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Distorted Prices and Targeted Taxes in the New Keynesian Network Model*

Anastasiia Antonova and Gernot J. Müller

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Abstract

When confronted with sectoral shocks, policymakers often resort to targeted, sector-specific taxes in an *ad hoc* fashion. Based on the New Keynesian Network model, we characterize the optimal tax response to sectoral shocks: it features twice as many tax instruments as there are sectors, is budget-neutral, and not confined to the sector where the shock originates. We show that the optimal policy can be approximated by a simple rule that responds to inflation in the shocked sector and adjusts tax instruments in other sectors according to input-output linkages. We study its quantitative performance in a calibrated version of the model.

Keywords: Sectoral shocks, sales taxes, production subsides, optimal tax policy, simple rules, network, pricing frictions

JEL-Codes: E32, E62

*Antonova: Aix-Marseille Université (email: anastasiia.antonova@univ-amu.fr); Müller: University of Tübingen, CEPR and CESifo (email: gernot.mueller@uni-tuebingen.de). We thank Eric Swanson, an anonymous referee, Luis Huxel, Raphael Schoenle, and seminar participants at KU Leuven, Maastricht University, the Riksbank, the Bundesbank, the University of Lausanne, and the Macro Committee of the German Economic Association for helpful comments and suggestions. The usual disclaimer applies.

1 Introduction

Macroeconomic shocks often originate in specific sectors of the economy or impact them disproportionally (Foerster et al. 2011; Gabaix 2011; Cox et al. 2024a). In response to such shocks, governments frequently implement targeted subsidies or taxes. For example, governments provided transfers and subsidies to address the energy crisis triggered by the Russian invasion of Ukraine, offered support to the financial sector during the global financial crisis, and extended financial aid to the service sector during the Covid-19 pandemic. Such targeted fiscal measures appear appropriate, particularly because monetary policy cannot be tailored to specific sectors, except through unconventional measures that have a distinct fiscal flavor.

However, these tax policies are typically implemented on an *ad hoc* basis, and little is known about how they should be optimally adjusted in response to sectoral shocks. For instance, should the response be confined to the sector where the shock originates, or should upstream and downstream sectors also be considered? What are the budgetary implications of the optimal policy? Does the nature of the shock—supply versus demand—matter? Can an efficient allocation be achieved, and if so, how many tax instruments are necessary to achieve it? Lastly, concerns may arise about the feasibility of the optimal policy. Specifically, what kind of information must policymakers have to execute the optimal policy?

We address these questions within a variant of the New Keynesian Network (NKN) model of Rubbo (2023). We augment the model by allowing for sector-specific and potentially time-varying sales taxes and production subsidies. As a result it becomes possible for the optimal policy to restore the efficient allocation in the presence of sectoral shocks. Crucially, the first-best policy requires the *joint* adjustment of *both* instruments across all sectors. This is essential: since only a subset of firms adjusts prices, relative prices are distorted both *within* and *across* sectors. Thus, in line with the principles of Tinbergen (1952), replicating the flexible-price allocation necessitates using two instruments to address both sides of the distortion. This involves subsidizing firms' production while simultaneously taxing their sales. We propose a *simple rule* that responds solely to sectoral inflation and show that it approximates the first-best policy arbitrarily well. This policy is budget-neutral and adjusts taxes and subsidies across *all* sectors based on their proximity to the sector where the shock originates and depending on the nature of the shock.

The NKN model offers a framework to systematically analyze sectoral stabilization policies. It features N sectors which are connected through input-output linkages. Production in each sector uses labor and intermediate goods, potentially sourced from all sectors. In each sector, there is a continuum of monopolistically competitive firms that operate identical technologies but adjust prices only infrequently and, importantly, asynchronously. Factor inputs within a sector are adjusted flexibly and instantaneously in order to meet demand at posted prices. Households allocate spending across sectors in order to minimize expenditures subject to sectoral demand shocks. There are also sector-specific shocks to total factor productivity, or "supply shocks," for short. We derive the canonical representation of the model featuring a set of dynamic IS-curves and Phillips curves.

The relation between sectoral inflation and the sectoral output gap features a tradeoff because adjusting a sector's relative price to close its output gap creates price dispersion within the sector, as not all firms adjust their prices simultaneously. Conversely, keeping prices constant to avoid within-sector price dispersion results in output gaps due to the lack of an adjustment of relative prices. A key property of the optimal policy follows directly: It relies on two instruments in each sector ($2N$ policy). Intuitively, by subsidizing production in a sector, the policy incentivizes firms that can adjust prices to keep them stable. Through sales taxes, which apply to consumers and intermediate goods trade alike, it steers demand across sectors to close sectoral output gaps. As a result, *seller prices* do not change in equilibrium under the optimal tax policy.[1] The network structure determines the response of

[1]Sales taxes effectively take over the job of ensuring allocative efficiency across sectors by altering *buyer prices*. In this sense, our results turn the "socialist calculation debate" about the allocative role of prices on its head (Von Mises 1953; Lerner 1934; Lange 1936). As prices fail to respond sufficiently, taxes can be adjusted in their stead to signal scarcity to buyers.

fiscal instruments across sectors: The optimal policy adjusts the sales tax and the production subsidy in all sectors, but the strength of the adjustment depends on the "distance" of a sector to the sector where the shock originates, as well as on the nature of the shock. The optimal policy is budget neutral as the subsidy is funded by the sales tax.

The first-best policy requires observing a rich set of sectoral shocks, which might be infeasible in practice. Hence, we propose a *simple rule* that also features $2N$ sectoral instruments but responds to sectoral inflation only rather than to the shock itself. As such, it is a generalization of a familiar result from the normative analysis of monetary policy. A policy reaction to inflation brings the economy closer to the efficient allocation when tracing the natural rate directly is infeasible (Galí 2015). In the NKN model, the implementation of the simple rule actually does not require observing inflation in every sector of the economy. It is sufficient to respond to the inflationary impact in the shocked sector and to adjust taxes and subsidies in the other sectors proportionally to their use of inputs from or their sales to the shocked sector.

We perform a quantitative assessment of $2N$ policies, as we calibrate the model to capture key features of the production network in the U.S. economy. Specifically, we consider $N = 373$ sectors based on the 6-digit classification of the Bureau of Economic Analysis and allow pricing frictions to differ in line with existing empirical evidence. We contrast policy responses to supply and demand shocks, highlighting how downstream and upstream proximity to the shocked sector shapes the strength of the response in each case. We also show that the simple $2N$ rule entails a substantial welfare improvement over rules that employ only a single instrument.

Finally, we show that our results extend to an open-economy setting with import-price shocks, which act as both supply and demand shocks and require distinct policy responses depending on a country's import dependence. We illustrate this by contrasting scenarios of high and low energy dependence, capturing—in a highly stylized way—the situations of the U.S. and Europe during the energy crisis following the Russian invasion of Ukraine.

The paper is structured as follows. In the remainder of the introduction, we place the paper in the context of the literature. Section 2 presents the model and derives its canonical representation, which we use to characterize the optimal policy in closed form and to analyze its features in Section 3. In Section 4 we characterize simple rules polices that could be implemented in practice. We calibrate and simulate the model in order to quantify our results in Section 5. Section 6 generalizes our results to an open economy setting. A final section concludes.

Related literature. Closest to our analysis is La'O & Tahbaz-Salehi (2025), who shows that fiscal instruments can ensure efficiency in economies with production networks and nominal rigidities. Using the Ramsey approach, the authors also find that the first-best policy involves $2N$ instruments, highlighting the connection with the literature on monetary–fiscal equivalence (Correia et al. 2008). Our analysis differs in that we derive the canonical representation of the NKN model to capture the relevant trade-offs and examine second-best fiscal policies that are more realistically implementable through simple rules. Cox et al. (2024b) focus on sectoral government spending—which we abstract from—and show, in a New Keynesian multi-sector model, that the optimal policy does not fully restore the first-best allocation because, when the level of public-good provision is initially set optimally, running "fiscal gaps" entails welfare costs.

More broadly, our paper relates to work on how sectoral shocks propagate through networks, typically with a focus on TFP shocks and in models without nominal frictions (Horvath 1998, 2000; Acemoglu et al. 2012; Caliendo et al. 2017), but also in versions of the NKN model (Pastén et al. 2024). The effects of sectoral government spending shocks are also investigated, in models with and without pricing frictions (Proebsting 2022; Bouakez et al. 2025; Flynn et al. 2022; Devereux et al. 2023), as well as the sectoral transmission of the economic impact of the Covid-19 pandemic (Guerrieri et al. 2022; Baqaee & Farhi 2022).[2]

[2] Woodford (2022) shows, assuming pre-set prices, that fiscal transfers can restore the first-best outcome in this context when incomplete markets prevent risk sharing across sectors.

The $2N$ result may appear to conflict with the classic Diamond-Mirrless result, according to which intermediate goods should not be taxed (Diamond & Mirrlees 1971b,a). Yet while Diamond-Mirrless is about avoiding distortions due to taxation in an otherwise efficient economy, we consider an economy subject to (pricing) frictions, which, as we show, can be undone through the appropriate choice of fiscal instruments.[3]

The analysis of optimal policy which accounts for nominal rigidities has yielded important insights for one-sector or open-economy models, highlighting possible constraints on monetary policy, either through fixed exchange rates or the zero-lower bound (Eggertsson & Woodford 2004; Adao et al. 2009; Correia et al. 2013; Schmitt-Grohé & Uribe 2016). Importantly, the influential study by Farhi et al. (2014) finds that "fiscal devaluations" in monetary unions also require a simultaneous adjustment of *several* tax instruments. Chen et al. (2021) and Egorov & Mukhin (2023) obtain similar results in an open-economy context when monetary policy is unconstrained but the law of one price fails. More generally, the need for two policy instruments to correct market distortions has been established in various contexts, such as environmental economics (Fullerton & Wolverton 2000; Bennear & Stavins 2007; Fullerton & Wolverton 2005) and electricity markets (Bobtcheff et al. 2024).

2 The model

We extend the NKN framework of Rubbo (2023) by allowing for time-varying sectoral sales taxes and production subsidies, incorporating sectoral demand shocks alongside productivity shocks, assuming immobile labor across the N sectors of the model, and permitting decreasing returns to scale in production. The following subsection provides a concise outline, with additional details presented in Appendix A which we provide as Supplementary Material to this paper. Section 2.2 discusses the distortions that arise in the model and the rationale for

[3] Also, because the $2N$ policy is budget neutral, we sidestep questions which, following Ramsey (1927), concern minimizing the distortionary impact of raising revenues—particularly on capital formation (Chamley 1986; Judd 1985; Straub & Werning 2020)—and the interaction with monetary policy in models both with and without price flexibility (Lucas & Stokey 1983; Chari et al. 1991; Schmitt-Grohé & Uribe 2004).

tax policies aimed at eliminating them. In Section 2.3 we derive the canonical representation of the NKN model that further characterizes the relevant tradeoffs.

2.1 Outline

A representative household enjoys expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \delta^t \left\{ \log(C_t) - \sum_i \frac{H_{t,i}^{1+\gamma}}{1+\gamma} \right\}, \tag{1}$$

where E_0 is the expectation operator, $\delta \in [0,1)$ is the discount factor, $H_{t,i}$ is labor supplied to sector i; $C_t = \prod_i C_{t,i}^{\beta_{t,i}}$ is a consumption basket composed of N sectoral goods $C_{t,i}$. Here $\beta_{t,i}$ is a demand shifter which tilts preferences towards sector-i goods, $\sum_i \beta_{t,i} = 1$. The consumer pays the *buyer price* $P_{t,i}$ for sectoral good i. It may differ from the *seller price* because of a sales tax introduced below. The consumer price index is then given by $P_t = \prod_i \left(\frac{P_{t,i}}{\beta_{t,i}}\right)^{\beta_{t,i}}$. Financial markets are complete, and the household's flow budget constraint reads as follows:

$$P_t C_t + E_t \left\{ Q_{t,t+1} \Xi_{t+1} \right\} = \Xi_t + \sum_i W_{t,i} H_{t,i} + T_t. \tag{2}$$

Here Ξ_{t+1} is the household's portfolio while $Q_{t,t+1}$ is the stochastic discount factor. $W_{t,i}$ wages, and T_t are lump-sum profits and government transfers. We rule out Ponzi schemes.

The sector-specific good is a bundle of varieties produced by monopolistically competitive firms, indexed by $k \in [0,\ 1]$: $Y_{t,i} = \left(\int_0^1 Y_{t,i,k}^{\frac{\epsilon-1}{\epsilon}} dk \right)^{\frac{\epsilon}{\epsilon-1}}$. Production exhibits potentially decreasing returns to scale, as captured by the parameter $x_i \leq 1$, and is given by:

$$Y_{t,i,k} = \left[A_{t,i} \cdot (H_{t,i,k})^{\alpha_i} \cdot \prod_j X_{t,ij,k}^{\omega_{ij}(1-\alpha_i)} \right]^{x_i}, \tag{3}$$

where $A_{t,i}$ is sector-specific productivity, $H_{t,i,k}$ labor used by firm k in sector i, $X_{t,ij,k}$ is the input sourced from sector j by firm k in sector i. ω_{ij} corresponds to the share of input-j in intermediate input costs, such that $\sum_j \omega_{ij} = 1$, and α_i is the labor share in total sector i cost. Production costs are a function of sectoral productivity, input prices, wages, and output:

$$Cost_{t,i,k} = \frac{\bar{A}}{A_{t,i}} \cdot W_{t,i}^{\alpha_i} \prod_j P_{t,j}^{\omega_{ij}(1-\alpha_i)} \cdot Y_{t,i,k}^{\frac{1}{x_i}}, \tag{4}$$

where $\bar{A}^{-1} = (\alpha_i)^{\alpha_i} \prod_j (\omega_{ij}(1-\alpha_i))^{\omega_{ij}(1-\alpha_i)}$.

Firms adjust prices subject to a Calvo-type price rigidity: the share of firms updating their prices in sector i in period t is $1-\lambda_i$ (λ_i is price stickiness). A generic firm k sets the seller price (pre-tax), $P^s_{t,i,k}$. The sector-i seller price index is given by $P^s_{t,i} = \left(\int_0^1 [P^s_{t,i,k}]^{1-\epsilon} dk\right)^{\frac{1}{1-\epsilon}}$ and demand for firm k goods in sector i is given by: $Y_{t,i,k} = \left(\frac{P^s_{t,i,k}}{P^s_{t,i}}\right)^{-\epsilon} Y_{t,i}$. As firms adjust their seller price in period t, they maximize the stream of expected future profits conditional on not resetting their price in the future:

$$\max_{P^{s,\star}_{t,i}} E_t \left\{ \sum_{s=t}^{\infty} Q_{t,s} \lambda_i^{s-t} \left(P^{s,\star}_{t,i,k} Y_{s,i,k} - (1 - \tilde{s}^p_{s,i}) \cdot Cost_{s,i,k} \right) \right\}, \tag{5}$$

subject to firm-specific demand and eq. (4). $\tilde{s}^p_{t,i}$ is a sector-specific production subsidy. We set $1 - \tilde{s}^p_{t,i} = (1 - \bar{s}^p) \cdot (1 - s^p_{t,i})$, with the constant component offsetting the distortion from monopolistic competition in steady state. Our focus is on how the time-varying component $s^p_{t,i}$ impacts the equilibrium allocation in response to shocks.

All sales of sectoral goods are taxed with a time-varying sales tax $\tau^s_{t,i}$ such that sectoral market prices are related to sellers prices as follows: $P_{t,i} = (1 + \tau^s_{t,i}) P^s_{t,i}$. Importantly, the subsidy is paid to producers, while taxes are paid by buyers (either a household or a downstream firm)—taxes and subsidies thus affect opposite sides of the market. With flexible prices, this distinction does not matter, but with sticky prices, the side of the market to which the tax or subsidy is applied becomes relevant (Poterba et al. 1986).

At each point in time and for each sector, fiscal policy sets sales taxes and production subsidies and ensures that the government budget is balanced via a lump-sum tax. Monetary policy controls the money supply M_t which equals nominal private spending $M_t = P_t C_t$. In equilibrium, all markets clear. Sectoral market clearing implies that sectoral output is used for consumption or as an intermediate input in production:

$$Y_{t,i} = C_{t,i} + \sum_{j,k} X_{t,ji,k}. \tag{6}$$

2.2 Discussion: taxes, market allocation, and distortions

Production subsidies and sales taxes influence seller and buyer prices at the sectoral level. The sales tax directly determines the ratio between the price paid by the buyer and the price received by the seller of a good. The production subsidy, in turn, affects the optimal price set by the seller for a given level of marginal costs. Hence, any set of sectoral seller and buyer (market) prices can be implemented with the two sets of tax instruments.[4] As a result, sectoral taxes and subsidies can be used to influence market allocations in order to reduce or eliminate distortions.

To characterize these distortions in general terms, we define wedges relative to a frictionless benchmark economy, as is often done in network models (Bigio & La'O 2020; Baqaee & Farhi 2020; Baqaee & Rubbo 2023). First, consider average marginal cost in sector i:

$$MC_{t,i} = \frac{1}{x_i} \cdot \frac{\bar{A}}{\chi_{t,i} A_{t,i}} \cdot W_{t,i}^{\alpha_i} \prod_j P_{t,j}^{\omega_{ij}(1-\alpha_i)} \cdot Y_{t,i}^{\frac{1}{x_i}-1}. \tag{7}$$

Here $\chi_{t,i} = \left[\int_0^1 \left(\frac{P^s_{t,i,k}}{P^s_{t,i}} \right)^{-\frac{\epsilon}{x_i}} dk \right]^{-1} \leq 1$ is the effective productivity loss due to price dispersion across firms within sector i. Second, the average markup in sector i is given by the market price paid for a sectoral good relative to marginal costs:

$$\mathcal{M}_{t,i} \equiv \frac{P_{t,i}}{MC_{t,i}}. \tag{8}$$

Wedges $\chi_{t,i}$ and $\mathcal{M}_{t,i}$ capture distortions to be addressed by the tax policy. Hence, we may anticipate our result below: the optimal policy should neutralize the impact of changes in marginal costs on the seller price via subsidies in order to keep sellers prices constant and eliminate the within sector distortion $\chi_{t,i}$. At the same time, it should ensure via taxes that the market price adjusts in such a way as to reflect the underlying marginal cost changes and to eliminate markup distortion $\mathcal{M}_{t,i}$, thus replicating the flexible-price allocation.

In practice, the use of tax instruments may be constrained—for example, by the lack

[4] We provide a heuristic proof in Appendix B, courtesy of an anonymous referee.

of timely or precise information—so achieving a fully efficient allocation may be infeasible. As a result, a tradeoff arises between stabilizing inflation and stabilizing markups. Tradeoffs of this kind are frequently analyzed in the New Keynesian literature in the context of monetary policy, typically using log-linear representations of the model. We adopt the same approach here but apply it to sector-specific taxes. In particular, we use sectoral inflation to capture within-sector price distortions and sectoral output gaps to capture inefficiencies stemming from markup fluctuations, thereby extending the canonical representation of the New Keynesian model (see, e.g., Galí (2015)) to a multi-sector environment. Based on this representation, we derive the first-best tax policy as a function of sector-specific shocks and propose simple, implementable policy rules that approximate the first best under weaker informational requirements.

2.3 Canonical representation

The canonical representation is based on a approximation of the model around a steady state with zero inflation, zero time-varying taxes/subsidies, and unit markups and prices. The steady-state share of intermediate inputs j in sector-i production is given by $\frac{X_{ij}}{Y_i} = x_i(1-\alpha_i)\,\omega_{ij}$, and consumption shares are $\frac{C_i}{C} = \beta_i$. We denote the ratio of production to consumption by $\xi_i = \frac{Y_i}{C}$ (Domar weight). We further collect the intermediate input share parameters in the input-output matrix Ω such that $\Omega_{ij} = \omega_{ij}$. In what follows, we denote the log-deviation of a variable Z from steady-state with lower-case letter z (unless specified otherwise) and use bold letters $\boldsymbol{z}$ to refer to column vectors $[z_1, ..., z_N]'$. Matrix I_z denotes a diagonal matrix with vector $\boldsymbol{z}$ on the diagonal and $\mathbf{1}$ is a column vector of ones.[5]

Given these definitions, we can cast the model into the canonical (system of) IS curve(s) and Phillips curve(s), see again Appendix A for details. By combining sectoral marginal cost, the definition of markups, and the equilibrium systems of sectoral wages and sales, we relate sectoral sellers prices to monetary policy m_t, markups $\mu_{t,i} = \log(\mathcal{M}_{t,i})$, sales taxes $\tau^s_{t,i}$,

[5]In terms of notation, we largely follow the applied literature on production networks (Acemoglu et al. 2012; Carvalho & Tahbaz-Salehi 2019; Rubbo 2023).

and sectoral productivity $a_{t,i}$ shocks and demand shocks $b_{t,i} = \beta_{t,i} - \bar{\beta}_i$:

$$\boldsymbol{p_t^s} = \mathbf{1} \cdot m_t + (\bar{L} - \hat{L} I_\xi) \cdot \boldsymbol{\mu}_t - \bar{L} \cdot \boldsymbol{a_t} + \hat{L} \cdot \boldsymbol{b_t} - \boldsymbol{\tau_t^s}, \tag{9}$$

where $\bar{L} = XL$, $\hat{L} = XL \cdot [I_{\frac{1-x}{x}} + \frac{\gamma}{1+\gamma} I_\alpha] \cdot I_\xi^{-1} \tilde{L}$ with $X = [I + LI_{\frac{1-x}{x}}]^{-1}$, $L = [I - I_{1-\alpha}\Omega]^{-1}$, and $\tilde{L} = [I - \Omega'(I - I_\alpha)I_x]^{-1}$.[6] Note that the natural price level—that is, the counterfactual level of prices in the absence of distortions—is given by $\boldsymbol{p}_t^n = \mathbf{1} \cdot m_t + \hat{L} \cdot \boldsymbol{b}_t - \bar{L} \cdot \boldsymbol{a}_t$ which obtains under zero markups and sales taxes.

We also introduce a vector of sectoral final output gaps $\boldsymbol{\tilde{y}_t}$, capturing the log-deviations of the sectoral consumption $C_{t,i}$ from its efficient level. The mapping from sectoral markups to sectoral output gaps is given by: $\boldsymbol{\tilde{y}_t} = -(\bar{L} - \hat{L} I_\xi) \cdot \boldsymbol{\mu_t}$. Using this to substitute for $\boldsymbol{\mu_t}$ in (9) yields a system of demand relations, characterized by a negative relationship between prices and sectoral output gaps.

We define a vector of sectoral seller price inflation, $\boldsymbol{\pi_t^s}$ (with $\pi_{t,i}^s = p_{t,i}^s - p_{t-1,i}^s$), and use (9) to compute its expectation in period $t+1$. This yields a *system* of dynamic IS equations:

$$\boldsymbol{\tilde{y}}_t = E_t \boldsymbol{\tilde{y}}_{t+1} - (\mathbf{1} \cdot R_t - E_t \boldsymbol{\pi}_{t+1}^s - \boldsymbol{r}_t^n) + E_t \Delta \boldsymbol{\tau}_{t+1}^s, \tag{10}$$

where $\boldsymbol{r}_t^n = -E_t[(\hat{L} \cdot \Delta \boldsymbol{b}_{t+1} - \bar{L} \cdot \Delta \boldsymbol{a}_{t+1})]$ is vector of sector-specific natural interest rates and $R_t = E_t[\Delta m_{t+1}]$ is the nominal interest rate.[7] Importantly, this system illustrates that natural rates differ across sectors to the extent that shocks are sector-specific and, hence, monetary policy will generally be unable to adjust the common nominal interest rate accordingly—one size doesn't fit all (sectors). And even if only one sector is experiencing a shock, in the presence of input-output linkages, natural rates will move differently across sectors. Note further, however, how (changes in) sales taxes emerge as an additional term in the system—an observation which will be relevant below as we derive the optimal tax response to sectoral shocks.

[6] Note that with constant returns to scale in all sectors $x_i = 1$, these matrices simplify and we have $X = I$ and $\bar{L} = L$, $\hat{L} = \frac{\gamma}{1+\gamma} L I_\alpha I_\xi^{-1} L'$.

[7] In order to link the nominal interest rate to money growth, we rely on the Euler equation of the model, which in turn governs the household's consumption–saving decision (see Appendix A).

The pricing decisions of firms link the vector of sectoral seller price inflation to sectoral output gaps, taxes $\tau^s_{t,i}$, and subsidies $s^p_{t,i}$, yielding a *system* of New Keynesian Phillips curves:

$$\boldsymbol{\pi^s_t} = K \cdot \boldsymbol{\tilde{y}_t} + \delta E_t \boldsymbol{\pi^s_{t+1}} + \tilde{I}_\lambda(\boldsymbol{\tau^s_t} - \boldsymbol{s^p_t}), \tag{11}$$

where $K = \tilde{I}_\lambda(\bar{L} - \hat{L}I_\xi)^{-1}$, $\tilde{I}_\lambda = I_\lambda^{-1}(I - I_\lambda)(I - \delta I_\lambda) \cdot I_x[I_x + (I - I_x)\epsilon]^{-1}$ and I_λ features sectoral price stickiness on the diagonal. Note that both sales taxes and production subsidies enter as additional terms in this Phillips curve system, thereby generating a trade-off between stabilizing the vectors of output gaps and inflation.

Our canonical representation of the NKN model is given by the set of equations (10) and (11). Sales taxes affect the dynamics of inflation and sectoral output gaps in both the IS equation system (10) and the Phillips curve system (11), whereas production subsidies enter exclusively in the Phillips curve system (11). This representation differs from Rubbo (2023), which links sectoral inflation rates to *aggregate* output through a set of suitable sectoral Phillips curves and an aggregate IS-curve in order to characterize monetary policy trade-offs. By contrast, our representation emphasizes movements in sector-specific natural interest rates, which, as we show below, are informative about the design of optimal sector-specific sales taxes.

3 First best policy

In this section, we present our main theoretical results. First, to set the stage, we discuss the limitations of monetary policy. Then we turn to fiscal policy and clarify the role of the network in shaping the first-best policy. We provide the derivations in Appendix B.

3.1 Limitations of monetary policy

Assume for now that time-varying fiscal instruments are kept at their steady-state level of zero. In this case, monetary policy is generally unable to achieve the first-best allocation, as our discussion above emphasizes. Nevertheless, monetary policy can still play an important stabilization role. In particular, Rubbo (2023) shows that stabilizing the output gap is the optimal monetary policy in the NKN model once one assumes full discounting (static economy).[8] In our model, such a policy can be implemented by setting the money supply to

$$m_t = -\boldsymbol{v}'_{\boldsymbol{opt}} \cdot [\hat{L} \cdot \boldsymbol{b}_t - \bar{L} \cdot \boldsymbol{a}_t], \tag{12}$$

where $\boldsymbol{v}_{\boldsymbol{opt}}$ is a vector of weights that depend on sectoral shares and price stickiness. Optimal monetary policy improves welfare, but a significant welfare loss remains (Rubbo 2023).

3.2 Optimal tax policy

Given the limitations of monetary policy, we turn to fiscal instruments, specifically to sectoral production subsidies $\boldsymbol{s}_{\boldsymbol{t}}^{\boldsymbol{p}}$ and sales taxes $\boldsymbol{\tau}_{\boldsymbol{t}}^{\boldsymbol{s}}$.[9] We show that these instruments are sufficient to restore the first-best allocation.[10] The following proposition establishes a closed-form solution for a combination of sector-specific sales taxes and production subsidies that simultaneously stabilize sectoral output gaps and seller price inflation in the face of sectoral shocks. An implication is that the aggregate output gap is also closed.

Proposition 1 (2N policy)**.** *The optimal tax policy ensures that sectoral output gaps and seller price inflation in all sectors are fully stabilized:* $\tilde{\boldsymbol{y}}_t = 0$, $\boldsymbol{\pi}_{\boldsymbol{t}}^{\boldsymbol{s}} = 0$. *Let initial seller prices be at their steady-state value* $\boldsymbol{p}_{\boldsymbol{-1}}^{\boldsymbol{s}} = 0$. *Then, the sectoral production subsidies and sales taxes achieving this outcome are*

$$\boldsymbol{s}_{\boldsymbol{t}}^{\boldsymbol{p}} = \boldsymbol{1} \cdot m_t + \hat{L} \cdot \boldsymbol{b}_t - \bar{L} \cdot \boldsymbol{a}_t, \tag{13}$$

$$\boldsymbol{\tau}_{\boldsymbol{t}}^{\boldsymbol{s}} = \boldsymbol{s}_{\boldsymbol{t}}^{\boldsymbol{p}}. \tag{14}$$

This result follows directly from our canonical representation—tax instruments should

[8] Output gap targeting remains nearly optimal in the dynamic economy, $\delta > 0$ (Rubbo 2023).

[9] Recall that the sales taxes apply to consumers and downstream firms alike, in contrast to conventional value-added taxes (VAT) for which producers are typically reimbursed.

[10] They are not necessary in the sense that for special cases of the network and/or the incidence of shocks a subset of instruments may suffice.

be chosen to eliminate the tradeoffs created by sectoral shocks in the systems of IS and Phillips curves. Note that our particular representation of the IS and Phillips curve systems, linking sectoral inflation to *sectoral* output gaps, allows us to characterize the first-best policy immediately, without solving a multidimensional Ramsey problem.[11]

Several remarks are in order. First, the optimal tax policy requires two tax instruments to be adjusted in each sector: the sales tax and the production subsidy. Hence, the optimal policy features $2N$ tax instruments in total.[12] Formally, the optimal sales tax insulates output gaps from changes in sectoral natural rates in the IS system (10), while the optimal production subsidy stabilizes sectoral seller price inflation in the Phillips curve system (11) by offsetting the Phillips curve residuals created by sales taxes.

Second, we emphasize that the optimal policy eliminates the *twofold* distortion due to sticky prices, within and across sectors. To the extent that prices are adjusted infrequently, sectoral shocks induce a misallocation within sectors. To eliminate this welfare loss, the optimal production subsidy offsets the effect of shocks on marginal costs within a sector. This incentivizes firms that can adjust prices to leave them unchanged. However, as a result, the relative prices across sectors would also remain unchanged, failing to induce a sectoral reallocation of expenditure which is called for in the face of sectoral shocks. This is where the sales tax comes in: it is designed to mimic the efficient pricing mechanism. It ensures that market prices continue to fluctuate, thus signaling relative scarcity, even when seller prices remain constant. In other words, while the subsidy eliminates the within-sector misallocation by stabilizing $\boldsymbol{\pi^s}$, the sales tax takes care of cross-sector misallocation by stabilizing sectoral output gaps $\tilde{\boldsymbol{y}}$.

Third, optimal sales taxes move exactly one-for-one with the vector of natural prices

[11] Gali & Monacelli (2008) use a similar approach to characterize optimal government spending in countries that form a monetary union.

[12] The $2N$ instruments are required for a given monetary policy. In case fiscal and monetary policy are coordinated to achieve the first-best allocation, $2 \cdot (N-1)$ tax instruments are sufficient since monetary policy can be tailored to stabilize one sector. For instance, one can adjust the money supply to eliminate the residual in the first equation of the demand system (10), while setting the tax and subsidy in this sector to 0. Then elimination of the remaining N-1 residuals would require adjusting taxes (and subsidies) in the remaining N-1 sectors.

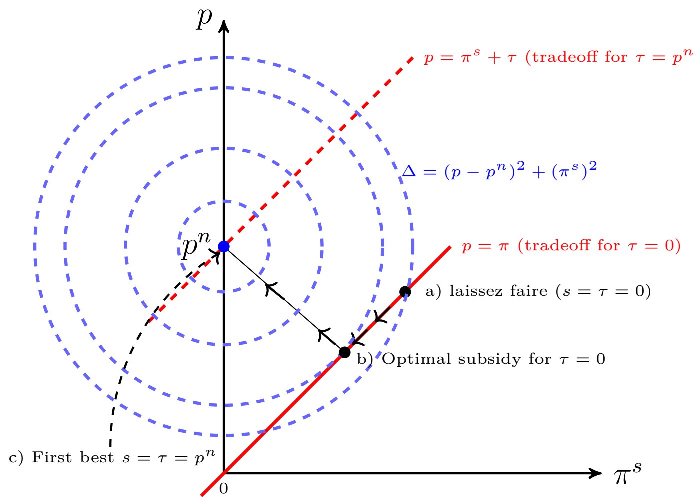
$\boldsymbol{\tau}_t^s = \boldsymbol{p}_t^n$. Hence, under the optimal policy seller prices are fully stabilized, $\boldsymbol{p_t^s} = 0$, while for buyer prices we have: $\boldsymbol{p}_t = \boldsymbol{p_t^s} + \boldsymbol{\tau}_t^s = \boldsymbol{\tau}_t^s = \boldsymbol{p}_t^n$. This is the distinct feature of the $2N$ policy: it implements the efficient allocation by ensuring that market prices move as if they were fully flexible—even though firms do not adjust prices at all. In this way, the optimal policy provides a remedy for the infrequent price adjustment, which is the defining friction of the New Keynesian model.

Fourth, the level of taxes and subsidies under the optimal policy is independent of sector-specific price rigidity; only the network structure matters. The optimal policy replicates the flexible-price outcome *regardless* of the degree of price rigidity or its heterogeneity across sectors, as it incentivizes firms capable of adjusting their prices to leave them unchanged. Consequently, the frequency with which firms can adjust prices in a given sector becomes irrelevant under the optimal policy. This is not to say that price rigidity is unimportant. In fact, it governs the deviation from the first-best outcome in the absence of the optimal policy and, as a consequence, determines its effectiveness.

Fifth, note that Proposition 1 implies that the money supply m_t shifts optimal taxes uniformly. That is, the optimal tax policy is able to achieve the first-best allocation for any given monetary policy. In this sense, the optimal tax/subsidy can in principle substitute for monetary policy.

To illustrate the issue graphically, Figure 1 zooms in on a generic sector. To simplify, the figure omits sector indices, assumes $\delta = 0$ (full discounting), $\boldsymbol{p_{t-1}} = 0$ (economy is in steady state at time $t-1$), and abstracts from the input-output network: $\Omega = 0$, ensuring that the welfare loss is independent across sectors. The horizontal and vertical axis measures seller price inflation and the market price of the sectoral good, respectively. The point $(0, 0)$ is the steady state. Consider an adverse sector-specific productivity shock that raises marginal costs, and hence the natural price to p^n. Absent policy intervention, the sticky price economy cannot attain the first-best point $(0, p^n)$ because an adjsutment of the sectoral price while

Figure 1: The relative price-inflation tradeoff in a generic sector



Notes: Illustration omits sector indices, abstracts from network, $\Omega = 0$, assumes full discounting, $\delta = 0$, and that the economy is initially in steady state ($p_{t-1} = 0$), see Appendix B for related derivations.

keeping inflation constant at the same time is infeasible. For any arbitrary point (π^s, p), the sectoral welfare loss is indicated by the radius of the dashed (blue) ellipse and given by $\Delta = f_p(p - p^n)^2 + f_\pi(\pi^s)^2$.

In the figure this laissez-faire scenario is indicated by point a). Absent any policy intervention, a fraction of firms in the sector will raise their price, creating sectoral sellers' price inflation. At the same time, there is an insufficient response of sectoral prices (captured by the gap between p and p^n), resulting in a sectoral output gap. Now consider a possible policy intervention and, more specifically, an adjustment of the fiscal instruments under consideration.[13] If fiscal policy relies on subsidies only, it faces a tradeoff, indicated by the red (solid) line. By paying a subsidy, it pushes the equilibrium outcome along this line towards the optimal point b): the firms that adjust prices respond less to the shock and price dispersion is reduced—but at the expense of a weaker response of sectoral market prices. The bliss point is indicated by c). Here price dispersion is zero and the relative price changes in line with the natural price. However, to get there, one needs to resort to taxes in addition to the

[13]Recall that by adjusting money supply, monetary policy affects all sectors simultaneously and can thus not be tailored to address the distortions in a specific sector.

subsidy. In the special case under consideration, the buyer price is linked to inflation in the following way: $p = \pi^s + \tau^s$ (since $p_{t-1} = 0$). Hence, raising sales taxes shifts the tradeoff up. In the figure, this corresponds to the shift of the solid (red) line to the dashed (red) line, attaining the first best.[14]

Finally, the fact that the optimal policy features tax instruments of the same size but of different signs (tax vs subsidy) in each sector implies that it is approximately budget neutral around the efficient steady state. The following Corollary establishes this result.

Corollary 1 (Budget neutrality)**.** *The net government revenue from sales taxes and production subsidies around zero-profit steady state is $T_\tau = \boldsymbol{\xi}'\boldsymbol{\tau^s_t} - \boldsymbol{\xi}'\boldsymbol{s^p_t}$. The optimal policy is budget-neutral to the first order, that is $T_\tau = 0$.*

Budget neutrality holds to first order only around the zero-profit steady state because the production subsidy applies to costs while the sales tax applies to sales.[15]

3.3 Network effects

Proposition 1 shows how sectoral supply and demand shocks, $\boldsymbol{a_t}$ and $\boldsymbol{b_t}$, affect the tax distribution across sectors depending on the network structure. Specifically, the impact of supply shocks is governed by the matrix $\bar{L}$, the ij-th element of which captures the effect of a shock in sector j on sector i. This matrix can be written as a composite $\bar{L} = XL$, where L is the Leontief inverse with element ij being the cost-based direct and indirect use share of input j in the production of i (the exact functional form of L is specified above). As such, this Leontief inverse provides a measure of *downstream proximity* (Acemoglu et al. 2016). Accordingly, the effect of a productivity shock in sector j on taxes and subsidies in sector i is stronger in more closely connected downstream sectors (i is downstream to j). Matrix X

[14]As we show in Appendix B, there is a tax/subsidy pair τ and s which uniquely pins down the pair of seller price inflation and the market price as: $\pi^s = \frac{1}{1+b} \cdot [p^n - (1-a)\cdot\tau^s - a\cdot s^p]$ and $p = \frac{1}{1+b}\cdot[p^n + (a-b)\cdot\tau^s - a\cdot s^p]$ where a and b are functions of model parameters. Under the reasonable assumption that $1 > a > b > 0$ the market price increases with the sales tax, while seller price inflation decreases. Both the market price and seller price inflation decrease with the subsidy.

[15]In a decreasing-returns-to-scale economy, a constant fixed cost ensures zero profits in steady state.

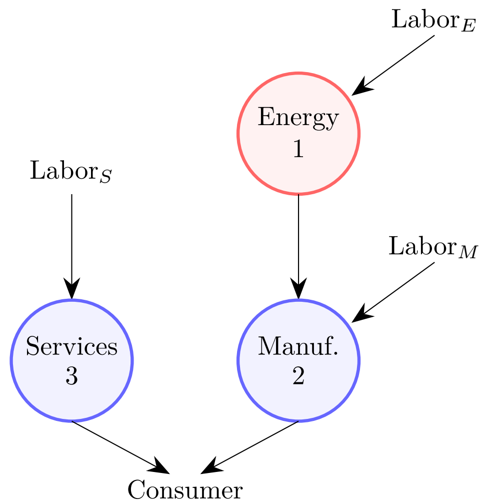
captures further propagation of shocks due to decreasing returns: recall that $X = I$ in the case of constant returns to scale, see definition of X above.

Similarly, the impact of demand shocks on taxes and subsidies is governed by the matrix $\hat{L}$. This is also a composite matrix $\hat{L} = \bar{L} \cdot [I_{\frac{1-x}{x}} + \frac{\gamma}{1+\gamma} I_\alpha] \cdot I_\xi^{-1} \tilde{L} I_\xi \cdot I_\xi^{-1}$ where cross-sector propagation is described by non-diagonal elements. In particular, matrix $I_\xi^{-1} \tilde{L} I_\xi$ is another Leontief inverse, such that the ij-th element is the direct and indirect sales share of sector-i purchased by sector j in the steady state (see Appendix D for a derivation). Hence, $I_\xi^{-1} \tilde{L} I_\xi$ provides a measure of *upstream proximity*. Accordingly, the effect of demand shocks in sector j on the optimal tax/subsidy in sector i is stronger for closely connected upstream sectors (i is upstream to j). In addition, matrix $\hat{L}$ features $\bar{L}$, reflecting the fact that demand shocks propagate first upstream, but then back downstream, as we explain in the context of an example below.

Finally, the term $[I_{\frac{1-x}{x}} + \frac{\gamma}{1+\gamma} I_\alpha]$ shows the demand shocks have a non-zero effect on the optimal tax only if either there is sector-specific labor ($\gamma \neq 0$) or in case of non-constant returns to scale ($x \neq 1$). If none of these conditions is met, we have $\hat{L} = 0$. Intuitively, sectoral demand shocks matter for the distribution of natural prices only as long as they affect the distribution of marginal cost across sectors. Marginal cost can be affected by the demand-driven increase in sectoral output, either through sectoral wages or through decreasing returns to scale. Otherwise, sectoral demand shocks do not affect natural prices, and hence are irrelevant for optimal taxes.

To develop intuition, consider a three-sector economy as an example. It consists of two final-good sectors, Services and Manufacturing, and one sector that produces intermediate goods, Energy. We assume that Manufacturing uses energy as input, while Services produces exclusively with labor; for simplicity we also assume constant returns to scale. Figure 2 provides a graphical illustration of the network structure. For the algebraic representation, we order the sectors as follows: Energy, Manufacturing, and Services. The vector of labor shares is then given by $\boldsymbol{\alpha} = [1,\ \alpha_M,\ 1]'$, while the vector of consumption shares is $\boldsymbol{\beta} =$

Figure 2: Three-sector economy



Notes: Graphical illustration of 3-sector economy. Services and Energy use labor as only input. Manufacturing uses labor and intermediate inputs sourced from Energy.

$[0,\ \beta_M,\ \beta_S]'$. The input–output matrix is such that $\Omega_{M,E} = 1$, and zero otherwise. The corresponding vector of Domar weights is $\boldsymbol{\xi} = [(1-\alpha_M)\beta_M,\ \beta_M,\ \beta_S]'$.

As discussed above, under the optimal policy the response of sectoral taxes to productivity shocks is determined by the Leontief inverse matrix which in the present case takes a particularly simple form:

$$\bar{L} = \begin{pmatrix} 1 & 0 & 0 \\ 1-\alpha_M & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}.$$

Its entries determine the optimal tax response to a productivity shock originating in either of the three sectors (columns) on the sector itself and the two other sectors (rows). For instance, the first column shows the effect of a productivity shock in Energy on taxes/subsidies in—from top to bottom—Energy, Manufacturing, and Services. In this example, the services sector is not taxed/subsidized under the optimal policy, but the other sectors are:

$$s_E^p = -a_E \text{ and } s_M^p = -(1-\alpha_M) \cdot a_E,$$

where a_E denotes the size of the energy productivity shock. The productivity shock in

Energy induces a policy adjustment downstream: a negative shock calls for a production subsidy in Energy but also in Manufacturing, exactly proportional to the energy use in manufacturing. These production subsidies are complemented by corresponding sales taxes under the optimal policy.

The optimal tax response to sectoral demand shocks, instead, is governed by the matrix:

$$\hat{L} = \frac{\gamma}{1+\gamma} \begin{pmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}.$$

A positive demand shock originating in Manufacturing (sector 2) thus calls for a production subsidy in Manufacturing but also in upstream Energy, according to

$$s_M^p = \frac{\gamma}{1+\gamma} b_M \quad \text{and} \quad s_E^p = \frac{\gamma}{1+\gamma} b_M,$$

where b_M is the manufacturing demand shock. The subsidy is to be complemented by a sales tax under the optimal policy. In this example, the upstream propagation is not followed by a subsequent downstream propagation because energy is not used in the production of other downstream goods or for final consumption. Instead, the demand shock would also require a policy response in the downstream sector if energy was used as input in the services sector, as we show in Appendix D.

4 Simple rules

The optimal policy, as established in Proposition 1, achieves the first-best allocation by responding directly to sectoral shocks. These shocks, however, are not necessarily observable in practice. We therefore consider, as an alternative, a *simple rule* constrained to respond only to potentially observable variables, following the approach in the analysis of optimal monetary policy (see, e.g., Galí 2015). In what follows, we first establish that a simple rule can approximate the first-best policy in the limit, then illustrate its operation in the context of a supply shock, and finally discuss potential limitations.

4.1 Targeting sectoral inflation through simple rules

We posit a rule that adjusts fiscal instruments in response to sectoral seller price inflation only—either observed directly or inferred from the source of the shock and the network structure. Intuitively, by adjusting subsidies and taxes to sectoral inflation rates, the rule responds indirectly to sectoral shocks to the extent that these affect marginal costs. The following proposition establishes that such a simple rule can approximate the first-best policy in the limit.

Proposition 2 (Simple rule)**.** *Consider the following rule for adjusting subsidies and taxes:*

$$\boldsymbol{s_t^p} = I_\phi \cdot \boldsymbol{\pi_t^s},$$

$$\boldsymbol{\tau_t^s} = \boldsymbol{s_t^p},$$

where $I_\phi = diag\{\phi_i\}$ is a matrix with ϕ_i governing the strength of the response to seller price inflation in sector i. Then, the resulting allocation becomes first best if, for all i, $\phi_i \to \infty$. For the static economy, $\delta = 0$ and $\boldsymbol{p_{t-1}^s} = 0$, the simple rule implies for the vector of subsidies:

$$\boldsymbol{s_t^p} = I_\phi \cdot (I + \bar{M} I_\phi)^{-1} \cdot \bar{M} \cdot \underbrace{(m_t \cdot \mathbf{1} + \hat{L}\boldsymbol{b_t} - \bar{L}\boldsymbol{a_t})}_{\text{optimal subsidy}};$$

and the buyer prices are $\boldsymbol{p}_t = (I + I_\phi) \cdot (\bar{M}^{-1} + I_\phi)^{-1} \cdot \boldsymbol{p}_t^n$, where $\bar{M} = [(\bar{L} - \hat{L} I_\xi)\tilde{I}_\lambda^{-1} + I]^{-1}$ and $\boldsymbol{p}_t^n$ is the vector of counterfactual flexible prices.

The strength of the policy response is governed by a set of parameters ϕ_i. They regulate by how much the outcome under the simple rule deviates from the first best. To see this, note that in the static case, the simple rule implies a policy response that is a "discounted" linear transformation of the response under the optimal policy: The larger ϕ_i, the more closely the simple rule resembles the optimal policy. Note that the simple rule with large ϕ_i represents a strong commitment to stabilize sectoral seller price inflation by adjusting sectoral production subsidies (and sales taxes). This commitment (representing a "threat" to react strongly to sectoral inflation) results in muted seller price inflation rather than in large subsidies/taxes.[16]

We can also show that in the flexible price economy ($\lambda_i \to 0$ for all i), the simple rule tax does not affect market prices: $\boldsymbol{p}_t = \boldsymbol{p}_t^n$. This is precisely because the tax in each sector is offset by a corresponding subsidy. As a result, similarly to the optimal policy, the simple rule has a meaningful effect on the market prices and the allocation only when prices are rigid.

4.2 Application: a supply shock

Now we consider the case of an (adverse) productivity shock originating in the energy sector and how policies adjust under the simple rule. While observing inflation across all disaggregated sectors is challenging and prone to errors, our simple rule does not necessarily require this information—it can be constructed as a response to a subset of sectoral inflation measures. In practice, tax/subsidy pairs in each sector can respond to the underlying sources of inflation—for example, higher prices of intermediate goods from the energy sector—rather than to sectoral inflation itself.

For a given shock, such as an adverse productivity shock in the energy sector, all that is required is observing inflation in the energy sector, and adjusting taxes and subsidies across sectors in proportion to the direct and indirect use of energy, as given by matrix $\bar{L}$. The tax/subsidy pair in sector i under the simple rule can be then set as

$$\tau_{t,i}^s = s_{t,i}^p = \phi_i \bar{l}_{i,E} \pi_{t,E}^s, \tag{15}$$

where $\bar{l}_{i,E}$ is the total use of energy and energy-intensive goods by sector i, and ϕ_i captures the strength of the tax reaction to the energy-induced increase in production cost. With this policy, the tax/subsidy pair reacts to inflation in sector i caused by an increase in the price of energy, without necessarily observing inflation in sector i. All that is needed to

[16]For $\delta = 0$, we obtain: $\boldsymbol{\pi_t^s} = \frac{\boldsymbol{s_t^p}}{\phi} = (I + \phi \bar{M})^{-1} \cdot \bar{M} \cdot (m_t \cdot \mathbf{1} + \hat{L}\boldsymbol{b_t} - \bar{L}\boldsymbol{a_t})$ which is decreasing in ϕ.

implement such a policy is observing inflation in the energy sector. We can show, as before, that when $\phi_i \to \infty$ we are at the optimal tax/subsidy response to this type of shock. Note that use-shares are relatively stable in the short run and hence can be easily used to design the applicable rule-based policy.

Turning to the three-sector example illustrated in Figure 2 above, this implies

$$s_E^p = \phi_i \cdot \pi_t^E \text{ and } s_M^p = \phi_i(1 - \alpha_M) \cdot \pi_t^E.$$

That is, the government needs to observe energy price inflation and to subsidize the energy sector itself, and the energy-intensive sector (Manufacturing) according to its use of energy, and impose corresponding offsetting sales taxes to induce the reallocation of resources from Manufacturing to Services, that are not energy-intensive.

Finally, note that while subsidizing energy use in response to energy inflation is a policy often applied in practice, our result suggests that this policy should be complemented by a tax that prevents the overconsumption of energy-intensive goods.

4.3 Discussion

A key advantage of simple rules over the first-best policy is that they require far less information. In this regard, we distinguish between two types of simple rules. In the first case, the policymaker observes all sectoral inflation rates and responds accordingly. In the second case, only a subset of sectoral inflation—such as energy inflation—is observed, and taxes are applied based on the network structure through which this observed inflation propagates. As demonstrated in the application above, this approach targets implied sectoral price changes rather than directly observed ones.

In the first case, the policy design has lower information requirements than the first-best policy. It requires observing the distribution of price changes across sectors, but not the distribution of the underlying economic shocks, which makes it more practical to implement. In the second case, the information requirements are even lower: the policymaker only needs to observe a subset of sectoral inflation—e.g., energy inflation—and understand the network structure of the economy, and the nature of the economic shock in question (supply or demand). This allows the construction of the implied price changes that result from the propagation of the observed sectoral inflation, to which the simple rule-based policy can then respond. As a result, this design is highly parsimonious in its information requirements and can be easily implemented in practice.

Beyond information requirements, another potential concern is the possibility that firms may strategically adjust their pricing to misrepresent their cost and obtain more subsidies. However, a key feature of our design is that the policy responds to sectoral price changes rather than firm-specific prices. As a result, an individual atomistic firm cannot affect the size of the subsidy by simply reporting higher prices—unless all firms within the sector coordinate to simultaneously do so. But in such a case, each firm would have an incentive to deviate by undercutting competitors—offering lower prices while still benefiting from the larger sector-wide subsidy. This undermines the incentive to collude, making our simple rule policy robust against such manipulation. In contrast, if some firms are large enough to influence sectoral prices, they can manipulate their prices to obtain subsidies in the first type of our simple rule design, which responds to own-sector inflation. In the second design, the manipulation is unlikely: the subsidy is not based on a firm's own-sector price, but rather on the prices in sectors that supply to or buy from it, giving firms less ability to influence the size of the subsidy through their individual pricing decisions.

5 Quantitative analysis

In what follows, we calibrate the model to assess the quantitative relevance of our findings. Specifically, we evaluate the extent to which simple policy rules approximate the optimal policy in response to both supply and demand shocks.

5.1 Model calibration and solution

Our baseline calibration targets the U.S. economy. To calibrate the input-output shares, we use the input-output account data for the year 2017 as reported in the "Use table" of the Bureau of Economic Analysis (BEA). This table contains information on intermediate input costs, labor costs, and consumption expenditures for 402 industries, based on a 6-digit classification. Following Baqaee & Farhi (2020), and in line with our model analysis above, we drop the government, scrap, and non-comparable import sectors from the data. Then we drop the industries for which no use data is available (for both intermediate input and final consumption). This leaves us with 373 sectors in total.[17] We then use the resulting table to determine for each sector i the intermediate input share ω_{ij} as the share of input-j costs in the total intermediate input costs, the labor share α_i as the ratio of employee compensation to total cost, and β_i as the ratio of final consumption expenditure to total final consumption expenditure across sectors.

Further, following Rubbo (2023), we assume constant returns to scale for the baseline case, but also compare our results to an alternative with decreasing returns (Appendix C). Finally, we set the elasticity of substitution between varieties within sectors to $\epsilon = 8$. As we set the remaining parameter values, we assume a period in the model represents a month. We account for sectoral heterogeneity in price rigidity and set $1 - \lambda_i$ to match the estimates for the sector-specific price flexibility reported by Antonova (2025). According to these estimates, price flexibility varies substantially across sectors, ranging from 0.052 to 0.989, with a median of 0.277.[18] Finally, we set the inverse Frisch elasticity to $\gamma = 2$. We set the discount factor $\delta = 0.997$.

Solving the model requires specifying stationary dynamic processes that govern sectoral productivity and demand shocks. We assume that both of them follow an AR(1) process in

[17] We provide a graphical illustration of the input-output matrix by means of a heatmap in Appendix C.

[18] This implies that 27.7% of firms reset their price within a month in the median sector, consistent with a median price duration of 4.3 months reported in Bils & Klenow (2004).

each sector with a common persistence parameter $\rho = 0.97$.[19] Given our calibration, solving the model amounts to finding the solution to the system of equations describing seller price dynamics, which we lay out in Appendix A. We find a solution to this system using the method of undetermined coefficients. The solution algorithm is described in Appendix C. The solution is unique under an exogenous money supply policy.[20]

5.2 Welfare measure

In order to study the performance of simple rules relative to the first best policy, we derive a microfounded measure for the welfare loss in Appendix D. Specifically, a quadratic approximation of the welfare loss in terms of *sectoral* output gaps and sectoral inflation rates yields

$$\Delta_t \approx \frac{1}{2} \cdot E_0 \sum_{t=0}^{\infty} \delta^t \cdot \{\tilde{\boldsymbol{y}}_t' \cdot F_y \cdot \tilde{\boldsymbol{y}}_t + \boldsymbol{\pi}_t^{s\prime} \cdot F_p \cdot \boldsymbol{\pi}_t^s\}, \tag{16}$$

where F_y and F_p are matrices determined by the model's parameters. Several remarks follow.

First, recall that the canonical representation introduced in Section 2.3 links *sectoral* output gaps to sectoral inflation rates, thereby allowing us to analyze the stabilizing role of sectoral tax instruments, including those beyond the first-best. For this reason, the loss measure (16) also features the vectors of sectoral output gaps and sectoral inflation rates. It differs, however, from the representation relevant for monetary policy trade-off analysis—such as in Rubbo (2023)—which expresses welfare in terms of sectoral inflation and the *aggregate* output gap.

The difference is that in an economy without time-varying taxes ($\boldsymbol{\tau}_t^s = \boldsymbol{s}_t^p = 0$), there is no trade-off between stabilizing $\tilde{\boldsymbol{y}}_t$ and $\boldsymbol{\pi}_t^s$, as can be seen from the Phillips-curve system (11).[21] In this case, the welfare loss function can be simplified to depend only on inflation: $\Delta_t \approx \frac{1}{2} E_0 \sum_{t=0}^{\infty} \delta^t \{\boldsymbol{\pi}_t^{s\prime} F_m \boldsymbol{\pi}_t^s\}$. And the only instrument—monetary policy—balances infla-

[19] Specifically, we assume that $\boldsymbol{a_t} = \rho \boldsymbol{a_{t-1}} + \boldsymbol{\epsilon_t^a}$ and $\boldsymbol{b_t} = \rho \boldsymbol{b_{t-1}} + \boldsymbol{\epsilon_t^b}$ where the vectors for sectoral productivity and demand shock innovations are given by $\boldsymbol{\epsilon_t^a}$ and $\boldsymbol{\epsilon_t^b}$, respectively.

[20] As we solve the model numerically we do not rely on the sectoral IS and Phillips curves, and hence do not encounter determinacy problems discussed in Gali & Monacelli (2008), see the Appendix C for details.

[21] The trade-off between sectoral inflation and the *aggregate* output gap, however, remains.

tion stabilization across sectors, stabilizing an appropriate aggregate inflation index (Aoki 2001; Woodford 2001; Benigno 2004; Huang & Liu 2005; Rubbo 2023). Once we allow for a tax instrument (either $\boldsymbol{\tau}_t^s$ or $\boldsymbol{s}_t^p$), however, a trade-off emerges in the Phillips curves between stabilizing the sectoral output gaps and sectoral inflation. This trade-off can be resolved by introducing another sectoral instrument. Without such an offsetting instrument, sectoral output gaps and sectoral inflation become two distinct sources of welfare loss.

Second, the multi-sector welfare loss in (16) is a natural generalization of the welfare loss function familiar from the one-sector model, which is nested as the special case $N = 1$ in our framework. In the one-sector model, the welfare loss depends on the aggregate output gap and aggregate inflation. As long as there is no trade-off between them in the Phillips curve, monetary policy can stabilize inflation by closing the output gap (divine coincidence).

Finally, in the multi-sector model, the first term in expression (16) captures the welfare loss due to sector-specific output gaps in turn linked to markups and thus reflects the misallocation of resources *across* sectors: because prices are sticky, sectoral prices will generally adjust insufficiently, causing inefficient sectoral output fluctuations. The second term in expression (16) represents the inefficiency due to *within*-sector misallocation: since some firms within a sector adjust prices and others do not, there is inefficient price dispersion within sectors. This within-sector inefficiency induces a welfare loss from inflation itself, which is a standard feature of sticky-price models. Sectoral tax instruments give rise to a trade-off between stabilizing sectoral output gaps and sectoral inflation absent in an economy without time-varying taxes, making the link between $\tilde{\boldsymbol{y}}_t$ and $\boldsymbol{\pi}_t^s$ more nuanced.

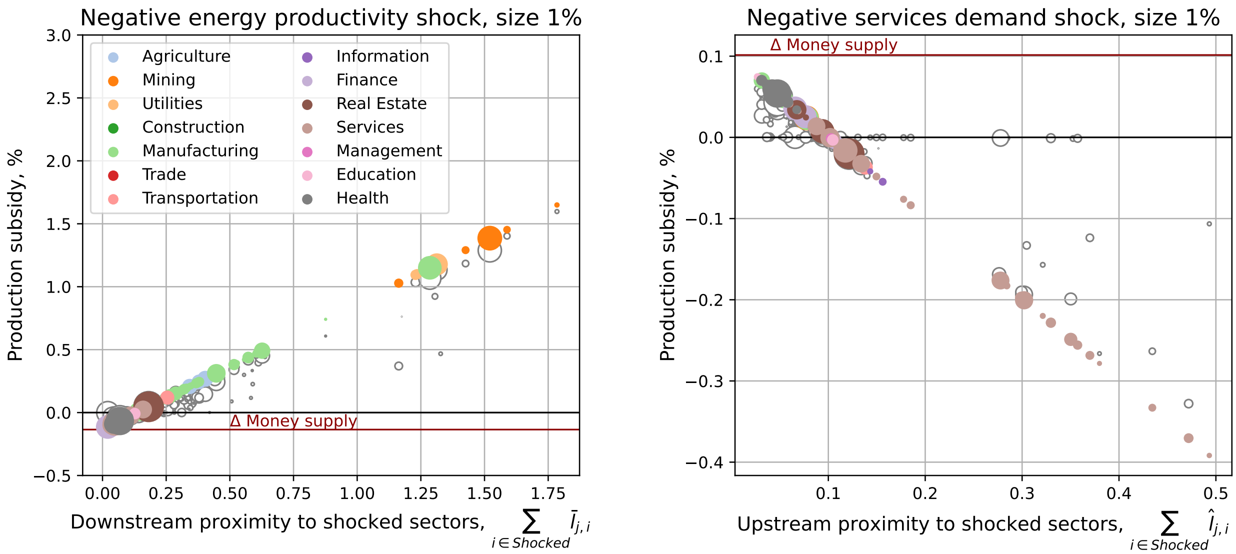
5.3 The policy response to supply and demand shocks

Based on the calibrated model, we study the quantitative implications of sectoral shocks for optimal tax policy. We consider two types of adverse shock scenarios: a supply shock in the energy sector and a demand shock in services, with these sectors understood in a broad sense. We define the first shock as an exogenous drop of productivity by one percent that simultaneously affects key energy-related industries within two broad sectoral groups defined by the 2-digit sectoral classification: 21 - "Mining" and 22 - "Utilities". Energy-related sectors in "Mining" include oil and gas extraction, while those in "Utilities" encompass electric power generation. Overall there are 10 6-digit sectors in these categories, accounting for about 10% of total sales in the economy. We define the second shock as an exogenous decline of demand by one percent in service-related industries within the 2-digit sector groups: 71 - "Arts, Entertainment, and Recreation," 72 - "Accommodation and Food Services," and 81 - "Other Services." In total, there are 22 6-digit sectors in these categories, accounting for about 7% of total sales in the economy.

For both shock scenarios, we first compute the optimal policy response to provide a quantitative illustration of Proposition 1, under the assumption that monetary policy stabilizes aggregate fluctuations according to rule (12). Second, we contrast results for the optimal policy with the policy response across sectors that is implied the simple rule, assuming a response coefficient of $\phi_i = 5$ for all sectors. For the negative supply shock this policy amounts to paying production subsidies based on direct and indirect energy use in each sector. This stabilizes seller price inflation when higher energy prices push up marginal costs. But as stressed above, under the simple rule, just like under the optimal policy, sales taxes have to be adjusted one-for-one with the production subsidy for buyer prices to signal the increased scarcity of energy. In case of the negative demand shock, the simple rule calls for a negative sales tax (sales subsidy) in a given sector based on its sales to the services sector, complemented by a negative production subsidy. In each case, the simple rule requires observing only inflation in the shocked sector.

We show results in Figure 3. In both panels, the colored circles represent the optimal policy response. In the left panel, we consider the adverse supply shock, and plot—for each sector—the production subsidy along the vertical axis against the sector's downstream network proximity to the "energy sector," measured along the horizontal axis. In the right panel, we show the response of the subsidy to the services demand shock in each sector,

Figure 3: Subsidy/tax response under optimal policy and simple-rule policy



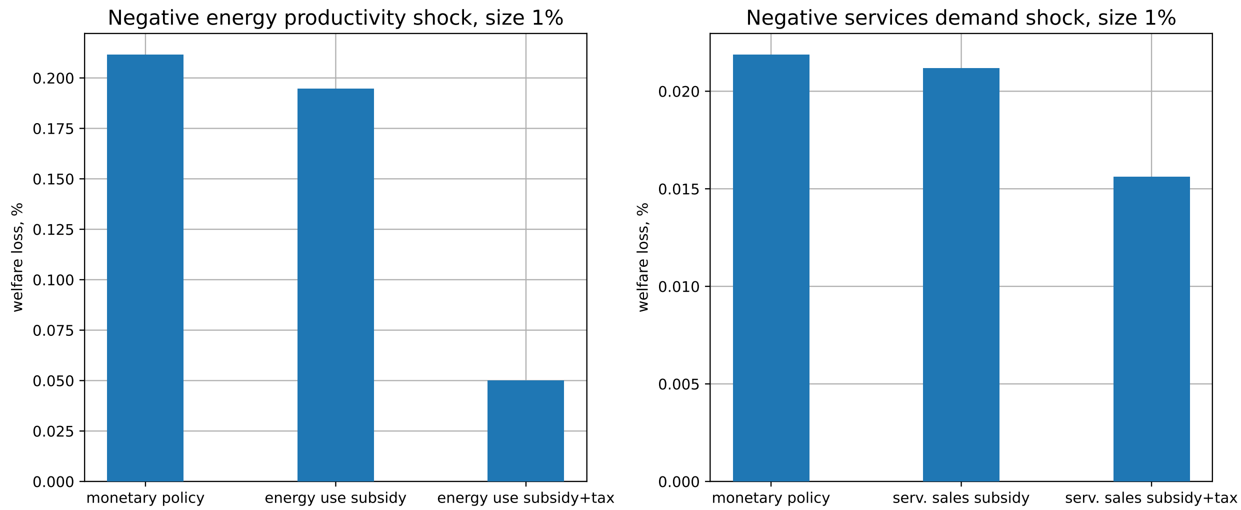
Notes: Colored circles show optimal policy response in each sector to a negative productivity shock in Energy (left) and a negative demand shock in Services (right). White circles show sectoral subsidy under the simple policy: based on energy use (left) and on sales to Services (right panel). Sensitivity in the simple rule is $\phi = 5$. The size of circles represents the size of sectors measured by sales share.

ordered by its upstream network proximity to the shocked sector. In each case, the offsetting tax adjusts by the same amount.

In both cases, the strength of the optimal policy (colored circles) increases with the network proximity to the shocked sector. For the adverse supply shock, the production subsidy is required in the energy-related sectors themselves, and a relatively smaller but still substantial subsidy is required in Manufacturing, reflecting its use of energy. The optimal response to the adverse services demand shock is a negative production subsidy and, hence, a negative sales tax in services and service-related sectors. Note that because monetary policy stabilizes aggregate fluctuations, subsidies adjust uniformly downward in panel a) and upward in panel b).

We contrast results for the first-best policy with the distribution of subsidies under the simple rule, given by the circles, in both panels of Figure 3. Generally, the distribution of subsidies/taxes across sectors under the simple rule is strongly correlated with the distri-

Figure 4: Welfare loss due to shock under different policies



Notes: The left bar on each graph is the welfare loss under monetary policy targeting the output gap. The middle bar is the welfare loss when sectoral subsidies are not offset by a corresponding sectoral tax. The right bar is welfare loss under the simple $2N$ rule, with response coefficient $\phi = 5$.

bution under the optimal policy. However, by construction the subsidy response under the simple rule is somewhat weaker compared to the optimal policy response. In the Appendix C, we also show the impulse responses to these two shocks.

We compute the welfare loss based on (16), measured as an equivalent percentage loss in per-period consumption, due to each of the shocks under three alternative policies: only monetary policy targeting the output gap (no tax instruments), sectoral subsidies w/o sales taxes (often implemented in practice), and the simple $2N$ policy which complements a production subsidy in each sector with the corresponding sales tax. Figure 4 shows the results. We see that the simple $2N$ policy (right bar of each panel) significantly improves welfare compared to when only monetary policy adjusts to the shock (left bar), especially for the supply shock.[22] Instead, if the subsidy is not accompanied by the corresponding tax, the welfare gains from the sectoral subsidy policy is much smaller (middle bar).[23]

[22]Note that the welfare loss due the shock can be sizable even as monetary policy targets the output gap due to the interaction of sticky prices and the production network, as stressed by Rubbo (2023).

[23]Simple rules also improve welfare from an ex ante point of view. To illustrate this, we calibrate the distribution of sectoral shocks and compute the unconditional welfare loss based on simulations. The results are reported in Appendix C.

Finally, we also compute policy response under decreasing (rather than constant) returns to scale and report results in Appendix C. We find the optimal policy response to differ slightly in both cases (correlations of 0.98 and 0.99 for supply and demand shocks, respectively), with decreasing returns leading to a stronger response to demand shocks. Moreover, the $2N$-rule policy continues to deliver significant welfare improvements in the presence of decreasing returns to scale. One notable difference, however, is that under decreasing returns to scale, demand shocks generate relatively higher welfare losses, whereas productivity shocks lead to lower losses. This finding is consistent with our theoretical analysis above, which shows that the demand-side effects of shocks become stronger as returns to scale decline.

6 External shocks—an open-economy extension

A distinct class of sectoral shocks arises at the global level—most notably energy-price shocks, as discussed above. We therefore extend our model to account for external shocks, building on the small open NKN framework of Antonova et al. (2025). The open-economy model of this section nests the closed-economy model of the previous sections as a special case. For brevity, we outline only the key elements here and delegate the details to Appendix A. We then generalize our theoretical results on optimal policy to the open-economy setting and examine the behavior of simple rules in response to an external energy-price shock, such as that observed during the Ukraine war, contrasting—albeit in stylized form—the U.S. and European experience.

6.1 Accounting for openness

Our open-economy setup shares many features with the canonical New Keynesian model of a small open economy such as, for instance, complete financial markets and the assumption that the domestic economy is small (Galí & Monacelli 2005). Our framework is distinct in that it features a production network and permits international trade at all stages of production. Specifically, we assume that the output of a generic sector, $\bar{Y}_{t,i}$, is now a combination of locally produced goods $Y_{t,i}$ and imports $IM_{t,i}$:

$$\bar{Y}_{t,i} = \left[(1-\gamma_i)^{\frac{1}{\eta}} \, Y_{t,i}^{\frac{\eta-1}{\eta}} + \gamma_i^{\frac{1}{\eta}} \, IM_{t,i}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} , \tag{17}$$

where γ_i denotes the trade openness of the sector, and η is the elasticity of substitution between imported and domestically produced goods. Sectoral output, in turn, is used for domestic consumption, as an intermediate input in domestic production, but also potentially exported: $\bar{Y}_{t,i} = C_{t,i} + \sum\limits_{j,k} X_{t,ji,k} + EX_{t,i}$, where $EX_{t,i} = \gamma_i D_{t,i} \cdot \frac{1}{P_{t,i}/\mathcal{E}_t}$ is an ad-hoc export demand function, with export demand shock $D_{t,i}$, and the exchange rate $\mathcal{E}_t$ (the price of foreign currency in units of domestic currency). Monetary policy, as before, fixes the money supply, and the exchange rate adjusts freely to clear the foreign exchange market. Given the definition of sectoral output (17), its price is

$$P_{t,i} = \left[(1-\gamma_i) \cdot [(1+\tau^s_{t,i}) P^s_{t,i}]^{1-\eta} + \gamma_i \cdot [\mathcal{E}_t P^w_{t,i}]^{1-\eta} \right]^{\frac{1}{1-\eta}} , \tag{18}$$

where $(1+\tau^s_{t,i})P^s_{t,i}$ is the market price of domestically produced goods, $\mathcal{E}_t P^w_{t,i}$ is domestic-currency price of goods imported by sector i and $P^w_{t,i}$ their (exogenous) world-market price. Prices are set in producer currency, and because sales taxes apply to all sales of domestically produced goods, they also indirectly affect exports. We assume that in steady state trade is balanced at the sectoral level. If $\gamma_i = 0$ for all i we are back to our baseline closed-economy case with $\bar{Y}_{t,i} = Y_{t,i}$, $IM_{t,i} = EX_{t,i} = 0$ and $P_{t,i} = (1+\tau^s_{t,i})P^s_{t,i}$.

6.2 First best policy in the open economy

We are now in a position to revisit our main result concerning the $2N$ policy established in Proposition 1. We find it extends naturally to the open-economy setting. By suitably redefining the upstream and downstream matrices and, crucially, the vectors of shocks, we establish in Appendix B that the first-best policy in the open economy is formally isomorphic to its closed-economy counterpart. Hence, we have a more general result:

Proposition 3 ($2N$ policy in the open economy)**.** *The optimal tax policy ensures that sectoral output gaps and domestic-seller price inflation in all sectors are fully stabilized. Assuming initial seller prices are at their steady-state value, the sectoral production subsidies and sales taxes achieving this outcome are*

$$\boldsymbol{s}_{\boldsymbol{t}}^{\boldsymbol{p}} = \mathbf{1} \cdot m_t + \hat{L} \cdot \hat{\boldsymbol{b}}_t - \bar{L} \cdot \hat{\boldsymbol{a}}_t, \tag{19}$$

$$\boldsymbol{\tau}_{\boldsymbol{t}}^{s} = \boldsymbol{s}_{\boldsymbol{t}}^{\boldsymbol{p}}, \tag{20}$$

with supply and demand shifters given by:

$$\hat{\boldsymbol{a}}_t = \boldsymbol{a}_t - I_{1-\alpha}\Omega I_\gamma \boldsymbol{p}_t^w, \tag{21}$$

$$\hat{\boldsymbol{b}}_t = I_{1-\gamma}\boldsymbol{b}_t + I_\gamma I_\xi[(\eta - 1)\boldsymbol{p}_t^w + \boldsymbol{d}_t], \tag{22}$$

and propagation matrices defined as $\hat{L} = Z\hat{L}^s$*,* $\bar{L} = Z\bar{L}^s$*, with* $Z = [1 + \bar{L}^s I_{1-\alpha}\Omega I_\gamma + (\eta - 1)\hat{L}^s I_\xi I_\gamma]^{-1}$*,* $\bar{L}^s = XL$ *and* $L = [I - I_{1-\alpha}\Omega]^{-1}$*. In turn,* $\hat{L}^s = \bar{L}^s \cdot [I_{\frac{1-x}{x}} + \frac{\gamma}{1+\gamma} I_\alpha] \cdot I_\xi^{-1}\tilde{L}$ *and* $X = [I + LI_{\frac{1-x}{x}}]^{-1}$*, and* $\tilde{L} = [I - (I - I_\gamma)\Omega'(I - I_\alpha)I_x]^{-1}$*.*

In the open economy, the supply and demand shifters no longer feature only domestic shocks. The supply shifter $\hat{\boldsymbol{a}}_t$ now includes, in addition to domestic productivity $\boldsymbol{a}_t$, the term $-I_{1-\alpha}\Omega I_\gamma \boldsymbol{p}_t^w$, thereby capturing the vector of import-price shocks $\boldsymbol{p}_t^w$ and their propagation across sectors through the production network ($\Omega \neq 0$), scaled with a sector's trade openness. The vector of demand shifters $\hat{\boldsymbol{b}}_t$ consists, as before, of sectoral shocks to domestic consumption demand $\boldsymbol{b}_t$, but also of import-price shocks $\boldsymbol{p}_t^w$ and export demand shocks $\boldsymbol{d}_t$. Note that import-price shocks have a positive demand effects only when elasticity of substitution between imported and domestically produced goods η exceeds unity.

Import-price shocks $\boldsymbol{p}_t^w$ enter both shifters because they operate simultaneously as both supply and demand shocks, as emphasized in Antonova et al. (2025). As they raise input costs for industries using foreign-produced goods, they push up prices and reduce output, just like an adverse supply shock. At the same time, they shift expenditures toward domestic substitutes, raising output and prices in local industries, just like a positive domestic demand shock. This point proves relevant in practice, as we demonstrate in what follows.

6.3 An external energy-price shock

To illustrate how the $2N$ policy operates in the face of an import-price shock, we consider the increase in global energy prices following the Russian invasion of Ukraine in 2022. We analyze two variants of the open-economy model: one with low dependence on energy imports and another with high dependence. In both cases, we keep all other parameters as in the baseline calibration above, while allowing for imports in the "Energy" sector. Specifically, in the low-energy-dependence scenario, which captures a key aspect of the U.S. economy, we set openness in energy to $\gamma^{US} = 0.17$ and the trade elasticity to $\eta^{US} = 4$. In the high-energy-dependence scenario, intended to approximate a typical European economy, we set $\gamma^{EU} = 0.63$ and $\eta^{EU} = 1$.[24] These calibrations reflect differences in import dependence and the fact that energy sources like oil and gas can be more easily substituted by domestic production in the U.S. than in Europe, which lacks sufficient domestic oil and gas resources.

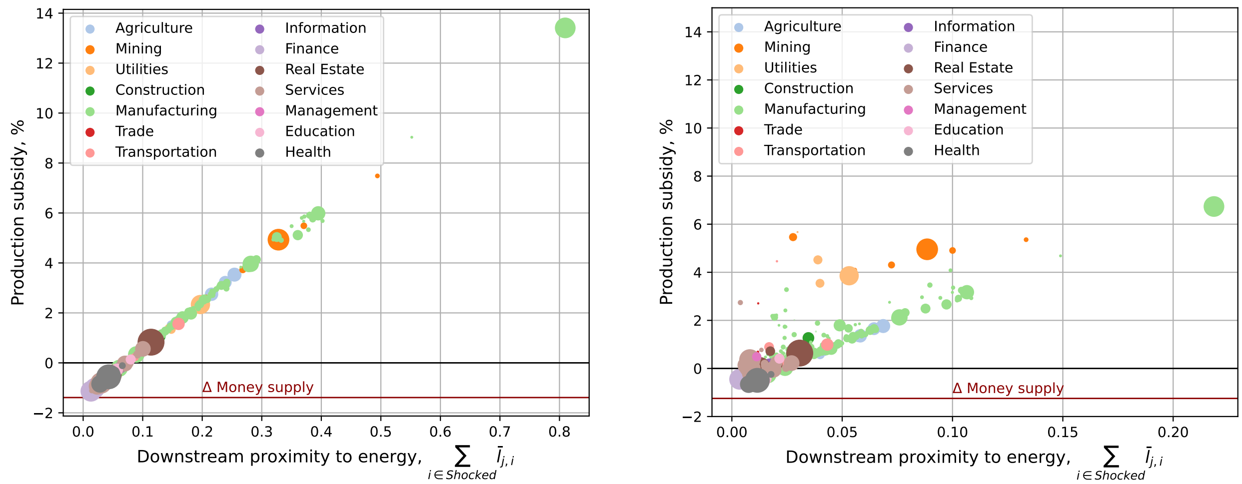
As a shock we consider an exogenous increase of world-energy prices by 24%, in line with data for the period after start of the War in Ukraine—between 2022M1 and 2022M4 (IMF Global price of Energy index data). In response, the model predicts that the energy sector expands in the "U.S." but contracts in "Europe," as shown in Appendix C. This outcome reflects that adverse supply effects dominate in Europe, whereas expansionary demand effects prevail in the U.S., as buyers substitute toward domestic energy sources. Non-energy sectors contract on average in both cases. The optimal policy response in the energy sector is qualitatively similar across both economies: it subsidizes energy production while simultaneously imposing a sales tax. This combination moderates the expansion of the energy sector in the "U.S." and amplifies its contraction in "Europe."

At the sectoral level, however, the policy response differs across the two scenarios. Figure

[24] These parameter values align with data from the following sources: the Energy Information Administration's Monthly Energy Review (2024), https://www.eia.gov/totalenergy/data/monthly/, and Ahmad et al. (2021) for the U.S., and Eurostat and Németh et al. (2011) for the EA.

Figure 5: Increase in Imported Energy Prices, size 24%: Optimal Subsidy/Tax

(a) Europe scenario (b) U.S. scenario



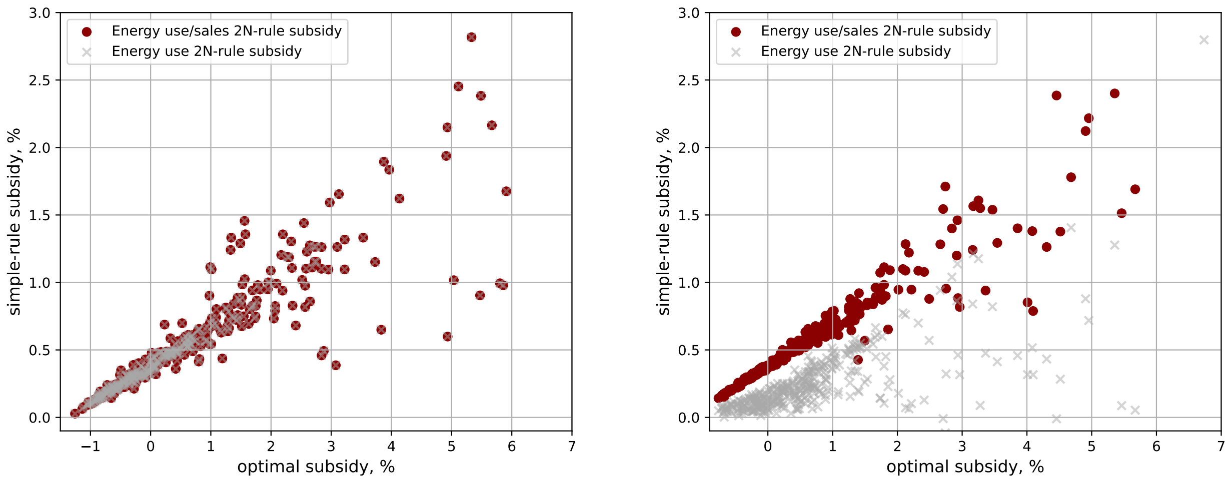
Notes: Panels show the distribution of optimal production subsidies against downstream proximity to the energy sector.

5 plots the optimal $2N$-policy response depending on downstream proximity to the energy sector. In Europe (left panel), the tax pattern is fully determined by downstream proximity, reflecting that the shock operates only on the supply side: with energy substitutability fixed at one, demand-side propagation is absent. In the U.S. (right panel), by contrast, the response is not driven solely by downstream proximity; domestic energy producers require additional subsidies. This reflects the demand effects of an import-price shock—higher import prices increase demand for substitutable domestic energy, raising marginal costs and induce upward pressure on prices unless offset by subsidies. Still, subsidies in manufacturing remain closely aligned with downstream proximity, underscoring the importance of supply-side effects in the U.S. scenario, too.

Turning to $2N$ simple-rule policies, we distinguish two possibilities for illustrative purposes. The first case of the $2N$ policy is restricted to account only for the *use* of energy (direct and indirect), aiming to mitigate the adverse supply effect of the energy-price shock. Under this rule, domestic sectors are subsidized (and their sales taxed) according to energy-use shares derived from the downstream matrix $\bar{L}$. The second case of $2N$ policy accounts

Figure 6: Increase in Imported Energy Prices, size 24%: optimal vs simple-rule policy

(a) Europe scenario (b) U.S. scenario



Notes: Panels show the distribution of optimal production subsidies against the two simple 2N-rule policies: energy use-and-sales-based policy, and energy use-based policy. Panel (a) plots results for the Europe scenario: correlations of use/sales and use-only policies with the optimal policy are 0.89 and 0.89. Panel (b) plots the results for the U.S. scenario: correlations are 0.94 and 0.66. All simple rules have coefficients $\phi = 5$.

for both energy use and energy sales. Under this rule, subsidies are based on a combination of downstream weights, $\bar{L}$, and upstream weights, $\hat{L}$.

Figure 6 plots, sector by sector, the production subsidies under these rules against the optimal subsidies for "Europe" (panel a) and the "U.S." (panel b). Crosses denote the policy based on energy use only, while dots denote the policy accounting for both use and sales. Overall, the simple $2N$ policies are strongly correlated with the optimal policy across sectors. However, they tend to imply lower subsidy rates, as indicated by the clustering of dots below the 45-degree line. In panel a), the use/sales policy coincides exactly with the use-only policy, since the low trade elasticity ($\eta = 1$) eliminates the demand effects of import shocks. By contrast, in panel b), subsidizing both energy use and sales requires larger subsidies than a use-only policy. Incorporating the demand-driven propagation of import shocks into policy design brings the simple-rule policy closer to the optimal policy.[25]

[25] In Appendix C, we also provide the ranking of welfare losses for these policies. The use-based policy improves welfare relative to monetary policy, while the use-and-sales policy further enhances welfare in the

A distinct feature of the $2N$ policy is that sales taxes move one-for-one with subsidies. This holds even in the presence of external shocks (see Proposition 3) and is particularly intuitive in the case of energy-price shocks. By raising sales taxes on energy, buyers are incentivized to reduce energy use. Against this background, it is noteworthy that actual policies in Europe partly subsidized energy consumption during the 2022 energy crisis, arguably to support financially vulnerable households, an aspect that is absent from our analysis (Langot et al. 2023; Bayer et al. 2025).

7 Conclusion

Economies are often subject to sectoral shocks that monetary policy cannot fully stabilize. Policymakers therefore rely on sectoral taxes and subsidies, typically in an *ad hoc* manner. We use the NKN model to characterize the optimal tax response. The optimal policy restores the first-best allocation but requires to adjust $2N$-instrument in response to shocks that may not be directly observable. Hence, we propose a simpler $2N$ rule that responds only to inflation in the shocked sector and adjusts other instruments according to input–output linkages. In a calibrated model, this rule delivers most of the welfare gains of the optimal policy.

Our results also extend to an open-economy setting, where we study the optimal response to import-price shocks, in particular the external energy-price shock triggered by the Russian invasion of Ukraine. A distinctive feature of such shocks is that they act simultaneously as supply and demand shocks, which in turn shapes the optimal tax response across the production network. We illustrate this by comparing economies with high and low import dependence, thereby capturing a key difference between the U.S. and a typical European economy. This distinction matters not only for the optimal policy response but also for the operation of the simple $2N$ policy: production subsidies and sales taxes are generally higher in Europe, but more dispersed across sectors in the U.S.

U.S. scenario, but not in the European one.

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