source* must be removed from the instrument to isolate the idiosyncratic shock.

This paper applies the *network granular instrumental variable* (N-GIV) approach developed by [Chodorow-Reich et al. \(2026\)](#) to isolate idiosyncratic shocks within a networked economy. To do so, the echo that neighbors return to the source must be stripped from their outcome variables. What remains is the neighbors’ own shocks and the echo from the rest of the network, which identifies how strongly shocks transmit to the source’s outcomes. With the echo removed, the instrument is no longer correlated

with the source’s own idiosyncratic shock, restoring the exogeneity the original GIV lacks in a networked economy.

The N-GIV is estimated over 2010 to 2019, a period covering the euro area response and adjustment to the Global Financial Crisis and the subsequent sovereign debt crisis among member states (particularly Portugal, Ireland, Italy, Greece and Spain). The early 2010s are characterized by fiscal consolidation, while the mid-to-late 2010s feature gradual fiscal easing as member states exit bailout programs and scale back austerity. The timing and depth of both differ across members, leaving fiscal policy fractured within the euro area. European Union (EU) and euro area rules limit deficits and debt at the national level but leave the composition of government expenditure as a slow-moving adjustment variable. The parameters estimated from the N-GIV approach are used to construct aggregate demand-induced propagation multipliers at the euro area level and at the sectoral level. These are then juxtaposed with the composition of government expenditure to identify significant sectors and emphasize the role of targeted fiscal policy.

To complement the empirical framework, this paper develops a theoretical model along the lines of [Acemoglu et al. \(2012\)](#); [Baqae and Farhi \(2019\)](#); [Carvalho and Tahbaz-Salehi \(2019\)](#). A static, multi-sectoral general equilibrium model with production linkages is developed, in which production is characterized by a constant elasticity of substitution (CES) production function. From the CES production function emerges different cases in which the elasticity of substitution governs whether price and quantity effects washout on net or one exceeds the other. The model, while unable to theoretically identify the parameters estimated by the empirical framework, is able to predict the channels on which different shocks propagate given a set of assumptions to achieve an analytically tractable solution.

This paper estimates two reduced-form propagation parameters,  $\gamma_d$  capturing demand-side transmission through backward (supplier) linkages and  $\gamma_s$  capturing supply-side transmission through forward (customer) linkages, using the N-GIV approach of [Chodorow-Reich et al. \(2026\)](#). The main findings show an asymmetry in how shocks spread through the euro area. Demand shocks are transmitted upstream through supplier linkages, with 41

percent and 32 percent of a given shock passing from one sector to another for employment and gross output, respectively. In contrast, supply shocks are transmitted downstream through customer linkages, with 40 percent of a given shock passing through to relative prices. These findings suggest that (i) shock transmission through production linkages is substantial and constitutes a specific policy concern for economies with significant government participation, and (ii) policymakers should account for the network topology of the economies they regulate when designing fiscal interventions, as the sectoral composition of fiscal adjustments (which sectors bear the cuts) matters for aggregate outcomes. The parameter estimates are then used in the estimation of euro area demand-induced propagation multipliers, which suggest 17 percent and 12 percent of the response to demand shocks emerges from the network for employment and gross output, respectively. The rest of the paper is organized as follows. Section 2 reviews the literature on production networks and shock propagation. Section 3 develops a multi-sectoral model with production linkages. Section 4 describes the data. Section 5 develops the empirical framework. Section 6 reports and discusses results. Section 7 concludes.

## 2 Literature

The sectoral incidence of economic shocks on production networks has grown rapidly in recent years. The canonical models of macroeconomics ignore linkages between firms within industries and between industries while highlighting the marginal consumption behavior of households that yields the Keynesian multiplier. [Lucas \(1977\)](#) famously dismissed the potential for microeconomic shocks to transmit between industries by illustrating how any shocks wash out if there are a large number of sectors and a diversity of linkages such that no firm/sector becomes a vector for amplification.

Following Lucas' critique theoretical models and empirical evidence emerged on cascading shocks through production linkages. Models like [Gabaix \(2011\)](#) and [Acemoglu et al. \(2012\)](#) argue that granularity (large firms or sectors) can result in aggregate fluctuations depending on the topology of the production network. If a single firm supplies to all other

firms, then a negative demand shock originating from this supplier will shift aggregate outcomes as downstream customers are unable to substitute away from this hub supplier. Conversely, a single firm purchasing from all other firms that experiences a negative supply shock will move aggregate outcomes as upstream suppliers are unable to easily substitute toward other customers.

Production network research (theoretical and empirical) has progressed significantly over the last three decades. [Long and Plosser \(1983\)](#) served as a benchmark for contemporary theoretical work, but it was [Horvath \(1998, 2000\)](#) that provided the first significant empirical rebuttal to Lucas by illustrating how microeconomic shocks decay at a rate slower than suggested by the law of large numbers due to limited options for input substitution. [Shea \(2002\)](#) identified the significance of IO linkages for the movement of shocks and their amplification through complementarities. [Foerster et al. \(2011\)](#) characterized the Greater Moderation as a reduction in aggregate volatility while idiosyncratic shocks accounted for nearly half of the volatility of industrial production. The model developed in the present paper belongs to the literature by incorporating production linkages explicitly into firm decision-making.

Models of production networks continue to explore and qualify the nature of microeconomic shocks into macroeconomic fluctuations. For instance, [Baqae \(2018\)](#) shows the role of industrial organization in producing a series of knock-on effects that cause a cascade of firm exits. Production network models assuming Cobb-Douglas production technologies, like [Acemoglu et al. \(2012, 2016\)](#), wash out nonlinearities and downstream propagation of demand shocks<sup>1</sup>. [Baqae and Farhi \(2022\)](#) build a multi-sectoral HANK model with IO linkages characterized by credit constraints, downward wage rigidities, and the zero lower bound. A simulated COVID supply and demand shock yield stagflation and deflation, respectively, with labor market slack accompanying both shocks. Input complementarities amplify supply shocks and mitigate demand shocks, limiting the effectiveness of aggregate demand stimulus.

The production network literature has typically assumed that there is no shock

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<sup>1</sup>Under this assumption, demand shocks do not travel downstream due to the horizontal supply curve produced by constant returns to scale and fixed factor prices.

amplification/attenuation within production networks; instead, focus has largely been on sectoral Domar weights as Hulten’s theorem claims productivity shocks are directly proportional to the output of sector relative to GDP (Hulten, 1978).<sup>2</sup> Baqaee and Farhi (2019) derive second-order equations showing a sector’s Domar weight is not give but, in fact, responsive to productivity shocks when the knife-edge Cobb-Douglas production function is rejected for complementarity/substitution between sectoral outputs. When theory moves beyond Hulten’s theorem, the result is amplification of sector specific shocks when inputs are GE-complements and attenuation when inputs are GE-substitutes. Our paper confirms the existence of these second-order effects by estimating the reduced-form degree of transmission present within production networks, where any value less than one is evidence of shock attenuation.

The empirical framework used in this paper draws on the foundational work of Gabaix (2011), which emphasizes how the disproportionate size of individual firms or sectors can generate aggregate fluctuations, and Acemoglu et al. (2012) (see also Acemoglu et al., 2016; Gabaix, 2016), which shows that both economic size and position within the production network shape their macroeconomic influence. When ignoring the relative size of a firm in the economy, economists tacitly accept the argument made by Lucas (1977) whereby aggregate volatility declines with the number of firms  $N$  according to  $1/\sqrt{N}$ ; at the macroeconomic level microeconomic shocks are imperceptible. Instead, when a large firm with an out-sized influence on the economy (e.g., BMW, Amazon, Walmart, etc.) relative to other firms is shocked, it amplifies shocks to other firms and generates macroeconomic disturbances that decay at a rate slower than the rate proposed in diversification argument made by Lucas (1977).

The GIV approach to macroeconometrics developed by Gabaix and Koijen (2023) operationalizes the theoretical contributions made by Gabaix (2011). Gabaix (2011) considers an economy in which a few large nodes make up a significant share of economic activity. GIVs use idiosyncratic shocks to economically important nodes that produce aggregate fluctuations, enabling the estimation of parameters, such as elasticities, that can

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<sup>2</sup>Examples of some papers include Gabaix (2011); Acemoglu et al. (2012, 2016).

be used to calculate various multipliers (see [Gabaix and Koijen, 2021](#); [Galaasen et al., 2020](#); [Baumeister and Hamilton, 2024](#); [Schubert et al., 2020](#); [Camanho et al., 2022](#); [Bogmans et al., 2024](#) for applications). However, this approach is agnostic to the network position of the large firms that can perturb the activity in adjacent and distantly connected markets. [Chodorow-Reich et al. \(2026\)](#) develop additional scaffolding to purge the network of any given node’s influence, while preserving the network’s influence on any given node. Idiosyncratic shocks landing throughout the network serve as valid instruments (N-GIVs) for the outcomes of neighboring nodes, assuming shocks are uncorrelated with common shocks and with one another. The present paper applies the N-GIV approach to causally estimated demand and supply propagation parameters to identify significant sectors in the transmission of shocks and to estimate demand-induced propagation multipliers.

### 3 Basic Theoretical Framework

To complement the present study’s empirical analysis, we develop a static multi-sectoral model with production linkages alongside a public sector that demands consumption goods. Each sector consists of a continuum of firms that produce a differentiated good that is aggregated by a CES bundler. Households and the government are the sole consumers of final goods. It is assumed households supply labor inelastically and do not save. This substantially simplifies the task of studying propagation and the conditions under which shocks are amplified or attenuated. The theoretical core of the framework is the constant elasticity of substitution (CES) production function which permits the analysis of various cases that are each characterized by specific propagation properties. This framework focuses on the network structure of the economy and the propagation of fiscal shocks, so the household plays a tertiary role in the analysis that follows.

#### 3.1 Monopolistic Competition

Consider an economy with  $n$  sectors indexed by  $i \in \{1, \dots, n\}$ . A sector consists of a continuum of firms, each producing a differentiated variety  $\nu$  along the lines of [Dixit](#)

and Stiglitz (1977). Varieties are aggregated at the sectoral level by a competitive CES bundler (see Galí, 2008, p. 69),

$$y_i = \left( \int_0^1 y_i(\nu)^{(\theta_i-1)/\theta_i} d\nu \right)^{\theta_i/(\theta_i-1)}, \quad (1)$$

where  $\theta_i > 1$  is the within-sector elasticity of substitution. Demand for variety  $\nu$  is given by

$$y_i(\nu) = \left( \frac{p_i(\nu)}{p_i} \right)^{-\theta_i} y_i, \quad (2)$$

where  $p_i = \left( \int_0^1 p_i(\nu)^{1-\theta_i} d\nu \right)^{1/(1-\theta_i)}$  is the sectoral price index.

### 3.2 Production

Suppose  $a_{ij}$  represents the CES share of sector  $j$  used by sector  $i$ , then let  $\mathbf{A} = [a_{ij}]$  be an  $n \times n$  matrix representing all sectoral CES shares.<sup>3</sup> Assuming only labor  $\ell$  and inputs  $x_{ij}$  are necessary for production, then

$$y_i(\nu) = z_i \left[ \alpha_i^{1/\sigma} \ell_i(\nu)^{(\sigma-1)/\sigma} + \sum_{j=1}^n a_{ij}^{1/\sigma} x_{ij}(\nu)^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}, \quad (3)$$

where  $x_{ij}(\nu)$  are inputs purchased by firm  $\nu$  in sector  $i$  from sector  $j$  which is aggregated by a competitive CES bundler such that  $x_{ij} = \left( \int x_{ij}(\nu)^{(\theta_j-1)/\theta_j} d\nu \right)^{\theta_j/(\theta_j-1)}$ . Clearly, (3) is constant returns to scale (CRS) and, for convenience, it is assumed  $\alpha_i + \sum_j a_{ij} = 1$ .<sup>4</sup> Where  $\alpha_i$  is the CES labor share and  $\sigma$  is the inter-sectoral elasticity of substitution.

Monopolists first minimize a cost function that yields a unit cost function. The

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<sup>3</sup>This is not to be confused with input requirements, which, in this case, depend on sectoral prices and marginal costs.

<sup>4</sup>Constant returns to scale is standard in the production network literature (e.g., Acemoglu et al. (2016, 2012); Baqaee and Farhi (2019); Baqaee (2018)); otherwise, closed-form solutions are infeasible.

producer's minimization problem is given by

$$\begin{aligned} \min_{\substack{\ell_i(\nu), \\ \{x_{ij}(\nu)\}_{j=1}^n}} \quad & W\ell_i(\nu) + \sum_{j=1}^n p_j x_{ij}(\nu) \\ \text{s.t.} \quad & z_i \left[ \alpha_i^{1/\sigma} \ell_i(\nu)^{(\sigma-1)/\sigma} + \sum_{j=1}^n a_{ij}^{1/\sigma} x_{ij}(\nu)^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)} \geq 1 \end{aligned} \quad (4)$$

for which the nominal wage  $W$  and sector  $j$ 's price level  $p_j$  are given. The first-order conditions yield conditional unit demand functions for labor and inputs,

$$\ell_i = \ell_i(\nu) = \frac{\alpha_i}{z_i W^\sigma} \left[ \alpha_i W^{1-\sigma} + \sum_{j=1}^n a_{ij} p_j^{1-\sigma} \right]^{\sigma/(1-\sigma)}, \quad (5)$$

$$x_{ij} = x_{ij}(\nu) = \frac{a_{ij}}{z_i p_j^\sigma} \left[ \alpha_i W^{1-\sigma} + \sum_{j=1}^n a_{ij} p_j^{1-\sigma} \right]^{\sigma/(1-\sigma)}. \quad (6)$$

Substituting (5) and (6) into (4) yields the producer's unit cost function and, given the CRS assumption, also yields its marginal cost function,

$$MC_i = \frac{1}{z_i} \left[ \alpha_i W^{1-\sigma} + \sum_{j=1}^n a_{ij} p_j^{1-\sigma} \right]^{1/(1-\sigma)}. \quad (7)$$

Given that labor (with a uniform nominal wage) and that inputs/outputs are bundled at sectoral prices, it follows that each sector has a uniform marginal cost function  $MC_i(\nu) = MC_i$ . Equation 7 permits the derivation of the producer's endogenous cost shares. That is, shares that respond to sectoral prices,

$$\tilde{\omega}_i = \frac{\partial \log MC_i}{\partial \log W} = \alpha_i \left( \frac{W}{z_i MC_i} \right)^{1-\sigma}, \quad (8)$$

$$\tilde{\omega}_{ij} = \frac{\partial \log MC_i}{\partial \log p_j} = a_{ij} \left( \frac{p_j}{z_i MC_i} \right)^{1-\sigma}. \quad (9)$$

These shares satisfy  $\tilde{\omega}_i + \sum_j \tilde{\omega}_{ij} = 1$ . Notice that when  $\sigma = 1$ , then (8) and (9) converge to the underlying CES shares  $\tilde{\omega}_i = \alpha_i$  and  $\tilde{\omega}_{ij} = a_{ij}$ , respectively. When  $\sigma \neq 1$ , cost shares respond to relative prices. Firms shift spending toward cheaper inputs ( $\sigma > 1$ ) or concentrate spending on expensive inputs ( $\sigma < 1$ ). With lower substitutability ( $0 < \sigma < 1$ ),

inputs whose prices have risen relative to  $i$ 's input bundle take a larger share of  $i$ 's costs.

### 3.3 Pricing

After calculating their marginal cost function (see (7)), each firm maximizes profits  $(p_i(\nu) - MC_i)y_i(\nu)$  subject to (2), taking the sectoral price index and aggregate demand as given. The first-order condition yields the standard constant-markup result, where  $\mu_i = 1/(\theta_i - 1)$ ,

$$p_i = (1 + \mu_i)MC_i. \quad (10)$$

The intra-sector elasticity  $\theta_i$  governs market power; the inter-sectoral elasticity  $\sigma$  governs network propagation. The two elasticities are entirely independent. Here we show that the continuum of firms within a given sector have identical markups determined by  $\theta_i$ . Thus, there is no intra-sectoral dispersion of prices as  $p_i(\nu) = p_i$ . Figure 1 depicts the sectoral distribution of markups.

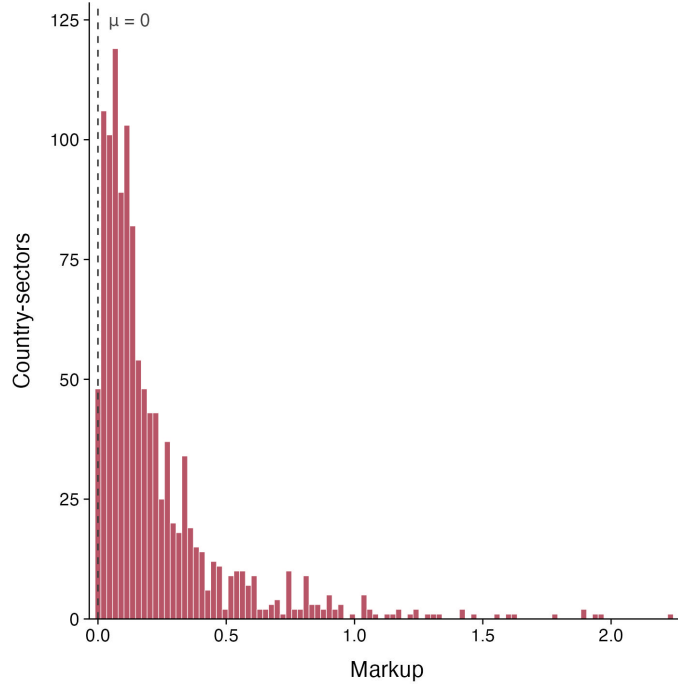


Figure 1: Distribution of Sectoral Markups

*Notes:* Author's own calculation from FIGARO and Eurostat sectoral national accounts. Markups are approximated by sectoral profit shares over gross output, net of capital consumption.

In an economy characterized by monopolistically competitive firms, the distinction

between a firm's cost share and revenue share requires care. The firm's revenue will always exceed its cost because consumers cannot perfectly substitute toward alternatives, and given that the intra-sectoral elasticity of substitution exceeds unity,  $\theta_i > 1$ , firms charge a positive markup. Equation 10 determines the relationship between the firm's cost share and revenue share, which conveniently translates this paper's theory to observable data,

$$\tilde{\omega}_{ij} = \frac{\lambda_j}{\lambda_i}(1 + \mu_i)\omega_{ij}, \quad (11)$$

where  $\omega_{ij} = p_j x_{ij} / p_j y_j$  is sector  $j$ 's revenue on purchases from sector  $i$  as a share of sector  $j$ 's revenue.<sup>5</sup> Equation 11 is the standard expression for relating revenue and cost shares in the production network literature (see also Baqaee and Farhi, 2019; Baqaee, 2018; Baqaee and Farhi, 2024 for similar expressions).

Log-linearizing the markup rule (10) after substituting marginal costs for (7), and given the labor share is  $\tilde{\omega}_i = 1 - \sum_j \tilde{\omega}_{ij}$  and  $\varepsilon_i = d \log(1 + \mu_i) - d \log z_i$ , yields

$$d \log p_i = \varepsilon_i + \tilde{\omega}_i d \log W + \sum_{j=1}^n \tilde{\omega}_{ij} d \log p_j. \quad (12)$$

Since  $(\mathbf{I} - \tilde{\mathbf{\Omega}})^{-1} \tilde{\mathbf{\omega}}_L = \mathbf{1}$ ,

$$d \log \mathbf{p} = \mathbf{1} d \log W + (\mathbf{I} - \tilde{\mathbf{\Omega}})^{-1} \boldsymbol{\varepsilon}, \quad (13)$$

where  $\tilde{\mathbf{\Omega}} = \text{diag}(\mathbf{1} + \boldsymbol{\mu}) \text{diag}(\boldsymbol{\lambda})^{-1} \mathbf{\Omega} \text{diag}(\boldsymbol{\lambda})$  is the matrix of cost shares and  $(\mathbf{I} - \tilde{\mathbf{\Omega}})^{-1}$  is the supply-side impact matrix.

Let  $P$  denote the price index of final expenditure, a geometric index weighted by final expenditure shares at the initial equilibrium, be expressed as a log-shock,

$$d \log P = \sum_{i=1}^n f_i^0 d \log p_i \quad (14)$$

so  $P$  is homogeneous of degree one in sectoral prices. Substituting (13) into (14) gives  $d \log P = d \log W + \mathbf{f}'_0 (\mathbf{I} - \tilde{\mathbf{\Omega}})^{-1} \boldsymbol{\varepsilon}$ , and subtracting from (13) removes the wage and yields

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<sup>5</sup>Revenue shares are expressed in terms of prices to reflect that data is observed in nominal terms.

the price equation.

**Proposition 1** (Supply propagation). *Shocks to relative prices operate solely through the supply channel,*

$$d \log \frac{\mathbf{p}}{P} = (\mathbf{I} - \mathbf{1} \mathbf{f}'_0) (\mathbf{I} - \tilde{\mathbf{\Omega}})^{-1} \boldsymbol{\varepsilon}. \quad (15)$$

*Final demand enters (15) only through the initial equilibrium weights  $\mathbf{f}$ , and not as a shock to prices itself, or  $\partial \log(\mathbf{p}/P)/\partial \chi' = 0$  and  $\partial \log(\mathbf{p}/P)/\partial G = 0$ .*

Notice that equation (9) depends on the ratio of supplier's price  $p_j$  to the marginal cost of the customer  $MC_i$ . Given constant sectoral markups, log-linearizing and differentiating equation (10) illustrates that  $\tilde{\omega}_{ij}$  shifts with relative prices and and productivity shocks depending on the inter-sectoral elasticity of substitution.

**Corollary 1** (Cost-share adjustment). *Cost shares respond to changes in relative prices as*

$$d \log \tilde{\omega}_{ij} = (1 - \sigma) \left[ d \log \frac{p_j}{P} - d \log \frac{p_i}{P} \right] - (1 - \sigma) d \log z_i.$$

*By Proposition 1, demand shocks leave relative prices unchanged, so the cost-share matrix is invariant to demand shocks. Supply shocks shift cost shares toward inputs whose relative price has fallen when  $\sigma > 1$  and toward inputs whose relative price has risen when  $\sigma < 1$ . When  $\sigma = 1$ , cost shares are fixed.*

### 3.4 Fiscal Policy

There are no behavioral assumptions that can easily capture public sector spending behavior given that political coalitions can be unstable and elections are frequent. Aggregate nominal government expenditure  $G$  can be disaggregated into its sectoral destinations such that  $G = \sum_i p_i g_i$ . The government runs a balanced budget and finances fiscal policy via a lump-sum tax on households.

### 3.5 Representative Household

Labor is supplied inelastically by a representative household, normalized to one ( $\sum_i \ell_i = 1$ ) and they do not save (intertemporal optimization is not permitted). The representative household only chooses the consumption bundle that maximizes their utility. The representative household's utility maximization problem is given by

$$\begin{aligned} \max_{\{c_i\}_i^n} U(c_1, \dots, c_n) &= \sum_{i=1}^n \beta_i \ln(c_i) \\ \text{s.t. } W + \Pi - \sum_{i=1}^n p_i g_i &\geq \sum_{i=1}^n p_i c_i. \end{aligned} \quad (16)$$

The first-order conditions yield the representative household's Marshallian demand for consumption bundle  $i$ ,

$$c_i = \frac{\beta_i}{p_i} \left( W + \Pi - \sum_{j=1}^n p_j g_j \right). \quad (17)$$

Clearly, as government expenditure rises household consumption falls by the relative price of  $j$  to  $i$  weighted  $i$ 's share of household consumption,  $\beta_i$ . Thus, increases in government demand crowd out household demand equal to  $\beta_i(p_j/p_i) \geq 0$ . While behaviorally restrictive and unrealistic, this modeling exercise is intended to isolate the channel and direction of travel of fiscal shocks through production networks.<sup>6</sup>

### 3.6 Market Clearing

Sectoral output is sold to the representative household, to the government, and to other firms as intermediate inputs. Market clearing for good  $i$  is

$$y_i = c_i + g_i + \sum_{j=1}^n x_{ji}, \quad (18)$$

where  $x_{ji}$  is the quantity of good  $i$  purchased by sector  $j$ .

Let  $\eta_{ji} \equiv x_{ji}/y_j$  denote the quantity of good  $i$  required per unit of sector  $j$ 's output.

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<sup>6</sup>Loosening of the household's behavioral assumptions is left for future work.

Substituting  $x_{ji} = \eta_{ji} y_j$  into (18) and written in matrix form gives the Leontief system

$$\mathbf{y} = \mathbf{c} + \mathbf{g} + \mathbf{H}\mathbf{y}, \quad \mathbf{H} = [\eta_{ji}]. \quad (19)$$

Input requirements are chosen by firms. From Shephard's lemma,  $\partial MC_j / \partial p_i = \eta_{ji}$ , so log-linearizing yields

$$d \log \eta_{ji} = d \log a_{ji} - \sigma (d \log p_i - d \log MC_j) + (\sigma - 1) d \log z_j. \quad (20)$$

By Proposition 1, every price moves with the wage,  $d \log \mathbf{p} = \mathbf{1} d \log W$ , and with constant markups so does marginal cost. All terms in (20) cancel given that  $d \log a_{ji} = 0$ , so  $d \log \eta_{ji} = 0$  for any  $\sigma$ , and  $\mathbf{H}$  is fixed. Differentiating (19),

$$d\mathbf{y} = (\mathbf{I} - \mathbf{H})^{-1} (d\mathbf{c} + d\mathbf{g}). \quad (21)$$

To express this in log changes, let  $\mathbf{D} = \text{diag}(\mathbf{y})$ . Since  $d \log \mathbf{y} = \mathbf{D}^{-1} d\mathbf{y}$ ,

$$d \log \mathbf{y} = \left( \mathbf{I} - \mathbf{D}^{-1} \mathbf{H} \mathbf{D} \right)^{-1} \mathbf{D}^{-1} (d\mathbf{c} + d\mathbf{g}) = (\mathbf{I} - \mathbf{\Omega}')^{-1} \text{diag}(\mathbf{y})^{-1} (d\mathbf{c} + d\mathbf{g}), \quad (22)$$

where  $(\mathbf{D}^{-1} \mathbf{H} \mathbf{D})_{ij} = \eta_{ji} y_j / y_i = x_{ji} / y_i = \omega_{ji}$ , the share of sector  $i$ 's output going to sector  $j$ .<sup>7</sup> The matrices  $\mathbf{H}$  and  $\mathbf{\Omega}'$  describe the same network but different aspects of it. The matrix  $\mathbf{H}$  describes the input requirements for producers (technological parameters), while  $\mathbf{\Omega}'$  describes the revenue shares for producers. As evident by equation (9) and equation (11), revenue shares are equilibrium objects and gross output responds to shocks through it.

For convenience, the nominal wage is normalized to one,  $W = 1$ . By Proposition 1, a demand shock leaves prices unchanged, so input requirements are fixed and real and nominal changes coincide. Writing  $x_i \equiv p_i y_i$  and  $F_i \equiv p_i (c_i + g_i)$  for nominal gross output and final demand, (22) becomes the following.

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<sup>7</sup>While revenue shares can be expressed as the ratio of real values, the observed data is expressed as a ratio of nominal values, or  $\omega_{ji} = p_i x_{ji} / p_i y_i$ .

**Proposition 2** (Demand propagation). *Holding productivity fixed, a change in final demand  $d\mathbf{F}$  moves real gross output by*

$$d \log \mathbf{y} = (\mathbf{I} - \boldsymbol{\Omega}')^{-1} \text{diag}(\mathbf{x})^{-1} d\mathbf{F}.$$

Write final demand as  $\mathbf{F} = C\boldsymbol{\beta} + G\boldsymbol{\chi}$ , where  $C \equiv \sum_i p_i c_i$  and  $G \equiv \sum_i p_i g_i$  are nominal consumption and government expenditure, and  $\boldsymbol{\beta}$  and  $\boldsymbol{\chi}$  are the vectors of consumption and government expenditure composition, with  $\mathbf{1}'\boldsymbol{\beta} = \mathbf{1}'\boldsymbol{\chi} = 1$ . Multiplying (17) by  $p_i$  and summing over  $i$  gives  $C = W + \Pi - G$ , so final demand can be written as

$$\mathbf{F} = (W + \Pi) \boldsymbol{\beta} + G (\boldsymbol{\chi} - \boldsymbol{\beta}).$$

Let  $\mathcal{M} \equiv (\mathbf{I} - \boldsymbol{\Omega}')^{-1} \text{diag}(\mathbf{x})^{-1}$  denote the demand-side impact matrix in Proposition 2.

**Corollary 2** (Fiscal component of demand propagation). *Holding productivity fixed, and given household demand (17), nominal consumption is  $C = W + \Pi - G$  and the private composition  $\boldsymbol{\beta}$  is fixed by preferences. The change in real gross output is then*

$$d \log \mathbf{y} = \underbrace{\mathcal{M} [(\boldsymbol{\chi} - \boldsymbol{\beta}) dG + G d\boldsymbol{\chi}]}_{\text{fiscal}} + \underbrace{\mathcal{M} \boldsymbol{\beta} d(W + \Pi)}_{\text{income}}.$$

*In particular, holding income  $W + \Pi$  fixed, a change in the level of government expenditure at fixed composition moves sectoral output by*

$$\frac{\partial \log \mathbf{y}}{\partial G} = \mathcal{M} (\boldsymbol{\chi} - \boldsymbol{\beta}),$$

*so that the deviation of public from private composition governs direct fiscal incidence. A change in composition at fixed government expenditure moves sectoral output by  $\mathcal{M} G d\boldsymbol{\chi}$ , so that  $G$  scales the effect of reallocating spending across sectors.*<sup>8</sup>

The fiscal component has two parts. One is a *level* effect,  $\boldsymbol{\chi} dG$ , where more expenditure is allocated in the existing proportions. The other is a *composition* effect,  $G d\boldsymbol{\chi}$ , where the

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<sup>8</sup>Note that  $\mathbf{1}' d\boldsymbol{\chi} = 0$ , as a compositional change, given fixed government expenditure, must be offset by decreasing expenditure elsewhere.

given level of expenditure is reallocated across sectors. Because  $\mathbf{1}'d\boldsymbol{\chi} = 0$ , the composition effect can redistribute output across sectors even when aggregate government expenditure does not change.

Finally, recall the demand for labor (5) and the labor share (8), where labor demand can be expressed as  $\ell_i = \tilde{\omega}_i MC_i y_i / W$ .

**Remark 1** (Employment). *Holding productivity, markups, and wages fixed, sectoral employment moves one-for-one with real gross output,  $d \log \ell = d \log \mathbf{y}$ . Employment inherits the decomposition in Corollary 2 and only loads on the demand channel.*

The model developed in this section establishes that the direction of shock propagation is determined by two assumptions, constant returns to scale and constant sectoral markups. The CRS assumption implies a perfectly elastic supply curve, preventing demand shocks from affecting sectoral prices and thereby restricting price transmission to the supply side, as shown in Proposition 1. Equations (10) and (11) make the channel explicit. Sectoral prices and the cost-share matrix are pinned down by constant markups over marginal cost, neither of which depends on the level of demand. The magnitude of supply-side propagation is determined by the inter-sectoral elasticity of substitution  $\sigma$ . When  $\sigma$  is greater than unity, greater substitutability attenuates shock propagation, and when  $\sigma$  is less than unity, less substitutability amplifies it. The empirical framework in Section 5 tests these predictions directly, with quantities expected to load on the demand channel  $\gamma_d$  and prices on the supply channel  $\gamma_s$ .

## 4 Data

The empirical analysis draws on three primary data sources, Eurostat’s Full International and Global Accounts for Research in Input-Output Analysis (FIGARO) for the production network structure, Eurostat National Accounts for sectoral employment and prices, and the Classification of the Functions of Government (COFOG) for the composition of government expenditure (Remond-Tiedrez and Rueda-Cantuche, 2019; Eurostat, 2025a,b,c).

FIGARO provides symmetric industry-by-industry input-output tables at the NACE Rev. 2 classification for all EU member states, recording inter-industry flows in millions of euros at basic prices. Each entry records the value of intermediate purchases between a supplier industry in one country and a customer industry in another or the same country, capturing both domestic and intra-EU trade linkages. The 2010 FIGARO table is used to characterize the IO structure of the European production network throughout the sample.

From the FIGARO tables two adjacency matrices are constructed. The demand-side revenue-share matrix  $A'_d$  normalizes each inter-industry flow by the supplier's total output, where entry  $a_{ji}^d$  captures the share of supplier  $i$ 's output purchased by customer  $j$ .<sup>9</sup> The supply-side cost-share matrix  $A_s$  normalizes the same flow by the customer's total costs, where entry  $a_{ji}^s$  captures the cost share of customer  $j$ 's inputs sourced from supplier  $i$ . The unit of observation is a country-sector pair. The sample includes 19 euro area member states and 62 NACE Rev. 2 sectors per country, yielding a cross-sectional dimension of approximately  $N = 1178$  country-sectors after excluding observations with missing outcome data.<sup>10</sup>

There are three outcome variables of interest and each are specified as annual log changes (sectoral gross output, sectoral employment, and sectoral relative prices).<sup>11</sup> Sectoral gross output is constructed from the FIGARO tables, while sectoral employment and sectoral relative prices are both calculated from Eurostat National Accounts ([Eurostat, 2025b,c](#)).

From the parameter estimates provided by the N-GIV approach we estimate fiscal multipliers at the macroeconomic and sectoral levels of aggregation using COFOG data and qualitatively matching its classifications to the 62 NACE Rev. 2 sector codes ([Eurostat, 2025a](#)).<sup>12</sup> Composition of government expenditure  $\chi$  is calculated from this data and relates variation in the aggregate fiscal stance to where it enters the production network.

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<sup>9</sup>Recall from Proposition 2 that the revenue-share matrix is transposed.

<sup>10</sup>FIGARO tables consist of 64 sectors but codes 'U' and 'T' are dropped as they are reliable zeros and will bias the intensity of shock propagation toward zero.

<sup>11</sup>Sectoral relative prices are defined as the ratio of sectoral value added deflators to the GDP deflator.

<sup>12</sup>A limitation of this approach is the loss of government expenditure classification. After matching COFOG classifications to NACE Rev. 2 codes we are unable to qualify the function of government expenditure in that sector.

## 5 Methods and Empirical Framework

This section sets out the empirical framework, which applies the N-GIV approach of Chodorow-Reich et al. (2026) (henceforth, CGV). We first parameterize the network as a function of the two propagation parameters  $\gamma_d$  and  $\gamma_s$  and define the demand-side and supply-side channel matrices constructed from the FIGARO tables. We then specify the reduced-form system in which each sector's outcomes respond to those of its network neighbors, along with the identifying assumption that idiosyncratic shocks are mean independent across sectors. Next, we describe how common factors are removed by principal component analysis. Finally, we present the N-GIV instrument and the iterative procedure used to estimate  $\gamma_d$  and  $\gamma_s$ , and close with a discussion of the plausibility of the identifying assumption in the euro area.

The N-GIV approach estimates a parameter  $\gamma \in \mathbb{R}^p$  of low dimensionality to characterize, for instance, a firm's elasticity of demand and supply or how trade shocks propagate through production networks. The present study estimates the degree to which idiosyncratic shocks propagate through production networks and whether they travel through demand or supply-side channels. The procedure requires estimating unobservables from observable information. For instance, each entry of an economy's adjacency matrix  $b_{ij}$  is observed but it is not known to what degree each depends on an unknown parameter  $\gamma$ , such that  $b_{ij} = b_{ij}(\gamma)$ . Each entry of the adjacency matrix may depend on a vector of parameters that characterize the propagation of specific shocks as they relate to specific outcome variables. For simplicity, this paper assumes  $b_{ij}(\gamma) = b_{ij}(\gamma_d, \gamma_s)$  where the matrix  $B$  depends on  $\gamma = (\gamma_d, \gamma_s)$  linearly.<sup>13</sup>

The  $N \times N$  matrix  $B$  is assumed to depend linearly on the unknown parameters such that  $B(\gamma_d, \gamma_s) = \gamma_d A'_d + \gamma_s A_s$ , where  $A'_d$  and  $A_s$  are the empirical counterparts to the transposed revenue-share matrix  $\Omega'$  and the cost-share matrix  $\tilde{\Omega}$ , respectively. The  $j$ th entry of  $A'_d$  is defined as

$$a_{ji}^d = \frac{p_i x_{ji}}{p_i y_i}, \quad (23)$$

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<sup>13</sup>It is entirely possible and likely each firm-to-firm linkage has a unique parameter, which is too computationally demanding to estimate for this empirical exercise. We opt for the more convenient estimation of one parameter per channel.

where  $x_{ji}$  can be understood as the volume of outputs produced by sector  $i$  that are purchased by sector  $j$  ( $x_{j \leftarrow i}$ ). On the supply-side, the  $ij$ th entry of  $A_s$  is defined as

$$a_{ij}^s = \frac{p_j x_{ij}}{C_i}, \quad (24)$$

where the inter-industry flow of inputs ( $x_{i \leftarrow j}$ ) is normalized by the customer sector's total costs  $C_i$ , which operationalizes sectoral total costs in section 3 ( $MC_i y_i$ ).

The subscript  $k \in \{d, s\}$  denotes the channel in which shocks propagate through, where  $d$  reflects the demand-side channel and  $s$  reflects the supply-side channel. For example, if the economy is broadly characterized by the Cobb-Douglas production function ( $\sigma = 1$ ), then demand shocks will only have a net effect when traveling up through the supply chain, but are washed out on net when traveling downstream. Conversely, in CES economies where the inter-sectoral elasticity of substitution differs from unity (whether elastic or inelastic), supply shocks that move relative prices shift cost shares and do not wash out on net.

To extract the idiosyncratic shocks consider the following regression equation,

$$\begin{aligned} Y_t &= B(\gamma)Y_t + u_t, \\ Y_t &= (\mathbb{I} - B(\gamma))^{-1}u_t. \end{aligned}$$

The idiosyncratic shock to  $i$  must be mean independent of the idiosyncratic shocks to all other units,  $\mathbb{E}[u_{it} \mid \{u_{jt}\}_{j \neq i}] = 0$ . The impact matrix  $(\mathbb{I} - B(\gamma))^{-1}$  traces shocks from unit  $i$  through each unit  $j$ , and this assumption is what allows  $\gamma^* = (\gamma_d^*, \gamma_s^*)$  to be identified. If  $j = i$  is not removed, the estimate of  $\gamma$  would be purely mechanical, as the endogenous regressor  $e_i' B(\gamma)Y_t$  carries the echo of  $u_{it}$  back to unit  $i$ .<sup>14</sup> Removing  $j = i$  allows the degree to which specific economic shocks to unit  $j$  are transmitted throughout the economy to be estimated, such that  $\mathbb{E}[u_{it} z_{it}] = 0$ .

In the context of the euro area, each country will respond to the business cycle of another, have a common response to external trade shocks, or have a bloc-wide interest

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<sup>14</sup>Where  $e_i$  is the  $i$ -th unit vector.

rate. This requires extraction of the common components to isolate the idiosyncratic components. The empirical strategy is captured by the following reduced-form regression,

$$Y_t = \gamma_d A_d' Y_t + \gamma_s A_s Y_t + \Lambda \eta_t + u_t, \quad (25)$$

$$Y_t = (\mathbb{I} - \gamma_d A_d' - \gamma_s A_s)^{-1} (\Lambda \eta_t + u_t), \quad (26)$$

where  $Y_t$  is a concatenated  $3n \times 1$  vector consisting of a vector of log differences of gross output, employment and relative prices.

The common, unobserved factors  $\eta_t$  are purged after the factor loadings  $\Lambda$  are estimated via principal component analysis (PCA). Sector and year fixed effects enter alongside the common factors in  $\Lambda \eta_t$ . Sector fixed effects absorb persistent differences in growth across sectors, while year fixed effects absorb annual shifts common to all sectors. The common-factor component allows sectors to have heterogeneous loadings on aggregate shocks. Each specification also controls for the country-sector's initial level to account for mean reversion in growth rates.

As derived by CGV (2026), the instrument is defined as

$$z_{it} := e_i' B_\gamma(\gamma) \mathbf{L}(\gamma) \tilde{u}_t^{-i}(\gamma),$$

where  $B_\gamma$  is the gradient of  $B$ ,  $\mathbf{L}(\gamma) = (\mathbb{I} - B(\gamma))^{-1}$  is the impact matrix, and  $Y_t = \mathbf{L}(\gamma)(\Lambda \eta_t + u_t)$  is the endogenous variable. The residual is defined as  $\tilde{v}_t = (\mathbb{I} - B(\gamma))Y_t$ , which can be expressed in units as the following,<sup>15</sup>

$$\tilde{v}_{it} = \Delta\gamma \cdot e_i' B_\gamma(\gamma) Y_t + \Lambda_i \eta_t + u_{it} + \mathcal{O}(\|\Delta\gamma\|^2).$$

Notice when  $\Delta\gamma = 0$ , then the residual depends only on the common factors and the idiosyncratic shocks  $\tilde{v}_{it} = \Lambda_i \eta_t + u_{it}$ .<sup>16</sup> This is achieved via an iterative process to estimate  $\gamma^*$ , where an initial guess  $\hat{\gamma} = \gamma^* + \Delta\gamma$  is made and updated until the moment condition  $\mathbb{E}[z_{it}(\gamma) \tilde{v}_{it}(\gamma) \mid \gamma = \gamma^*] = 0$  is satisfied, this is analogous to the previously stated moment

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<sup>15</sup>For the derivations, see CGV (2026) section 2.2 and onward.

<sup>16</sup>The term  $\mathcal{O}(\|\Delta\gamma\|^2)$  is the higher-order terms in the Taylor expansion, so it is approximately zero.

condition as  $\tilde{v} \rightarrow u$  when factors are purged  $\gamma$  converges. Each guess is updated via OLS estimation of

$$\tilde{v}_{it} = \Delta\gamma \cdot z_{it} + b_i \eta_t^{-i,\perp} + \varepsilon_{it}.$$

The estimation of the coefficient  $\Delta\gamma$  is the change in guess  $\hat{\gamma}$  around the true value of the parameter  $\gamma^*$  controlling for the common factors  $\eta_t^{-i,\perp}$  excluding unit  $i$  and orthogonal to the instrument  $z_{it}$ . The procedure continues until convergence  $\Delta\gamma = 0$  is achieved.

The plausibility of cross-sectoral independence rests on what remains after the common components are removed. Fiscal stances respond to the business cycle and to aggregate shocks, and these responses, together with euro area-wide disturbances such as commodity price movements and the European Central Bank's monetary stance, load on the common factors and year fixed effects. What remains in  $u_{it}$  is variation specific to each country-sector, such as firm-level events, sector-specific regulation, or technology shocks. Linkages between sectors do not violate the assumption, as they are modeled explicitly through  $B(\gamma)$ . The assumption would be violated by shocks common to a subset of sectors that the factors fail to capture, for instance a country-specific crisis affecting all sectors within a single member state.

The institutional heterogeneity of European fiscal regimes plays a different role. The aggregate fiscal stance is shaped by the business cycle, EU fiscal rules, and supranational constraints, while its sectoral allocation is shaped by slow-moving institutional features such as ministerial organization, procurement rules, political coalitions, and budget rigidities. This heterogeneity does not identify the propagation parameters. Instead, it generates the cross-country differences in the composition of government expenditure  $\chi$  that determine where fiscal shocks enter the network, and therefore shape the multipliers reported in Section 6.

## 6 Results and Discussion

### 6.1 Network Propagation

The main results are illustrated in Table 1. The results should be interpreted as averages over the entire sample period and Table 1 reports the results of the reduced-form specification. The results are reported across three outcome variables where  $\hat{\gamma}_k$  is estimated as the degree of shock propagation specific to each outcome variable. At full pass-through, each estimate of  $\gamma_k$  would equal unity, whereas an estimate below unity is evidence of shock attenuation as a portion of each shock is absorbed by each sector upon transmission.

Table 1: Two-Channel Network GIV: Joint Estimation of Output and Employment and Price (3 PCs, Annual Panel 2010–2019)

| Outcome    | Supplier $\leftarrow$ Customer ( $A^d$ ) | Supplier $\rightarrow$ Customer ( $A^s$ ) |
|------------|------------------------------------------|-------------------------------------------|
|            | $\hat{\gamma}_d$                         | $\hat{\gamma}_s$                          |
| Output     | 0.3163***<br>(0.0863)                    | 0.1477<br>(0.1185)                        |
| Employment | 0.4133***<br>(0.0812)                    | 0.2070<br>(0.1592)                        |
| Price      | -0.0144<br>(0.0819)                      | 0.4032***<br>(0.1119)                     |

*Notes:* Two-channel Network GIV, outcomes estimated jointly and have a shared factor structure (joint PCA) cleaning the stacked residual. Robust (HC0) standard errors in parentheses, from the joint covariance. Cross-outcome test  $H_0 : \gamma_d$  equal:  $\chi^2(2) = 14.98$ ,  $p = 0.001$ .  $H_0 : \gamma_s$  equal:  $\chi^2(2) = 2.64$ ,  $p = 0.268$ . \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

The results confirm two predictions of the theoretical model derived in section 3. The model predicts demand shocks are limited to transmitting through the revenue (demand) side of the economy ( $\gamma_d^{output} > 0$  and  $\gamma_s^{output} = 0$ ) and is confirmed by the results displayed in Table 1, where  $\hat{\gamma}_d^{output} = 0.32$ . Intuitively, when a demand shock (such as a fiscal shock) hits the production network it is repeatedly transmitted upstream via sectoral demand for inputs and, given the parameter is below unity, on average 32 percent of the shock is passed on at each transmission. Prices, on the other hand, respond to shocks when input prices change. That is, prices respond to shocks solely through the production network's supply/cost side and sectors pass through 40 percent of the received shock. Employment operates through the same channel as output where each sector passes through 41 percent

of the shock received from its customers to its suppliers. The parameter estimates of  $\gamma_s^{output}$ ,  $\gamma_s^{emp}$ , and  $\gamma_d^{price}$  are not statistically different from zero, providing no evidence that shocks to the networked economy shift gross output or employment through the supply channel or prices through the demand channel.

The reported results illustrate a demand-supply asymmetry across the outcome variables, where shocks propagate upstream via the demand channel and downstream via the supply channel. When shocks travel upstream from customer to supplier it is because customer demand for its supplier’s output has changed, whereas downstream traveling shocks from supplier to customer operate through the supplier’s cost structure and/or the degree of substitutability of its output. Firms cannot easily substitute away from dear or toward inexpensive inputs, as establishing new relationships with novel suppliers is costly and slow (Barrot and Sauvagnat, 2016; Boehm et al., 2019). By extension, the production network literature emphasizes that relatively small shocks to upstream firms or industries can become amplified as they travel downstream toward the final consumer, generating aggregate fluctuations. However, the results reported in this section provide evidence that shocks are attenuated as they pass through the euro area production network.

The model predicts which channels are open but not the degree of attenuation (the propagation parameters). Within the model, demand shocks pass fully through the observed revenue shares. The inter-sectoral elasticity of substitution is unable to explain shock attenuation, as it only generates asymmetric supply-side responses to positive and negative shocks rather than lowering average pass-through. Estimates below unity therefore indicate attenuation emerging from features outside the model, such as nominal rigidities or propagation over a horizon longer than one year.<sup>17</sup>

The model also explains why  $\hat{\gamma}_d$  is not significant for relative prices. The demand channel captures spending that reaches a sector through its customers’ purchases of inputs. Under constant returns and a mobile labor force, a sector’s price is determined by its costs and is independent of its scale of production (Proposition 1). Prices change only

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<sup>17</sup>According to production network theory, demand shocks can travel both upstream and downstream if, for instance, labor is imperfectly mobile or prices are sticky (Baqaee and Farhi, 2022; La’O and Tahbaz-Salehi, 2022; Rubbo, 2023). Neither is present in the model developed in section 3.

when costs change, and cost changes are passed forward to customers in proportion to their input shares. This is the supply channel, where  $\hat{\gamma}_s^{price}$  is significant. Higher input demand from downstream customers raises the supplier’s gross output and employment (Proposition 2 and Remark 1), but not its price. This is the demand channel, where  $\hat{\gamma}_d^{output}$  and  $\hat{\gamma}_d^{emp}$  are significant. The pattern matches the standard asymmetry in production network models, including the one presented in section 3, in which quantities respond upstream to demand while prices respond downstream to costs (Acemoglu et al., 2016; Carvalho and Tahbaz-Salehi, 2019). The asymmetry breaks down when marginal costs rise with output, for example under capacity constraints or sector-specific factors (Baqae and Farhi, 2019).

## 6.2 Propagation Multipliers

The propagation parameters estimated above can be used to construct demand-induced propagation multipliers that measure how far a demand shock travels through the euro area production network.<sup>18</sup> Following CGV, let  $\mathbf{L}(\hat{\gamma}) = (\mathbb{I} - \hat{\gamma}_d A'_d - \hat{\gamma}_s A_s)^{-1}$  denote the estimated impact matrix. The propagation multiplier for country-sector  $j$ ,

$$m_j = \frac{\lambda' \mathbf{L} \mathbf{e}_j}{\lambda_j},$$

is the change in euro area gross output following a one euro increase in demand for the output of  $j$ . It is the empirical counterpart of the demand-side impact matrix in Proposition 2, with full pass-through through the observed revenue shares replaced by the estimated propagation parameters. The own-sector effect  $L_{jj}$  captures the response of  $j$  to its own shock, including the portion that returns to  $j$  through the network, so the ratio  $m_j/L_{jj}$  measures how much of the response emerges from the rest of the network. Because  $m_j$  sums all walks through the network that originate at  $j$ , each dampened by the estimated propagation parameters, it can also be interpreted as a measure of centrality similar to Katz-Bonacich centrality (Ballester et al., 2006).

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<sup>18</sup>Supply shocks are not considered here given that shocks from the public sector shift aggregate demand.

Table 2: Euro Area Propagation Multipliers

|                              | Output              | Employment          |
|------------------------------|---------------------|---------------------|
| Total, $m_{agg}$             | 1.149***<br>(0.046) | 1.226***<br>(0.060) |
| Own-sector, $m_{self}$       | 1.015***<br>(0.004) | 1.021***<br>(0.006) |
| Amplification, $\mathcal{A}$ | 1.133***<br>(0.040) | 1.202***<br>(0.052) |

*Notes:* Multipliers are computed from  $\mathbf{L}(\hat{\gamma}) = (\mathbf{I} - \hat{\gamma}_d \mathbf{A}'_d - \hat{\gamma}_s \mathbf{A}_s)^{-1}$  and aggregated with Domar weights  $\boldsymbol{\lambda}$ . One euro of government spending is allocated by the euro area COFOG composition  $\boldsymbol{\chi}$ . Delta-method standard errors in parentheses, based on the HC0 robust covariance of  $\hat{\gamma}$ . One-sided tests against the null of unity, \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table 2 aggregates these country-sector propagation multipliers by weighting them with the composition of government expenditure,  $m_{agg} = \boldsymbol{\lambda}' \mathbf{L} \text{diag}(\boldsymbol{\lambda})^{-1} \boldsymbol{\chi}$ . A fiscal shock allocates one euro according to the euro area composition of fiscal expenditure  $\boldsymbol{\chi}$ . The own-sector propagation multiplier is the sum of all shocks to  $i = j$ ,  $m_{self} = \sum_j \chi_j l_{jj}$ . The ratio of the aggregate propagation multiplier to the own-sector propagation multiplier gives the amplification that originates from the other sectors,  $\mathcal{A} = m_{agg}/m_{self}$ . The aggregate gross output propagation multiplier is 1.15 and the own-sector multiplier is 1.02, so roughly 12 percent of the response emerges from the network.<sup>19</sup> The corresponding share for employment is 17 percent. However,  $\boldsymbol{\chi}$  is sparse, so the results in table 2 suggest the potential for targeted fiscal interventions to generate large network propagation.

Table 3 lists the fifteen country-sectors with the largest output multipliers, which are concentrated in transport, basic metals, and electronics. Nearly all of them receive a negligible share of government expenditure. The sectors where an additional euro of public spending would travel furthest through the network are therefore not the sectors where public spending currently lands (given by table 4), which forms the basis for the role of targeted fiscal policy emphasized in section 1. Tables 3 and 4 are intended to be indicative of significant sectors in the euro area for generating network effects. However, all  $m_j$  depend on the same two estimated parameters  $(\hat{\gamma}_d, \hat{\gamma}_s)$ , so their standard errors are highly correlated, unlike the results in table 2.

<sup>19</sup>The total network shock is calculated by  $1 - 1/\mathcal{A}$ .

Table 3: Top 15 Country-Sectors by Output Multiplier

| Country   | Sector            | $m_j$    | SE      | $L_{jj}$ | $m_j/L_{jj}$ | $\chi_j$ (%) |
|-----------|-------------------|----------|---------|----------|--------------|--------------|
| France    | Water transport   | 2.144*** | (0.359) | 1.051    | 2.040        | 0.000        |
| Cyprus    | Water transport   | 2.082*** | (0.362) | 1.036    | 2.009        | 0.000        |
| Belgium   | Water transport   | 2.008*** | (0.333) | 1.025    | 1.960        | 0.000        |
| Malta     | Electronics       | 2.005*** | (0.322) | 1.108    | 1.810        | 0.001        |
| Lithuania | Basic metals      | 1.988*** | (0.333) | 1.011    | 1.967        | 0.000        |
| Belgium   | Air transport     | 1.936*** | (0.292) | 1.002    | 1.932        | 0.000        |
| Ireland   | Printing          | 1.896*** | (0.309) | 1.005    | 1.887        | 0.000        |
| Cyprus    | Air transport     | 1.893*** | (0.261) | 1.003    | 1.887        | 0.000        |
| Estonia   | Electronics       | 1.890*** | (0.282) | 1.001    | 1.888        | 0.002        |
| Germany   | Water transport   | 1.798*** | (0.268) | 1.007    | 1.785        | 0.000        |
| Slovakia  | Pharmaceuticals   | 1.787*** | (0.242) | 1.001    | 1.786        | 0.020        |
| Finland   | Paper             | 1.787*** | (0.287) | 1.168    | 1.529        | 0.000        |
| Estonia   | Refined petroleum | 1.787*** | (0.289) | 1.008    | 1.772        | 0.000        |
| Latvia    | Basic metals      | 1.782*** | (0.296) | 1.027    | 1.735        | 0.000        |
| Slovakia  | Basic metals      | 1.781*** | (0.302) | 1.059    | 1.681        | 0.000        |

Notes: Top 15 country-sectors by  $m_j$ .  $m_j = \lambda' \mathbf{L} \mathbf{e}_j / \lambda_j$  is the gross output response per euro of spending in sector  $j$ , and  $L_{jj}$  is the own-sector effect. Delta-method standard errors (HC0 robust). All  $m_j$  depend on the same two estimated parameters, so standard errors are highly correlated across sectors. These results are meant to be indicative of sectors capable of generating large fluctuations. One-sided tests against the null of unity, \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table 4: Output Multipliers of the Top 15 Country-Sectors by Government Spending

| Country     | Sector                | $m_j$    | SE      | $L_{jj}$ | $m_j/L_{jj}$ | $\chi_j$ (%) |
|-------------|-----------------------|----------|---------|----------|--------------|--------------|
| Germany     | Public administration | 1.157*** | (0.052) | 1.006    | 1.150        | 9.070        |
| France      | Public administration | 1.111*** | (0.033) | 1.003    | 1.108        | 8.494        |
| Italy       | Public administration | 1.114*** | (0.034) | 1.002    | 1.112        | 6.454        |
| Spain       | Public administration | 1.128*** | (0.040) | 1.002    | 1.125        | 4.559        |
| France      | Education             | 1.088*** | (0.030) | 1.003    | 1.085        | 4.394        |
| Germany     | Education             | 1.098*** | (0.029) | 1.027    | 1.070        | 4.366        |
| France      | Health                | 1.088*** | (0.026) | 1.007    | 1.081        | 4.042        |
| Italy       | Health                | 1.154*** | (0.044) | 1.039    | 1.111        | 3.443        |
| Germany     | Health                | 1.123*** | (0.035) | 1.019    | 1.102        | 3.329        |
| Italy       | Education             | 1.085*** | (0.026) | 1.004    | 1.080        | 3.054        |
| Germany     | Social work           | 1.110*** | (0.033) | 1.006    | 1.104        | 2.709        |
| Netherlands | Public administration | 1.167*** | (0.049) | 1.007    | 1.159        | 2.637        |
| France      | Social work           | 1.092*** | (0.027) | 1.000    | 1.092        | 2.352        |
| Spain       | Health                | 1.130*** | (0.038) | 1.026    | 1.101        | 2.181        |
| Spain       | Education             | 1.072*** | (0.023) | 1.005    | 1.066        | 2.022        |

Notes: Top 15 country-sectors by their share of euro area government expenditure  $\chi_j$ .  $m_j = \lambda' \mathbf{L} \mathbf{e}_j / \lambda_j$  is the gross-output response per euro of spending in sector  $j$ , and  $L_{jj}$  is the own-sector effect. Delta-method standard errors (HC0 robust). All  $m_j$  depend on the same two estimated parameters, so standard errors are highly correlated across sectors. These results are meant to be indicative of sectors that can generate the largest fluctuations given composition government expenditure. One-sided tests against the null of unity, \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

## 7 Conclusion

This paper estimates the intensity of shock propagation through European production networks over the 2010–2019 period using the N-GIV framework of [Chodorow-Reich et al. \(2026\)](#). The identification strategy exploits the network structure itself, using the idiosyncratic shocks of other sectors, propagated through production linkages, as instruments for the outcomes of each sector’s neighbors. What remains identifies each sector’s own response to the rest of the network.

The central finding is a demand-supply asymmetry in shock transmission. Demand shocks are transmitted upstream through supplier linkages, with 41 percent and 32 percent of a given shock passing from one sector to another for employment and gross output, respectively. In contrast, supply shocks are transmitted downstream through customer linkages, with 40 percent of a given shock passing through to relative prices. This asymmetry suggests that the employment and gross output costs of fiscal adjustment operate principally through the demand channel. A sector facing reduced government demand contracts its employment and gross output, reducing its own demand for intermediate inputs, which transmits the shock upstream to its suppliers.

The propagation multipliers imply that roughly 12 percent of the gross output response and 17 percent of the employment response to a euro of government spending emerge from the network. The sectors with the largest propagation multipliers receive a negligible share of government expenditure, while the sectors receiving substantial shares have smaller propagation multipliers. These results are relevant for policymakers weighing the full impact of changes to fiscal policy within a bloc of integrated economies, such as the euro area.

The analysis is subject to several limitations. The propagation parameters are estimated as averages over the full sample period and may vary across fiscal consolidation or expansion, but dividing the full sample into sub-samples that coincide with the two fiscal regimes will limit the precision of the estimator. The idiosyncratic residuals driving identification contain all sector-specific variation after removing common factors, not exclusively fiscal shocks. The model predicts which channels are open but not the degree of attenuation.

Estimating the inter-sectoral elasticity of substitution directly from changes in FIGARO cost shares, as implied by Corollary 1, can provide a tighter link between the estimates and production primitives. The country-sector propagation multipliers should be interpreted with caution given that all  $m_j$  are derived from the same two propagation parameters.

Two extensions become clear from this analysis. First, researchers can expand on the econometrics of production networks by estimating a vector of propagation parameters to characterize each sector within an economy. This approach can distinguish sectors that absorb shocks from those that propagate them. Second, as illustrated by Corollary 1, the cost-share matrix is not invariant to supply shocks when the inter-sectoral elasticity of substitution differs from unity. FIGARO provides more than a decade of annual input-output tables, so changes in cost shares can be used to estimate this elasticity directly and to relax the assumption of a fixed production network.

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