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Connected for Better or Worse? The Role of Production Networks in Financial Crises

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Abstract:

We study how production networks shape the severity of Sudden Stops. We build a small open economy model with collateral constraints and input–output linkages, derive a sufficient statistic that maps network structure onto the amplification of tradable shocks, and show that a planner optimally introduces sectoral wedges to reduce amplification. Using OECD input–output data and Sudden Stop episodes, we document systematic network differences between emerging and advanced economies and show they predict crisis severity. A calibrated three-sector DSGE model disciplined by these differences reveals that endowing an advanced economy with an emerging-market production network moves most of the way toward the observed emerging–advanced Sudden Stop gap.

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1 Introduction

Financial crises occur more frequently and with greater severity in emerging markets than in advanced economies (e.g., Calvo et al., 2006; Mendoza, 2010; Bianchi and Mendoza, 2020). Episodes of Sudden Stops, characterized by sharp reversals in capital inflows, often trigger deep recessions and protracted recoveries. The prevailing view attributes these disparities primarily to differences in financial development (Garcia-Cicco et al., 2010) and to the greater volatility and persistence of external shocks faced by emerging markets (Aguiar and Gopinath, 2007). While these factors are undoubtedly important, they do not fully explain the systematic cross-country variation in crisis severity.

This paper highlights a neglected structural factor in the analysis of financial crises: the role of production networks in amplifying or mitigating Sudden Stops.[1] We argue that differences in intersectoral linkages play a central role in shaping how external and financial shocks translate into macroeconomic outcomes. In particular, economies whose production networks are more "diagonal" (that is, with weaker intersectoral linkages) and commodity-intensive are more sensitive to Sudden Stops than economies in which nontradables supply and use more intermediate inputs to and from the tradable sector.

We proceed in three steps. First, we develop a small open economy model with two production sectors, tradables and nontradables, connected through an input–output matrix and subject to an occasionally binding collateral constraint on external borrowing. Starting from an equilibrium in which the borrowing constraint is just about to bind, we show that the impact of a shock to tradable productivity on tradable consumption and on the relative price of nontradables can be summarized by a single amplification index. This index is a function of four objects: input–output shares, sectoral profit shares, consumption shares, and the tightness of the collateral constraint. Intuitively, the index captures how strongly a given real shock is transmitted into collateral values and thus into the tightness of the borrowing constraint. Holding financial development and the size of shocks fixed, economies with different production networks have different amplification indexes and therefore different Sudden Stop outcomes.

Hulten's theorem (Hulten, 1978) provides a useful benchmark for thinking about how production networks affect the propagation of sectoral shocks to macroeconomic outcomes. In frictionless production network models, Domar weights (that is, sectoral sales relative to GDP) are sufficient statistics for the first-order effect of technology shocks on

[1] Fadinger et al. (2022), McNerney et al. (2022), and Gloria et al. (2024) document how production network heterogeneity accounts for income differences across countries. Miranda-Pinto (2021) and Miranda-Pinto et al. (2023) emphasize how production network structures drive cross-country differences in output volatility and skewness.

real GDP (e.g., Hulten, 1978; Acemoglu et al., 2012; Baqaee and Farhi, 2019). We show that this result survives the introduction of a collateral constraint: Production-side Hulten still holds. However, Sudden Stop amplification is about consumption, not GDP. In the presence of household-level borrowing constraints, the response of consumption to tradable shocks depends on how sectoral profits respond to price and quantity changes, which in turn depends on the entire production network and on how profits enter the collateral constraint. Domar weights are therefore no longer sufficient for consumption. We show that, if the objective is to mitigate financial crises, then starting from a given production network, introducing small sectoral wedges that tilt the network toward stronger linkages from tradables to nontradables, is desirable. These wedges break Hulten's sufficiency for GDP but reduce the sensitivity of collateral to tradable shocks and thus reduce Sudden Stop amplification.

Second, we take the logic of the simple model to the data. Using OECD input–output tables and the Sudden Stop dates of Bianchi and Mendoza (2020), we measure how commodity, non-commodity tradable, and nontradable sectors are interconnected in a broad sample of emerging and advanced economies. Three robust differences emerge. Relative to advanced economies, emerging markets (i) rely more heavily on commodity inputs in both tradable and nontradable production; (ii) feature tradable sectors that are more self-reliant and less connected to nontradable suppliers; and (iii) have nontradable sectors that are less central as suppliers to the rest of the economy. In short, emerging-market production networks are closer to a diagonal, commodity-intensive structure, whereas advanced-economy networks feature nontradables that are more deeply embedded as input suppliers.

We then use the sufficient-statistic formula from the two-sector model in two diagnostic exercises. First, we feed country-specific input–output and expenditure data into the simple model, fixing financial parameters at common benchmark values. The implied amplification index for aggregate consumption is systematically larger in emerging markets than in advanced economies, even though financial parameters are held constant. Second, we estimate panel regressions that interact Sudden Stop indicators with pre-crisis input–output shares and sector sizes. Conditional on experiencing a Sudden Stop, countries whose networks look more "advanced-economy-like" (that is, stronger nontradable-supplier and nontradable-buyer roles, weaker commodity and own-tradable links) display significantly smaller contractions in consumption and GDP. These are conditional correlations, not causal effects, but they align closely with the mechanism implied by the simple model.

Third, we embed the Sudden Stop mechanism into a fully dynamic, three-sector DSGE model with a commodity sector, a non-commodity tradable sector, and a nontradable sector. Production in each sector uses a composite of intermediate inputs from all sectors with decreasing returns, and the economy faces sector-specific productivity risk and an occasionally binding collateral constraint on external debt. This richer structure allows for substitution across inputs when relative prices move, so policy interventions or shocks that shift relative prices endogenously reshape the effective production network. We calibrate the model separately for an "average" emerging economy and an "average" advanced economy, disciplining production and expenditure shares using OECD input–output tables and sectoral dynamics using KLEMS data. The model preserves the key feature of the simple framework: The strength of amplification is governed by a network-based index that depends on input–output shares and profit shares but now in a fully stochastic and dynamic environment.

The calibrated model delivers three main quantitative results. First, when exposed to the same exogenous global financial risk process, the emerging-market calibration exhibits more frequent and more severe Sudden Stops than the advanced-economy calibration, even though both share similar average tradable consumption shares and face the same world interest rate process. Second, an advanced economy that is identical to the baseline advanced-economy calibration in terms of financial development and shock processes but endowed with the emerging-market production network behaves much more like an emerging economy: The long-run probability of a Sudden Stop rises by about one-half, and the typical Sudden Stop features a substantially larger GDP decline and current-account reversal. In the model, replacing an advanced-economy-style network with an emerging-market-style network moves the economy most of the way toward emerging-market-type Sudden Stop outcomes, holding finance and shocks fixed. Third, these differences are driven by the same network features identified in the simple model: More diagonal, commodity-intensive networks make sectoral profits—and hence collateral—more sensitive to tradable shocks, strengthening the Fisher deflation mechanism.

We then turn to normative analysis. We characterize the planner's problem in the three-sector model and show that, with production networks and collateral constraints, the planner faces two distinct sources of inefficiency. On the demand side, there is a pecuniary externality in the spirit of Bianchi (2011): Private agents ignore how their borrowing and spending decisions affect relative prices and thus the value of collateral. In a multi-sector environment, this externality operates at the sectoral level, and its strength depends on the production network that maps prices onto profits. On the supply side, the planner distorts firms' input choices: When the borrowing constraint binds, sectoral input demands affect sectoral profits and therefore the tightness of the collateral constraint, a margin that firms do not internalize in the competitive equilibrium. These production-side wedges vanish in the frictionless benchmark but are first-order when sectors are interconnected and collateral constraints are occasionally binding.

We use the quantitative model to evaluate two simple policy instruments. The first is a flat macroprudential tax on debt that raises the cost of external borrowing. Consistent with the planner logic, a modest positive debt tax can improve welfare and reduce the frequency of Sudden Stops in both emerging and advanced economies. However, the welfare and stabilization effects of the tax are highly sensitive to the underlying production network. In an advanced economy with an emerging-market-style network, for example, even relatively small debt taxes can be welfare-reducing, despite lowering crisis risk, because they interact unfavorably with the way shocks propagate through the input–output structure. Macroprudential debt taxes are therefore not one-size-fits-all; their effectiveness depends on how financial frictions coexist with the economy's production architecture.

The second instrument is a set of permanent sectoral taxes on purchases of final and intermediate goods. These taxes act as network wedges: By changing relative prices, they tilt the economy toward or away from more stabilizing input mixes. In our baseline emerging-market calibration, a tax on commodity inputs is always welfare-reducing, even though it modestly lowers the probability of Sudden Stops, because it compresses margins in the sector whose price cannot adjust in crises. By contrast, moderate taxes on non-commodity tradable and nontradable inputs can raise welfare by shifting production away from diagonal, commodity-intensive structures and toward networks in which nontradables are more central suppliers. This comes at the cost of somewhat higher crisis frequency. The planner is willing to accept some loss of static production efficiency—and thus to "break Hulten"—in exchange for lower Sudden Stop amplification.

Overall, our results point to an important and underappreciated role for production network structure in shaping both the probability and severity of Sudden Stops. They also show that the performance of macroprudential and industrial policies depends crucially on the underlying production architecture. Financial stability frameworks that ignore the domestic input–output network miss a key determinant of macro-financial fragility.

Related Literature. Our work contributes to four strands of literature.

First, we contribute to the Sudden Stops literature (e.g., Mendoza, 2010; Bianchi, 2011; Bianchi et al., 2016; Benigno et al., 2013; Bianchi and Mendoza, 2020) by incorporating production network structure into macroeconomic models of financial crises. Canonical models of Sudden Stops emphasize collateral constraints, liability dollarization, and external shocks in otherwise aggregate environments. We show that differences in domestic production architecture—specifically the density and composition of input linkages across sectors—can substantially affect the amplification and severity of crises even when financial development and external shocks are held fixed. In this sense, our paper complements Rojas and Saffie (2022), who emphasize how non-homothetic preferences alter the transmission of Sudden Stops. Our research also relates to work on policy stabilization under financial frictions, including Bianchi and Sosa-Padilla (2024), who show how international reserves mitigate amplification via collateral constraints, and Sosa-Padilla (2018), who study feedback between sovereign default and banking fragility.

Second, we contribute to the literature on production networks and macroeconomic fluctuations (e.g., Horvath, 1998; Foerster et al., 2011; Acemoglu et al., 2012; Baqaee and Farhi, 2019; Bigio and La'o, 2020; McNerney et al., 2022). This work has shown how sectoral interlinkages shape the propagation of shocks, the distribution of sectoral influence, and the role of sectoral wedges, often through Hulten-type sufficient statistics and the Leontief inverse. Our innovation is to embed these network structures in a dynamic, multi-sector small open economy with occasionally binding collateral constraints and to show that while production-side Hulten results for GDP survive, Sudden Stop amplification for consumption depends on additional network-based objects tied to collateral values. Existing models with production networks are typically static or solved using local perturbation methods (Long and Plosser, 1983; Pasten et al., 2020; Vom Lehn and Winberry, 2022). By contrast, we use a globally solved model with CES production and occasionally binding constraints, following numerical strategies similar to De Groot et al. (2023), which allows us to explore nonlinear dynamics and policy tradeoffs in response to large shocks.[2]

Third, we contribute to the international economics literature by emphasizing a dimension that has received far more attention in international trade than in international finance: the structure of domestic production networks. A large literature in trade—including Antràs et al. (2012), Antrás and Chor (2022), and Yi (2010)—has documented how sourcing patterns, offshoring, and global value chains shape aggregate and distributional outcomes. This work highlights how firm-level and sectoral decisions propagate through domestic and international input–output networks. By contrast, models in international finance have largely abstracted from these internal production structures, typically assuming endowment economies or disconnected production structures. Our

[2]Our comparative statics and general equilibrium logic also build on recent work using sequence-space Jacobians and determinants in heterogeneous-agent models (Auclert et al., 2021; Wolf, 2023; Auclert et al., 2024).

results show that production structure plays a first-order role in shaping macro-financial fragility and the effectiveness of policy interventions and that observed emerging-market versus advanced-economy differences in production networks go a long way toward accounting for observed differences in Sudden Stop severity.

Finally, we contribute to the emerging literature on industrial policies in disaggregated macroeconomic models. Existing work on sectoral policies in production network models (e.g., Liu, 2019; Miranda-Pinto, 2018; Buera and Trachter, 2024) typically studies closed economies in static or linearized environments with sectoral distortions. We instead consider a dynamic small open economy featuring an aggregate, nonlinear borrowing constraint, sectoral risk, and a commodity sector whose price is exogenous to the small open economy and determined in global markets. Our results point to the importance of the network structure in shaping the resilience of the economy to frequent and sharp Sudden Stops and to the tradeoffs implied by network-tilting policies that improve crisis resilience at the expense of static efficiency. Relative to papers investigating the role of policies in open economy models of financial crises (e.g., Benigno et al., 2023; Ottonello et al., 2024), we emphasize the role of domestic sectoral linkages in determining a country's borrowing capacity and the network dependence of macroprudential policy effectiveness.

Outline. The rest of the paper is structured as follows. Section 2 presents the two-sector theoretical model, derives the amplification index for Sudden Stops, and relates it to Hulten's theorem. Section 3 documents empirical differences in three-sector production networks between emerging and advanced economies and relates them to the severity of Sudden Stops. Section 4 describes the three-sector quantitative model, its calibration to emerging-market and advanced-economy data, and the quantitative results, including the counterfactual in which an advanced economy is endowed with an emerging-market production network. Section 5 presents the planner problem and the normative analysis of macroprudential and sectoral taxes. Section 6 concludes.

2 Analytical Framework

We consider a canonical small open economy with two goods, tradables and nontradables, and a collateral constraint on households. Production is organized through an input–output structure that links the tradable and nontradable sectors. We work in discrete time on an infinite horizon and focus on deterministic perfect foresight equilibria around a marginally binding borrowing constraint.

2.1 Environment

2.1.1 Households

There is a continuum of identical households of measure one. They maximize

$$\sum_{t=0}^{\infty} \beta^t u(c_t), \qquad \beta \in (0,1), \tag{1}$$

where aggregate consumption c_t is a CES aggregator of nontradables c_t^N and tradables c_t^T:

$$c_t = \Big[(1-\omega)(c_t^N)^{-\eta} + \omega(c_t^T)^{-\eta}\Big]^{-\frac{1}{\eta}}, \qquad \eta \in (-1,\infty),\ \omega \in (0,1). \tag{2}$$

Households trade one-period non-state-contingent bonds b_{t+1}^* at exogenous price q and receive profits π_t^N from the nontradable sector and π_t^T from the tradable sector. The period budget constraint is

$$p_t^N c_t^N + c_t^T + q b_{t+1}^* = \pi_t^N + \pi_t^T + b_t^*, \tag{3}$$

where all prices are quoted in units of tradables, so p_t^N is the relative price of nontradables.

Households face an occasionally binding borrowing constraint:

$$q b_{t+1}^* \geq -\kappa\big(\pi_t^N + \pi_t^T\big), \tag{4}$$

so they can pledge up to a fraction $\kappa \in (0,1)$ of current profits as collateral.

Optimality conditions. Let $u_T(t) \equiv u'(c_t)\,\partial c_t/\partial c_t^T$. The intratemporal FOC between c_t^N and c_t^T implies

$$p_t^N = \frac{1-\omega}{\omega}\left(\frac{c_t^T}{c_t^N}\right)^{1+\eta}. \tag{5}$$

Let $\mu_t \geq 0$ be the multiplier on the borrowing constraint. The Euler equation for bonds is

$$u_T(t) = \beta R^* u_T(t+1) + \mu_t, \tag{6}$$

$$0 = \mu_t\Big(q b_{t+1}^* + \kappa(\pi_t^N + \pi_t^T)\Big), \tag{7}$$

with $R^* = q^{-1}$. When $\mu_t > 0$, the constraint binds and borrowing is limited by collateral.

2.1.2 Firms and production networks

Each sector uses both goods as intermediate inputs and exhibits decreasing returns to scale. This guarantees that the nontradable price p_t^N is determined in equilibrium by demand conditions, allowing for the deflationary mechanism that is central in Sudden Stop models. We adopt decreasing returns for simplicity; the same logic could be implemented with CRS production and sector-specific fixed factors.[3]

Nontradable sector. Output is

$$y_t^N = A^N z_t^N (m_{Nt}^N)^{\alpha_N^N} (m_{Tt}^N)^{\alpha_T^N}, \qquad \alpha_N^N + \alpha_T^N \in [0,1), \tag{8}$$

with $A^N = (\alpha_T^N)^{-\alpha_T^N}(\alpha_N^N)^{-\alpha_N^N}$ and inputs m_{Nt}^N and m_{Tt}^N denoting nontradable and tradable intermediates used by the nontradable sector. Profits are

$$\pi_t^N = p_t^N y_t^N - p_t^N m_{Nt}^N - m_{Tt}^N. \tag{9}$$

Profit maximization yields the nontradable supply schedule

$$y_t^N(z_t^N, p_t^N) = \left[z_t^N (p_t^N)^{\alpha_T^N} \right]^{\frac{1}{1-\alpha_N^N-\alpha_T^N}}. \tag{10}$$

Tradable sector. Output is

$$y_t^T = A^T z_t^T (m_{Tt}^T)^{\alpha_T^T} (m_{Nt}^T)^{\alpha_N^T}, \qquad \alpha_N^T + \alpha_T^T \in [0,1), \tag{11}$$

with $A^T = (\alpha_T^T)^{-\alpha_T^T}(\alpha_N^T)^{-\alpha_N^T}$. Profits are

$$\pi_t^T = y_t^T - p_t^N m_{Nt}^T - m_{Tt}^T, \tag{12}$$

and the supply schedule is

$$y_t^T(z_t^T, p_t^N) = \left[z_t^T (p_t^N)^{-\alpha_N^T} \right]^{\frac{1}{1-\alpha_T^T-\alpha_N^T}}. \tag{13}$$

[3] Relative prices do not depend on demand conditions in a multi-sector model with one perfectly mobile factor of production and constant returns to scale technologies. That is, the supply side alone pins down relative prices. Introducing sector-specific fixed factors or decreasing returns restores a role for demand in determining p_t^N. See the discussion in Mendoza (2005) and Bianchi (2011).

2.1.3 Market clearing and equilibrium

Market clearing for nontradables requires

$$c_t^N + m_{Nt}^N + m_{Nt}^T = y_t^N. \tag{14}$$

The aggregate tradable resource constraint is

$$c_t^T + m_{Tt}^T + m_{Tt}^N = y_t^T - qb_{t+1}^* + b_t^*. \tag{15}$$

A sequence of allocations $\{c_t^N, c_t^T, b_t^*, y_t^N, y_t^T, m_{Nt}^N, m_{Tt}^N, m_{Nt}^T, m_{Tt}^T\}_{t\geq 0}$ and prices $\{p_t^N\}_{t\geq 0}$ constitutes a competitive equilibrium if households and firms optimize given prices and the borrowing constraint, and market clearing conditions (14)–(15) hold.

2.2 Sudden Stops in the two-sector model

We now focus on a perfect foresight environment with $\beta R^* = 1$ and a marginally binding borrowing constraint so that the unconstrained steady-state allocation is feasible in the absence of shocks.[4] We then study the effects of a one-time, wealth-neutral shock to tradable productivity that is large enough for the borrowing constraint to bind, generating a Sudden Stop.[5] When the constraint binds, $qb_{t+1}^* = -\kappa(\pi_t^N + \pi_t^T)$, and the equilibrium at date t can be summarized by a two-dimensional system in (c_t^T, p_t^N), which we describe in the following section.

2.2.1 Characterization of the perfect foresight equilibrium

Using (5) and the nontradable market-clearing condition (14), we define the "PP curve" for date t as

$$p_t^N = \left(\frac{c_t^T}{c_t^N(p_t^N; z_t^N, z_t^T)}\right)^{1+\eta} \frac{1-\omega}{\omega}, \tag{16}$$

[4]See Mendoza (2005), Mendoza and Rojas (2019), and Rojas and Saffie (2022) for related analyses in this class of settings.

[5]We define a Sudden Stop as an event in which a wealth-neutral time-0 shock to tradable productivity is large enough to make the borrowing constraint binding. Because the constraint is marginally binding prior to the shock, a decline in productivity activates the Fisherian deflation mechanism characteristic of this class of models.

where nontradable consumption is

$$c_t^N = (1 - \alpha_N^N)\, y_t^N(p_t^N; z_t^N) - \alpha_N^T \frac{y_t^T(p_t^N; z_t^T)}{p_t^N}. \tag{17}$$

Next, when the borrowing constraint binds, the bond position is pinned down by profits, so the tradable resource constraint (15) and the household budget constraint deliver the "BB curve":

$$c_t^T = \kappa_N\, \pi_t^N(p_t^N; z_t^N) + (1 + \kappa_T)\, \pi_t^T(p_t^N; z_t^T) + b_0, \tag{18}$$

where

$$\kappa_N = \kappa - \frac{\alpha_T^N}{1 - \alpha_N^N - \alpha_T^N}, \qquad \kappa_T = \kappa + \frac{\alpha_N^T}{1 - \alpha_T^T - \alpha_N^T},$$
$$\pi_t^N = (1 - \alpha_N^N - \alpha_T^N) p_t^N y_t^N, \qquad \pi_t^T = (1 - \alpha_T^T - \alpha_N^T) y_t^T,$$

and b_0 is the initial bond position inherited at t.

The PP and BB curves determine (c_t^T, p_t^N) at the unconstrained steady-state allocation. We present the following two propositions that characterize the slope properties of these curves.

Proposition 1. *The PP curve (16) is upward-sloping in (c_t^T, p_t^N) for any production network $\{\alpha_N^N, \alpha_T^N, \alpha_N^T, \alpha_T^T\}$.*

Proposition 2. *The slope of the BB curve (18) in (c_t^T, p_t^N) depends on the network structure. If*

$$\kappa_N \frac{\partial \pi_t^N}{\partial p_t^N} + (1 + \kappa_T) \frac{\partial \pi_t^T}{\partial p_t^N} \geq 0,$$

then the BB curve is upward-sloping. Otherwise, it is downward-sloping.

Proofs are included in Appendix A.1 and A.2. The key message is that the BB curve embeds the effect of p_t^N on profits and thus on the tightness of the collateral constraint, in a way that depends on the input–output coefficients.

2.3 A sufficient statistic for the impact of tradable productivity shocks

Before deriving a general characterization, we illustrate how production structure shapes the severity of a Sudden Stop using a set of benchmark production networks. We consider four simple production network matrices:

$$\Omega^{\text{dense}} = \begin{bmatrix} \frac{\alpha}{2} & \frac{\alpha}{2} \\ \frac{\alpha}{2} & \frac{\alpha}{2} \end{bmatrix}, \quad \Omega^{\text{NT}\leftarrow\text{T}} = \begin{bmatrix} \frac{\alpha}{2} & \frac{\alpha}{2} \\ 0 & \alpha \end{bmatrix},$$
$$\Omega^{\text{diagonal}} = \begin{bmatrix} \alpha & 0 \\ 0 & \alpha \end{bmatrix}, \quad \Omega^{\text{T}\leftarrow\text{NT}} = \begin{bmatrix} \alpha & 0 \\ \frac{\alpha}{2} & \frac{\alpha}{2} \end{bmatrix},$$

where α is the common intermediate share. In the Ω^{diagonal} economy, each sector uses only its own output; in $\Omega^{\text{NT}\leftarrow\text{T}}$, the nontradable sector buys from the tradable sector; and so on. Taken together, these networks range from tightly interconnected to largely segmented production structures. This range helps clarify how stronger or weaker intersectoral linkages amplify the real effects of a Sudden Stop.

Figure 1 shows PP and BB curves for these networks, before and after a 10 percent drop in tradable productivity. The PP curve is always upward-sloping and nearly linear near the equilibrium, while the slope and curvature of the BB curve vary significantly with the network, consistent with Propositions 1–2.

Figure 1 illustrates how different production structures can amplify the severity of Sudden Stops. While the PP–BB geometry is informative, the dependence of amplification on the full network structure makes it difficult to generalize from specific examples. We next derive a sufficient statistic that summarizes the amplification properties of a given production network in response to a wealth-neutral decline in tradable productivity.

Define

$$\gamma_t^N = \frac{\kappa_N \pi_t^N}{c_t^T}, \qquad \gamma_t^T = \frac{(1+\kappa_T)\pi_t^T}{c_t^T}, \qquad \delta_t^N = \frac{(1-\alpha_N^N) y_t^N}{c_t^N},$$
$$\varepsilon_{p_t^N}^{y_t^N} = \frac{\alpha_T^N}{1-\alpha_N^N-\alpha_T^N}, \qquad \varepsilon_{z_t^T}^{y_t^T} = \frac{1}{1-\alpha_N^T-\alpha_T^T}, \qquad \varepsilon_{p_t^N}^{y_t^T} = -\frac{\alpha_N^T}{1-\alpha_T^T-\alpha_N^T}.$$

Let

$$\mathcal{K} = \left(\frac{1}{1+\eta} - \gamma_t^N + (\delta_t^N - 1) + (\delta_t^N - \gamma_t^N)\varepsilon_{p_t^N}^{y_t^N} + (1 - \gamma_t^T - \delta_t^N)\varepsilon_{p_t^N}^{y_t^T} \right)^{-1}.$$

Proposition 3. *Consider a wealth-neutral decline in tradable productivity starting from an equilibrium in which the borrowing constraint is marginally binding. The responses of tradable con-*

sumption and the nontradable price are

$$\frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} = \mathcal{K}\Big[(\gamma_t^N + \gamma_t^T)(\delta_t^N - 1) + \big(\gamma_t^N(\delta_t^N - 1) + \delta_t^N \gamma_t^T\big)\varepsilon_{p_t^N}^{y_t^N} + \frac{\gamma_t^T}{1+\eta}\Big]\varepsilon_{z_t^T}^{y_t^T} \geq 0,$$
$$\frac{\mathrm{d}\log p_t^N}{\mathrm{d}\log z_t^T} = \mathcal{K}\big[(\delta_t^N - 1) + \gamma_t^T\big]\varepsilon_{z_t^T}^{y_t^T} \geq 0.$$

Appendix A.3 includes the proof for this proposition. The impulse acts initially through tradable production, captured by $\varepsilon_{z_t^T}^{y_t^T}$, and is then amplified or dampened by general equilibrium effects encoded in $\mathcal{K}$ and the bracketed terms. Proposition 3 shows that, irrespective of the production network, a decline in tradable productivity always reduces c_t^T and p_t^N in this setup. The size of these declines, however, depends on the network through $(\gamma_t^N, \gamma_t^T, \delta_t^N, \varepsilon_{p_t^N}^{y_t^N}, \varepsilon_{p_t^N}^{y_t^T})$.

2.4 A directional implication of the sufficient statistic

We now use Proposition 3 to derive a directional implication of the sufficient statistic, in the sense that it pins down whether Sudden Stop severity increases or decreases as the production structure tilts along a specific margin. In particular, we study how Sudden Stop severity changes when nontradable production becomes more intensive in tradable intermediate inputs, holding overall returns to scale fixed.

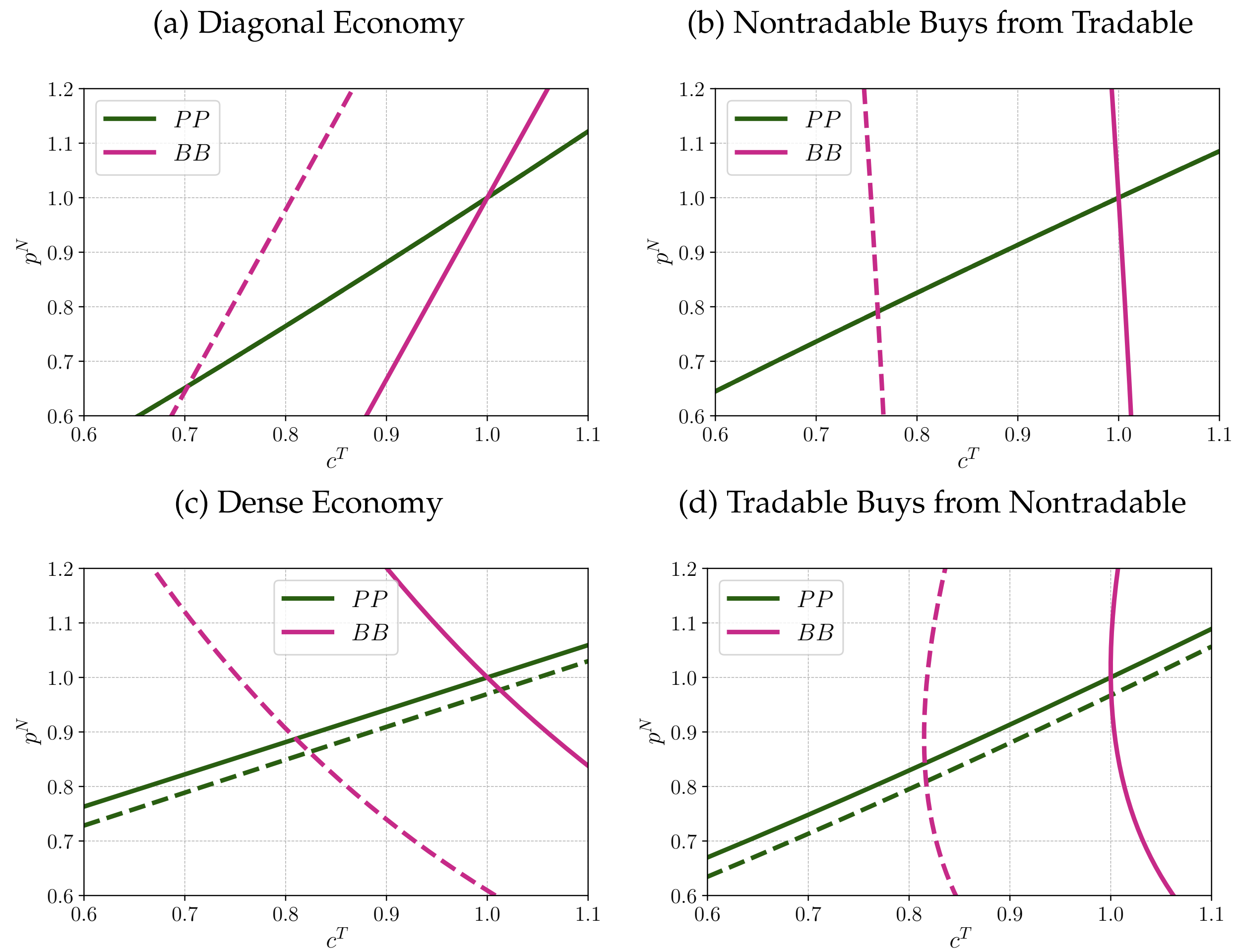
Consider the "nontradables buy from tradables" network

$$\Omega^{\mathrm{NT}\leftarrow\mathrm{T}} = \begin{bmatrix} \alpha_N^N & \alpha_T^N \\ 0 & \alpha_T^T \end{bmatrix}.$$

In this economy, the tradable sector uses only its own output as an intermediate input, while the nontradable sector uses both tradable and nontradable intermediates. To isolate the role of production linkages, we hold decreasing returns constant across economies so that $\bar{\alpha}^N = \alpha_N^N + \alpha_T^N$ and $\bar{\alpha}^T = \alpha_T^T$ are the same across networks.

We compare this economy with a diagonal benchmark in which each sector uses only its own output as an intermediate input. Let $\varepsilon^{BB}(G)$ and $\varepsilon^{PP}(G)$ denote the elasticities of the BB and PP curves under network $G \in \{D, N\}$, evaluated at the marginally binding equilibrium. The sufficient statistic implies that Sudden Stop severity depends on how the BB curve responds relative to the PP curve as production linkages vary along this margin.

Figure 1: PP and BB curves under different network structures



Note: Each panel shows PP (green) and BB (pink) curves under a given network. Solid lines denote the initial equilibrium, dotted lines a 10% decline in tradable productivity. We set $\eta = 0.2035$, $\alpha = 0.4$ (average emerging-market intermediate share), $\kappa = 0.3$, $b_0 = -0.3$, and $\omega = 0.5$. See Appendix B for details.

Proposition 4. *Consider a decline in tradable productivity from a marginally binding equilibrium. If*

$$\left|\gamma^T(N)\frac{\varepsilon^{PP}(N)\varepsilon^{BB}(N)}{\varepsilon^{BB}(N)-\varepsilon^{PP}(N)}\right| \leq \left|\gamma^T(D)\frac{\varepsilon^{PP}(D)\varepsilon^{BB}(D)}{\varepsilon^{BB}(D)-\varepsilon^{PP}(D)}\right|,$$

then moving along the tradable-to-nontradable input margin attenuates Sudden Stop severity. In particular,

$$\left|\frac{\mathrm{d}\log(c_t^T)^{NT\leftarrow T}}{\mathrm{d}\log z_t^T}\right| \leq \left|\frac{\mathrm{d}\log(c_t^T)^{Diagonal}}{\mathrm{d}\log z_t^T}\right|,$$

and

$$\left|\frac{\mathrm{d}\log(p_t^N)^{NT\leftarrow T}}{\mathrm{d}\log z_t^T}\right| \leq \left|\frac{\mathrm{d}\log(p_t^N)^{Diagonal}}{\mathrm{d}\log z_t^T}\right|.$$

Appendix A.4 includes the proof for this proposition. Intuitively, increasing the use of tradable intermediates in nontradable production dampens the endogenous tightening of the borrowing constraint following a negative tradable productivity shock. Because tradable profits decline by less than the do in the diagonal economy, collateral values fall by less, weakening the Fisherian deflationary feedback between prices, borrowing capacity, and consumption. Panels (a) and (b) of Figure 1 illustrate this mechanism: For the same 10 percent decline in z_t^T, both tradable consumption and the nontradable price fall more in the diagonal economy than in the economy with tradable-to-nontradable input linkages.

2.5 Hulten, networks, and sectoral wedges

We close this section by relating the model to Hulten's theorem and to the role of sectoral wedges. In a frictionless network economy, sectoral Domar weights are a sufficient statistic for the response of real GDP to technology shocks (e.g., Acemoglu et al., 2012; Baqaee and Farhi, 2019). In models with sectoral wedges, this equivalence breaks down (e.g., Bigio and La'o, 2020).

In our environment, the collateral constraint does not appear as a production-side wedge; it distorts intertemporal allocation but leaves firms' static FOCs unchanged. As a result:

Lemma 1 (Hulten with collateral constraints)**.** *In the preceding two-sector model, without sectoral taxes or subsidies, the first-order impact of a small technology shock* $(\mathrm{d}\log z^N, \mathrm{d}\log z^T)$ *on real GDP is*

$$\mathrm{d}\log rGDP = \lambda_N \mathrm{d}\log z^N + \lambda_T \mathrm{d}\log z^T,$$

where $\lambda_i \equiv p_i y_i / nGDP$ *are Domar weights. The borrowing constraint does not affect the first-order production-side response of real GDP.*

The proof follows standard arguments and is provided in Appendix A.5. Even in the presence of collateral constraints, Hulten's theorem holds.

The Sudden Stop amplification we care about, however, concerns *consumption*, not real GDP. Proposition 3 shows that the response of c_t^T—and, as shown in Proposition 5, the response of aggregate consumption c_t—to a tradable shock depends on the full network and on how profits feed into the borrowing constraint, not solely on Domar weights. Starting from a given network, a planner may therefore wish to introduce sectoral wedges that "break Hulten" to reduce the amplification of tradable shocks to aggregate consumption.

To see this, consider a set of small ad valorem subsidies τ on inputs used by the non-tradable sector, which tilts the effective input shares $\tilde{\alpha}_T^N$ up and $\tilde{\alpha}_N^N$ down, holding $\alpha_T^N + \alpha_N^N$ fixed. This moves the economy locally in the direction of the NT←T network analyzed earlier.

Proposition 5 (Breaking Hulten to reduce amplification)**.** *In the two-sector model with a marginally binding collateral constraint, there is a set of subsidies τ on intermediate inputs such that the resulting network structure generates a strictly smaller consumption response to a given negative tradable productivity shock, that is.*

$$\left|\frac{\mathrm{d}\log c_t(\tau)}{\mathrm{d}\log z_t^T}\right| < \left|\frac{\mathrm{d}\log c_t(0)}{\mathrm{d}\log z_t^T}\right|.$$

Appendix A.6 includes a formal proof. The result follows from Proposition 4 and continuity: Moving the network toward stronger NT←T linkages reduces the sufficient statistic for amplification.

Importantly, the subsidies represent production wedges and therefore break Hulten's sufficiency for real GDP. Lemma 1 thus implies that the planner is willing to trade static production efficiency for lower Sudden Stop amplification. The two-sector analysis therefore delivers: (i) a sufficient statistic linking production networks to Sudden Stop severity, (ii) a sharp prediction that stronger NT←T linkages attenuate Sudden Stops, and (iii) a normative result that a planner may optimally introduce sectoral wedges that break Hulten to reduce amplification. In Section 5, we return to this idea in the full three-sector DSGE and quantify the welfare effects of sectoral taxes and subsidies that tilt networks in this way.

3 Empirical Analysis

3.1 From the two-Sector model to a three-sector empirical index

The two-sector model in Section 2 delivers a sharp characterization of how production linkages shape Sudden Stop dynamics. Proposition 3 shows that, starting from a marginally binding constraint, the response of tradable consumption and the nontradable price to a tradable productivity shock can be written as

$$\frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} = \mathcal{A}(\alpha_j^i, \kappa, \eta; \text{equilibrium objects}) \times \varepsilon_{z_t^T}^{y_t^T},$$

where $\mathcal{A}(\cdot)$ is a network-based amplification term that depends on input–output shares, profit and consumption shares, and the collateral parameter. In this sense, $\mathcal{A}(\cdot)$ is a sufficient statistic for how a given production network amplifies tradable shocks into consumption drops in the simple model.

We use this result in two steps. First, we construct a *two-sector* model-implied sufficient statistic for each country. We take the production network objects (input–output coefficients, sectoral profits, consumption shares) from the data, fix (κ, η) at common benchmark values, and plug them into the expressions in Proposition 3. Operationally, we aggregate the input-output (IO) data to two sectors by grouping commodity and other tradable sectors into T and nontradables into N and compute

$$\frac{\mathrm{d}\log c_t}{\mathrm{d}\log z_t^T} = \frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} - \frac{(1-\omega)}{1+\eta}\frac{\mathrm{d}\log p_t^N}{\mathrm{d}\log z_t^T},$$

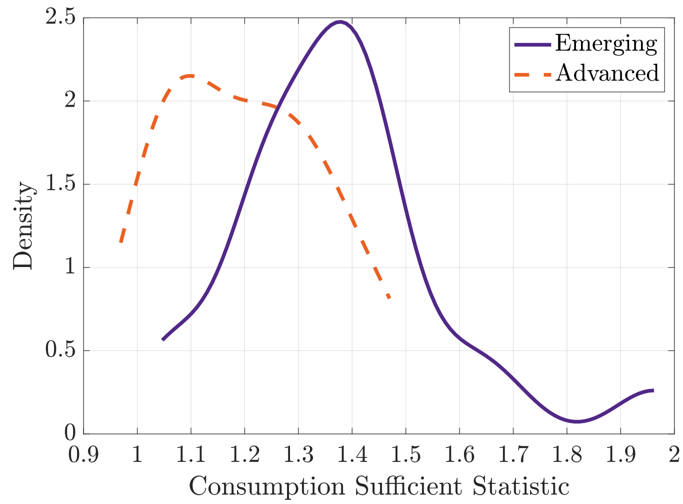
which is the aggregate-consumption counterpart implied by the cost-minimization problem.

We set the collateral parameter and the elasticity of substitution between tradables and nontradables to $\kappa = 0.3$ and $1/(1+\eta) = 0.83$, respectively, and keep them *constant* across countries. Thus, cross-country variation in the sufficient statistic comes exclusively from differences in (i) consumption expenditure shares and (ii) production structures, as summarized by the IO network and sectoral profits.

Figure 2 plots the kernel distribution of this sufficient statistic for emerging-market economies (EMEs) and advanced economies (AEs). The model-implied index is systematically larger in EMEs, implying that, for a given tradable productivity shock, the two-sector model predicts larger aggregate consumption responses (that is, more severe Sudden Stops) in EMEs than in AEs. This exercise is purely diagnostic; it takes the stylized two-sector structure seriously, feeds it with country-specific IO objects, and asks whether the implied amplification index aligns up with the basic fact that Sudden Stops are more severe in EMEs.

Second, for the empirical analysis and the quantitative model, we move to a *three-sector* aggregation: commodities, other tradables, and nontradables. This is the minimal level of disaggregation that (i) is robustly comparable across countries in the IO data we use and (ii) matches the sectoral structure of the DSGE model in Section 4. The three-

Figure 2: Aggregate Consumption: Two-sector model sufficient statistic



Note: This figure shows the model-implied sufficient statistic for aggregate consumption $\mathrm{d}\log c_t/\mathrm{d}\log z_t^T$ in the two-sector framework. We combine the closed-form responses for $\mathrm{d}\log p_t^N$ and $\mathrm{d}\log c_t^T$ with the solution to the cost-minimization problem, $\frac{\mathrm{d}\log c_t}{\mathrm{d}\log z_t^T} = \frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} - \frac{(1-\omega)}{1+\eta}\frac{\mathrm{d}\log p_t^N}{\mathrm{d}\log z_t^T}$.

sector environment is a straightforward extension of the two-sector benchmark. The same mechanism and comparative statics apply, but the algebra is less transparent. Rather than reproduce the full multi-sector derivation, we use the two-sector sufficient-statistic logic to guide how we summarize the three-sector IO structure and interpret our results. The exact mapping from the three-sector IO coefficients to the simple model's objects is provided in the empirical appendix.

3.2 Stylized Facts on Three-Sector Networks

In this subsection, we document how commodity, tradable non-commodity, and nontradable sectors are interconnected in EMEs and AEs. The goal is descriptive: We ask whether, in the data, EMEs and AEs differ systematically in the production structures that the simple model highlights as relevant for Sudden Stop amplification.

We use the sample of countries in Bianchi and Mendoza (2020) and the 2021 release of OECD input–output tables. Sectors are classified as tradable or nontradable based on gross trade intensity: sectors with a ratio of gross trade to gross output above 20 percent (using the cross-country average) are classified as tradable. Within tradables, we distinguish a commodity sector from other tradable goods. Appendix C provides details on sector and country classifications. Unless otherwise noted, all statistics reported as follows use data for 1995, the first year for which the IO tables are available.

For a sector i in country c, we measure the input share from sector j as the ratio of intermediate purchases from j over total gross output of i:

$$\alpha^i_{j,c} = \frac{p^j_c m^i_{jc}}{p^i_c y^i_c},$$

where we use both domestic and imported intermediates. Results are similar if we restrict attention to domestic inputs.

Table 1 reports average intermediate input shares for EMEs and AEs across the three sectors. Three robust facts emerge.

Table 1: Average Intermediate Input Shares: Emerging versus Advanced

Buyer/Seller	Commodity	Tradable	Nontradable
Panel (a): Emerging			
Commodity	23.42	17.12	8.12
Tradable	12.17	32.72	11.31
Nontradable	5.03	17.57	16.37
Panel (b): Advanced			
Commodity	22.92	21.69	9.99
Tradable	7.70	33.20	13.30
Nontradable	1.56	15.45	21.21
Panel (c): Difference (Emerging - Advanced)			
Commodity	0.50	−4.57	−1.87
Tradable	4.47	−0.48	−1.99
Nontradable	3.47	2.12	−4.84

Note: This table reports the average intermediate input share (in percentage points) for emerging-market economies (EMEs) (panel a) and advanced economies (AEs) (panel b). Panel (c) reports the percentage point difference between emerging and advanced economies. Rows represent buyers, and columns represent suppliers. Intermediate input shares are expenditure on intermediate inputs from the column sector by the row sector over the gross output of the row sector.

Fact 1. In AEs, the commodity sector is less connected, as a supplier, to the rest of the economy.

Fact 2. In AEs, the tradable sector is less connected, as a supplier, to the nontradable sector.

Fact 3. In AEs, the nontradable sector, as a supplier, is more connected to the rest of the economy.

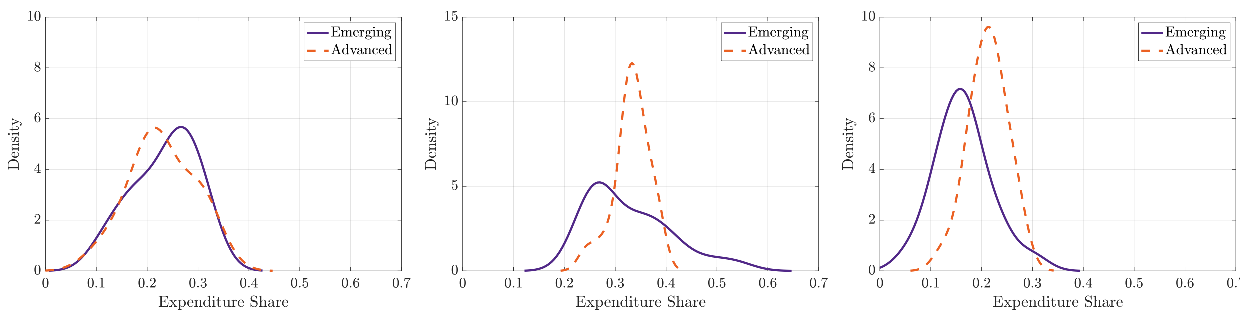
To get a sense of magnitudes, consider a standard production-network environment (e.g., Acemoglu et al., 2012). In such models, the Leontief inverse and consumption shares determine the impact of sectoral productivity shocks on aggregate output. Using average consumption expenditure shares of 8 percent, 44 percent, and 48 percent for commodities, non-commodity tradables, and nontradables in 1995 (common across EMEs and AEs), the differences in Table 1 imply that a 10 percent decline in commodity-sector TFP leads to a 2.15 percent decline in real GDP in AEs and a 3.03 percent decline in EMEs, even before introducing borrowing constraints or non-unit elasticities of substitution. In other words, EMEs start with a production structure that, in a frictionless benchmark, already delivers larger output effects of commodity shocks.

Figures 3–6 show the full distributions of intermediate input shares across countries.

Figure 3 plots own-sector intermediate input shares. The commodity sector exhibits similar self-dependence in EMEs and AEs. The nontradable sector is more self-reliant in AEs than in EMEs. The tradable sector has a heavier right tail in EMEs, reflecting a subset of countries with very high own-tradable input usage; the medians are more similar.

Figure 3: Distribution of intermediate input shares from the same sector

(a) Commodities to Commodities (b) Tradable to Tradable (c) Nontradable to Nontradable

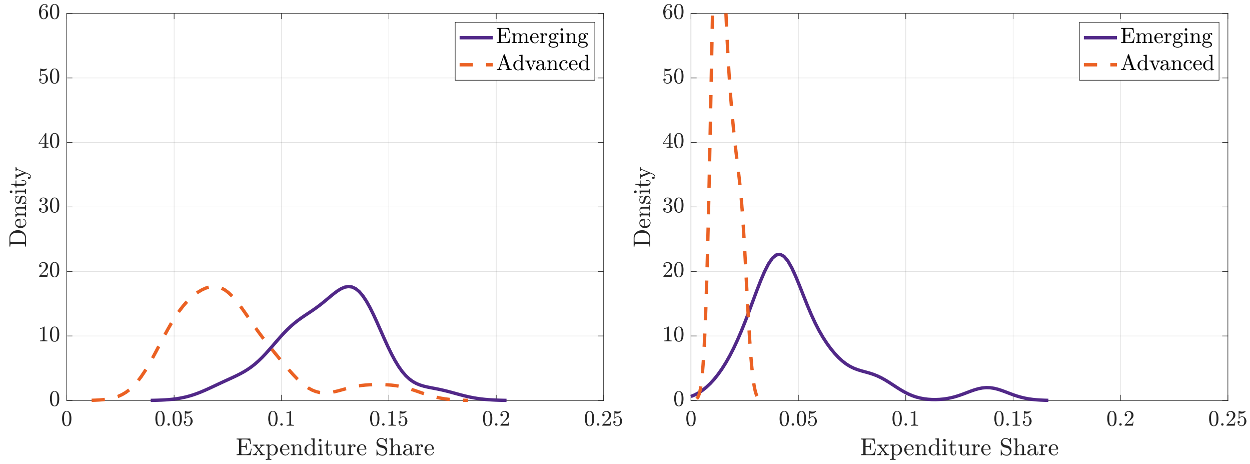


Note: This figure shows the distribution of intermediate input usage from the same sector. Solid lines depict EMEs, dashed lines AEs.

Figure 4 documents how important commodity inputs are in the production of tradables and nontradables. Commodity inputs are systematically more important in EMEs for both tradable and nontradable production.

Figure 4: Use of commodity inputs by tradable and nontradable sectors

(a) Commodity to Tradable (b) Commodity to Nontradable

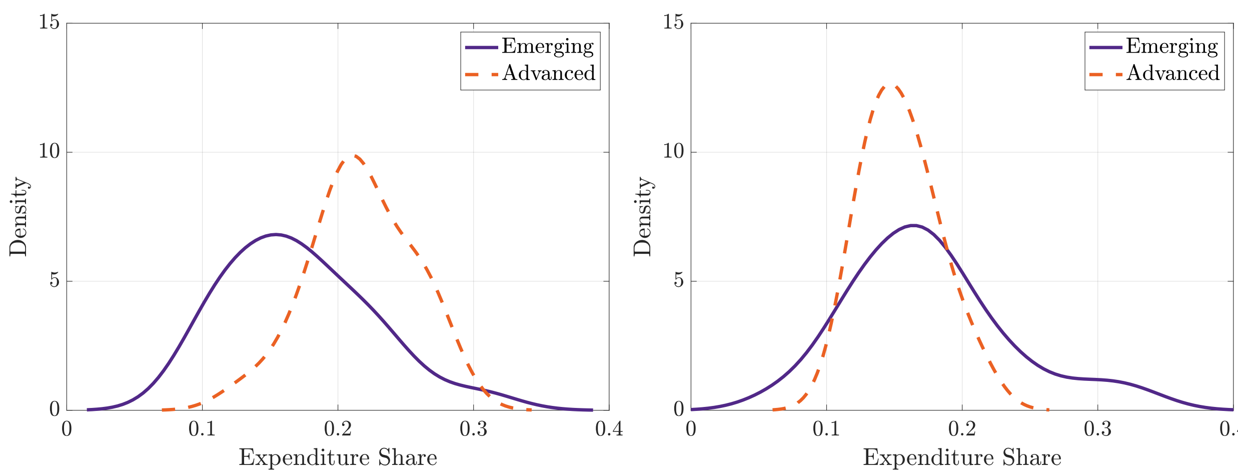


Note: This figure shows the intermediate input usage of commodities by the tradable and nontradable sectors. Solid lines depict EMEs, dashed lines AEs.

Figure 5 highlights heterogeneity in the use of tradable inputs. Commodity sectors in AEs use a larger share of tradable inputs than in EMEs, while nontradable sectors in EMEs rely more heavily on tradable inputs than their AE counterparts.

Figure 5: Use of tradable inputs by commodity and nontradable sectors

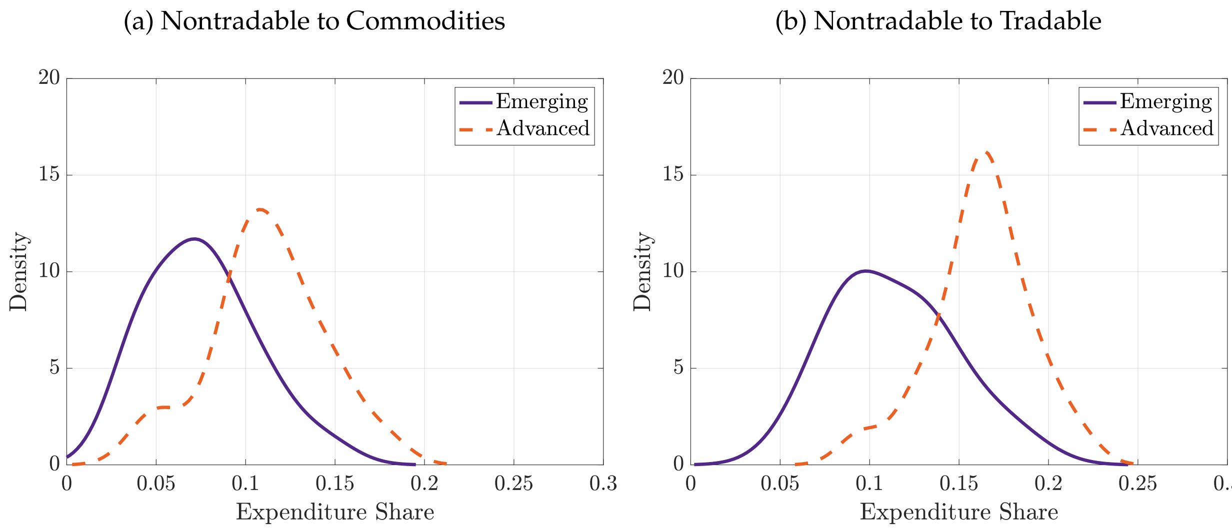
(a) Tradable to Commodity (b) Tradable to Nontradable



Note: This figure shows the intermediate input usage of tradables by the commodity and nontradable sectors. Solid lines depict EMEs, dashed lines AEs.

Finally, Figure 6 shows that, in AEs, both the commodity and tradable sectors use a larger share of inputs from the nontradable sector than in EMEs. Nontradables are more deeply embedded as suppliers in AEs.

Figure 6: Use of nontradable inputs by commodity and tradable sectors



Note: This figure shows the intermediate input usage of nontradables by the commodity and tradable sectors. Solid lines depict EMEs, dashed lines AEs.

Taken together, these facts show that EMEs look more "diagonal" and commodity-intensive, while AEs have nontradables that are more central suppliers. In the simple model, these are exactly the kinds of differences that affect the network-based amplification term in Proposition 3. The next subsection examines whether these network differences are systematically related to cross-country differences in Sudden Stop outcomes.

3.3 Regression Analysis

We now relate the three-sector production structures documented earlier to the severity of Sudden Stops. The objective is descriptive: We ask whether countries with "better" networks, in the sense of the simple model, tend to experience smaller drops in economic activity and smaller current-account reversals during Sudden Stops and whether these patterns differ between EMEs and AEs. We do not interpret the estimates as causal effects.

We estimate panel regressions of the form

$$y_{ct} = \alpha + \alpha_c + \alpha_t + \beta_0 \, \mathrm{SS}_{ct} + \sum_{i \neq j} \beta_{ij} \, \mathrm{SS}_{ct} \times \omega^i_{j,c} + \sum_k \beta_k \, \mathrm{SS}_{ct} \times \mathrm{Size}_{k,c} + \varepsilon_{ct}, \tag{19}$$

where y_{ct} is an outcome variable for country c in year t, SS_{ct} is an indicator equal to one in years classified as Sudden Stops by Bianchi and Mendoza (2020), $\omega^i_{j,c}$ is the share of intermediate inputs from sector j in the total intermediate input expenditure of sector i in country c, and $\text{Size}_{k,c} = \text{Sales}_{k,c}/\text{nGDP}_c$ is the Domar weight (sales-to-GDP ratio) of sector k in country c. Country and year fixed effects are denoted by α_c and α_t.

Input–output shares and sectoral sizes are measured in 1995, the first year with IO data, and are treated as time-invariant characteristics of each country's production network over the sample. We consider three outcomes: real consumption growth, real GDP growth, and the current account-to-GDP ratio. Real consumption and GDP are obtained from the World Development Indicators (WDI). Sudden Stop dates are taken from Bianchi and Mendoza (2020). For readability and comparability of coefficients, the network variables are standardized to mean zero and unit standard deviation, and the sector size variables are demeaned.

This specification allows us to ask: Conditional on experiencing a Sudden Stop, do countries whose networks look "more like" the AE pattern (e.g., stronger nontradable-supplier links, weaker commodity and own-tradable links) display milder contractions in consumption and output and smaller current-account reversals? This is a conditional-correlation exercise, not an identification strategy.

Table 2 reports the regression results. Columns (1)–(2) consider real consumption growth, columns (3)–(4) real GDP growth, and columns (5)–(6) the current account-to-GDP ratio. In specifications that only interact the Sudden Stop dummy with an EM dummy (not shown in the table), EMEs exhibit substantially larger drops in consumption and output than AEs during Sudden Stops, consistent with the descriptive evidence in Bianchi and Mendoza (2020).

Columns (2), (4), and (6) replace the EM dummy interaction with interactions between the Sudden Stop dummy and the IO-based network and size measures. Several of these interactions are statistically significant and jointly increase the explanatory power of the regression relative to the EM-dummy specification: The R^2 is higher when we allow heterogeneity in network structure to matter within EMEs and AEs. Evaluating the coefficients at the average network configuration of EMEs and AEs, the implied Sudden Stop contractions in consumption and output are substantially larger for EMEs than for AEs, and the differences are statistically significant. For the current account, the EME–AE differences implied by the network interactions are smaller and not statistically significant at conventional levels.

These results indicate that the production network structure is systematically associated with how Sudden Stops translate into macroeconomic outcomes, consistent with the mechanism in the simple model: Countries whose IO matrices look closer to the "AE pattern" tend to experience milder Sudden Stop contractions, conditional on having a

Sudden Stop at all. We emphasize again that these are conditional correlations, not causal effects.

In Section 4, we then build a three-sector DSGE model calibrated to EMEs and AEs and ask whether the same network mechanism can account quantitatively for a sizable fraction of the observed EME–AE gap in Sudden Stop frequency and severity of the order observed in the data. Throughout, we interpret the model as a disciplined quantitative laboratory rather than a source of causal identification.

Table 2: Real GDP and Consumption during Sudden Stops

	Consumption		GDP		CA/GDP	
	(1)	(2)	(3)	(4)	(5)	(6)
$SS_{ct} \times EM_c$	-0.0528***		-0.0654***		0.0069	
	(0.015)		(0.016)		(0.015)	
$SS_{ct} \times \omega^{C}_{T,c}$		0.3020		0.3513		-0.1967
		(0.208)		(0.229)		(0.254)
$SS_{ct} \times \omega^{C}_{NT,c}$		1.0094***		0.2429		0.5918
		(0.342)		(0.380)		(0.364)
$SS_{ct} \times \omega^{T}_{C,c}$		0.1171		-0.0088		-0.0748
		(0.273)		(0.327)		(0.237)
$SS_{ct} \times \omega^{T}_{NT,c}$		-0.7235*		-0.4517		-0.9499***
		(0.422)		(0.308)		(0.321)
$SS_{ct} \times \omega^{NT}_{C,c}$		-1.6905***		-1.4465**		0.8668**
		(0.457)		(0.600)		(0.437)
$SS_{ct} \times \omega^{NT}_{T,c}$		1.0007***		0.7962***		-0.5752**
		(0.252)		(0.288)		(0.271)
$SS_{ct} \times$ Tradable Size_c		-0.0087		0.0236		-0.0120
		(0.034)		(0.043)		(0.032)
$SS_{ct} \times$ Nontradable Size_c		-0.1656*		-0.0021		-0.0051
		(0.093)		(0.096)		(0.077)
$SS_{ct} \times$ Commodity Size_c		-0.1405*		-0.0602		-0.2499***
		(0.077)		(0.090)		(0.092)
SS_{ct}	-0.0112***	-0.2176***	-0.0026	-0.1477	0.0106	0.1836***
	(0.004)	(0.083)	(0.005)	(0.108)	(0.010)	(0.065)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared within	0.059	0.091	0.070	0.094	0.003	0.017
Observations	1463	1463	1517	1517	1434	1434

Note: Time period: 1979–2019, annual frequency. The sample includes both countries that do and do not experience Sudden Stops during the period. Two-way clustered standard errors at the country and year level. *,**,*** denote significance at the 10, 5, and 1 percent level, respectively. The panel is unbalanced, comprising 37 countries: 17 EMEs and 20 AEs. $\omega^{i}_{j,c} = \alpha^{i}_{j,c} / \sum_{j \in \{C,X,NT\}} \alpha^{i}_{j,c}$ is intermediate input expenditure on j by i as a fraction of i total intermediate input expenditure.

4 Quantitative Model

This section embeds the Sudden Stop mechanism from Section 2 into a three-sector small open economy with commodities, non-commodity tradables, and nontradables. The goal is to discipline the model's production structure using the input–output differences between EMEs and AEs documented in Section 3 and to assess, within the model, how much of the observed gap in Sudden Stop severity can be rationalized by these network differences.

The logic is as follows. The two-sector model delivers a sufficient statistic for the response of aggregate consumption to a tradable productivity shock, and when evaluated in the data, it already suggests larger Sudden Stop-type responses in EMEs than in AEs. The empirical section then shows that EMEs and AEs differ systematically in how commodities, tradables, and nontradables are connected and that these differences are systematically related to the severity of Sudden Stops in reduced-form regressions. The quantitative model takes these network patterns as targets, embeds them in a full dynamic small open economy with sectoral risk and collateral constraints, and asks whether the same mechanism can quantitatively generate EME–AE gaps in Sudden Stop frequency and severity of the order observed in the data.

Relative to the simple two-sector framework, the quantitative model: (i) separates tradables into a commodity good with an exogenous world price and a differentiated tradable good facing a finite-elasticity demand; and (ii) introduces aggregate risk via sector-specific productivity shocks in a fully dynamic setting.

4.1 Households

The representative household maximizes expected lifetime utility

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \, u(c_t) \right], \qquad \beta \in (0,1). \tag{20}$$

Aggregate consumption is a constant-elasticity of substitution (CES) aggregate of a nontradable good c_t^N and a composite tradable good c_t^T:

$$c_t = \left[(1-\omega)(c_t^N)^{-\eta} + \omega (c_t^T)^{-\eta} \right]^{-\frac{1}{\eta}}, \tag{21}$$

where the tradable composite is itself a CES aggregate of a commodity good c_t^C and a non-commodity tradable good c_t^X:

$$c_t^T = \left[\omega_T (c_t^C)^{-\eta_T} + (1-\omega_T)(c_t^X)^{-\eta_T}\right]^{-\frac{1}{\eta_T}}. \tag{22}$$

To simplify notation, we write c_t instead of $c(s^t)$ for the state-contingent consumption plan; the same convention applies to other variables.

Both tradable goods C and X are produced domestically and can be exported. The household trades one-period non–state-contingent bonds at exogenous price q and receives flow income from sectoral profits in commodities, non-commodity tradables, and nontradables:

$$p_t^N c_t^N + p_t^C c_t^C + p_t^X c_t^X + q b_{t+1} = \pi_t^N + \pi_t^C + \pi_t^X + b_t, \tag{23}$$

where the left-hand side is total expenditure on consumption plus bond purchases, and the right-hand side is total income from profits and initial bond holdings. All prices are expressed in units of the commodity good, which is the numeraire. Thus, p_t^X and p_t^N are the relative prices of the non-commodity tradable and nontradable goods, respectively.

The household faces an occasionally binding collateral constraint. It can borrow up to a fraction κ of current flow income (the sum of sectoral profits):

$$q b_{t+1} \geq -\kappa\left(\pi_t^N + \pi_t^C + \pi_t^X\right). \tag{24}$$

Foreign demand for X. Following Benguria et al. (2024) and Saffie et al. (2020), foreign demand for the differentiated tradable good X has the same price elasticity as domestic demand. Let Γ denote the foreign demand shifter. Given the tradable price index p_t^T (defined later), domestic demand for X is

$$c_t^X = (1-\omega_T)^{\frac{1}{1+\eta_T}} \left(\frac{p_t^X}{p_t^T}\right)^{-\frac{1}{1+\eta_T}} c_t^T, \tag{25}$$

foreign demand is

$$\hat{c}_t^X = \Gamma \left(\frac{p_t^X}{p_t^T}\right)^{-\frac{1}{1+\eta_T}}, \tag{26}$$

and market clearing for X requires

$$c_t^X + \hat{c}_t^X = y_t^X - \sum_i m_{X,t}^i. \tag{27}$$

4.2 Production Structure

There are three sectors $i \in \{C, X, N\}$. Each sector uses a CES composite of intermediate inputs from all sectors and exhibits decreasing returns to scale:

$$y_t^i = z_t^i \left[\left(\sum_{j \in \{C,X,N\}} (\omega_j^i)^{\frac{1}{\chi^i}} (m_{jt}^i)^{\frac{\chi^i - 1}{\chi^i}} \right)^{\frac{\chi^i}{\chi^i - 1}} \right]^{\gamma^i}, \tag{28}$$

with $\sum_j \omega_j^i = 1$ for all i, $\gamma^i \in (0,1)$, and $\chi^i > 0$. The parameters (γ^i, χ^i) are sector-specific and govern the degree of decreasing returns and the elasticity of substitution across inputs, respectively. The sector-specific productivity shock z_t^i follows an AR(1) process with persistence ρ_i and innovation variance σ_i^2.

Given prices $\{p_t^j\}$, each sector-i firm chooses input demands $\{m_{jt}^i\}_{j \in \{C,X,N\}}$ to maximize static profits:

$$\pi_t^i = \max_{\{m_{jt}^i\}_{j \in \{C,X,N\}}} \left\{ p_t^i y_t^i - \sum_{j \in \{C,X,N\}} p_t^j m_{jt}^i \right\} \tag{29}$$
$$\text{subject to (28).}$$

From the firm first-order conditions, in steady-state, we have

$$\frac{p_j m_j^i}{p_i y_i} = \omega_j^i \gamma^i, \qquad \frac{p_j m_j^i}{\sum_k p_k m_k^i} = \omega_j^i,$$

so the ω_j^i parameters can be mapped directly to observed input shares, and the γ^i parameters are calibrated using sectoral labor shares (even though labor is not explicitly modeled).

4.3 Equilibrium Conditions

The household's intratemporal optimality conditions imply

$$\frac{p_t^N}{p_t^T} = \frac{1-\omega}{\omega}\left(\frac{c_t^T}{c_t^N}\right)^{1+\eta}, \tag{30}$$

$$p_t^X = \frac{1-\omega_T}{\omega_T}\left(\frac{c_t^C}{c_t^X}\right)^{1+\eta_T}, \tag{31}$$

where p_t^T is the price index of the tradable composite.

Let $u_C(t)$ denote the marginal utility of the numeraire (commodity) good. The Euler equation for bond holdings and the borrowing constraint are:

$$u_C(t) = q^{-1}\beta\,\mathbb{E}_t\left[u_C(t+1)\right] + \mu_t, \tag{32}$$

$$qb_{t+1} \geq -\kappa\big(\pi_t^N + \pi_t^C + \pi_t^X\big), \tag{33}$$

where $\mu_t \geq 0$ is the Lagrange multiplier on the borrowing constraint, with the usual complementary slackness condition.

Goods market clearing conditions are:

$$c_t^X + \hat{c}_t^X = y_t^X - \sum_i m_{X,t}^i, \tag{34}$$

$$c_t^N = y_t^N - \sum_i m_{N,t}^i, \tag{35}$$

$$c_t^C + qb_{t+1} = y_t^C - \sum_i m_{C,t}^i + b_t + p_t^X \hat{c}_t^X. \tag{36}$$

The tradable price index implied by the CES aggregator over C and X is

$$p_t^T = \left[\omega_T^{\frac{1}{1+\eta_T}} + (1-\omega_T)^{\frac{1}{1+\eta_T}}\,(p_t^X)^{\frac{\eta_T}{1+\eta_T}}\right]^{\frac{\eta_T+1}{\eta_T}}. \tag{37}$$

Together with the firm optimality conditions for $\{m_{jt}^i\}$ and p_t^i, these equations characterize the competitive equilibrium of the three-sector small open economy with an occasionally binding collateral constraint.

4.4 Quantitative Analysis

4.4.1 Calibration

We calibrate the model separately for an "average" emerging economy and an "average" advanced economy. The key discipline for the three-sector structure comes from the OECD input–output tables and the sector and country classifications described in Appendix C. We then discipline sectoral dynamics using KLEMS data.

Production and consumption shares by sector are matched to 2018 IO moments. Sectoral output volatility and persistence are disciplined by KLEMS sectoral gross output for countries with available data. We use HP-filtered (log) output to construct moments both in the data and in the model. Due to data availability, the EM sectoral autocorrelation and volatility targets are based on Hungary (treated as representative). For AEs, we use Austria, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, the Netherlands, and Portugal.

Table 3 reports parameter values for the EM and AE calibrations. Table 4 reports the targeted moments and the model-implied moments for each group. The three key features are:

(i) The IO parameters ω_j^i differ between the EM and AE calibrations in a way consistent with the empirical averages in Section 3 (in particular, the EM calibration gives less weight to nontradable suppliers and more weight to commodity and tradable suppliers).

(ii) Preferences $(\beta, \omega, \omega_T, \eta, \eta_T)$ and the basic financial environment (world interest rate) are taken from standard values, while the collateral parameter κ is chosen to match average leverage and the frequency of Sudden Stops in each group.

(iii) Sectoral productivity processes $\{z_t^i\}$ are chosen so that the volatility and persistence of sectoral outputs in the model line up with the median sectoral moments in the data.

4.4.2 Exercises and Results

Baseline EM versus AE. We first study the long-run behavior of the EM and AE calibrations under their respective parameter values. A Sudden Stop is defined as an event in which the current account-to-GDP ratio is at least two standard deviations above its long-run average and the collateral constraint is binding.

We simulate each economy for 100,000 periods, discard the first 1,000 observations, and compute long-run averages. The EM calibration exhibits higher macro volatility, a more frequent binding of the borrowing constraint, and a higher Sudden Stop probability

Table 3: Parameter values

Parameter	Description	EM	AE
Preferences and financial frictions			
β	subjective discount factor	0.9	0.95
σ	curvature of utility	2	–
ω	consumption weight of tradables	0.165	–
ω_T	weight of non-commodity tradables in c^T	0.2	–
κ	collateral constraint parameter	0.32	0.46
Production and technology			
γ	decreasing returns to scale	0.8	–
ω_C^C	commodity input share in C	0.5	0.5
ω_X^C	tradable input share in C	0.37	0.35
ω_N^C	nontradable input share in C	0.13	0.15
ω_C^X	commodity input share in X	0.20	0.13
ω_X^X	tradable input share in X	0.61	0.59
ω_N^X	nontradable input share in X	0.19	0.28
ω_C^N	commodity input share in N	0.18	0.06
ω_X^N	tradable input share in N	0.35	0.34
ω_N^N	nontradable input share in N	0.47	0.6
χ	elasticity of substitution across inputs	0.6	–
$\frac{1}{1+\eta} = \frac{1}{1+\eta_T}$	trade elasticity	0.83	–
R^*	steady-state world interest rate	1.04	–
$\{z_L^C, z_H^C\}$	low–high productivity C	$\{1.9, 2.05\}$	$\{1.735, 1.745\}$
$\{z_L^X, z_H^X\}$	low–high productivity X	$\{1.95, 2.05\}$	$\{1.71, 1.77\}$
$\{z_L^N, z_H^N\}$	low–high productivity N	$\{1.98, 2.05\}$	$\{1.71, 1.77\}$
$\mathbb{P}_C$	prob. stay in z_L^C	0.75	–
$\mathbb{P}_X$	prob. stay in z_L^X	0.9	–
$\mathbb{P}_N$	prob. stay in z_L^N	0.88	–

Note: Parameter values for the EM and AE calibrations. The calibration is annual. "–" indicates that the AE calibration uses the same value as the EM calibration.

than the AE calibration, despite having a lower average debt-to-GDP ratio. These differences reflect a combination of financial, shock, and network differences in the calibrated model. In the next step, we isolate the role of the network.

Advanced economy with emerging market network. To gauge the contribution of production networks, we construct a counterfactual AE economy that inherits the production network of the average EM while keeping all other parameters and stochastic processes at their AE values. This isolates, within the model, the effect of moving from an AE-style network to an EM-style network, holding financial development and shock processes

Table 4: Targeted Moments for Emerging and Advanced Economies

Moment	**Emerging Economies**		**Advanced Economies**	
	Data	**Model**	**Data**	**Model**
Macroeconomic moments				
Debt to GDP	-0.428	-0.307	-0.609	-0.47
Trade balance to GDP	-0.0003	0.01	0.007	0.02
$\sigma(\text{CA}/\text{GDP})$	0.032	0.012	0.031	0.008
$\sigma(\text{GDP})$	0.035	0.070	0.020	0.018
$\rho(\text{GDP})$	0.617	0.402	0.615	0.540
Sudden Stop probability	0.03	0.033	0.017	0.0088
Expenditure shares and sectoral moments				
$p_t^C c_t^C / \sum_j p_t^j c_t^j$	0.04	0.05	0.04	0.05
$p_t^X c_t^X / \sum_j p_t^j c_t^j$	0.19	0.17	0.19	0.17
$p_t^N c_t^N / \sum_j p_t^j c_t^j$	0.77	0.78	0.77	0.78
$\sigma(y_t^C)$	0.09	0.06	0.05	0.05
$\sigma(y_t^X)$	0.07	0.06	0.06	0.04
$\sigma(y_t^N)$	0.06	0.06	0.04	0.04
$\rho(y_t^C)$	0.39	0.44	0.23	0.14
$\rho(y_t^X)$	0.57	0.57	0.42	0.62
$\rho(y_t^N)$	0.57	0.54	0.46	0.61
$p^C m_C^C / \sum_k p^k m_k^C$	0.49	0.48	0.47	0.45
$p^X m_X^C / \sum_k p^k m_k^C$	0.37	0.38	0.35	0.38
$p^N m_N^C / \sum_k p^k m_k^C$	0.14	0.14	0.18	0.17
$p^C m_C^X / \sum_k p^k m_k^X$	0.20	0.19	0.12	0.11
$p^X m_X^X / \sum_k p^k m_k^X$	0.60	0.62	0.59	0.60
$p^N m_N^X / \sum_k p^k m_k^X$	0.20	0.19	0.29	0.29
$p^C m_C^N / \sum_k p^k m_k^N$	0.11	0.17	0.04	0.05
$p^X m_X^N / \sum_k p^k m_k^N$	0.43	0.36	0.34	0.34
$p^N m_N^N / \sum_k p^k m_k^N$	0.46	0.48	0.62	0.61

Note: Sectoral moments come from OECD input–output tables and KLEMS data. Volatility and persistence of sectoral output correspond to the median across sectors and countries in each group. Macroeconomic moments are computed using annual data for the 41 countries in our network sample over 1970–2019. Debt-to-GDP comes from IMF government gross debt data. Current account-to-GDP comes from Lane and Milesi-Ferretti (2017) (updated 2023). Trade balance-to-GDP and GDP come from the World Bank's World Development Indicators. GDP is in constant 2015 US dollars, HP-filtered (log) with $\lambda = 100$. For comparability across exercises, we keep the same consumption shares across economies.

fixed.

Long-run moments. Table 5 summarizes the main long-run moments for three cases: (i) the EM calibration; (ii) the AE calibration with the EM network ("AE with EM Network"); and (iii) the baseline AE calibration.

A key observation is that the average debt-to-GDP ratio in the "AE with EM Network" economy is essentially the same as in the baseline AE economy (-46.23 versus -46.68), yet the Sudden Stop probability rises from 0.88 to 1.47 percent, and the constraint binds roughly twice as often (29.64 versus 15.84 percent). In the model, replacing the AE network with the EM network substantially raises the frequency of Sudden Stops without meaningfully changing average leverage. This highlights that network structure alone can materially affect the likelihood that the collateral constraint becomes binding.

Table 5: Selected long-run moments

Moment	EM	AE with EM Network	AE
$\mathbb{E}(b/Y)$ (%)	-30.77	-46.23	-46.68
$\sigma(\text{CA}/Y)$ (%)	1.25	0.73	0.84
$(p^C m_C^C / \sum_k p^k m_k^C) \times 100$	48.06	47.81	45.39
$(p^N m_N^C / \sum_k p^k m_k^C) \times 100$	13.91	13.90	16.74
$(p^C m_C^X / \sum_k p^k m_k^X) \times 100$	18.78	18.70	11.10
$(p^N m_N^X / \sum_k p^k m_k^X) \times 100$	19.48	19.48	29.39
$(p^C m_C^N / \sum_k p^k m_k^N) \times 100$	16.59	16.52	5.00
$(p^N m_N^N / \sum_k p^k m_k^N) \times 100$	47.57	47.57	61.50
Sudden Stop probability (%)	3.33	1.47	0.88
$\mathbb{P}(\mu_t > 0)$ (%)	43.68	29.64	15.84
ΔGDP_{SS} (%)	-12.23	-4.94	-3.80
$\Delta\text{CA/GDP}_{SS}$ (%)	3.90	2.44	1.91

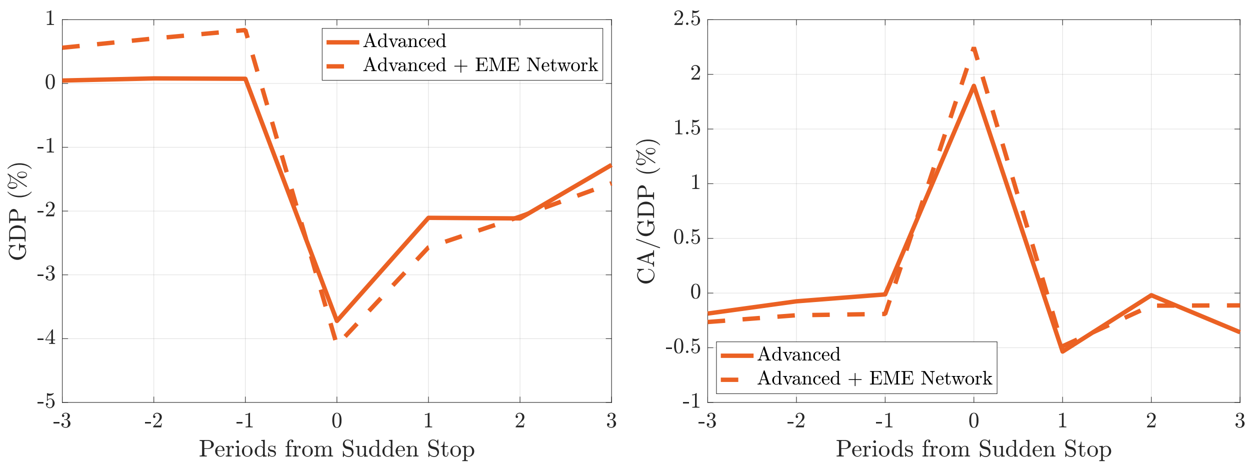
Note: Long-run moments for the EM calibration, the AE calibration with the EM network, and the baseline AE calibration. We simulate each economy for 100,000 periods, discard the first 1,000, and compute sample moments from the remaining observations. ΔGDP_{SS} and $\Delta\text{CA/GDP}_{SS}$ denote peak-to-trough changes during Sudden Stop events.

Average Sudden Stop severity. Beyond long-run frequencies, we also examine the severity of Sudden Stops in each economy. Figure 7 plots the dynamics of GDP (in units of the commodity good) and the current account-to-GDP ratio during an average Sudden Stop episode. The solid line corresponds to the baseline AE calibration; the dashed line corresponds to the AE calibration with the EM network.

Panel (a) shows that the AE with EM network experiences a larger GDP decline than the baseline AE economy; the peak-to-trough GDP drop is about 30% larger in the counterfactual network configuration. Panel (b) shows that the current account reversal is also larger in the AE with EM network—approximately 28% larger than in the baseline AE. Within the model, moving from an AE-style production network to an EM-style network, holding other parameters fixed, amplifies both the probability and the severity of Sudden Stops. This matches the direction and rough magnitude of the EM–AE differences in the data, and ties the reduced-form regression evidence on networks and Sudden Stops directly to a structural mechanism.

Figure 7: GDP and CA during an average Sudden Stop

(a) GDP (b) CA/GDP



Note: GDP (panel a) and current account-to-GDP ratio (panel b) around an average Sudden Stop. The solid line depicts the baseline AE calibration; the dashed line depicts the AE calibration with the same production network as the average EM.

In sum, the calibrated three-sector model with collateral constraints delivers EM–AE differences in Sudden Stop frequency and severity that are broadly consistent with the data, and shows that replacing an AE-style network with an EM-style network—holding financial frictions and shocks fixed—substantially raises both the probability and the severity of Sudden Stops. In Section 5, we use the same calibrated model to study the normative implications of these network effects and the performance of simple macroprudential and sectoral tax instruments.

5 Normative Analysis

This section studies the normative implications of the Sudden Stop amplification mechanism developed earlier. We start from the quantitative three-sector model and consider a planner that internalizes the collateral externality and the effect of sectoral production networks on the value of collateral. Building on the two-sector result in Section 2 that a planner would like to tilt the network toward stronger NT←T linkages to reduce Sudden Stop amplification, we ask how simple policies perform in the empirically disciplined three-sector environment. We first characterize the key wedges that distinguish the planner allocation from the competitive equilibrium, emphasizing how production linkages enter. We then use the quantitative model to evaluate simple implementable policies: a macroprudential debt tax and permanent sectoral input taxes.

5.1 Setup

The planner's problem can be stated in recursive form as follows:

$$V(b,\boldsymbol{e}) = \max_{\boldsymbol{x}} \quad U(c^C, c^X, c^N) + \beta \mathbb{E}\left[V(b', \boldsymbol{e}')\right],$$

subject to

$$c^C + m_C^C + m_C^X + m_C^N + qb' = y^C + p^X(c^C, c^X)\hat{c}^X\big(p^X(c^C, c^X)\big) + b \quad (\lambda_1), \tag{38}$$

$$c^X + \hat{c}^X\big(p^X(c^C, c^X)\big) + m_X^C + m_X^X + m_X^N = y^X \qquad (\lambda_2), \tag{39}$$

$$c^N + m_N^C + m_N^X + m_N^N = y^N \qquad (\lambda_3), \tag{40}$$

$$qb' \geq -\kappa\big(\pi^C + \pi^X + \pi^N\big) \qquad (\mu), \tag{41}$$

where $\boldsymbol{x} = \{c^C, c^X, c^N, m_N^N, m_X^N, m_C^N, m_N^X, m_X^X, m_C^X, m_N^C, m_X^C, m_C^C, b'\}$ collects all planner choice variables and $\boldsymbol{e} = \{\{z^i\}_{i\in\{C,X,N\}}\}$ collects the exogenous sectoral productivities. The multipliers λ_1, λ_2, and λ_3 correspond to the resource constraints for the commodity, non-commodity tradable, and nontradable goods, respectively, and μ is the multiplier on the collateral constraint.

Profits depend on prices and inputs as

$$\pi^i = \pi^i\big(p^N(c^N, c^T), p^X(c^X, c^T), y^i, \{m_j^i\}_{j\in\{C,X,N\}}\big), \qquad \forall i \in \{C, X, N\},$$

where the relative prices p^N and p^X are equilibrium objects determined by households' demand, firms' input choices, and market clearing. The planner takes the same pricing functions as in the competitive equilibrium but internalizes how its choices of $\boldsymbol{x}$ move those prices and hence the value of collateral.

5.2 Key equations

We now highlight the wedges that separate the planner allocation from the competitive equilibrium and how they depend on the production network. Full derivations are included in the Appendix D.

Pecuniary externality. As in canonical Sudden Stop models, the planner internalizes the effect of current choices on the value of collateral. With multiple sectors and endogenous prices, this externality depends on the entire production network.

The first-order condition with respect to c^C can be written as

$$\lambda_1 = U_C + \Theta, \tag{42}$$

where U_C is the marginal utility of the numeraire consumption good and Θ is a wedge given by

$$\Theta = \underbrace{\frac{\mu\,\kappa\,\frac{\partial \pi}{\partial c^C}}{1 - \frac{\partial p^X}{\partial c^C}\hat{c}^X \frac{\eta_T}{1+\eta_T}}}_{\text{Collateral (pecuniary) externality}} + \underbrace{\frac{U_C \frac{\partial p^X}{\partial c^C}\hat{c}^X \frac{\eta_T}{1+\eta_T} - \lambda_2 \frac{\partial \hat{c}^X}{\partial c^C}}{1 - \frac{\partial p^X}{\partial c^C}\hat{c}^X \frac{\eta_T}{1+\eta_T}}}_{\text{Terms-of-trade motive}}. \tag{43}$$

The numerator of the first term captures the effect of a marginal change in c^C on the value of collateral $\pi = \pi^C + \pi^X + \pi^N$ through prices:

$$\frac{\partial \pi}{\partial c^C} = \frac{\partial p^X}{\partial c^C} \sum_{i \in \{C,X,N\}} \frac{\partial \pi^i}{\partial p^X} + \frac{\partial p^N}{\partial c^C} \sum_{i \in \{C,X,N\}} \frac{\partial \pi^i}{\partial p^N}. \tag{44}$$

Equation (44) shows explicitly how the production network enters the strength of the collateral externality: The responses of sectoral profits $\partial \pi^i / \partial p^X$ and $\partial \pi^i / \partial p^N$ depend on input shares and substitution elasticities across inputs. In a diagonal economy, shocks to relative prices affect profits only through own-sector terms, so the aggregate collateral effect is limited. In contrast, when sectors are tightly connected through input-output linkages, changes in p^X and p^N propagate across sectors and can substantially amplify the effect of c^C on collateral.

The denominator in (43) reflects the fact that the planner also internalizes the effect of

c^C on the export price p^X and thus on export revenues $p^X \hat{c}^X$, which feeds back into the resource constraint and the collateral constraint.

Terms-of-trade manipulation. The second term in (43) captures a pure terms-of-trade motive that is present even when the collateral constraint is slack ($\mu = 0$). The planner recognizes that higher c^C increases the relative price of the differentiated tradable, $\partial p^X / \partial c^C > 0$. Given exports $\hat{c}^X$, this raises export revenues and effective income, but it also reduces the quantity exported because $\partial \hat{c}^X / \partial p^X < 0$. Both effects show up in the wedge through the dependence of $\hat{c}^X$ on p^X and of p^X on c^C.

Production-side distortions. The planner also distorts firms' input choices when the collateral constraint binds. To see this, compare the first-order condition for a particular input under the competitive equilibrium and under the planner.

Take m_C^N, the quantity of commodity inputs used in nontradable production. Under the competitive equilibrium, profit maximization implies

$$p^N \frac{\partial y^N}{\partial m_C^N} = 1,$$

i.e., the value of the marginal nontradable unit produced with an additional unit of m_C^N equals the marginal cost of that input (the commodity good is the numeraire, $p^C = 1$).

Under the planner's problem, the corresponding condition can be written as

$$p^N \frac{\partial y^N}{\partial m_C^N} = \frac{\lambda_1 + \mu\kappa}{U_C + \mu\kappa \left(1 + \frac{1}{p^N} \frac{\partial \pi}{\partial c^N}\right)}, \tag{45}$$

When the collateral constraint is slack ($\mu = 0$) and there are no terms-of-trade motives, we derive $U_C = \lambda_1$, and the right-hand side is equal to one: The social and private marginal conditions coincide. When $\mu > 0$, the right-hand side generally differs from one, so the planner and the competitive equilibrium choose different input allocations. The reason is again a pecuniary externality: Relative to firms, the planner internalizes that input choices affect sectoral outputs, sectoral profits, and therefore the collateral constraint. The term $\partial \pi / \partial c^N$ embeds the same network structure as in (44), so the magnitude and sign of the optimal deviation from the competitive allocation depend on the production network.

In sum, with a binding borrowing constraint and a nontrivial input-output structure, the planner faces both consumption-side and production-side wedges that are tightly linked to the network.

5.3 Quantitative Analysis

We now study quantitatively how simple implementable policy instruments perform in the full three-sector model. Rather than solving the full Ramsey problem, we focus on two classes of policies that are widely discussed in practice and are tractable in our environment: a non-state-contingent macroprudential tax on debt, and permanent sectoral taxes on final goods and intermediate inputs. All revenues are rebated lump-sum to households.

5.3.1 Macroprudential Debt Tax

We first introduce a non-state-contingent tax τ^b on household borrowing. The tax raises the effective cost of borrowing from R to $(1+\tau^b)R$. The proceeds are rebated lump-sum to the household. We then vary τ^b over a range of values and compute, for each calibration, the associated welfare (in consumption-equivalent units) and the long-run probability of Sudden Stops.

Figure 8 summarizes the results for three model calibrations: an average emerging market (solid purple line), an average advanced economy (solid orange line), and an average advanced economy with the production network of emerging markets (dashed orange line).

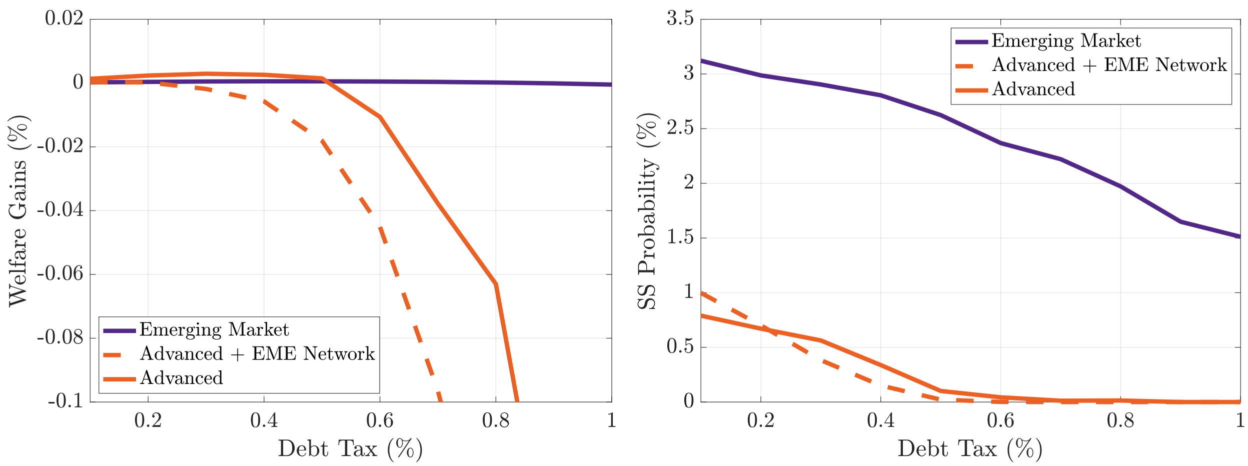
Panel (a) shows that small positive debt taxes can generate welfare gains in both the EM and AE calibrations by lowering the frequency and severity of Sudden Stops. However, as the tax rate increases, welfare becomes non-monotonic, and relatively large taxes produce sizable welfare losses, especially in the AE calibration. In the AE economy endowed with the EM network, the debt tax is much less attractive; welfare is flat or decreasing even for relatively small tax rates.

Panel (b) reports the associated Sudden Stop probabilities. As expected, higher τ^b reduces the likelihood of Sudden Stops in all calibrations by weakening borrowing incentives. The reduction is steepest in the AE-with-EM-network case, but this comes at the cost of the welfare losses in panel (a). Together, these results suggest that the effectiveness and desirability of a uniform macroprudential debt tax depend not only on financial development but also on the underlying production network structure. A "one-size-fits-all" debt tax can be particularly costly in economies whose networks already make them fragile.

Figure 8: Welfare gains and Sudden Stop probability due to a debt tax

(a) Welfare Gains

(b) Sudden Stop Probability



Note: This figure shows welfare gains (panel a) and the Sudden Stop probability (panel b) for different debt tax rates (x-axis). We consider three calibrations: an average emerging market (solid purple line), an average advanced economy (solid orange line), and an average advanced economy with the production network structure of emerging markets (dashed orange line).

5.3.2 Sectoral Taxes

We next consider permanent sectoral taxes/subsidies that tilt the production network. We assume that the government can tax or subsidize purchases of final goods and intermediate inputs. Households and firms face these taxes when buying goods and inputs, and the resulting revenues are rebated lump-sum to households.

Figure 9 reports the results for our baseline emerging-market calibration. We consider three simple instruments:

- a tax on nontradable inputs (solid gray line),
- a tax on commodity inputs (dashed green line), and
- a tax on non-commodity tradable inputs (short dashed pink line).

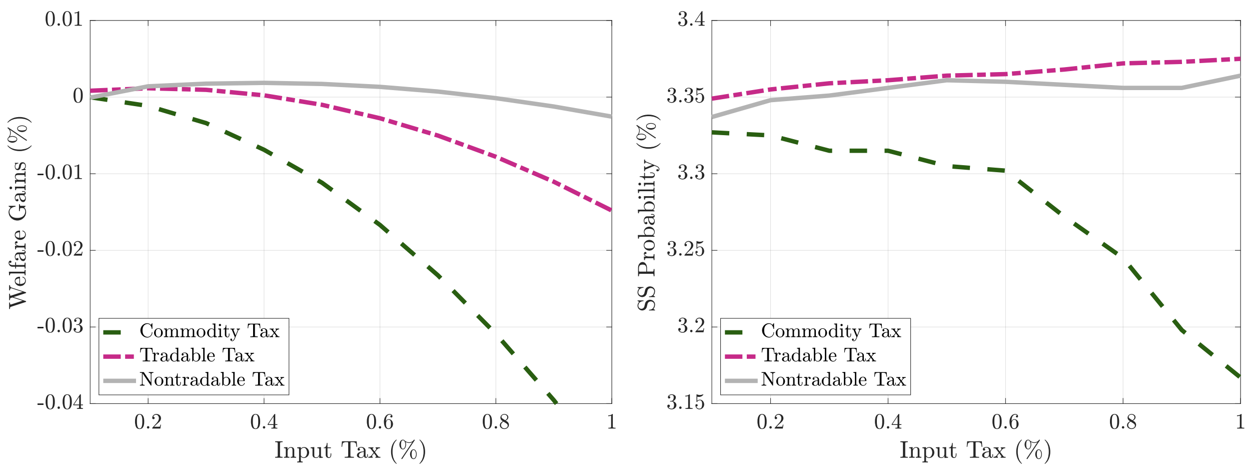
Panel (a) shows welfare effects. A constant tax on commodity inputs is uniformly welfare-decreasing in this calibration. In contrast, moderate taxes on nontradable and tradable inputs can generate small welfare gains, although large taxes eventually become harmful. Taxes on nontradable inputs are somewhat less likely to generate sharp welfare losses over the range we consider.

Panel (b) shows the associated Sudden Stop probabilities. A tax on commodity inputs lowers the Sudden Stop probability, while taxes on nontradable and tradable inputs increase it slightly. The mechanism is straightforward: Debt is denominated in units of the commodity good, so taxing commodity inputs works similarly to a direct tax on the numeraire and discourages reliance on the sector whose price cannot adjust in crises. Instead, taxes on nontradable and tradable inputs make production more commodity-intensive by raising the relative cost of inputs whose prices can move in response to shocks. This tilting of the network toward the numeraire sector increases financial fragility and raises the frequency of Sudden Stops.

Figure 9: Welfare gains and Sudden Stop probability due to sectoral taxes: baseline EM

(a) Welfare Gains

(b) Sudden Stop Probability



Note: This figure shows welfare gains (panel a) and the Sudden Stop probability (panel b) for different sectoral input taxes in the baseline emerging-market calibration. The solid gray line corresponds to a tax on nontradable inputs, the dashed green line to a tax on commodity inputs, and the short dashed pink line to a tax on non-commodity tradable inputs.

Viewed through the lens of Section 2, the commodity-input tax in the three-sector model plays a similar role to the tradable-input subsidy in the two-sector benchmark once debt is denominated in the commodity numeraire; both tilt the network away from the sector in which collateral is measured and dampen the Sudden Stop amplification mechanism, at the cost of distorting production. Overall, the quantitative exercises confirm the central normative message of the paper. In the presence of collateral constraints, production networks are not innocuous; they shape both the size of pecuniary externalities and the strength of Sudden Stop amplification. Simple policy instruments that tilt the network can move the economy closer to the planner allocation, but they also entail nontrivial tradeoffs between average output and crisis severity, especially once the actual network structure of emerging and advanced economies is taken into account.

6 Conclusion

This paper argues that production networks are a first-order determinant of how global financial shocks translate into Sudden Stops, and that differences in network structure help explain why crises are systematically more severe in emerging economies than in advanced economies. We develop a simple two-sector small open economy model in which a collateral constraint, Fisherian deflation, and input–output linkages jointly determine the response of tradable consumption and relative prices to tradable productivity shocks. We take the model's sufficient-statistic logic to the data and to a three-sector quantitative model to assess how much of the emerging–advanced gap in Sudden Stop severity can be rationalized by observed differences in production structures.

In the two-sector framework, we show that starting from a marginally binding constraint, the response of tradable consumption and the nontradable price to a tradable shock can be written as a network-based amplification term multiplied by the direct tradable supply elasticity. This amplification term depends on input–output coefficients, profit shares, and consumption shares but not on higher-order details of the equilibrium path. A key conceptual result is that, even with collateral constraints, Hulten's theorem still holds: Domar weights remain sufficient for the impact of technology shocks on real GDP. By contrast, the consumption response that matters for Sudden Stops depends on the full network and the way sectoral profits feed into collateral, not just on Domar weights. Starting from a given network, a planner who cares about Sudden Stop amplification will, in general, want sectoral wedges that deliberately break Hulten.

Our empirical analysis documents that, in the data, emerging economies look more "diagonal" and commodity- and own-tradable-intensive. By contrast, advanced economies feature nontradables that are more central as suppliers and weaker links from commodities and tradables to the rest of the economy. When we feed each country's input–output structure into the closed-form expressions from the two-sector model, holding financial parameters fixed, the implied sufficient statistic for the consumption response to tradable shocks is systematically larger in emerging markets. In reduced-form regressions, countries whose three-sector IO matrices resemble the advanced-economy pattern exhibit milder consumption and output contractions during Sudden Stops. Once we allow Sudden Stop effects to vary with network structure, the residual "emerging-market dummy" loses much of its explanatory power for real activity, although not for the current account.

The quantitative three-sector DSGE model aggregates sectors into commodities, non-commodity tradables, and nontradables, disciplines the production structure using OECD IO tables, and matches basic macro and sectoral moments for average emerging and advanced economies. Under a common global financial risk process and collateral constraint, the emerging calibration exhibits higher macro volatility, a more frequently binding borrowing constraint, and more frequent and more severe Sudden Stops than the advanced calibration. A counterfactual advanced economy that keeps its financial and shock environment but adopts the emerging production network displays substantially higher Sudden Stop probability and larger peak-to-trough declines in GDP and the current account, despite similar average leverage. Within the model, replacing an advanced-style network with an emerging-style network moves the economy a long way toward the emerging-market crisis profile.

Finally, our normative analysis shows that, in the presence of collateral constraints, production networks generate wedges on both consumption and production margins that the competitive equilibrium does not internalize. A planner recognizes that sectoral input choices and relative prices affect the value of collateral through profits across the entire network. Simple macroprudential debt taxes can reduce the frequency of Sudden Stops and yield modest welfare gains in some calibrations, but they can also be blunt and welfare-reducing, especially when the underlying network is already fragile. Sectoral input taxes and subsidies that tilt the network away from the diagonal, emerging-style configuration can lower amplification by weakening the link between tradable shocks and collateral values but only by creating production wedges that sacrifice static efficiency. The broader lesson is that macroprudential and sectoral policies should be designed with explicit attention to "who produces for whom" in the domestic economy, not just to aggregate leverage or exposure to external finance.

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A Proofs

A.1 Proof of Proposition 1

Totally differentiating the PP curve (16),

$$\mathrm{d}\log p_t^N = (1+\eta)\,\mathrm{d}\log c_t^T - (1+\eta)\,\mathrm{d}\log c_t^N.$$

This implies

$$\frac{\mathrm{d}\log p_t^N}{\mathrm{d}\log c_t^T} = \frac{(1+\eta)}{1+(1+\eta)\,\frac{\mathrm{d}\log c_t^N}{\mathrm{d}\log p_t^N}}.$$

Since $\eta > -1$, it suffices to show that $\frac{\mathrm{d}\log c_t^N}{\mathrm{d}\log p_t^N} \geq 0$.

Differentiating the nontradable market clearing condition (14),

$$\mathrm{d}\log c_t^N = \frac{(1-\alpha_N^N)y_t^N}{c_t^N}\,\mathrm{d}\log y_t^N - \alpha_N^T \frac{y_t^T}{p_t^N c_t^N}\big(\mathrm{d}\log y_t^T - \mathrm{d}\log p_t^N\big),$$
$$\frac{\mathrm{d}\log c_t^N}{\mathrm{d}\log p_t^N} = \frac{(1-\alpha_N^N)y_t^N}{c_t^N}\frac{\mathrm{d}\log y_t^N}{\mathrm{d}\log p_t^N} - \alpha_N^T \frac{y_t^T}{p_t^N c_t^N}\left(\frac{\mathrm{d}\log y_t^T}{\mathrm{d}\log p_t^N} - 1\right).$$

Using the supply schedules (10)–(13),

$$\frac{\mathrm{d}\log y_t^N}{\mathrm{d}\log p_t^N} = \frac{\alpha_T^N}{1-\alpha_N^N-\alpha_T^N} \geq 0, \qquad \frac{\mathrm{d}\log y_t^T}{\mathrm{d}\log p_t^N} = -\frac{\alpha_N^T}{1-\alpha_T^T-\alpha_N^T} \leq 0,$$

so $\frac{\mathrm{d}\log c_t^N}{\mathrm{d}\log p_t^N} \geq 0$. This implies the denominator in the expression for $\mathrm{d}\log p_t^N/\mathrm{d}\log c_t^T$ is positive, so the PP curve is upward-sloping. This concludes the proof.

A.2 Proof of Proposition 2

Totally differentiating the BB curve (18),

$$\mathrm{d}c_t^T = \kappa_N\,\mathrm{d}\pi_t^N(p_t^N; z_t^N) + (1+\kappa_T)\,\mathrm{d}\pi_t^T(p_t^N; z_t^T). \tag{46}$$

Along the BB curve, only p_t^N and c_t^T change, so

$$\mathrm{d}\pi_t^N = \frac{\partial \pi_t^N}{\partial p_t^N}\,\mathrm{d}p_t^N, \tag{47}$$

$$\mathrm{d}\pi_t^T = \frac{\partial \pi_t^T}{\partial p_t^N}\,\mathrm{d}p_t^N. \tag{48}$$

Substituting (47)–(48) into (46) and solving for $\mathrm{d}p_t^N/\mathrm{d}c_t^T$,

$$\frac{\mathrm{d}p_t^N}{\mathrm{d}c_t^T} = \frac{1}{\kappa_N \frac{\partial \pi_t^N}{\partial p_t^N} + (1+\kappa_T)\frac{\partial \pi_t^T}{\partial p_t^N}}.$$

Hence, the sign of the BB slope is the sign of

$$\kappa_N \frac{\partial \pi_t^N}{\partial p_t^N} + (1+\kappa_T)\frac{\partial \pi_t^T}{\partial p_t^N},$$

as stated in the proposition.

A.3 Proof of Proposition 3

The proof follows a linearization approach. For convenience, rewrite the equilibrium system in terms of outputs and prices:

$$p_t^N = \left(\frac{c_t^T}{c_t^N(p_t^N; z_t^N, z_t^T)}\right)^{1+\eta} \frac{1-\omega}{\omega} \qquad \text{(PP)}, \tag{49}$$

$$\begin{aligned} c_t^T &= \left(\kappa(1-\alpha_N^N-\alpha_T^N)-\alpha_T^N\right) p_t^N y_t^N(p_t^N; z_t^N) \\ &\quad + \left(\kappa(1-\alpha_N^T-\alpha_T^T)+1-\alpha_T^T\right) y_t^T(p_t^N; z_t^T) + b_0 \qquad \text{(BB)}. \end{aligned} \tag{50}$$

Define elasticities $\varepsilon_x^y \equiv \partial \log y / \partial \log x$. Totally differentiating (49)–(50) yields

$$\mathrm{d}\log p_t^N = (1+\eta)\left(\mathrm{d}\log c_t^T - \mathrm{d}\log c_t^N\right), \tag{51}$$

$$\mathrm{d}\log c_t^T = \gamma_t^N\left(\mathrm{d}\log p_t^N + \mathrm{d}\log y_t^N\right) + \gamma_t^T\,\mathrm{d}\log y_t^T, \tag{52}$$

where

$$\gamma_t^N = \frac{\kappa_N \pi_t^N}{c_t^T}, \qquad \gamma_t^T = \frac{(1+\kappa_T)\pi_t^T}{c_t^T}.$$

Next, use that y_t^N, y_t^T, and c_t^N are functions of (p_t^N, z_t^N, z_t^T):

$$\begin{aligned}
\mathrm{d}\log y_t^N &= \varepsilon^{y_t^N}_{p_t^N}\,\mathrm{d}\log p_t^N + \varepsilon^{y_t^N}_{z_t^N}\,\mathrm{d}\log z_t^N, \\
\mathrm{d}\log y_t^T &= \varepsilon^{y_t^T}_{p_t^N}\,\mathrm{d}\log p_t^N + \varepsilon^{y_t^T}_{z_t^T}\,\mathrm{d}\log z_t^T, \\
\mathrm{d}\log c_t^N &= \varepsilon^{c_t^N}_{p_t^N}\,\mathrm{d}\log p_t^N + \varepsilon^{c_t^N}_{z_t^N}\,\mathrm{d}\log z_t^N + \varepsilon^{c_t^N}_{z_t^T}\,\mathrm{d}\log z_t^T.
\end{aligned}$$

Substituting these into (51)–(52) yields

$$\begin{aligned}
\mathrm{d}\log c_t^T &= \left(\tfrac{1}{1+\eta} + \varepsilon^{c_t^N}_{p_t^N}\right)\mathrm{d}\log p_t^N + \varepsilon^{c_t^N}_{z_t^N}\mathrm{d}\log z_t^N + \varepsilon^{c_t^N}_{z_t^T}\mathrm{d}\log z_t^T, \\
\mathrm{d}\log c_t^T &= \left[\gamma_t^N(1+\varepsilon^{y_t^N}_{p_t^N}) + \gamma_t^T\varepsilon^{y_t^T}_{p_t^N}\right]\mathrm{d}\log p_t^N + \gamma_t^N\varepsilon^{y_t^N}_{z_t^N}\mathrm{d}\log z_t^N + \gamma_t^T\varepsilon^{y_t^T}_{z_t^T}\mathrm{d}\log z_t^T.
\end{aligned}$$

For future reference, define PP and BB elasticities:

$$\begin{aligned}
\varepsilon_t^{PP} &= \left(\frac{1}{1+\eta} + \varepsilon^{c_t^N}_{p_t^N}\right)^{-1}, \\
\varepsilon_t^{BB} &= \left(\gamma_t^N(1+\varepsilon^{y_t^N}_{p_t^N}) + \gamma_t^T\varepsilon^{y_t^T}_{p_t^N}\right)^{-1}.
\end{aligned}$$

We write the system compactly as

$$\begin{bmatrix} 1 & -\left(\frac{1}{1+\eta} + \varepsilon^{c_t^N}_{p_t^N}\right) \\ 1 & -\left(\gamma_t^N(1+\varepsilon^{y_t^N}_{p_t^N}) + \gamma_t^T\varepsilon^{y_t^T}_{p_t^N}\right) \end{bmatrix} \begin{bmatrix} \mathrm{d}\log c_t^T \\ \mathrm{d}\log p_t^N \end{bmatrix} = \begin{bmatrix} \varepsilon^{c_t^N}_{z_t^N} & \varepsilon^{c_t^N}_{z_t^T} \\ \gamma_t^N\varepsilon^{y_t^N}_{z_t^N} & \gamma_t^T\varepsilon^{y_t^T}_{z_t^T} \end{bmatrix} \begin{bmatrix} \mathrm{d}\log z_t^N \\ \mathrm{d}\log z_t^T \end{bmatrix}. \tag{53}$$

Let the left-hand matrix be $\mathcal{H}^{-1}$ and the right-hand one $\mathcal{P}$. Provided the determinant of $\mathcal{H}^{-1}$ is nonzero, we invert:

$$\begin{bmatrix} \mathrm{d}\log c_t^T \\ \mathrm{d}\log p_t^N \end{bmatrix} = \mathcal{H}\,\mathcal{P} \begin{bmatrix} \mathrm{d}\log z_t^N \\ \mathrm{d}\log z_t^T \end{bmatrix}. \tag{54}$$

The determinant of $\mathcal{H}^{-1}$ equals

$$\Delta = \left[\tfrac{1}{1+\eta} + \varepsilon^{c_t^N}_{p_t^N}\right] - \left(\gamma_t^N(1+\varepsilon^{y_t^N}_{p_t^N}) + \gamma_t^T \varepsilon^{y_t^T}_{p_t^N}\right).$$

Using the nontradable market clearing condition, one can show

$$\varepsilon^{c_t^N}_{p_t^N} = \delta_t^N \varepsilon^{y_t^N}_{p_t^N} + (1-\delta_t^N)(\varepsilon^{y_t^T}_{p_t^N} - 1),$$

where

$$\delta_t^N = \frac{(1-\alpha_N^N)y_t^N}{c_t^N}, \qquad 1-\delta_t^N = -\frac{\alpha_N^T y_t^T / p_t^N}{c_t^N}.$$

By construction, $\delta_t^N \geq 1$. Substituting into Δ yields

$$\Delta = \frac{1}{1+\eta} - \gamma_t^N + (\delta_t^N - 1) + (\delta_t^N - \gamma_t^N)\varepsilon^{y_t^N}_{p_t^N} + (1-\gamma_t^T - \delta_t^N)\varepsilon^{y_t^T}_{p_t^N}.$$

Under our parameter restrictions, $\eta > -1$, $\gamma_t^N \in [0,1]$, $\gamma_t^T \geq 0$, $\delta_t^N \geq 1$, $\varepsilon^{y_t^N}_{p_t^N} \geq 0$, $\varepsilon^{y_t^T}_{p_t^N} \leq 0$, one can verify $\Delta > 0$. Define

$$\mathcal{K} = \Delta^{-1} = \frac{1}{\frac{1}{1+\eta} - \gamma_t^N + (\delta_t^N - 1) + (\delta_t^N - \gamma_t^N)\varepsilon^{y_t^N}_{p_t^N} + (1-\gamma_t^T - \delta_t^N)\varepsilon^{y_t^T}_{p_t^N}}. \tag{55}$$

We now focus on the effect of a tradable productivity shock, setting $\mathrm{d}\log z_t^N = 0$ and $\mathrm{d}\log z_t^T \neq 0$. After some algebra, the first row of (54) yields

$$\frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} = \mathcal{K}\Big[-\left(\gamma_t^N(1+\varepsilon^{y_t^N}_{p_t^N}) + \gamma_t^T \varepsilon^{y_t^T}_{p_t^N}\right)\varepsilon^{c_t^N}_{z_t^T} + \left(\tfrac{1}{1+\eta} + \varepsilon^{c_t^N}_{p_t^N}\right)\gamma_t^T \varepsilon^{y_t^T}_{z_t^T}\Big].$$

Using $\varepsilon^{c_t^N}_{z_t^T} = (1-\delta_t^N)\varepsilon^{y_t^T}_{z_t^T}$ and the expression for $\varepsilon^{c_t^N}_{p_t^N}$, this simplifies to

$$\frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} = \mathcal{K}\Big[(\gamma_t^N + \gamma_t^T)(\delta_t^N - 1) + \left(\gamma_t^N(\delta_t^N - 1) + \delta_t^N \gamma_t^T\right)\varepsilon^{y_t^N}_{p_t^N} + \tfrac{\gamma_t^T}{1+\eta}\Big]\varepsilon^{y_t^T}_{z_t^T}.$$

Similarly, the second row of (54) yields

$$\frac{\mathrm{d}\log p_t^N}{\mathrm{d}\log z_t^T} = \mathcal{K}\left[(\delta_t^N - 1) + \gamma_t^T\right]\varepsilon_{z_t^T}^{y_t^T}.$$

Since $\mathcal{K} > 0$, $\varepsilon_{z_t^T}^{y_t^T} > 0$, $\delta_t^N \geq 1$, and $\gamma_t^T \geq 0$, both derivatives are non-negative. Thus, a negative tradable productivity shock reduces c_t^T and p_t^N. This proves Proposition 3.

For aggregate consumption, note from the Hicksian demand for tradables under CES preferences that

$$\mathrm{d}\log c_t^T = \frac{1}{1+\eta}\,\mathrm{d}\log p_t + \mathrm{d}\log c_t = \frac{1}{1+\eta}(1-\omega)\,\mathrm{d}\log p_t^N + \mathrm{d}\log c_t,$$

so

$$\frac{\mathrm{d}\log c_t}{\mathrm{d}\log z_t^T} = \frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} - \frac{1-\omega}{1+\eta}\frac{\mathrm{d}\log p_t^N}{\mathrm{d}\log z_t^T},$$

which can be expressed in terms of the same sufficient statistics.

Justification for $\gamma_t^N \in [0,1]$

Recall

$$\gamma_t^N = \frac{\kappa_N \pi_t^N}{c_t^T} = \frac{(\kappa(1-\alpha_N^N - \alpha_T^N) - \alpha_T^N)p_t^N y_t^N}{c_t^T}.$$

To have $\gamma_t^N \geq 0$, it suffices that

$$\kappa(1-\alpha_N^N - \alpha_T^N) - \alpha_T^N \geq 0 \quad \Leftrightarrow \quad \kappa \geq \frac{\alpha_T^N}{1-\alpha_N^N-\alpha_T^N} = \frac{m_{Tt}^N}{\pi_t^N} \equiv \tilde{\alpha}_T^N.$$

This indicates that the collateral parameter κ must be at least as large as the ratio of non-tradable spending on tradable inputs to nontradable profits; otherwise, the effective κ_N would be negative and the BB curve would slope down. Under this condition, one can also show that $\gamma_t^N < 1$, since $\gamma_t^N \geq 1$ would imply an inconsistency with the resource constraint (that is, it would require $c_t^T \leq 0$ once the BB identity is imposed). Hence, for parameter values of interest, $\gamma_t^N \in [0,1]$.

A.4 Proof of Proposition 4

Start from the general representation in (54) and define the PP and BB elasticities as above:

$$\varepsilon_t^{PP} = \left(\frac{1}{1+\eta} + \varepsilon_{p_t^N}^{c_t^N}\right)^{-1}, \qquad \varepsilon_t^{BB} = \left(\gamma_t^N(1+\varepsilon_{p_t^N}^{y_t^N}) + \gamma_t^T \varepsilon_{p_t^N}^{y_t^T}\right)^{-1}.$$

Then, we rewrite (53) as

$$\begin{bmatrix} \mathrm{d}\log c_t^T \\ \mathrm{d}\log p_t^N \end{bmatrix} = \frac{1}{(\varepsilon_t^{PP})^{-1} - (\varepsilon_t^{BB})^{-1}} \begin{bmatrix} -(\varepsilon_t^{BB})^{-1} & (\varepsilon_t^{PP})^{-1} \\ -1 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{z_t^N}^{c_t^N} & \varepsilon_{z_t^T}^{c_t^N} \\ \gamma_t^N \varepsilon_{z_t^N}^{y_t^N} & \gamma_t^T \varepsilon_{z_t^T}^{y_t^T} \end{bmatrix} \begin{bmatrix} \mathrm{d}\log z_t^N \\ \mathrm{d}\log z_t^T \end{bmatrix}.$$

Consider a pure tradable shock: $\mathrm{d}\log z_t^T \neq 0$, $\mathrm{d}\log z_t^N = 0$. Then

$$\begin{bmatrix} \mathrm{d}\log c_t^T \\ \mathrm{d}\log p_t^N \end{bmatrix} = \frac{1}{(\varepsilon_t^{PP})^{-1} - (\varepsilon_t^{BB})^{-1}} \begin{bmatrix} -(\varepsilon_t^{BB})^{-1} & (\varepsilon_t^{PP})^{-1} \\ -1 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{z_t^T}^{c_t^N} \\ \gamma_t^T \varepsilon_{z_t^T}^{y_t^T} \end{bmatrix} \mathrm{d}\log z_t^T.$$

Thus,

$$\begin{aligned} \frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} &= \frac{1}{(\varepsilon_t^{PP})^{-1} - (\varepsilon_t^{BB})^{-1}} \Big(-\varepsilon_{z_t^T}^{c_t^N} (\varepsilon_t^{BB})^{-1} + \gamma_t^T \varepsilon_{z_t^T}^{y_t^T} (\varepsilon_t^{PP})^{-1} \Big), \\ \frac{\mathrm{d}\log p_t^N}{\mathrm{d}\log z_t^T} &= \frac{1}{(\varepsilon_t^{PP})^{-1} - (\varepsilon_t^{BB})^{-1}} \Big(-\varepsilon_{z_t^T}^{c_t^N} + \gamma_t^T \varepsilon_{z_t^T}^{y_t^T} \Big). \end{aligned}$$

Under the diagonal and NT←T examples in the main text, the tradable sector does not directly use nontradables as inputs, so $\varepsilon_{z_t^T}^{c_t^N} = 0$. Moreover, the direct tradable supply elasticity $\varepsilon_{z_t^T}^{y_t^T}$ is the same across the two networks because the tradable production parameters are held fixed. Hence,

$$\begin{aligned} \frac{\mathrm{d}\log c_t^T}{\mathrm{d}\log z_t^T} &= \frac{1}{(\varepsilon_t^{PP})^{-1} - (\varepsilon_t^{BB})^{-1}} \gamma_t^T \varepsilon_{z_t^T}^{y_t^T} (\varepsilon_t^{PP})^{-1} \\ &= \frac{\varepsilon_t^{BB} \varepsilon_t^{PP}}{\varepsilon_t^{BB} - \varepsilon_t^{PP}} \gamma_t^T \varepsilon_{z_t^T}^{y_t^T} (\varepsilon_t^{PP})^{-1} \\ &= \frac{\varepsilon_t^{BB}}{\varepsilon_t^{BB} - \varepsilon_t^{PP}} \gamma_t^T \varepsilon_{z_t^T}^{y_t^T}, \end{aligned}$$

and

$$\frac{\mathrm{d}\log p_t^N}{\mathrm{d}\log z_t^T} = \frac{1}{(\varepsilon_t^{PP})^{-1} - (\varepsilon_t^{BB})^{-1}} \gamma_t^T \varepsilon_{z_t^T}^{y_t^T}$$
$$= \frac{\varepsilon_t^{BB}\varepsilon_t^{PP}}{\varepsilon_t^{BB} - \varepsilon_t^{PP}} \gamma_t^T \varepsilon_{z_t^T}^{y_t^T}.$$

Let $G \in \{D, N\}$ index the diagonal and NT←T networks. Evaluating at the marginally binding equilibrium, the condition

$$\left| \gamma^T(N) \frac{\varepsilon^{PP}(N)\varepsilon^{BB}(N)}{\varepsilon^{BB}(N) - \varepsilon^{PP}(N)} \right| \leq \left| \gamma^T(D) \frac{\varepsilon^{PP}(D)\varepsilon^{BB}(D)}{\varepsilon^{BB}(D) - \varepsilon^{PP}(D)} \right|$$

implies

$$\left| \frac{\mathrm{d}\log(c_t^T)^{NT\leftarrow T}}{\mathrm{d}\log z_t^T} \right| \leq \left| \frac{\mathrm{d}\log(c_t^T)^{\text{Diagonal}}}{\mathrm{d}\log z_t^T} \right|,$$
$$\left| \frac{\mathrm{d}\log(p_t^N)^{NT\leftarrow T}}{\mathrm{d}\log z_t^T} \right| \leq \left| \frac{\mathrm{d}\log(p_t^N)^{\text{Diagonal}}}{\mathrm{d}\log z_t^T} \right|.$$

This concludes the proof to Proposition 4.

A.5 Proof of Lemma 1

Fix a date t and suppress time subscripts for clarity. Let nominal GDP ($nGDP$) be

$$nGDP = p^N y^N + p^T y^T.$$

Define real GDP ($rGDP$) as a Divisia index, where changes in real GDP satisfy:

$$\mathrm{d}\log rGDP = \mathrm{d}\log nGDP - \mathrm{d}\log p^Y,$$

where $\mathrm{d}\log p^Y$ represents a change in the GDP deflator.

On the production side, firms solve

$$\max_{m_N^i, m_T^i} p^i y^i - p^N m_N^i - m_T^i,$$

subject to the Cobb-Douglas technologies (8)–(11). The borrowing constraint affects only households' intertemporal problem and does not appear in these static FOCs. Hence, conditional on prices and productivities (p^N, z^N, z^T), the production side is identical to a frictionless competitive network economy with no wedges.

Standard results for such economies (Hulten's theorem) imply that the first-order effect of a small productivity shock $(\mathrm{d}\log z^N, \mathrm{d}\log z^T)$ on $rGDP$ is

$$\mathrm{d}\log rGDP = \lambda_N \mathrm{d}\log z^N + \lambda_T \mathrm{d}\log z^T,$$

where $\lambda_i \equiv p^i y^i / nGDP$ are Domar weights. Intuitively, Domar weights coincide with the fixed-point solution of the Leontief system that maps sectoral output shares onto sales shares, and the marginal contribution of a productivity change in sector i to aggregate output is proportional to its sales-to-GDP ratio.

The borrowing constraint affects the equilibrium values of (p^N, y^N, y^T), and thus the levels of λ_i, but it does not alter the structure of the first-order derivative of $\log rGDP$ with respect to $(\log z^N, \log z^T)$ because it does not enter firms' FOCs or introduce sectoral wedges. Therefore, the Hulten formula holds exactly as in the frictionless case, proving Lemma 1.

A.6 Proof of Proposition 5

We now show that there exists a subsidy that mitigates the Sudden Stop effect on consumption at the cost of distorting the firms' first-order condition. Before stating our argument in terms of the subsidy, the following lemma shows the condition under which the Sudden Stop effect on aggregate consumption is larger in the diagonal economy than in the $NT \leftarrow T$ economy:

Lemma 2 (Aggregate consumption response)**.** *In the two-sector model, without sectoral taxes* *or subsidies, the decline in aggregate consumption after a Sudden Stop is larger in the diagonal economy than in the $NT \leftarrow T$ economy*

$$\left.\frac{\mathrm{d}\log c_t}{\mathrm{d}\log z_t^T}\right|_{G=D} \geq \left.\frac{\mathrm{d}\log c_t}{\mathrm{d}\log z_t^T}\right|_{G=N}$$

if:

$$\frac{\frac{\varepsilon^{BB}(D)\varepsilon^{PP}(D)\gamma^T(D)}{(\varepsilon^{BB}(D)-\varepsilon^{PP}(D))}}{\frac{\varepsilon^{BB}(N)\varepsilon^{PP}(N)\gamma^T(N)}{(\varepsilon^{BB}(N)-\varepsilon^{PP}(N))}} \geq \frac{1}{\omega}\left(\frac{\varepsilon^{PP}(D)-\varepsilon^{PP}(N)(1-\omega)}{\varepsilon^{PP}(N)}\right).$$

Proof. To save on notation, we will let $\mathcal{R}_y^x(G) = \frac{\mathrm{d}\log x}{\mathrm{d}\log y}$ denote the general equilibrium response of a variable x to variable y under network G. We also omit time indexes whenever it causes no confusion.

From the proof of Proposition 4, we write

$$\mathcal{R}_{z^T}^{p^N}(G) = \varepsilon^{PP}(G)\mathcal{R}_{z^T}^{c^T}(G),$$

where $G = \{D, N\}$ represents either the diagonal or the $NT \leftarrow T$ economy.

Using the preceding result, we can write an expression for aggregate consumption under network G:

$$\mathcal{R}_{z^T}^{c}(G) = \left(1 - \frac{\varepsilon^{PP}(G)(1-\omega)}{(1+\eta)}\right)\mathcal{R}_{z^T}^{c^T}(G).$$

For future reference, recall from Proposition 4

$$\mathcal{R}_{z^T}^{c^T}(G) = \frac{\varepsilon^{BB}(G)}{\varepsilon^{BB}(G)-\varepsilon^{PP}(G)}\gamma^T(G)\varepsilon_{z^T}^{y^T},$$

where $\varepsilon_{z^T}^{y^T}$ is not indexed by the network, as both networks exhibit the same value.

Now consider the diagonal and the $NT \leftarrow T$ economy. For aggregate consumption to decline more under the diagonal economy, we require

$$\frac{\mathcal{R}_{z^T}^{c}(D)}{\mathcal{R}_{z^T}^{c}(N)} \geq 1,$$

$$\frac{\left(1-\frac{\varepsilon^{PP}(D)(1-\omega)}{(1+\eta)}\right)\mathcal{R}^{c^T}_{z^T}(D)}{\left(1-\frac{\varepsilon^{PP}(N)(1-\omega)}{(1+\eta)}\right)\mathcal{R}^{c^T}_{z^T}(N)}\geq 1,$$

$$\frac{\left(1-\frac{\varepsilon^{PP}(D)(1-\omega)}{(1+\eta)}\right)\frac{\varepsilon^{BB}(D)}{\varepsilon^{BB}(D)-\varepsilon^{PP}(D)}\gamma^T(D)\varepsilon^{y^T}_{z^T}}{\left(1-\frac{\varepsilon^{PP}(N)(1-\omega)}{(1+\eta)}\right)\frac{\varepsilon^{BB}(N)}{\varepsilon^{BB}(N)-\varepsilon^{PP}(N)}\gamma^T(N)\varepsilon^{y^T}_{z^T}}\geq 1.$$

We note $\varepsilon^{PP}(D)=(1+\eta)$. Using this result, eliminating $\varepsilon^{y^T}_{z^T}$ and rearranging the preceding expression, we derive:

$$\frac{\frac{\varepsilon^{BB}(D)\varepsilon^{PP}(D)\gamma^T(D)}{(\varepsilon^{BB}(D)-\varepsilon^{PP}(D))}}{\frac{\varepsilon^{BB}(N)\varepsilon^{PP}(N)\gamma^T(N)}{(\varepsilon^{BB}(N)-\varepsilon^{PP}(N))}}\geq\frac{1}{\omega}\left(\frac{\varepsilon^{PP}(D)-\varepsilon^{PP}(N)(1-\omega)}{\varepsilon^{PP}(N)}\right),$$

which is the stated condition. This concludes the proof. □

The condition highlighted here is stronger than our previous condition when deriving Proposition 4 because the right-hand side of the inequality is ≥ 1.

We now prove that a subsidy can generate a continuous path in the network space. In doing so, we will prove that there exists a set of subsidies that mitigates the impact of the sudden stop on aggregate consumption.

Let α^D denote the *limiting* diagonal network ($\alpha^N_T(D)\to 0$) and α^N the NT←T network. We construct a one-dimensional family of networks $\{\tilde{\alpha}(\tau)\}_{\tau\in[0,\bar{\tau}]}$ by introducing a set of ad valorem subsidies $\tau=\{\tau^i_j\}$ on intermediate inputs usage. For example, a subsidy on tradable inputs reduces the tradable price paid by the nontradable sector from 1 to $(1-\tau^{NT}_T)$.

Let $\tilde{\alpha}^i_j(\tau)=\frac{p^j(\tau)m^i_j(\tau)}{p^i(\tau)y^i(\tau)}$ denote the effective share of intermediate input j in sector i's gross output, given τ. Absent subsidies, the effective share equals the Cobb-Douglas input coefficient, $\tilde{\alpha}^i_j(0)=\frac{p^j(0)m^i_j(0)}{p^i(0)y^i(0)}=\alpha^i_j$.

The planner's desired expenditure shares $(\tilde{\alpha}^N_N(\tau),\tilde{\alpha}^N_T(\tau))$ move continuously from the diagonal to the $NT\leftarrow T$ economy while holding fixed $\tilde{\alpha}^N_N(\tau)+\tilde{\alpha}^N_T(\tau)$. Given our Cobb-Douglas assumption and regularity conditions, the mapping $\tau\mapsto\tilde{\alpha}(\tau)$ is continuous, satisfies $\tilde{\alpha}(0)=\alpha^D$, and for some $\bar{\tau}$ hits the $NT\leftarrow T$ network exactly, $\tilde{\alpha}(\bar{\tau})=\alpha^N$.

For each τ, define

$$\mathcal{R}^{c}_{z^T}(\tau) \equiv \mathcal{R}^{c}_{z^T}(\alpha(\tau)) = \left.\frac{\mathrm{d}\log c}{\mathrm{d}\log z^T}\right|_{\text{under network } \alpha(\tau)}.$$

This expression is continuous in each of the parameters and shares. Because $\alpha(\tau)$ is continuous in τ, all relevant shares are continuous in τ as well. Therefore, $\mathcal{R}^{c}_{z^T}(\tau)$ is continuous in τ.

By construction, $\alpha(0) = \alpha^D$ and $\alpha(\bar{\tau}) = \alpha^N$. Since $\mathcal{R}^{c}_{z^T}(D) \geq \mathcal{R}^{c}_{z^T}(N)$, then

$$\mathcal{R}^{c}_{z^T}(0) \geq \mathcal{R}^{c}_{z^T}(\bar{\tau}).$$

By continuity, there exists τ^* such that

$$\mathcal{R}^{c}_{z^T}(0) \geq \mathcal{R}^{c}_{z^T}(\tau^*).$$

Therefore, there is a set of subsidies that mitigates the Sudden Stop effect on aggregate consumption.

The set of subsidies τ^* introduces sectoral wedges; it changes the static first-order conditions of nontradable firms and therefore breaks the sufficiency of Domar weights for the response of real GDP (Hulten's theorem). Nevertheless, it strictly reduces the amplification of a tradable productivity shock on aggregate consumption. This establishes Proposition 5.

B Numerical Analysis of the Simple Model

In this section, we present a numerical analysis of the perfect foresight version of the two-sector model. We calibrate the network parameters to mimic key features of emerging economies and compare Sudden Stop dynamics across alternative production structures.

Following Section 2, we first solve for the equilibrium in different economies that all start from a marginally binding borrowing constraint. We consider four cases:

1. A *baseline* economy in which the tradable and nontradable sectors are interconnected.

2. A *diagonal* economy in which the two sectors operate independently and do not use each other's inputs.

3. An economy in which the tradable sector uses only tradable inputs, while the nontradable sector uses both goods (*T No NT*).

4. An economy in which the nontradable sector uses only nontradable inputs, while the tradable sector uses both goods (*NT No T*).

We use the simple model to illustrate how different production structures affect the severity of Sudden Stops, defined as wealth-neutral collapses in tradable productivity that trigger a binding borrowing constraint and the associated Fisherian deflation.

For the baseline case, we set $\eta = 1.2035$, $\beta = 1/1.04$, $R = 1.04$, $\omega = 0.3$, and $\kappa = 0.3$, following Bianchi (2011). We choose production parameters so that the tradable sector uses $\alpha_T^T = 0.46$ and $\alpha_N^T = 0.10$, while the nontradable sector uses $\alpha_T^N = 0.21$ and $\alpha_N^N = 0.18$. We set $z^T = z^N = 1$ in the initial equilibrium.

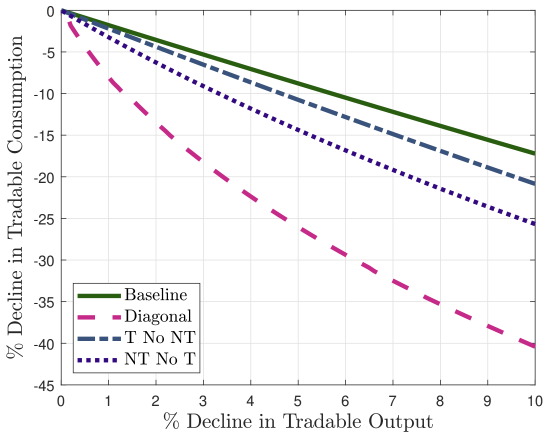
For the diagonal economy, we choose $\alpha_T^T = 0.56$ and $\alpha_N^N = 0.39$ so that the degrees of decreasing returns match those of the baseline economy. These choices do not automatically guarantee that the initial allocation of (c^T, p^N) is the same across models, so we adjust z^T and z^N to ensure that the initial c^T and p^N coincide across economies. The remaining parameters are identical to the baseline.

The hybrid economies are parametrized similarly. In the *T No NT* economy, we set $\alpha_T^T = 0.56$, $\alpha_N^T = 0$, $\alpha_T^N = 0.21$, and $\alpha_N^N = 0.18$. In the *NT No T* economy, we set $\alpha_T^T = 0.46$, $\alpha_N^T = 0.10$, $\alpha_T^N = 0$, and $\alpha_N^N = 0.39$. In both cases, we recalibrate z^T and z^N so that the initial (c^T, p^N) matches the baseline.

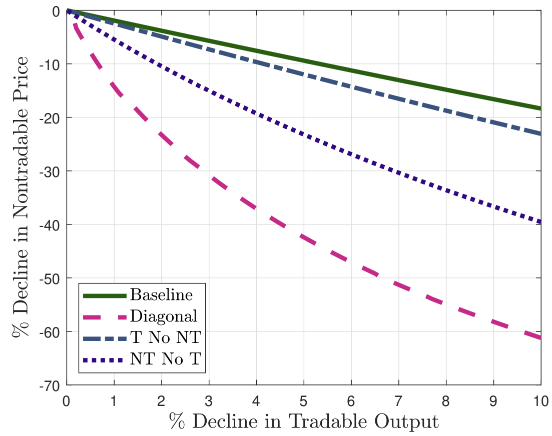
We then simulate Sudden Stops by introducing shocks of varying severity to z^T. Figure 10 summarizes the responses of tradable consumption, the relative price of nontradables, and the debt-to-GDP ratio across the four economies.

Figure 10: Sudden Stops across Different Production Structures

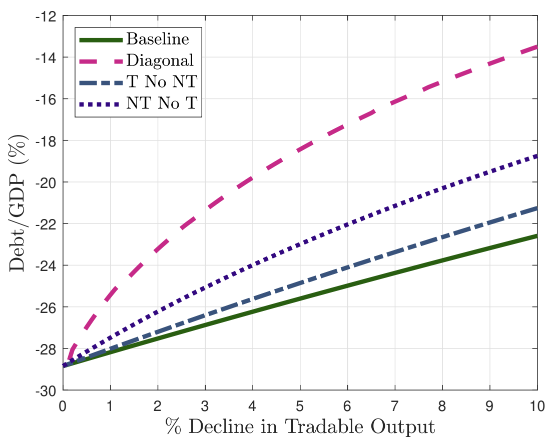
(a) Tradable Consumption (c^T)



(b) Nontradable Price (p^N)



(c) Debt-to-GDP (b/GDP)



The solid green line shows the baseline economy; the dashed pink line corresponds to the diagonal economy; the dash-dotted blue line to the *T No NT* economy; and the dotted purple line to the *NT No T* economy.

Consistent with the analytical results, sectoral linkages act as a hedge against adverse tradable productivity shocks. When z^T falls by 10 percent, tradable consumption in the baseline economy falls by about 17 percent, whereas in the diagonal economy, it collapses by almost 40 percent. The relative price of nontradables and the debt-to-GDP ratio also display a much steeper deflationary spiral and deleveraging in the diagonal economy.

The hybrid cases lie in between: When only one sector is disconnected from the other, the amplification relative to the baseline is present but substantially milder than in the fully disconnected case. For the particular parametrization shown, the economy in which the nontradable sector does not use tradables as inputs (*NT No T*) tends to exhibit the worst hedging properties among the hybrids, though still much better than the diagonal economy.

These numerical experiments confirm that the structure of production networks can substantially attenuate or amplify Sudden Stops and that these effects become more pronounced for larger shocks.

C Sector Definitions and Country Classifications

This appendix documents the mapping from detailed OECD input–output sectors to the three broad sectors used in the analysis: *commodities*, *tradables* (non-commodity), and *nontradables*. The underlying sectoral classification follows the OECD 2021 IO release. As discussed in the main text, sectors are assigned to the tradable or nontradable group based on their average gross trade intensity across countries; within tradables, we separate commodity-producing sectors.

Table 6: Sector Names and Definitions

OECD IO Sector	Broad Sector
Agriculture, hunting, forestry	Commodity
Fishing and aquaculture	Commodity
Mining and quarrying, energy producing products	Commodity
Mining and quarrying, non-energy producing products	Commodity
Mining support service activities	Tradable
Food products, beverages and tobacco	Tradable
Textiles, textile products, leather and footwear	Tradable
Wood and products of wood and cork	Tradable
Paper products and printing	Tradable
Coke and refined petroleum products	Tradable
Chemical and chemical products	Tradable
Pharmaceuticals, medicinal chemical and botanical products	Tradable
Rubber and plastics products	Tradable
Other non-metallic mineral products	Tradable
Basic metals	Commodity
Fabricated metal products	Tradable
Computer, electronic and optical equipment	Tradable
Electrical equipment	Tradable
Machinery and equipment, nec	Tradable
Motor vehicles, trailers and semi-trailers	Tradable
Other transport equipment	Tradable
Manufacturing nec; repair and installation of machinery	Tradable
Electricity, gas, steam and air conditioning supply	Nontradable
Water supply; sewerage, waste management and remediation activities	Nontradable
Construction	Nontradable
Wholesale and retail trade; repair of motor vehicles	Tradable
Land transport and transport via pipelines	Tradable
Water transport	Tradable
Air transport	Tradable
Warehousing and support activities for transportation	Tradable
Postal and courier activities	Nontradable
Accommodation and food service activities	Nontradable
Publishing, audiovisual and broadcasting activities	Nontradable
Telecommunications	Nontradable
IT and other information services	Tradable
Financial and insurance activities	Nontradable
Real estate activities	Nontradable
Professional, scientific and technical activities	Nontradable
Administrative and support services	Nontradable
Public administration and defence; compulsory social security	Nontradable
Education	Nontradable
Human health and social work activities	Nontradable
Arts, entertainment and recreation	Nontradable
Other service activities	Nontradable

Note: This table reports the mapping from detailed OECD IO sectors to the three broad sectors used in the empirical and quantitative analysis: commodities, tradables, and nontradables. "nec" denotes "not elsewhere classified."

Table 7: Country Classification by Development Group

Emerging	Advanced
Argentina	Australia
Bulgaria	Austria
Brazil	Canada
Chile	Switzerland
China	Germany
Colombia	Denmark
Croatia	Spain
Hungary	Finland
Indonesia	France
Korea	United Kingdom
Morocco	Greece
Mexico	Iceland
Malaysia	Italy
Peru	Japan
Philippines	Netherlands
Poland	Norway
Russian Federation	New Zealand
Thailand	Portugal
Tunisia	Sweden
Türkiye	United States
South Africa	

Note: Country groups follow the classification in Bianchi and Mendoza (2020).

D Planner's Problem: Derivations

This appendix collects the conditions for the planner's problem and the expressions used in the main text to characterize the pecuniary externality and the production-side wedge.

D.1 Planner's problem and prices

The planner solves

$$V(b, \boldsymbol{e}) = \max_{\boldsymbol{x}} U(c^C, c^X, c^N) + \beta \mathbb{E}\left[V(b', \boldsymbol{e}')\right],$$

subject to

$$c^C + m_C^C + m_C^X + m_C^N + qb' = y^C + p^X(c^C, c^X)\hat{c}^X\big(p^X(c^C, c^X)\big) + b, \quad (\lambda_1) \tag{56}$$

$$c^X + \hat{c}^X\big(p^X(c^C, c^X)\big) + m_X^C + m_X^X + m_X^N = y^X(m_N^X, m_X^X, m_C^X), \qquad (\lambda_2) \tag{57}$$

$$c^N + m_N^C + m_N^X + m_N^N = y^N(m_N^N, m_X^N, m_C^N), \qquad (\lambda_3) \tag{58}$$

$$qb' \geq -\kappa(\pi^C + \pi^X + \pi^N) \equiv -\kappa\pi, \qquad (\mu) \tag{59}$$

where $\boldsymbol{x} = \{c^C, c^X, c^N, m_N^N, m_X^N, m_C^N, m_N^X, m_X^X, m_C^X, m_N^C, m_X^C, m_C^C, b'\}$ collects all choice variables and $\boldsymbol{e}$ collects the exogenous productivities z^i.

The planner takes as given the same pricing schedules as in the competitive equilibrium; the relative prices of the non-commodity tradable and the nontradable are functions of consumptions,

$$p^X = p^X(c^C, c^X),$$
$$p^N = p^N(c^C, c^N),$$

and the export demand for the differentiated tradable is

$$\hat{c}^X = \hat{c}^X\big(p^X(c^C, c^X)\big),$$

with export demand elasticity

$$\chi \equiv \frac{\partial \hat{c}^X}{\partial p^X}\frac{p^X}{\hat{c}^X} = \frac{\partial \log \hat{c}^X}{\partial \log p^X}.$$

Profits in each sector are given by

$$\pi^i = \pi^i\big(p^N(c^C, c^N), p^X(c^C, c^X), y^i, \{m^i_j\}_{j\in\{C,X,N\}}\big), \qquad i \in \{C, X, N\},$$

and aggregate collateral is $\pi = \pi^C + \pi^X + \pi^N$.

D.2 First-order conditions

Consumption. The first-order conditions with respect to c^C, c^X and c^N are

$$c^C: \quad U_C - \lambda_1\Big(1 - \frac{\partial p^X}{\partial c^C}\hat{c}^X - p^X\frac{\partial \hat{c}^X}{\partial p^X}\frac{\partial p^X}{\partial c^C}\Big) - \lambda_2\frac{\partial \hat{c}^X}{\partial p^X}\frac{\partial p^X}{\partial c^C} + \kappa\mu\frac{\partial \pi}{\partial c^C} = 0, \tag{60}$$

$$c^X: \quad U_X + \lambda_1\Big(\frac{\partial p^X}{\partial c^X}\hat{c}^X + p^X\frac{\partial \hat{c}^X}{\partial p^X}\frac{\partial p^X}{\partial c^X}\Big) - \lambda_2\Big(1 + \frac{\partial \hat{c}^X}{\partial p^X}\frac{\partial p^X}{\partial c^X}\Big) + \kappa\mu\frac{\partial \pi}{\partial c^X} = 0, \tag{61}$$

$$c^N: \quad U_N - \lambda_3 + \kappa\mu\frac{\partial \pi}{\partial c^N} = 0. \tag{62}$$

Inputs. For compactness, write m^i_j for the input from sector j used in sector i, and $y^i = y^i(m^i_C, m^i_X, m^i_N)$. The FOCs for all intermediate inputs can be written as

$$m^N_j: \quad -\lambda_j + \lambda_3\frac{\partial y^N}{\partial m^N_j} + \mu\kappa\frac{\partial \pi^N}{\partial m^N_j} = 0, \qquad j \in \{C, X, N\}, \tag{63}$$

$$m^X_j: \quad -\lambda_j + \lambda_2\frac{\partial y^X}{\partial m^X_j} + \mu\kappa\frac{\partial \pi^X}{\partial m^X_j} = 0, \qquad j \in \{C, X, N\}, \tag{64}$$

$$m^C_j: \quad -\lambda_j + \lambda_1\frac{\partial y^C}{\partial m^C_j} + \mu\kappa\frac{\partial \pi^C}{\partial m^C_j} = 0, \qquad j \in \{C, X, N\}. \tag{65}$$

In particular, the "own-input" conditions $j = i$ imply

$$\frac{\partial y^N}{\partial m^N_N} = 1, \quad \frac{\partial y^X}{\partial m^X_X} = 1, \quad \frac{\partial y^C}{\partial m^C_C} = 1, \tag{66}$$

so that the marginal product of each sector's own input equals its cost.

Bonds, envelope, and collateral constraint. The FOC for b' is

$$b': \quad \beta \mathbb{E}_t \left[\frac{\partial V'}{\partial b'} \right] - \lambda_1 q + q\mu = 0,$$

and the envelope condition with respect to b is

$$b: \quad \frac{\partial V}{\partial b} = \lambda_1.$$

Combining both delivers the bond Euler equation:

$$\lambda_1 = \frac{\beta}{q} \mathbb{E}_t \left[\lambda_1' \right] + \mu. \tag{67}$$

The complementary slackness condition for the collateral constraint (59) is

$$\left(qb' + \kappa \pi \right) \mu = 0. \tag{68}$$

D.3 Profit derivatives and collateral response

We now collect expressions used in the main text to characterize the pecuniary externality.

Profit derivatives with respect to inputs. Using the sectoral profits

$$\pi^i = p^i y^i - \sum_{j \in \{C,X,N\}} p^j m_j^i, \qquad i \in \{C, X, N\},$$

the derivative with respect to an input m_j^i is

$$\frac{\partial \pi^i}{\partial m_j^i} = p^i \frac{\partial y^i}{\partial m_j^i} - p^j, \qquad \forall i, j \in \{C, X, N\}. \tag{69}$$

Using the pricing schedules from the competitive equilibrium, relative prices satisfy

$$p^i = \frac{U_i}{U_C}, \qquad i \in \{C, X, N\},$$

so we can rewrite (69) as

$$\frac{\partial \pi^i}{\partial m_j^i} = \frac{U_i}{U_C}\frac{\partial y^i}{\partial m_j^i} - \frac{U_j}{U_C}, \qquad \forall i, j \in \{C, X, N\}. \tag{70}$$

Profit derivatives with respect to consumption. Let $\pi = \pi^C + \pi^X + \pi^N$. Using

$$\pi^N = p^N y^N - \sum_j p^j m_N^j, \qquad \pi^X = p^X y^X - \sum_j p^j m_X^j, \qquad \pi^C = y^C - \sum_j p^j m_C^j,$$

and the resource constraints (56)–(58), it follows that

$$\frac{\partial \pi}{\partial c^N} = \frac{\partial p^N}{\partial c^N}\left(y^N - \sum_j m_N^j\right) = \frac{\partial p^N}{\partial c^N} c^N, \tag{71}$$

$$\frac{\partial \pi}{\partial c^X} = \frac{\partial p^X}{\partial c^X}\left(y^X - \sum_j m_X^j\right) = \frac{\partial p^X}{\partial c^X}(c^X + \hat{c}^X), \tag{72}$$

$$\frac{\partial \pi}{\partial c^C} = \frac{\partial p^N}{\partial c^C}\left(y^N - \sum_j m_N^j\right) + \frac{\partial p^X}{\partial c^C}\left(y^X - \sum_j m_X^j\right) \tag{73}$$

$$= \frac{\partial p^N}{\partial c^C} c^N + \frac{\partial p^X}{\partial c^C}(c^X + \hat{c}^X). \tag{74}$$

Using (74), the definition of the export demand elasticity χ, and the structure of the tradable aggregator, one can rewrite the FOC for c^C in (60) in the wedge form reported in the main text:

$$\lambda_1 = U_C + \Theta, \tag{75}$$

$$\Theta = \underbrace{\frac{\mu\,\kappa\,\frac{\partial \pi}{\partial c^C}}{1 - \frac{\partial p^X}{\partial c^C}\hat{c}^X \frac{\eta_T}{1+\eta_T}}}_{\text{Collateral (pecuniary) externality}} + \underbrace{\frac{U_C \frac{\partial p^X}{\partial c^C}\hat{c}^X \frac{\eta_T}{1+\eta_T} - \lambda_2 \frac{\partial \hat{c}^X}{\partial c^C}}{1 - \frac{\partial p^X}{\partial c^C}\hat{c}^X \frac{\eta_T}{1+\eta_T}}}_{\text{Terms-of-trade motive}}, \tag{76}$$

where η_T is the elasticity parameter from the tradable aggregator (see Section 4).

Similarly, combining (63) for m_C^N with (62) and the pricing relations yields the production-side wedge used in the main text:

$$p^N \frac{\partial y^N}{\partial m_C^N} = \frac{\lambda_1 + \mu\kappa}{U_C + \mu\kappa\left(1 + \frac{1}{p^N}\frac{\partial \pi}{\partial c^N}\right)}, \tag{77}$$

which reduces to $p^N \partial y^N / \partial m_C^N = 1$ when $\mu = 0$ and differs from one when the collateral constraint binds. The term $\partial \pi / \partial c^N$ embeds the production network via (74), so the strength of this production-side distortion depends on the input-output structure of the economy.