# Foreign Exchange Risk Management Spillovers Across the Production Network

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**Abstract**

Foreign exchange risk management is usually viewed as a decision that stabilizes the hedging firm's own cash flows. This paper shows that, with financial frictions and production networks, a firm's hedging also stabilizes its suppliers and customers. In a model of hedging in a production network, firms finance production before collecting revenue at a borrowing rate that falls with their financial position. By shifting resources across exchange-rate states, hedging changes a firm's borrowing costs, prices, and input purchases, and thereby the costs and demand of connected firms. Using new hand-collected data on U.S. firms' foreign exchange derivatives from 10-K filings, linked to their supply-chain relationships, I find that when a firm's customers (suppliers) first begin to hedge, the volatility of its sales (cost of goods sold) falls by 3.1 percentage points relative to matched firms. In a model calibrated to the U.S. input-output network, hedging offsets one-quarter to two-fifths of the volatility amplification generated by the borrowing-cost channel. An industry's own hedge accounts for almost all of the stabilization of its net worth, whereas the hedging of other industries accounts for about half of the stabilization of its output, and hedging affects other industries most when undertaken by central suppliers. Foreign exchange risk management is thus both a private stabilizer of financial positions and a network stabilizer of real activity.

*JEL Classification Numbers*: F31, F41, G32, E44
*Keywords*: exchange rate transmission, foreign exchange hedging, production networks, financial frictions, international finance

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# 1 Introduction

Understanding how exchange-rate shocks propagate through the economy is a central question in international economics and finance. For U.S. firms, the dominance of the dollar suggests that the question is of limited importance at first glance: 93 percent of U.S. imports and 97 percent of U.S. exports are invoiced in dollars (Goldberg and Tille, 2008; Gopinath, Itskhoki and Rigobon, 2010; Gopinath, 2015; Goldberg and Tille, 2016). However, dollar invoicing limits U.S. firms' transaction exposure, the revaluation of their foreign-currency receivables and payables (Adams and Verdelhan, 2021), but not their economic exposure, which takes two forms. On the export side, they face *foreign exchange demand risk*: foreign customers pay for dollar-invoiced goods with their own currencies, so a dollar appreciation raises the price these customers effectively pay and lowers their demand. On the import side, they face *foreign exchange price risk*: the dollar prices of imported inputs respond to the exchange rate, even though only 7 percent of U.S. imports are invoiced in foreign currencies.[1] Firms that neither import nor export are exposed as well, through domestic suppliers and customers whose costs and demand move with the exchange rate (Dhyne et al., 2021).[2]

Firms manage these exposures with financial derivatives. Using new data hand-collected from 10-K filings, Figure 1 shows that the share of U.S. firms using foreign exchange derivatives rose from about 12 percent in 2000 to more than 18 percent in recent years, while the average notional amount among hedging firms rose from less than 20 percent of sales to about 60 percent. Hedging is conventionally viewed as a firm-level decision: a firm hedges its own exposure to protect its own cash flows and investment (Froot, Scharfstein and Stein, 1993; Rampini, Sufi and Viswanathan, 2014). Production networks challenge this view. If hedging stabilizes the prices a firm charges and the inputs it buys, it also stabilizes the costs and demand of the firm's suppliers and customers. This paper asks whether such hedging spillovers exist, through which mechanism they operate, and whether they matter in the aggregate.

[1] For example, Intel Corporation's 2023 annual report notes that "an increase in the value of the dollar can increase the real cost to our customers of our products in those markets outside the U.S. where we sell in dollars," which describes demand risk, and that "a weakened dollar can increase the cost of expenses ... as well as non-U.S. dollar capital expenditures," which describes price risk. Consistent with these channels, a large literature documents that dollar appreciation lowers U.S. import prices and puts downward pressure on the prices of U.S. exporters (Campa and Goldberg, 2005; Goldberg and Campa, 2010; Gopinath and Itskhoki, 2010).

[2] U.S. firms are also exposed to exchange-rate risk through other channels, such as offshore production and competition from foreign firms. Appendix B.1 provides examples.

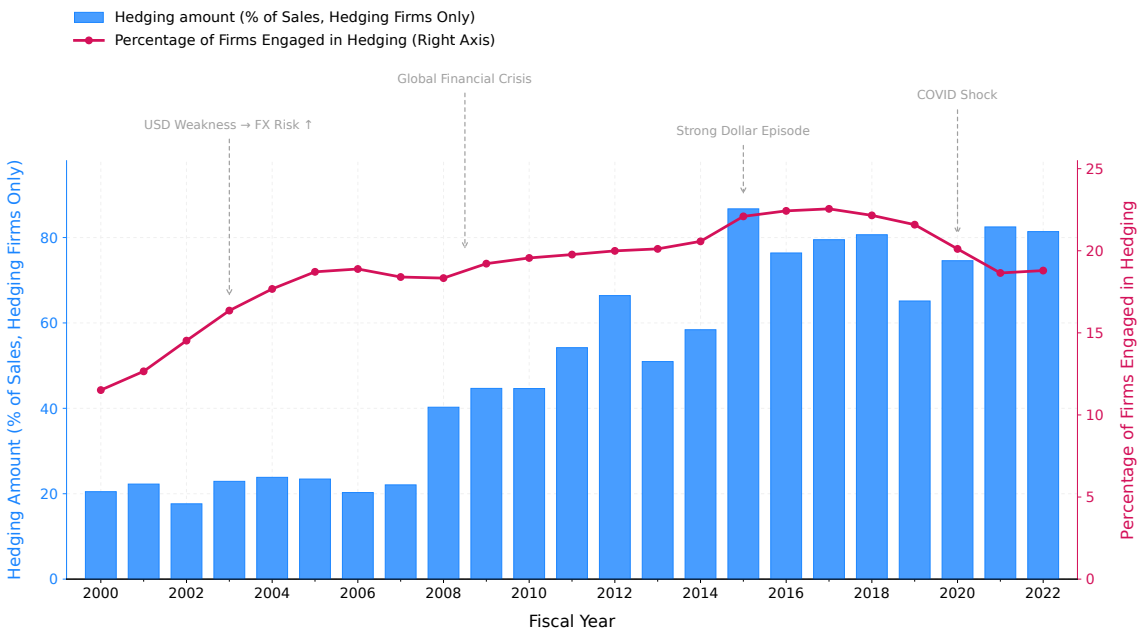



Figure 1: Foreign Exchange Hedging by U.S. Firms

*Notes:* This figure plots foreign exchange hedging by U.S. firms over fiscal years 2000–2022. The line (right axis) shows the percentage of firm-year observations that report using foreign exchange derivatives in their 10-K filings. The bars (left axis) report the average notional amount of foreign exchange derivatives relative to sales among hedging firms. Notional amounts classified as under-reported are kept at their recorded values rather than imputed upward, so the bars provide a conservative measure of hedging intensity. The data are hand-collected from firms' 10-K filings; Appendix C describes the collection and classification procedures.

I answer these questions by combining a model of hedging in a production network, new data on U.S. firms' derivative positions linked to their suppliers and customers, matched event-study evidence, and a quantitative version of the model calibrated to the U.S. input-output network. The main finding is that hedging spills over: when a firm's customers or suppliers begin to hedge, the firm's sales or production costs become more stable. The evidence points to borrowing costs as the channel. In the calibrated model, an industry's own hedge accounts for almost all of the stabilization of its net worth, but the hedging of other industries accounts for about half of the stabilization of its output. Foreign exchange hedging is therefore both a private stabilizer of financial positions and a network stabilizer of real activity.

The model combines the risk-management motive in Froot, Scharfstein and Stein (1993) and the working-capital financing in Almeida, Carvalho and Kim (2024) with dollar invoicing and price rigidity as in Gopinath et al. (2020) and vertical production linkages as in Acemoglu, Akcigit and Kerr (2016). Firms finance their production costs before collecting revenue, and the rate at which they borrow falls with their financial position.

A forward contract moves resources across exchange-rate states. Because the borrowing rate depends on the financial position, this transfer changes the firm's borrowing cost in each state and, because the firm repays its financed costs with interest, its marginal cost, its price, and its purchases from suppliers. I call this mechanism the *borrowing-cost channel*. Through it, a supplier's hedge changes the input prices its customers pay, and a customer's hedge changes the demand its suppliers face. The model delivers three results that guide the empirical analysis. First, a firm hedges to move resources toward the states in which they are most valuable, which depends on the size of its financed production bill and the slope of its credit schedule. In benchmark examples, an importer hedges against a dollar depreciation, whereas an exporter hedges against an appreciation only when its credit schedule is sufficiently steep; with a constant borrowing rate, firms do not hedge at all. Second, a hedge that moves resources toward the state in which net worth is low stabilizes the firm's net worth and borrowing costs. Third, a supplier's hedge can dampen the exchange-rate sensitivity of the input prices its customers pay, and a customer's hedge can stabilize the purchases it makes from its suppliers. Because a firm's own hedge acts on its finances, whereas its counterparties' hedges act on its input prices and demand, hedging in a firm's network matters particularly for the stability of its operations. Because each firm takes prices and demand as given, these effects on connected firms do not enter its own hedging decision.

To test these predictions, I construct a new dataset of foreign exchange derivative positions for U.S. nonfinancial firms. Commercial databases do not report the notional amounts of firms' foreign exchange derivatives comprehensively, so I identify filings that discuss such derivatives with textual analysis following Hoberg and Moon (2017) and manually collect the reported notional amounts from 10-K filings for 2000–2022. I link these data to firm-to-firm supply-chain relationships from Compustat Segment and FactSet Revere, which allows me to observe, for each firm and year, whether its suppliers and customers hedge.

Using these data, I exploit the first observed year in which at least one of a firm's customers, or at least one of its suppliers, begins to hedge. I compare each adopting firm with a matched control whose counterparties remain unhedged, selected within the same year and industry on pre-treatment balance-sheet characteristics and on the level and trend of the outcome before adoption. Following the model, I study sales volatility for downstream adoption, which affects the demand a firm faces, and the volatility of cost of goods sold (COGS) for upstream adoption, which affects its input costs. Across 1,351 downstream and 1,321 upstream matched pairs, the first adoption of hedging by customers is followed by a decline of 3.1 percentage points in the treated firm's sales volatility, and

the first adoption by suppliers by a decline of 3.1 percentage points in its COGS volatility, averaged over the year of adoption and the following three years. These effects equal 12 to 14 percent of treated firms' pre-adoption volatility, and joint tests do not reject parallel pre-treatment dynamics. The estimates are essentially unchanged when I control for the firm's own hedging, firm-specific exchange-rate volatility, or contemporaneous changes in its supplier and customer relationships, and they remain negative, and if anything larger, among transitions after which counterparties keep hedging for several years.

I then turn to the mechanism. Within firms, years with greater own hedging are years of more stable sales, costs, cash holdings, and market net worth. Firms that enter a year with stronger book or market net worth subsequently pay lower interest rates on their debt, consistent with a borrowing rate that falls with the financial position. The data also show where in the network hedging takes place. Hedge participation rises from below 10 percent among firms with no observed customers or suppliers to about 37 and 45 percent among firms with ten or more customers or suppliers, and the relationship survives controls for the firm's own foreign sales and sourcing. This pattern is consistent with the model's implication that exposure transmitted through the network creates a motive to hedge beyond direct trade exposure.

To assess the aggregate implications, I calibrate a multi-industry version of the model to the 2022 input-output accounts of the Bureau of Economic Analysis for 60 industries. The model is calibrated to match the aggregate notional value of reported foreign exchange derivatives relative to gross output. Although the allocation of hedging across industries is not targeted, the model captures the broad ranking of hedging intensity across sectors in the data, with a rank correlation of 0.83. Three results emerge. First, hedging stabilizes financial positions much more than operations. It lowers the exchange-rate-driven volatility of terminal net worth by 31 to 48 percent and that of sales, costs, and output by 1 to 6 percent. Second, the two forms of stabilization have different sources. To separate them, I compare economies in which no industry, only the industry itself, only the other 59 industries, or all industries can hedge. A Shapley decomposition attributes 97 percent of the stabilization of an industry's net worth to its own hedge, but about half of the stabilization of its output, 60 percent of the stabilization of its sales, and 34 to 38 percent of the stabilization of its costs to the hedging of other industries. Even when an industry cannot hedge, other industries' hedging achieves about half of the reduction in its output volatility. This operating stabilization from counterparties' hedging is the margin that the event study measures. Third, removing the hedge of a single industry changes value added mostly in other industries, and the response outside the source industry rises with the source's centrality as a supplier, most clearly when the exchange rate operates through

import prices. No single industry accounts for much of the aggregate stabilization, which instead reflects hedging by many industries across the network. In the aggregate, hedging smooths production across exchange-rate states while leaving expected production essentially unchanged. Relative to an economy in which each industry borrows at a constant rate equal to its average rate, the borrowing-cost channel amplifies the exchange-rate-driven volatility of aggregate value added by about 10 percent, and optimal hedging offsets one-quarter to two-fifths of this amplification.

Foreign exchange risk management is not only a corporate finance decision. A firm's hedge stabilizes its own finances, but through borrowing costs, prices, and input purchases it also stabilizes the operations of its suppliers and customers, including firms that never trade internationally. A large part of the operating stability that hedging delivers therefore comes from hedging elsewhere in the production network, and its aggregate effects depend on where in the network hedging takes place.

**Related Literature.** This paper contributes to five related strands of literature. Its central departure is to treat corporate foreign exchange hedging not only as a response to exchange-rate risk, but also as a determinant of how that risk propagates across firms.

First, this paper contributes to the empirical literature on corporate foreign exchange hedging. Existing work examines firms' incentives to hedge and the extent of their derivative use (Géczy, Minton and Schrand, 1997; Guay and Kothari, 2003; Purnanandam, 2008; Boyer and Marin, 2013; Almeida, Hankins and Williams, 2020), the interaction between financial and operational hedging (Allayannis, Ihrig and Weston, 2001; Kim, Mathur and Nam, 2006; Hoberg and Moon, 2017), the implications of hedging and exchange-rate pass-through for firms' measured currency exposure and the pricing of currency risk in equity markets (Allayannis and Ofek, 2001; Bodnar, Dumas and Marston, 2002; Bartram, Brown and Minton, 2010; Brusa, Ramadorai and Verdelhan, 2014), and the effects of hedging on firm value and real activity (Allayannis and Weston, 2001; Pérez-González and Yun, 2013; Bartram, 2019). Recent studies use data from outside the United States to examine hedging, trade invoicing, and exports (Lyonnet, Martin and Mejean, 2016; Alfaro, Calani and Varela, 2021a, 2024); Jung (2025), in particular, identifies the real effects of shocks to intermediaries supplying FX derivatives using Korean microdata. Using reported FX gains and losses across six major currency areas, Adams and Verdelhan (2021) document limited financial and operational hedging and show that the resulting exposures affect profits, payouts, and investment, while measured exposures are relatively small for U.S. firms whose trade is largely invoiced in dollars (see also Verdelhan and Dernaoui, 2021). I extend this literature in two directions. I construct new firm-level data on U.S. firms' FX

derivative notionals, documenting substantial hedging activity despite the dominance of dollar invoicing, which limits transaction exposure but not economic exposure through foreign demand and input prices. More importantly, I link these positions to firms' suppliers and customers and show that hedging has consequences beyond the hedging firm: entering a network with hedging counterparties is followed by greater operating stability, and firms with more production-network connections are more likely to hedge.

Second, this paper extends the theory of corporate risk management. Classic explanations for hedging emphasize taxes, financial distress, information frictions, and costly external finance (Smith and Stulz, 1985; Froot, Scharfstein and Stein, 1993; DeMarzo and Duffie, 1995). When external finance is costly, hedging reallocates internal resources toward states in which their marginal value is highest (Froot, Scharfstein and Stein, 1993). Dynamic models develop the interaction between risk management, investment, and financing (Bolton, Chen and Wang, 2011), while Rampini and Viswanathan (2010, 2013) and Rampini, Sufi and Viswanathan (2014) emphasize that financing and hedging compete for scarce collateral. Building on the working-capital financing framework of Almeida, Carvalho and Kim (2024), I study a setting in which external borrowing finances production and its cost depends on the firm's financial position. Hedging therefore affects not only the allocation of financial resources across states, but also borrowing costs, marginal costs, prices, and input purchases. The optimal hedge is governed by the state-contingent marginal value of resources rather than the sign of foreign exchange exposure alone, and a privately optimal hedge need not stabilize net worth. Embedding corporate risk management in a production network reveals a distinction between the private and network effects of hedging. In the calibrated model, an industry's own hedge accounts for nearly all of the stabilization of its net worth, whereas the hedging of other industries accounts for approximately half of the stabilization of its output. Hedging therefore operates both as a private stabilizer of financial positions and as a network stabilizer of real activity.

Third, the paper contributes to the literature on shock propagation through production networks (Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi, 2012; Acemoglu, Akcigit and Kerr, 2016; Carvalho and Tahbaz-Salehi, 2019). Existing evidence documents the transmission of idiosyncratic shocks through supplier-customer relationships (Barrot and Sauvagnat, 2016; Boehm, Flaaen and Pandalai-Nayar, 2019; Carvalho, Nirei, Saito and Tahbaz-Salehi, 2021), the propagation of international shocks through domestic production linkages (di Giovanni, Levchenko and Mejean, 2018; Dhyne, Kikkawa, Mogstad and Tintelnot, 2021; Adão, Carrillo, Costinot, Donaldson and Pomeranz, 2022), and the transmission of financial news and distress across connected firms (Cohen and Frazzini, 2008; Hertzel, Li, Officer and Rodgers, 2008; di Giovanni and Hale, 2022). Financial frictions

shape these propagation mechanisms (Bigio and La'O, 2020; Liu, 2019; Altinoglu, 2021), while credit disruptions and liquidity shortfalls can spread along supply chains (Jacobson and von Schedvin, 2015; Costello, 2020; Alfaro, García-Santana and Moral-Benito, 2021b; Demir, Javorcik, Michalski and Ors, 2024). Closest in spirit, Hardy, Saffie and Simonovska (2026) show how trade-credit relationships transmit dollar risk from indebted firms to domestic production partners. Whereas these studies primarily examine how shocks propagate through economic relationships, I examine how firms' risk-management decisions, made before shocks are realized, alter that propagation. Rather than changing the network itself, as in models of endogenous production relationships (Kopytov, Mishra, Nimark and Taschereau-Dumouchel, 2021; Elliott, Golub and Leduc, 2022), hedging changes the sensitivity of borrowing costs, prices, and purchases to exchange-rate shocks within the network. The quantitative results further show that hedging by central suppliers has larger effects on activity elsewhere in the network, paralleling the importance of upstream sectors in Liu (2019).

Fourth, this paper contributes to the international macroeconomics literature on exchange-rate pass-through. A large literature studies how invoicing currencies, nominal rigidities, and imported inputs determine the transmission of exchange rates into prices and quantities (Goldberg and Tille, 2008; Gopinath, Itskhoki and Rigobon, 2010; Gopinath and Itskhoki, 2010; Amiti, Itskhoki and Konings, 2014; Gopinath, 2015; Goldberg and Tille, 2016; Gopinath, Boz, Casas, Díez, Gourinchas and Plagborg-Møller, 2020; Amiti, Itskhoki and Konings, 2022). Related work measures pass-through into import and consumer prices, heterogeneity across firms, and transmission through input linkages (Campa and Goldberg, 2005; Goldberg and Campa, 2010; Berman, Martin and Mayer, 2012; Burstein and Gopinath, 2014; Auer, Levchenko and Sauré, 2019). A growing literature emphasizes the financial transmission of exchange rates through dollar credit and working-capital financing (Bruno, Kim and Shin, 2018; Bruno and Shin, 2023), credit constraints on trade (Amiti and Weinstein, 2011; Manova, 2013), currency mismatches on corporate balance sheets (Salomao and Varela, 2022), and the interaction between banking and the international role of the dollar (Gopinath and Stein, 2021). I contribute by making firms' hedging decisions an endogenous determinant of exchange-rate transmission. In the model, exchange-rate shocks affect financial positions and borrowing costs, which enter firms' marginal costs and prices, linking the cost channel of monetary policy (Barth and Ramey, 2001) and evidence on financial conditions and firm pricing (Gilchrist, Schoenle, Sim and Zakrajšek, 2017) to production-network transmission. Hedging changes this financial response and thereby the exchange-rate sensitivity of input prices and customer purchases. Quantitatively, the borrowing-cost channel amplifies the volatility of aggregate

value added by approximately 10 percent, in the spirit of the financial accelerator (Kiyotaki and Moore, 1997; Bernanke et al., 1999), while hedging offsets one-quarter to two-fifths of this amplification.[3]

Finally, the paper relates to the literature on public goods, strategic interactions, and externalities in networks (Ballester, Calvó-Armengol and Zenou, 2006; Bramoullé and Kranton, 2007; Bramoullé, Kranton and D'Amours, 2014; Allouch, 2015; Elliott and Golub, 2019). A firm's hedging decision can benefit connected firms that do not bear its hedging cost, with the strength of these spillovers depending on the firm's network position. Unlike direct payoff spillovers in standard network games, the effects here operate through endogenous market prices, borrowing costs, and demand, resembling the pecuniary externalities that arise in economies with financial frictions (Dávila and Korinek, 2018). These operating spillovers do not by themselves establish strategic complementarities in hedging or a welfare inefficiency. Instead, the paper identifies a distinct network transmission mechanism and shows quantitatively that the location of hedging matters: risk management by more central suppliers has larger effects on other industries' activity.

**Outline.** Section 2 presents the model and characterizes the borrowing-cost channel. Section 3 describes the data. Section 4 presents the event-study evidence on network hedging, and Section 5 examines the financial mechanism. Section 6 documents the allocation of hedging across the network, calibrates the model, quantifies the stabilization from hedging and decomposes it into the contributions of own and other industries' hedging, examines how individual industries' hedges propagate through the network, and studies the aggregate effects on production, prices, and the amplification generated by borrowing costs. Section 7 concludes.

[3]The paper also relates to the international finance literature on currency markets. A common dollar factor explains a substantial share of bilateral exchange-rate movements (Lustig, Roussanov and Verdelhan, 2011; Verdelhan, 2018), currency risk premia drive wedges between forward rates and expected spot rates (Lustig and Verdelhan, 2007; Verdelhan, 2010; Lustig, Roussanov and Verdelhan, 2014; Lustig, Stathopoulos and Verdelhan, 2019), and deviations from covered interest parity reflect intermediary balance-sheet costs that affect currency hedging (Du, Tepper and Verdelhan, 2018). The model abstracts from currency risk premia by pricing the forward at the expected spot rate and captures hedging costs through a convex resource cost. Its single-forward structure also relates to the implications of incomplete spanning studied by Lustig and Verdelhan (2019). Whereas Liao and Zhang (2025) examine how financial investors' hedging demand affects exchange rates, I study how nonfinancial firms' hedging decisions affect the transmission of exchange-rate movements to real activity.

# 2 A Model of Foreign Exchange Hedging in Production Networks

I develop a partial-equilibrium model in which foreign exchange hedging affects connected firms through a borrowing-cost channel. Firms finance their variable production costs before collecting sales revenue, and the rate they pay depends on their financial position. A hedge redistributes resources across exchange-rate states, which changes the firm's borrowing rate in each state and therefore its marginal cost, its price, and its purchases from suppliers. These responses reach firms that do not trade internationally through their input prices and through the demand of their customers. Section 2.1 describes the environment, Section 2.2 characterizes the hedging decision and its stabilizing effect, and Section 2.3 characterizes transmission across the network. Proofs are in Appendix A.

The model combines working-capital financing as in Almeida et al. (2024), the risk-management motive in Froot et al. (1993), price rigidity and dollar invoicing as in Gopinath et al. (2020), and vertical transmission through production relationships as in Acemoglu et al. (2016). The financial friction is a smooth premium on external finance: firms obtain the financing needed to meet demand, but a weaker financial position raises the rate they pay.

## 2.1 Environment

### 2.1.1 Production Network

The stylized network in Figure 2 places five domestic positions between foreign input suppliers and foreign buyers. Direct importers purchase foreign inputs, primary importers buy from direct importers, midstream firms connect the two sides, primary exporters sell to direct exporters, and direct exporters sell abroad. Import-price risk moves downstream through input costs, while export-demand risk moves upstream through purchases from suppliers.[4]

[4]The analysis does not otherwise rely on the vertical structure. Appendix A.8 extends the price results to a general input-output network, and Section 6 solves the model on the full 60-industry U.S. input-output network, in which each industry buys inputs from and sells output to many industries.The quantitative analysis retains the separation of the two channels by studying an import-price economy and a foreign-demand economy on the same network.

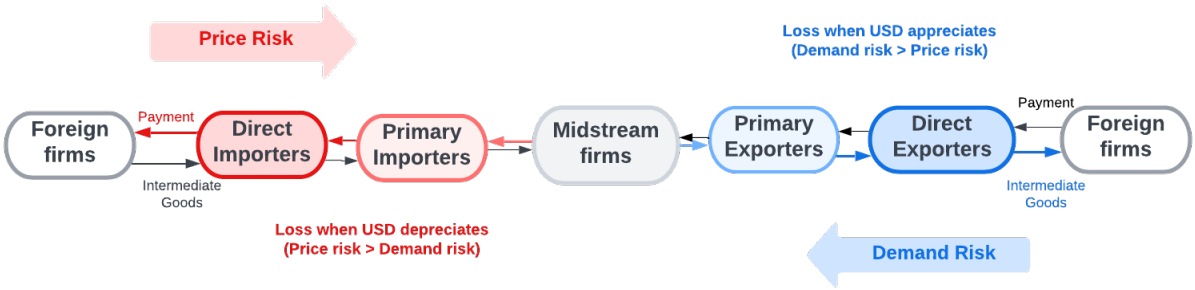



Figure 2: Foreign exchange risk in a stylized production network

*Notes:* This figure presents a diagram of the model, illustrating the pass-through of foreign exchange price and demand risks in a simplified vertical production network. It shows that foreign exchange price risk travels from direct importers through primary imports to midstream firms, and then downstream. Conversely, foreign exchange demand risk originates from direct exporters, moves through primary exporters to midstream firms, and then further upstream.

For analytical clarity, I study two three-sector chains, labeled $1 \to 2 \to 3$ in each (Figure 3). In the price-risk chain, sector 1 imports an intermediate input and sector 2 is the primary importer. In the demand-risk chain, sector 3 sells abroad and sector 2 is the primary exporter. The chains are an expositional device that isolates the two transmission channels, which push in opposite directions for a given exchange-rate movement: a dollar appreciation lowers the cost of imported inputs but also lowers foreign demand. A firm exposed to both might therefore appear naturally hedged. In practice, the offset is limited. Import payments and export receipts typically fall due at different dates, so firms tend to hedge each side separately, locking in known exchange rates for their payables and receivables rather than relying on one exposure to offset the other, consistent with the limited operational hedging documented by Adams and Verdelhan (2021). Studying the two channels separately is therefore a reasonable approximation of how firms manage the two exposures.

*(A) Price risk* *(B) Demand risk*

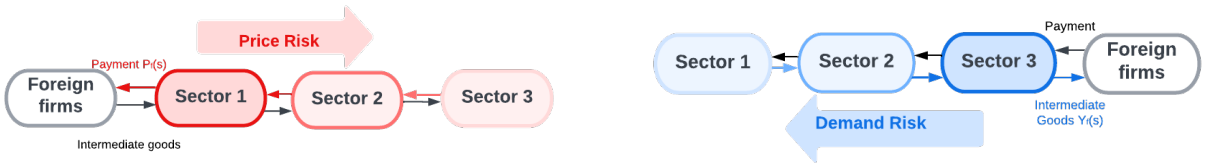



Figure 3: Decomposing price-risk and demand-risk transmission

*Notes:* Both panels use the local domestic labels $1 \to 2 \to 3$. Sector 1 is the direct importer in panel (A), and sector 3 is the direct exporter in panel (B).

Each domestic sector $i$ contains a unit mass of monopolistically competitive firms $k \in [0,1]$, whose varieties are combined into a sector composite. Firm $ik$ combines the composite of its supplier sector $j$ with labor,

$$y_{ik}(s) = x_{ij,k}(s)^{\alpha_{ij}} \ell_{ik}(s)^{1-\alpha_{ij}}, \qquad 0 < \alpha_{ij} < 1. \tag{1}$$

The wage $W > 0$ is exogenous, and labor is supplied perfectly elastically at this wage. In each sector, varieties are combined with a constant-elasticity-of-substitution (CES) aggregator,

$$Y_i(s) = \left[ \int_0^1 y_{ik}(s)^{(\epsilon_i - 1)/\epsilon_i} \, dk \right]^{\epsilon_i/(\epsilon_i - 1)}, \qquad \epsilon_i > 1, \tag{2}$$

which yields the sector price index and firm-level demand,

$$P_i(s) = \left[ \int_0^1 p_{ik}(s)^{1-\epsilon_i} \, dk \right]^{1/(1-\epsilon_i)}, \qquad y_{ik}(s) = \left[ \frac{p_{ik}(s)}{P_i(s)} \right]^{-\epsilon_i} Y_i(s). \tag{3}$$

Firms are atomistic: each takes sector prices, sector demand, and its suppliers' prices as given.

### 2.1.2 Timing

There are three dates. At $t = 0$, before the exchange-rate state $s \in S$ is realized, firm $ik$ chooses a signed forward position $q_{ik}$ and a dollar preset price $\bar{p}_{ik}$, which applies if the firm cannot reset its price; firm's initial resources $a_{ik}^0$ are given. At $t = 1$, the state and each firm's pricing status are realized, the forward settles, and the lender quotes a borrowing rate. The firm then purchases inputs, produces, and, if permitted, sets its price. At $t = 2$, the firm collects revenue, repays the loan with interest, and pays out its terminal net worth.

Because the rate is quoted after the state is realized, it varies across states, and because the firm anticipates repayment, the rate enters its input and pricing decisions at $t = 1$.

### 2.1.3 Financing and Borrowing Costs

Resources after the forward settles and the hedging cost is paid are

$$v_{ik}(s) = a^0_{ik} + [e(s) - e_f]q_{ik} - \Gamma_{ik}(q_{ik}), \tag{4}$$

where $\Gamma_{ik}$ is the resource cost of the hedge, specified below. The variable production cost is externally financed,

$$b_{ik,\tau}(s) = P_j(s)x_{ij,k,\tau}(s) + W\ell_{ik,\tau}(s), \qquad \tau \in \{R, F\}, \tag{5}$$

where $\tau$ indexes rigid ($R$) and flexible ($F$) pricing realizations. The loan finances the entire production cost, so the firm's initial resources $a^0_{ik}$ and the payoff from its hedge matter only through the firm's financial position, which determines the rate it pays.

The lender evaluates projected operating net worth before interest, $z$, while the firm's payout is terminal net worth after interest, $\omega$:

$$z_{ik,\tau}(s) = v_{ik}(s) + p_{ik,\tau}(s)y_{ik,\tau}(s) - b_{ik,\tau}(s), \tag{6}$$

$$\omega_{ik,\tau}(s) = z_{ik,\tau}(s) - [r_{ik,\tau}(s) - 1]b_{ik,\tau}(s) = v_{ik}(s) + p_{ik,\tau}(s)y_{ik,\tau}(s) - r_{ik,\tau}(s)b_{ik,\tau}(s). \tag{7}$$

Terminal net worth is paid out as the date-2 dividend. The lender sets the rate with a credit schedule $R_{ik,\tau}(\cdot)$ that maps the firm's projected net worth into a gross borrowing rate, so the rate the firm pays in state $s$ is

$$r_{ik,\tau}(s) = R_{ik,\tau}\Big(z_{ik,\tau}(s)\Big), \qquad R_{ik,\tau}(z) = R_{\min} + \Delta R \exp\left[-\gamma \frac{z - z^0_{ik,\tau}}{\mathrm{Rev}^0_i}\right], \tag{8}$$

where $R_{\min} \geq 1$ is the floor, $\gamma > 0$ governs how steeply the rate falls with net worth, and $\Delta R = R_{ik,\tau}(z^0_{ik,\tau}) - R_{\min} > 0$ is the premium over the floor at the reference position. Throughout, $R_{ik,\tau}$ denotes this credit schedule and $r_{ik,\tau}(s)$ the rate it assigns to the firm's projected net worth in state $s$. The reference centers $z^0_{ik,\tau}$ and the scale $\mathrm{Rev}^0_i > 0$, a revenue normalization common to both pricing types in sector $i$, are predetermined and do not change when the firm changes its hedge or preset. The credit schedule is decreasing and convex, $R'_{ik,\tau}(z) < 0$ and $R''_{ik,\tau}(z) > 0$, so a stronger financial position lowers the rate, and by more when the position is weak. Section 5 shows that firms entering a period with stronger

net worth face lower borrowing costs, consistent with a decreasing credit schedule.

**Timing of the borrowing rate.** After the state is realized, the lender quotes a borrowing rate that anticipates the operating plan it finances. The firm then sets its price and production at this rate. The rate enters the firm's marginal cost, so a lower rate leads a flexible-price firm to charge a lower price. Because the rate is already agreed when the firm sets its price, the firm does not take into account how its price would change the rate. The hedge and the preset, by contrast, are chosen at date 0, before the rate is quoted, so the firm anticipates how they change its rate in each state. Hedging therefore affects prices through the borrowing rate: it changes the firm's financial position in each state, which changes the rate at which the firm prices and produces.

### 2.1.4 Exchange-Rate Exposure and Hedging

The exchange rate $e(s) > 0$ is dollars per unit of foreign currency, so an increase is a dollar depreciation. In the price-risk chain, the dollar price of the imported input is

$$P_f(s) = \eta P_x e(s) + (1-\eta)\bar{P}_x, \qquad 0 \le \eta \le 1, \tag{9}$$

where $\eta$ is the foreign-currency-invoiced share and the remainder has a fixed dollar price. Its exchange-rate elasticity is $\eta P_x e/P_f$, so dollar invoicing dampens the direct price exposure.

In the demand-risk chain, foreign demand for sector 3's composite is

$$Y_{3f}(s) = \bar{Y}_{3f}\left[\frac{e(s)}{e_0}\right]^{\beta_f^X}\left[\frac{P_3(s)}{P_3^0}\right]^{-\chi_f}, \qquad \beta_f^X > 0, \quad \chi_f > 0. \tag{10}$$

The elasticity $\beta_f^X$ governs the response to the exchange rate at given dollar prices, and $\chi_f$ the response to the sector's dollar price; constant-elasticity demand in the foreign-currency price $P_3/e$ is the special case $\beta_f^X = \chi_f$. Because exports are invoiced in dollars, a dollar appreciation lowers foreign demand even when dollar prices are unchanged. When sector 3 sells only abroad, $Y_3 = Y_{3f}$; with domestic final demand as well, the export elasticities apply only to the export component.

A risk-neutral outside intermediary offers a forward with dollar payoff

$$h_{ik}(s) = [e(s) - e_f]q_{ik}, \qquad e_f = \sum_{s\in S}\pi(s)e(s), \qquad \pi(s) > 0, \quad \sum_{s\in S}\pi(s) = 1. \tag{11}$$

A positive $q_{ik}$ is long foreign currency and pays in depreciation states; a negative $q_{ik}$ pays in appreciation states. The forward is fairly priced, so its expected settlement is zero, but it provides a single risky payoff pattern rather than a complete set of state-contingent claims. Its notional value, $e_f|q_{ik}|$, is the model counterpart of the reported notional amounts in Section 3.1. Hedging incurs a quadratic resource cost,

$$\Gamma_{ik}(q) = c_{ik}q^2 = \frac{\kappa(e_f q)^2}{2D_{H,ik}}, \qquad \kappa > 0, \quad D_{H,ik} > 0, \tag{12}$$

where $D_{H,ik}$ is a predetermined scale. The cost is paid once, in equation (4). Firms may choose either sign; importer or exporter status describes an exposure, not a constraint on the position.

### 2.1.5 Price Rigidity and the Firm's Problem

**Assumption 1** (Price rigidity)**.** *A fraction $\lambda_i \in [0,1]$ of firms in sector $i$ uses the dollar preset $\bar{p}_{ik}$ chosen at date 0. The remaining fraction $1-\lambda_i$ sets its price after the state is realized. The preset is constant across states within an equilibrium but may differ across equilibria with different hedging policies.*

**State problem.** Let $\mathcal{E}_s$ denote the aggregate environment in state $s$: the supplier price $P_j(s)$, the sector price index $P_i(s)$, and sector demand $Y_i(s)$. Given its resources $v$ and the rate $r$ quoted for the state, a flexible-price firm chooses its price and inputs to maximize terminal net worth,

$$V_{ik,F,s}(v,r;\mathcal{E}_s) = \max_{p,x,\ell} v + p\,y - r\Big(P_j(s)x + W\ell\Big) \quad \text{subject to} \quad y = \left[\frac{p}{P_i(s)}\right]^{-\epsilon_i} Y_i(s), \qquad y \le x^{\alpha_{ij}}\ell^{1-\alpha_{ij}}. \tag{13}$$

The firm chooses its output through its price, since it meets the demand at that price, and chooses its inputs to produce that output at minimum cost. A rigid-price firm solves the same problem with its price fixed at $\bar{p}$, so it chooses only its inputs; I write its value as $V_{ik,R,s}(v,r,\bar{p};\mathcal{E}_s)$. The firm faces no borrowing limit: it borrows its entire production cost at the quoted rate.

**Date-0 problem.** The quoted rate must equal $R_{ik,\tau}(z)$ at the plan it finances. Substituting this rate into the state value gives the continuation value

$$\mathcal{V}_{ik,\tau,s}(v,\bar{p};\mathcal{E}_s) = V_{ik,\tau,s}\Big(v, r_{ik,\tau,s}(v,\bar{p}), \bar{p};\mathcal{E}_s\Big), \tag{14}$$

where $r_{ik,\tau,s}(v,\bar{p})$ solves $r = R_{ik,\tau}(z)$ at the associated operating plan; the flexible type's value does not depend on $\bar{p}$. At a given rate, the state value is linear in resources, $\partial V/\partial v = 1$, because the loan finances the entire production cost. Resources are worth more than one for one only because they strengthen the firm's financial position and lower its rate, which makes $\mathcal{V}$ nonlinear in $v$ and gives the firm a motive to hedge. The date-0 firm chooses its hedge and preset to solve

$$\max_{q_{ik},\bar{p}_{ik}>0} \sum_{s\in S} \pi(s)\Big[\lambda_i \mathcal{V}_{ik,R,s}\Big(v_{ik}(s),\bar{p}_{ik};\mathcal{E}_s\Big) + (1-\lambda_i)\mathcal{V}_{ik,F,s}\Big(v_{ik}(s);\mathcal{E}_s\Big)\Big], \tag{15}$$

with $v_{ik}(s)$ given by equation (4). The same hedge applies to both pricing realizations. In choosing its hedge and preset, the firm takes the aggregate environments $\mathcal{E}_s$ and the reference scales as given, but accounts for how these choices change its own rates and operating choices in each state.

**Assumption 2** (Interiority and stability)**.** *Equilibrium allocations satisfy the following conditions: (i) firms meet demand; (ii) projected net worth, terminal net worth, and operating profit after interest, $p_{ik,\tau}(s)y_{ik,\tau}(s) - r_{ik,\tau}(s)b_{ik,\tau}(s)$, are positive; and (iii) each firm's projected net worth is differentiable in its resources and, once the responses of its rate and price are taken into account, rises by at least one dollar for each additional dollar of resources, $dz_{ik,\tau}(s)/dv_{ik}(s) \geq 1$.*

I focus on equilibria that satisfy this assumption. Conditions (i) and (ii) rule out rationing and default. Condition (iii) ensures that additional resources strengthen the firm's financial position and lower its rate, and that its rate and operating plan respond smoothly to its resources and to the prices and demand it faces, so that the equilibrium can be characterized with derivatives. Appendix A.1 discusses this assumption, and Appendix A.4.1 gives sufficient conditions for the firm's objective to be concave in the hedge.

### 2.1.6 Equilibrium

**Definition 1** (Equilibrium)**.** *Given technologies, the wage, final-demand schedules, exchange-rate states and probabilities, initial resources, credit schedules, and reference scales, an equilibrium consists of forward positions and preset prices; state flexible prices and borrowing quotes; sector prices and quantities; and firm-level output, input use, borrowing, and terminal dividends such that (i) each firm's date-0 choices solve problem (15); (ii) its state operating choices are optimal at its given rate, and the quote satisfies $r = R(z)$; (iii) demand for each variety satisfies equation (3); and (iv) goods, labor, and forward markets clear.*

Goods-market clearing accounts for every use of each domestic composite,

$$Y_i(s) = \sum_{d \in \mathcal{C}(i)} \int_0^1 x_{di,k}(s)\, dk + F_i^D\Big(P_i(s)\Big) + F_i^X\Big(P_i(s), e(s)\Big), \tag{16}$$

where $\mathcal{C}(i)$ is the set of domestic customer sectors and each final-demand component is included only when present. Labor demand is met at $W$, and the outside intermediary takes the opposite side of all forwards. I focus on equilibria that are symmetric within each sector and pricing type. CES accounting implies $P_i Y_i = \int_0^1 p_{ik} y_{ik}\, dk$, and aggregate variable production expenditure, the model counterpart of COGS, equals $\int_0^1 b_{ik}\, dk$.

### 2.2 Hedging and Firm Stabilization

Write $\varepsilon_{X,e} = d \log X / d \log e$ for the elasticity of $X$ with respect to the exchange rate, holding date-0 choices fixed. These local derivatives treat the exchange rate as a continuous index of states around a given realization; the sign and variance results in Propositions 3 and 4 are stated directly for the finite state space.

**Proposition 1** (Operating costs, pricing, and price-risk transmission)**.** *Under Assumption 2, the unit factor cost, borrowing bill, and flexible price are*

$$C_i(s) = \left[\frac{P_j(s)}{\alpha_{ij}}\right]^{\alpha_{ij}} \left[\frac{W}{1-\alpha_{ij}}\right]^{1-\alpha_{ij}}, \qquad b_{ik,\tau}(s) = C_i(s) y_{ik,\tau}(s), \qquad p_{ik,F}(s) = M_i r_{ik,F}(s) C_i(s), \tag{17}$$

*where $M_i = \epsilon_i/(\epsilon_i - 1)$. With symmetry within each pricing type, the sector price is*

$$P_i(s) = \left[\lambda_i \bar{p}_i^{\,1-\epsilon_i} + (1-\lambda_i) p_{i,F}(s)^{1-\epsilon_i}\right]^{1/(1-\epsilon_i)}. \tag{18}$$

*Let $\vartheta_i = (1-\lambda_i) p_{i,F}^{1-\epsilon_i} / P_i^{1-\epsilon_i}$ denote the expenditure share of flexible varieties. Then*

$$\varepsilon_{P_i,e} = \vartheta_i \Big(\alpha_{ij} \varepsilon_{P_j,e} + \varepsilon_{r_{i,F},e}\Big), \qquad \varepsilon_{r_{i,F},e} = -\iota_{i,F}\, e \frac{dz_{i,F}}{de}, \qquad \iota_{i,F} = \frac{\gamma(r_{i,F} - R_{\min})}{\mathrm{Rev}_i^0\, r_{i,F}} > 0. \tag{19}$$

*For a direct importer, $\varepsilon_{P_j,e} = \eta P_x e / P_f$.*

*Proof.* See Appendix A.2.

The borrowing rate enters marginal cost because the firm repays the financed bill with interest. Its exchange-rate elasticity depends on the full response of projected net worth, $dz/de = q + d(py - b)/de$ at a fixed hedge, which includes both the hedge settlement and the operating response to the shock. Flexible varieties contribute to the sector price

in proportion to their expenditure share $\vartheta_i$ rather than their mass $1-\lambda_i$. Full price flexibility does not imply complete pass-through, since input shares, invoicing, and financing responses also enter.

**Proposition 2** (Demand transmission and input purchases)**.** *Suppose sector $i$ sells its composite only as an intermediate input to downstream sector $d$. Let $\widetilde{Y}_d = \int_0^1 y_{dk}\,dk$ and $\Delta_d = \widetilde{Y}_d/Y_d$. Then*

$$Y_i = \left(\frac{\alpha_{di}}{1-\alpha_{di}}\right)^{1-\alpha_{di}} \left(\frac{W}{P_i}\right)^{1-\alpha_{di}} \Delta_d Y_d, \tag{20}$$

*so that*

$$\varepsilon_{Y_i,e} = \varepsilon_{Y_d,e} - (1-\alpha_{di})\varepsilon_{P_i,e} + \varepsilon_{\Delta_d,e}. \tag{21}$$

*For a terminal sector selling only to the foreign demand in equation (10),*

$$\varepsilon_{Y_3,e} = \beta_f^X - \chi_f \varepsilon_{P_3,e}, \tag{22}$$

*which equals $\chi_f(1-\varepsilon_{P_3,e})$ when $\beta_f^X = \chi_f$. The dispersion factor satisfies $\Delta_d \geq 1$, with equality when variety output is equal almost everywhere.*

*Proof.* See Appendix A.3.

Foreign-demand movements reach suppliers through the inputs required for downstream production. The dispersion term arises because rigid and flexible varieties produce different quantities, so the arithmetic sum of variety output differs from the CES composite. The proposition describes input quantities; expenditure on the input, $P_i Y_i$, has elasticity $\varepsilon_{Y_d,e} + \alpha_{di}\varepsilon_{P_i,e} + \varepsilon_{\Delta_d,e}$, which is the relevant object when relating the model to COGS.

**Proposition 3** (Optimal hedging and the marginal value of resources)**.** *Let $m_{ik,\tau}(s) = \partial \mathcal{V}_{ik,\tau,s}/\partial v$ denote the marginal value of resources and $\zeta_{ik,\tau}(s) = dz_{ik,\tau}(s)/dv$ the response of projected net worth to resources, both along the response of the rate. Under Assumption 2,*

$$m_{ik,\tau}(s) = 1 + b_{ik,\tau}(s)\,\psi_{ik,\tau}(s)\,\zeta_{ik,\tau}(s), \qquad \psi_{ik,\tau}(s) = -R'_{ik,\tau}\Big(z_{ik,\tau}(s)\Big) > 0. \tag{23}$$

*For a rigid-price firm, $\zeta_{ik,R} = 1$. For a flexible-price firm,*

$$\zeta_{ik,F} = \left[1 - \frac{\epsilon_i(r_{ik,F}-1)}{r_{ik,F}}\, b_{ik,F}\,\psi_{ik,F}\right]^{-1}. \tag{24}$$

*Hence $m_{ik,\tau} > 1$. Let $m_{ik}(s) = \lambda_i m_{ik,R}(s) + (1-\lambda_i) m_{ik,F}(s)$. At a differentiable interior optimum,*

$$\Gamma'_{ik}(q^*_{ik}) = 2c_{ik}q^*_{ik} = \frac{\mathrm{Cov}_\pi\Big(m_{ik}(s;q^*_{ik}), e(s)\Big)}{\mathbb{E}_\pi[m_{ik}(s;q^*_{ik})]}. \tag{25}$$

*If, at a given preset and aggregate environment, the objective in problem (15) is strictly concave in $q_{ik}$ on an interval containing zero and attains an interior maximum, then*

$$\operatorname{sgn}(q_{ik}^*) = \operatorname{sgn}\operatorname{Cov}_\pi\Big(m_{ik}(s;0), e(s)\Big). \tag{26}$$

*With two states $e_H > e_L$, $\operatorname{sgn}(q_{ik}^*) = \operatorname{sgn}[m_{ik,H}(0) - m_{ik,L}(0)]$.*

*Proof.* See Appendix A.4; sufficient conditions and examples are in Appendix A.4.2.

Hedging moves resources toward states in which they are more valuable. An additional dollar is worth more than one dollar because it strengthens the financial position and lowers the rate paid on the financed bill, so its value is higher when the bill is larger or the credit schedule is steeper. Exposure alone therefore does not determine the hedge sign. Appendix A.4.2 shows that a rigid-price importer goes long, whereas a rigid-price exporter goes short only when the credit schedule is steep enough relative to the variation in its financed bill. With a constant borrowing rate, $m = 1$ in every state and the optimal hedge is zero.

**Proposition 4** (Local financial stabilization)**.** *For an outcome $X_s(t)$ that is differentiable in a parameter $t$, with fixed state probabilities,*

$$\frac{d\operatorname{Var}_\pi(X_s(t))}{dt} = 2\operatorname{Cov}_\pi\left(X_s(t), \frac{dX_s(t)}{dt}\right), \tag{27}$$

*and the same holds for $\log X_s$ when $X_s > 0$. Consider a firm of a given pricing type with two states and a small hedge $q = \sigma t$ from $q = 0$, holding its preset and the aggregate environment fixed. Under Assumption 2: (i) a long position ($\sigma = 1$) lowers the variance of terminal net worth if $\omega_H(0) < \omega_L(0)$, and a short position ($\sigma = -1$) lowers it if $\omega_H(0) > \omega_L(0)$; (ii) if projected net worth $z_s(0)$ has the same ordering as $\omega_s(0)$, the same position also lowers the variance of the borrowing rate.*

*Proof.* See Appendix A.5.

The proposition recovers the insurance interpretation locally. A long position raises resources in the depreciation state, which is the weak state for an importer, and a short position raises resources in the appreciation state, which is the weak state for an exporter.

**Optimal hedging and stabilization.** Propositions 3 and 4 rest on different orderings. The sign of the firm's optimal hedge follows the ordering of marginal values $m_s$, while the stabilizing direction follows the ordering of net worth $\omega_s$. In the rigid-price importer example of Appendix A.4.2, both orderings point toward a long position, so the optimal

hedge stabilizes net worth. In the exporter example, the financed bill is larger in the high-demand state, which raises the marginal value of resources there; the optimal hedge is short, and therefore stabilizing, only when condition (A9) holds. Net-worth stabilization also need not translate one for one into operating stabilization. A rigid-price firm that meets demand does not change its output after a resource transfer, even though its borrowing rate and terminal net worth change, whereas a flexible-price firm lowers its price and raises its output (Appendix A.5).

### 2.3 Hedging Spillovers Across the Production Network

A firm can face exchange-rate risk through its suppliers or customers even when it does not trade internationally. When those counterparties hedge, their borrowing rates, flexible prices, and input purchases respond differently to the exchange rate, which changes the focal firm's environment. Because firms are atomistic, a single counterparty's hedge does not move sector prices or quantities; transmission operates through the hedging of the supplier or customer sector as a whole.

**Proposition 5** (Downstream transmission through supplier prices)**.** *In the price-risk chain* $f \to 1 \to 2$*, the price elasticity of sector 2 is*

$$\varepsilon_{P_2,e} = \underbrace{\vartheta_2 \alpha_{21} \vartheta_1 \alpha_{1f} \varepsilon_{P_f,e}}_{\text{imported-input transmission}} + \underbrace{\vartheta_2 \alpha_{21} \vartheta_1 \varepsilon_{r_{1,F},e}}_{\text{supplier financing response}} + \underbrace{\vartheta_2 \varepsilon_{r_{2,F},e}}_{\text{own financing response}}, \tag{28}$$

*where the financing elasticities are defined in equation* (19)*. Holding the other terms fixed, a smaller supplier financing response lowers the price sensitivity of sector 2 as long as it does not reverse the sign of the total response.*

*Proof.* See Appendix A.6.

Hedging enters equation (28) through the financing responses. By Proposition 1, $\varepsilon_{r_{i,F},e} = -\iota_{i,F}\, e\, dz_{i,F}/de$, where $dz_{i,F}/de = q_i + d(p_{i,F}y_{i,F} - b_{i,F})/de$ contains the hedge settlement. A hedge that pays when the shock weakens the supplier's financial position therefore dampens the response of its borrowing rate and, through its price, the input cost of sector 2. Supplier hedging thus insures an unhedged buyer through its input price, with a transmission coefficient that contains the input share and the flexible expenditure share on each link.

**Proposition 6** (Upstream transmission through customer demand)**.** *In the demand-risk chain* $1 \to 2 \to 3 \to f$*, suppose sector 3 sells only abroad and sector 2 sells only to sector 3.*

*Then*

$$\varepsilon_{Y_2,e} = \beta_f^X - \chi_f \varepsilon_{P_3,e} - (1-\alpha_{32})\varepsilon_{P_2,e} + \varepsilon_{\Delta_3,e}. \tag{29}$$

*With* $K_3 = \chi_f \vartheta_3 \alpha_{32} + 1 - \alpha_{32}$ *and the pricing identities in Proposition 1,*

$$\varepsilon_{Y_2,e} = \underbrace{\beta_f^X}_{\text{foreign-demand shift}} \quad \underbrace{-\chi_f \vartheta_3 \varepsilon_{r_{3,F},e}}_{\text{customer financing response}} \quad \underbrace{-K_3 \vartheta_2 \left(\alpha_{21}\varepsilon_{P_1,e} + \varepsilon_{r_{2,F},e}\right)}_{\text{own cost and financing response}} + \varepsilon_{\Delta_3,e}. \tag{30}$$

*The customer's financing response therefore affects upstream purchases even when the supplier has no direct foreign-demand exposure.*

*Proof.* See Appendix A.7.

A short hedge by the exporting customer strengthens its financial position in appreciation states, lowers its borrowing rate relative to the unhedged response, and supports its purchases from suppliers. The supplier's revenue elasticity also includes its own price response, since sales equal $P_2 Y_2$ (equation (A12)).

## 3 Data and Measurement

I combine newly collected firm-level foreign exchange hedging data with firm-to-firm production-network relationships and standard accounting data for publicly traded U.S. firms. The resulting panel allows me to observe whether a firm hedges foreign exchange risk, whether its suppliers and customers hedge, and how the focal firm's operating and financial outcomes evolve as hedging enters its production network. The main sample spans 2000–2022. I exclude financial firms and regulated utilities and require firms to be incorporated in the United States. The empirical analysis is conducted at the firm–fiscal-year level. Appendix Table A1 reports summary statistics.

### 3.1 Firm-Level Foreign Exchange Hedging

A key contribution of the paper is a new firm-level dataset on foreign exchange derivative usage constructed from firms' 10-K filings. Because existing commercial accounting databases do not provide comprehensive information on the notional amount of foreign exchange derivatives used by U.S. nonfinancial firms, I combine textual analysis of annual filings with manual data collection to measure firms' foreign exchange hedging activity.

I identify filings that discuss foreign exchange derivatives using combinations of terms related to foreign currency exposure, derivative instruments, and hedging contracts, following the textual approach in Hoberg and Moon (2017). For candidate firm-years, I

manually collect the reported notional amount of foreign exchange derivatives, including forwards, futures, options, swaps, and cross-currency instruments used to manage foreign exchange risk. Foreign-currency positions are converted into U.S. dollars and aggregated within the firm-year. I focus on notional amounts rather than fair values because notionals more directly capture the scale of the underlying derivative position.

Let $FXNotional_{it}$ denote the total reported notional amount of foreign exchange derivatives for firm $i$ in fiscal year $t$. I define the intensive-margin hedging measure as

$$FXHedge_{it} = \frac{FXNotional_{it}}{Assets_{it}},$$

where $Assets_{it}$ denotes positive total assets. I also define the extensive-margin indicator

$$AnyHedge_{it} = \mathbf{1}\{FXNotional_{it} > 0\},$$

for firm-years with observed hedging information. Thus, $AnyHedge_{it} = 1$ when the firm reports a positive foreign exchange derivative position and equals zero when the observed notional amount is zero; firm-years with unobserved hedging information remain missing. Appendix C provides further details on the identification, collection, validation, and currency-conversion procedures.

### 3.2 Production-Network Relationships

I construct firm-level production networks by combining supplier–customer relationships from the Compustat Segment customer data and FactSet Revere Supply Chain Relationships. A directed relationship runs from supplier to customer. For each focal firm, I separately identify its *upstream* network of suppliers and its *downstream* network of customers, since supplier hedging can stabilize input costs whereas customer hedging can stabilize demand. The Compustat Segment data identify major customers reported by suppliers, while FactSet Revere provides substantially broader coverage of direct supplier–customer relationships. The Segment data are available from 2000 to 2022 and the Revere data from 2003 to 2022, so analyses based on the combined network cover 2003 to 2022, the period in which both sources are available. For Revere, I retain relationships active at the focal firm's fiscal-year-end and match each connected firm to its latest completed accounting state as of that date. I then combine the two sources at the focal-firm-year, direction, and connected-firm level, counting relationships appearing in both sources only once.

### 3.3 Network Hedging Measures

For each focal firm-year, I map the foreign exchange hedging status of its connected firms onto the hybrid production network using the accounting-date alignment described above. A connected firm is classified as a hedger when its observed foreign exchange derivative notional is positive and as a non-hedger when the observed notional is zero. Missing hedging information remains missing and is never mechanically recoded as zero.

My primary network-hedging measures indicate whether hedging is observed among the focal firm's upstream suppliers or downstream customers. Let $\mathcal{S}_{it}$ and $\mathcal{C}_{it}$ denote the sets of observed suppliers and customers of firm $i$. I define

$$UpAnyHedge_{it} = \mathbf{1}\left\{\exists j \in \mathcal{S}_{it} : AnyHedge_{j,\tau(i,j,t)} = 1\right\},$$
$$DownAnyHedge_{it} = \mathbf{1}\left\{\exists j \in \mathcal{C}_{it} : AnyHedge_{j,\tau(i,j,t)} = 1\right\},$$

where $\tau(i,j,t)$ denotes the connected firm's time-aligned accounting state. A zero requires an observed network state with observed hedging information and no counterparty observed to hedge; incomplete network or hedging coverage is retained as missing.

The baseline treatment is the first observed consecutive-year transition from zero to one in the corresponding network-hedging indicator. I define upstream adoption by

$$UpAnyHedge_{i,t-1} = 0, \qquad UpAnyHedge_{it} = 1,$$

and downstream adoption analogously. Section 4.1 uses transitions in these indicators to define the treatment events. Appendix E.1 provides further details on the construction of network-hedging exposures.

### 3.4 Firm Performance and Characteristics

I measure firm-level operating instability using the absolute annual log changes in sales and cost of goods sold (COGS). Sales volatility is the absolute annual log change in sales and serves as the primary outcome for the downstream hedging analysis, while COGS volatility is defined analogously and serves as the primary outcome for the upstream hedging analysis. I also construct book- and market-based measures of net worth following Rampini et al. (2014). Book net worth is measured using shareholders' equity, while market net worth is constructed by replacing book common equity in total assets with its market value and subtracting book liabilities. Net-worth volatility is measured as the absolute annual log change in the corresponding net-worth measure.

I obtain additional firm characteristics from Compustat. The principal covariates used

in the matching and mechanism analyses include firm size, leverage, cash holdings, asset tangibility, and trade credit. Firm size is measured as the logarithm of total assets, leverage as debt relative to assets, cash holdings as cash relative to assets, tangibility as tangible assets relative to total assets, and trade credit as accounts payable relative to COGS.

### 3.5 Foreign Exchange Exposure and Exchange-Rate Measures

I construct firm-specific currency exposure from country mentions in firms' 10-K filings following Hoberg and Moon (2017). Country mentions associated with sales, customers, and other offshore-output activities are classified as output-side exposure, while mentions associated with suppliers, sourcing, production, and other offshore-input activities are classified as input-side exposure. For firm $i$, currency $c$, and fiscal year $t$, I aggregate country-level occurrences to the corresponding currency and define the output- and input-side currency shares, $w^{out}_{i,c,t}$ and $w^{in}_{i,c,t}$, as the currency's occurrences relative to the firm's total foreign-country occurrences on that side. Because the denominator includes countries whose currencies fall outside the set of currencies used in the analysis, the shares need not sum to one. Appendix D describes the text classification, currency mapping, and validation procedures in detail.

For each currency, I measure realized bilateral exchange-rate volatility over the firm's fiscal interval,

$$FXVol_{i,c,t} = \left( \sum_{d \in \mathcal{T}_{it}} (\Delta \log S_{c,d})^2 \right)^{1/2}, \tag{31}$$

where $S_{c,d}$ is the bilateral exchange rate on day $d$ and $\mathcal{T}_{it} = \{d : datadate_{i,t-1} < d \leq datadate_{i,t}\}$ is firm $i$'s fiscal interval. I combine these bilateral measures with the firm's currency shares to obtain exposure-weighted realized volatility,

$$FXVol^{j}_{it} = \sum_{c} w^{j}_{i,c} FXVol_{i,c,t}, \qquad j \in \{out, in\}, \tag{32}$$

where output-side weights capture exposure relevant to sales and input-side weights capture exposure relevant to input costs. The timing of the weights is specified where the measure is used. Missing exposure or exchange-rate observations are retained as missing rather than recoded as zero.

# 4 Network Hedging Stabilizes Connected Firms

## 4.1 First Adoption of Network Hedging

I begin by examining whether the adoption of foreign exchange hedging by a firm's production-network counterparties is followed by a decline in the firm's operating volatility. The empirical design exploits the timing of the first observed transition into a hedging network and compares adopting firms with observably similar firms whose counterparties remain unhedged over the event window. I implement the analysis separately for upstream and downstream network hedging because the model predicts that the two margins operate through distinct channels: upstream hedging stabilizes input costs, while downstream hedging stabilizes demand and revenues.

**Treatment definition.** I define treatment using the network-hedging indicators in Section 3.3. For direction $r \in \{u, d\}$, let $D^r_{it}$ denote $UpAnyHedge_{it}$ or $DownAnyHedge_{it}$, respectively. Firm $i$ is treated in year $T^r_i$ if

$$D^r_{i,T^r_i-1} = 0 \qquad \text{and} \qquad D^r_{i,T^r_i} = 1,$$

where the two observations correspond to consecutive fiscal years. I use the first observed $0 \to 1$ transition and do not include a later transition that may exhibit greater persistence. This restriction is important because subsequent apparent exits and re-entries may partly reflect changes in supply-chain coverage or the availability of counterparty hedging information rather than genuine economic changes in network hedging status. The event window spans three years before through three years after adoption, $k \in [-3, 3]$, where $k = t - T^r_i$. The year immediately preceding adoption, $k = -1$, is the omitted reference period.

**Matched control firms.** The central identification challenge is that firms exposed to hedging counterparties may differ systematically from firms whose counterparties do not hedge. I therefore construct a one-to-one matched control for each treated firm using information available strictly before adoption.

For a treated firm with adoption year $T^r_i$, a potential control must have an observed zero value of the corresponding network hedging indicator in years $T^r_i - 1$ through $T^r_i + 3$. Thus, the control is observed to remain untreated throughout the treatment and post-treatment portion of the event window. Missing network observations are never interpreted as zero.

I require exact matching on the calendar year of treatment and search for controls

hierarchically within industry. I first search within the treated firm's two-digit SIC industry. If no eligible control is available, I search within the corresponding one-digit SIC industry, and, if necessary, within the same broad SIC division.

Among eligible controls, I select the nearest neighbor using a standardized covariate-distance measure. Matching is performed with replacement. The matching variables include firm size, leverage, the cash-to-assets ratio, asset tangibility, and trade credit, measured prior to treatment. When available for both members of a potential pair, I also incorporate the firm's own foreign exchange hedging intensity. I also match firms on the pre-treatment history of the primary outcome. For downstream adoption, the primary outcome is the absolute annual log change in sales; for upstream adoption, it is the absolute annual log change in cost of goods sold (COGS). The matching distance therefore incorporates the outcome in event years $-3$, $-2$, and $-1$, as well as the changes in the outcome between $-3$ and $-2$ and between $-2$ and $-1$. I place greater weight on these pre-treatment outcome levels and slopes than on the remaining firm characteristics. This procedure is designed to select controls with similar pre-treatment outcome dynamics rather than merely similar balance-sheet characteristics.

Formally, let $\mathbf{Z}_i$ collect standardized pre-treatment firm characteristics and let

$$\mathbf{H}_i = \left(Y_{i,-3},\, Y_{i,-2},\, Y_{i,-1},\, Y_{i,-2} - Y_{i,-3},\, Y_{i,-1} - Y_{i,-2}\right)'$$

denote the standardized pre-treatment outcome history. For treated firm $i$ and eligible control $j$, the matching distance takes the form

$$\mathcal{D}_{ij}^2 = 2\left\|\mathbf{H}_i - \mathbf{H}_j\right\|^2 + \left\|\mathbf{Z}_i - \mathbf{Z}_j\right\|^2. \tag{33}$$

I select the eligible control that minimizes $\mathcal{D}_{ij}$.

**Matching balance.** Appendix Table A2 reports pre-treatment balance. Matching aligns treated and control firms closely in the pre-treatment outcome changes that govern the trajectory into treatment, with post-match standardized mean differences of at most 0.026 in absolute value in both directions. Matched controls have somewhat lower pre-treatment outcome levels; such level differences are absorbed by the treated-firm indicator in the event-study specification, so identification rests on the parallel evolution of the treated-control gap rather than on equal outcome levels.

**Outcome variables.** The primary downstream outcome is sales volatility, while the primary upstream outcome is COGS volatility, as defined in Section 3.4.

**Matched-pair event-study specification.** After constructing the matched sample, I estimate dynamic treatment effects using a matched-pair event-study specification:

$$Y_{ipt} = \alpha_p + \delta_t + \theta\, Treat_{ip} + \sum_{\substack{k=-3 \\ k\neq -1}}^{3} \beta_k \Big[ Treat_{ip} \times \mathbf{1}\{t - T_p = k\} \Big] + \varepsilon_{ipt}, \tag{34}$$

where $p$ indexes matched treated-control pairs, $T_p$ is the adoption year of the treated firm in pair $p$, $\alpha_p$ denotes matched-pair fixed effects, and $\delta_t$ denotes fiscal-year fixed effects. $Treat_{ip}$ equals one for the adopting firm and zero for its matched control. Event year $-1$ is the omitted category, so each $\beta_k$ measures the change in the treated-control outcome gap at event time $k$ relative to the gap in the year immediately preceding adoption.

Matched-pair fixed effects absorb time-invariant differences across matched pairs, while the treatment indicator captures a common treated-control level difference in the omitted reference period. Each event-time coefficient therefore measures the change in the treated-control outcome gap relative to event year $-1$. The design does not require treated and control firms to have identical pre-treatment outcome levels. Instead, the identifying assumption is that, absent network-hedging adoption, the treated-control outcome gap would have evolved similarly over the event window. I assess pre-treatment dynamics using the coefficients $\beta_{-3}$ and $\beta_{-2}$ and test whether they are jointly zero.

Because matching is conducted with replacement, the same underlying control firm may appear in multiple matched pairs. I therefore cluster standard errors by the underlying firm rather than treating repeated appearances of the same firm as independent observations.

This design compares the evolution of operating volatility around the first observed adoption of network hedging with the contemporaneous evolution of a pre-treatment-matched untreated firm. The event-study coefficients therefore capture differential changes in volatility following network hedging adoption, conditional on the matching design, pair fixed effects, and common fiscal-year shocks.

Table 1 summarizes the resulting matched samples and the baseline estimates. I identify 1,856 first observed downstream adoption events and 1,634 first observed upstream adoption events before matching. The matching procedure yields 1,351 downstream matched pairs and 1,321 upstream matched pairs. Matched adoption events span fiscal years 2003 through 2019 in both directions. Appendix Figure A6 reports the corresponding treatment-year and industry distributions.

Table 1: Baseline Matched First-Adoption Sample and Estimates

| | Downstream | Upstream |
|---|---|---|
| | Sales volatility | COGS volatility |
| First-adoption events | 1,856 | 1,634 |
| Matched pairs | 1,351 | 1,321 |
| Matched treatment years | 2003–2019 | 2003–2019 |
| Average post effect, 0 to +3 | -0.031*** | -0.031*** |
| | (0.011) | (0.010) |
| Average post effect, +1 to +3 | -0.035*** | -0.037*** |
| | (0.012) | (0.012) |
| Joint pre-trend $p$-value | 0.978 | 0.122 |

*Notes:* This table summarizes the baseline matched first-adoption design. Downstream adoption is the first observed transition from no hedging downstream counterparty to at least one hedging downstream counterparty, with sales volatility as the primary outcome. Upstream adoption is defined analogously, with COGS volatility as the primary outcome. Matching is one-to-one with replacement. Average post effects are obtained from the matched-pair event-study specification in equation (34) over event years 0 through +3 and +1 through +3, respectively. Event year −1 is the omitted reference period. Regressions include a treated-firm indicator and absorb matched-pair and fiscal-year fixed effects, and standard errors are clustered by the underlying firm. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

I summarize the post-adoption response using the average of the four post-treatment coefficients,

$$\bar{\beta}^{Post} = \frac{1}{4}(\beta_0 + \beta_1 + \beta_2 + \beta_3),$$

and also report the corresponding average over event years +1 through +3, which excludes the contemporaneous transition year. Standard errors for these linear combinations are calculated using the full estimated variance–covariance matrix. I assess pre-treatment dynamics using a joint test of $\beta_{-3} = \beta_{-2} = 0$.

The average post-adoption effects are negative and similar in magnitude across the two directions: −0.031 for downstream sales volatility and −0.031 for upstream COGS volatility over event years 0 through +3. Excluding the transition year produces slightly larger estimates of −0.035 and −0.037, respectively. The joint pre-trend tests do not reject the null of zero pre-treatment coefficients in either direction, with $p$-values of 0.978 downstream and 0.122 upstream. I next examine the full event-time paths underlying these summary estimates.

### 4.2 Upstream and Downstream Hedging Stabilizes Connected Firms

Figure 4 presents the baseline matched-pair event-study estimates. For the prespecified primary outcomes, the first observed transition into a hedged production network is

followed by lower operating volatility: downstream hedging adoption is associated with lower sales volatility, while upstream hedging adoption is associated with lower COGS volatility.

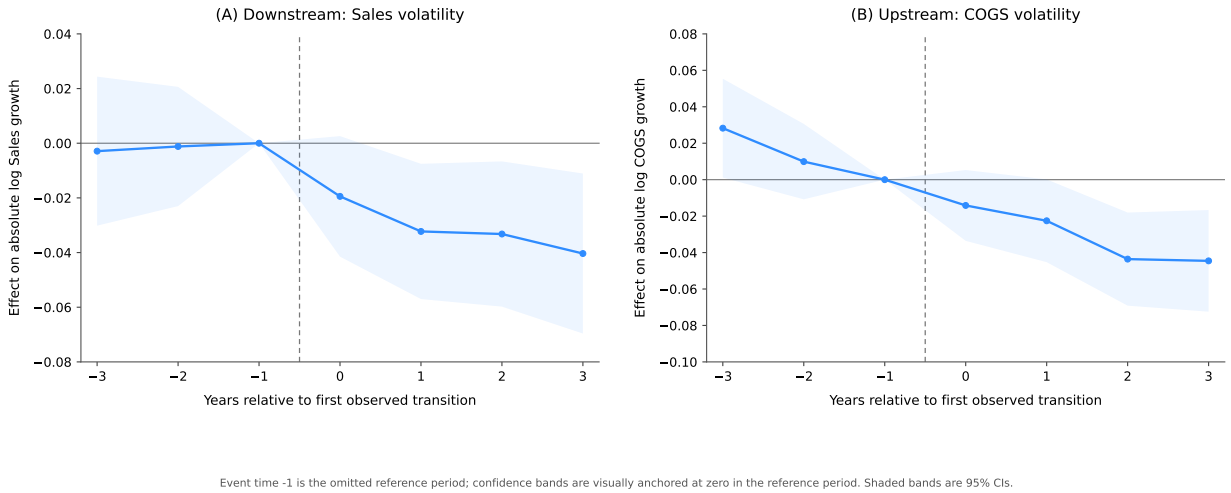



Figure 4: Network hedging transitions and firm operating volatility

*Notes:* This figure presents matched-pair event-study estimates of changes in focal-firm operating volatility around the first observed transition into a hedged production network. Panel (A) reports downstream hedging adoption and the absolute annual log change in sales; Panel (B) reports upstream hedging adoption and the absolute annual log change in COGS. Event time −1 is the omitted reference period. Regressions include a treated-firm indicator and absorb matched-pair and fiscal-year fixed effects, and standard errors are clustered by the underlying firm. Shaded areas denote 95% confidence intervals and are visually anchored at zero in the omitted reference period.

**Downstream hedging and sales volatility.** Panel (A) shows little evidence of differential pre-trends before adoption. Following the transition into a hedged downstream network, sales volatility declines progressively relative to the matched control, with the reduction persisting throughout the post-treatment window. The average post-adoption effect corresponds to a decline of approximately 3.1 percentage points in annual sales instability relative to the pre-adoption treated-control gap.

**Upstream hedging and COGS volatility.** Panel (B) shows a similar post-adoption decline in COGS volatility, with the reduction persisting throughout the post-treatment window. The average post-adoption effect corresponds to a decline of approximately 3.1 percentage points in annual COGS instability relative to the pre-adoption treated-control gap. The joint pre-trend test does not reject the null of zero pre-treatment coefficients ($p = 0.122$), although the event-time −3 coefficient is individually positive and statistically significant.

These results indicate that entering a hedged production network is followed by

economically meaningful reductions in focal-firm operating instability. Consistent with the model, the downstream sales outcome maps naturally to the demand side of the production relationship, while the upstream COGS outcome maps to the input-cost side.

### 4.3 Alternative Explanations

The baseline estimates could reflect developments that coincide with the transition into a hedged network rather than the risk management of connected firms. I examine three such alternatives: contemporaneous changes in the focal firm's own hedging, firm-specific movements in exchange-rate volatility, and contemporaneous reorganization of the focal firm's production network. For each alternative, I augment equation (34) with a time-varying control vector $\mathbf{W}_{ipt}$:

$$Y_{ipt} = \alpha_p + \delta_t + \theta\, Treat_{ip} + \sum_{\substack{k=-3 \\ k\neq -1}}^{3} \beta_k \Big[ Treat_{ip} \times \mathbf{1}\{t - T_p = k\} \Big] + \boldsymbol{\gamma}' \mathbf{W}_{ipt} + \varepsilon_{ipt}. \tag{35}$$

The treatment events, matched pairs, event window, outcome definitions, fixed effects, and clustering rule are unchanged, and no rematching is performed. Because each control is observed for only part of the baseline sample, I estimate the specification with and without $\mathbf{W}_{ipt}$ on an exact common sample, so that any difference between the two sets of estimates reflects conditioning on $\mathbf{W}_{ipt}$ rather than changes in sample composition. Figure 5 reports the results. Appendix Table A3 reports standard errors, pre-trend tests, and sample sizes for all specifications in this section and in Section 4.4.

#### 4.3.1 Changes in the Focal Firm's Own Hedging

The transition into a hedged production network may coincide with changes in the focal firm's own foreign exchange risk management, which the model predicts also stabilizes firm outcomes. In that case, the baseline decline in operating volatility could reflect the focal firm's own hedging rather than that of its connected firms. I therefore set $\mathbf{W}_{ipt}$ equal to the focal firm's hedging intensity, $FXHedge_{it}$. The common sample on which this measure is observed retains 1,347 matched pairs downstream and 1,319 upstream, compared with 1,351 and 1,321 in the full baseline sample.

Row (i) of Figure 5 shows that conditioning on own hedging intensity leaves the network-hedging coefficients essentially unchanged. The average post-transition effect over event years 0 through +3 moves from −0.0290 to −0.0290 downstream and from −0.0306 to −0.0308 upstream, and the individual event-time coefficients are similarly

stable. Conditioning instead on lagged own hedging intensity yields the same conclusion: on the common sample with an observed one-year lag, the downstream estimate moves from −0.0291 to −0.0292 and the upstream estimate from −0.0296 to −0.0295. The baseline network-hedging effects are therefore not driven by contemporaneous or lagged changes in the focal firm's measured hedging intensity.

### 4.3.2 Firm-Specific Exchange-Rate Conditions

Firms may enter hedged production networks during periods of unusually high foreign exchange volatility. If that volatility subsequently mean-reverts, the post-transition decline in sales or COGS volatility could reflect improving currency conditions rather than stabilization transmitted through the production network. Fiscal-year fixed effects absorb aggregate shocks but not heterogeneity in currency exposure across firms.

I therefore set $\mathbf{W}_{ipt}$ equal to the exposure-weighted realized volatility measure in equation (32), with two adjustments specific to the event-study setting. First, I hold the currency weights fixed at their event-year −1 values, $w^{j}_{i,c,T_p-1}$, so that post-treatment changes in firms' geographic composition do not mechanically affect the control; the matched control's weights are measured in the same year. Second, I use output-side weights for downstream transitions, matching the sales-volatility outcome, and input-side weights for upstream transitions, matching the COGS-volatility outcome. I standardize the measure within each direction-specific estimation sample. The common samples contain 16,682 observations from 1,336 matched pairs downstream and 16,489 observations from 1,311 pairs upstream.

Row (ii) of Figure 5 shows that conditioning on realized FX volatility has virtually no effect on the event-study estimates. The average post-transition effect moves from −0.0359 to −0.0361 downstream and from −0.0269 to −0.0269 upstream. The joint pre-trend $p$-values move from 0.914 to 0.916 downstream and remain at 0.120 upstream. The baseline pattern is therefore not explained by firms entering hedged networks during periods of elevated firm-specific FX volatility followed by mean reversion.

### 4.3.3 Contemporaneous Network Reorganization

The first transition into a hedged network may coincide with broader changes in the focal firm's set of production relationships, so the estimated decline in volatility could reflect network reorganization rather than exposure to connected-firm hedging. Using exact counterparty identities, I construct the number of newly entering and exiting counterparties in

the relevant network direction,

$$NewLinks_{it} = \left|\mathcal{N}_{it} \setminus \mathcal{N}_{i,t-1}\right|, \qquad ExitLinks_{it} = \left|\mathcal{N}_{i,t-1} \setminus \mathcal{N}_{it}\right|,$$

where $\mathcal{N}_{it}$ denotes firm $i$'s set of counterparties in year $t$, equaling $\mathcal{S}_{it}$ for upstream and $\mathcal{C}_{it}$ for downstream transitions. A change in source classification for the same counterparty does not count as entry or exit. I first set $\mathbf{W}_{ipt} = \log(1 + NewLinks_{it})$ and then additionally include $\log(1 + ExitLinks_{it})$.

Row (iii) of Figure 5 shows that the event-study paths are essentially unchanged after conditioning on relationship entry and remain stable after additionally conditioning on relationship exits, in both directions. Observable expansion or contraction of the focal firm's production network therefore does not account for the baseline stabilization pattern.

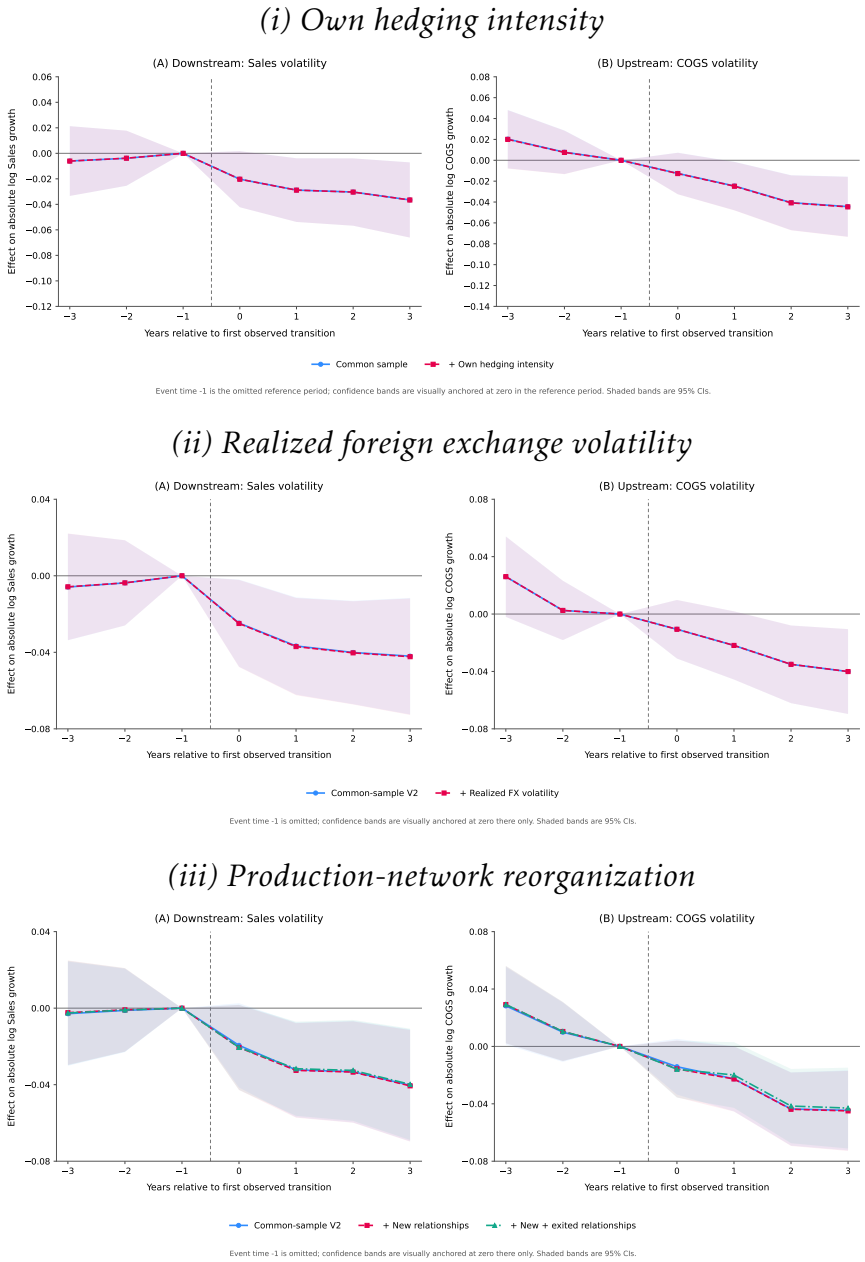



Figure 5: Alternative explanations for the baseline estimates

*Notes:* This figure reports matched-pair event-study estimates from equation (35) with and without the indicated time-varying control. Within each row, both specifications are estimated on the exact common sample for which the control is observed. Row (i) adds the focal firm's contemporaneous foreign exchange derivative notional relative to total assets. Row (ii) adds the standardized exposure-weighted realized FX-volatility measure, constructed from the focal firm's pre-transition output-side (downstream) or input-side (upstream) currency exposure held fixed over the event window. Row (iii) adds the log of one plus the number of newly entering counterparties and, separately, both this variable and the log of one plus the number of exiting counterparties, constructed from exact counterparty identities. In each row, the left panel reports downstream hedging transitions and sales volatility, and the right panel reports upstream hedging transitions and COGS volatility. Treatment events, matched pairs, and the event window are unchanged, and no rematching is performed. Event time $-1$ is the omitted reference period. Regressions include a treated-firm indicator and absorb matched-pair and fiscal-year fixed effects, and standard errors are clustered by the underlying firm. Shaded areas denote 95% confidence intervals and are visually anchored at zero in the omitted reference period.

### 4.4 Sensitivity to Design Choices

The baseline design rests on two choices that are not uniquely determined: the definition of the treatment event and the relative weight placed on pre-treatment outcome dynamics in the matching distance. For each alternative, I reconstruct the matched sample while holding all other elements of the design fixed and re-estimate equation (34). Figure 6 reports the results.

#### 4.4.1 Persistence of Network Hedging Transitions

The baseline treatment requires only that the network hedging indicator change from zero in event year −1 to one in event year 0. Some of these transitions may be short-lived, either because connected firms subsequently cease hedging or because observed network coverage changes. I therefore impose three increasingly stringent persistence requirements while retaining the same first observed transition year: the indicator must remain equal to one through event year +1 (011), through +2 (0111), or through +3 (01111). When an event fails a requirement, I do not substitute a later transition. For each definition, I reconstruct the matched sample using the baseline matching procedure. These restrictions test whether the baseline pattern is concentrated among transitory changes in observed network hedging status.

Row (i) of Figure 6 reports the results. The average post-transition effect remains negative and statistically significant under every requirement, ranging from −0.033 to −0.047 downstream and from −0.027 to −0.048 upstream, compared with −0.031 in the baseline in both directions, and the joint pre-trend test does not reject in any specification (Appendix Table A3).

Requiring persistence through +3 reduces the sample to 577 downstream and 514 upstream matched pairs, reflecting observed reversals, incomplete future network coverage, and the exclusion of later cohorts without sufficiently long post-transition histories. Differences in magnitude across definitions therefore should not be read as effects of persistence itself; the exercise shows that the negative post-transition dynamics are not confined to short-lived $0 \to 1$ changes.

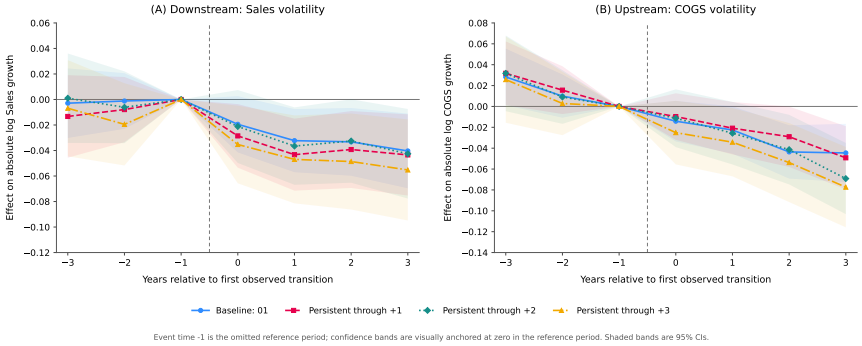
#### 4.4.2 Matching-Distance Weights

The baseline distance in equation (33) assigns weight two to each standardized pre-treatment outcome level and slope and weight one to the remaining matching characteristics. I re-match using outcome-history weights of one, which weights all matching variables equally, and four, while holding the treatment definition, matching variables, standardiza-

tion procedure, and nearest-neighbor algorithm fixed and restricting all matches to the treated firm's broad SIC division.

Row (ii) of Figure 6 shows that the estimates are stable across weightings: the average post-transition effect is −0.031 and −0.029 downstream and −0.031 and −0.028 upstream for weights one and four, compared with −0.031 in the baseline, and remains significant at the 1 percent level with no evidence of differential pre-trends (Appendix Table A3).

*(i) Persistence of network hedging transitions*




*(ii) Matching-distance weights*

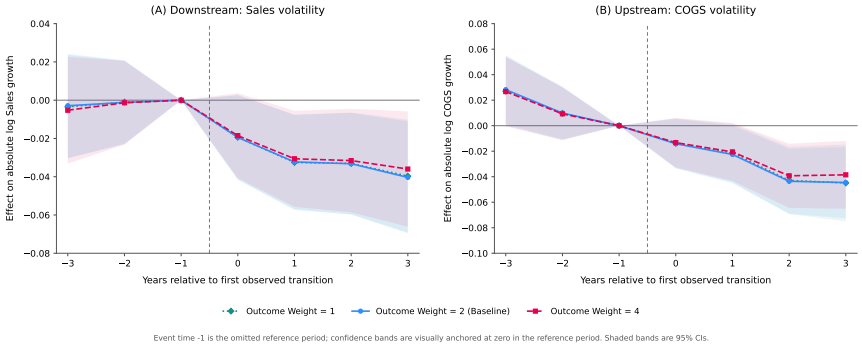



Figure 6: Sensitivity to design choices

*Notes:* This figure reports matched-pair event-study estimates from equation (34) under alternative design choices; each alternative is matched independently using the baseline procedure with the indicated modification. Row (i) varies the persistence requirement on the observed transition into a hedged production network: "Baseline: 01" requires the network hedging state to change from zero in event year −1 to one in event year 0, and "Persistent through $+h$" additionally requires it to remain equal to one through event year $+h$. Each persistence specification retains the same first observed transition year and does not substitute a later qualifying transition. Row (ii) varies the weight on the standardized pre-treatment outcome levels and slopes in the matching distance relative to the remaining matching covariates; weight two is the baseline. In each row, the left panel reports downstream hedging transitions and sales volatility, and the right panel reports upstream hedging transitions and COGS volatility. Event time −1 is the omitted reference period. Regressions include a treated-firm indicator and absorb matched-pair and fiscal-year fixed effects, and standard errors are clustered by the underlying firm. Shaded areas denote 95% confidence intervals and are visually anchored at zero in the omitted reference period.

# 5 Mechanism: Financial Stabilization and External Financing

The borrowing-cost channel in the model rests on two links: hedging stabilizes a firm's financial position, and a stronger financial position lowers the rate at which the firm borrows. This section examines both links in firm-level data. First, firms that hedge more have more stable operating and financial outcomes. Second, firms that enter a year with stronger net worth subsequently pay lower borrowing costs.

## 5.1 Own FX Hedging and Firm Stability

I first examine whether a firm's own foreign exchange hedging is associated with more stable operating and financial outcomes. For each outcome $X_{it}$, I measure instability as the absolute annual log change, $|\Delta \log X_{it}|$, for sales, cost of goods sold, cash holdings, and market net worth, and estimate

$$|\Delta \log X_{it}| = \alpha_i + \delta_t + \beta FXHedge_{it} + Z'_{it}\Gamma + \varepsilon_{it}, \tag{36}$$

where $FXHedge_{it}$ is the firm's FX derivative notional relative to total assets (Section 3.1), and $\alpha_i$ and $\delta_t$ are firm and fiscal-year fixed effects. In the controlled specifications, $Z_{it}$ contains firm size, leverage, cash holdings, tangibility, and trade credit. A negative $\beta$ means that firms that hedge more have more stable outcomes.

Table 2 shows that $\beta$ is negative for every outcome. Holding the controls fixed, an increase in hedging intensity of 0.1, a notional equal to 10 percent of assets, is associated with a decline in the absolute annual growth rate of 1.2 percentage points for sales, 1.0 for COGS, 2.9 for cash holdings, and 1.4 for market net worth. All four coefficients are statistically significant and close to their counterparts without controls. These patterns are consistent with the model's mechanism, in which hedging transfers resources across exchange-rate states and thereby dampens the volatility of the firm's financial position and of its operations.

Table 2: Own FX Hedging and Operating and Financial Stability

| Dep. var.: | Sales | | COGS | | Cash | | Market Net Worth | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| FX hedging | -0.122*** | -0.117*** | -0.105*** | -0.104*** | -0.315*** | -0.293*** | -0.168*** | -0.141** |
| | (0.039) | (0.037) | (0.038) | (0.037) | (0.088) | (0.088) | (0.064) | (0.064) |
| Log assets | | -0.011** | | -0.003 | | -0.039*** | | -0.023*** |
| | | (0.004) | | (0.004) | | (0.006) | | (0.005) |
| Leverage | | -0.016* | | -0.014 | | 0.004 | | 0.040*** |
| | | (0.008) | | (0.009) | | (0.012) | | (0.009) |
| Cash / Assets | | 0.135*** | | 0.063*** | | | | 0.049** |
| | | (0.021) | | (0.023) | | | | (0.024) |
| Tangibility | | -0.157*** | | -0.178*** | | -0.183*** | | 0.041 |
| | | (0.030) | | (0.032) | | (0.048) | | (0.037) |
| Trade credit | | 0.012*** | | 0.030*** | | 0.005*** | | 0.000 |
| | | (0.002) | | (0.002) | | (0.002) | | (0.002) |
| Observations | 79,753 | 79,159 | 79,621 | 79,218 | 79,822 | 79,212 | 68,578 | 68,211 |
| Adjusted $R^2$ | 0.383 | 0.388 | 0.343 | 0.361 | 0.227 | 0.228 | 0.270 | 0.272 |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Controls | No | Yes | No | Yes | No | Yes | No | Yes |

*Notes:* This table reports estimates of equation (36), firm-level fixed-effects regressions relating firms' own foreign exchange hedging intensity to operating and financial stability. FX hedging is the firm's reported foreign exchange derivative notional amount divided by total assets. The dependent variables are the absolute annual log changes in sales, cost of goods sold (COGS), cash holdings, and market net worth, respectively. Lower values therefore indicate greater stability. All continuous variables are winsorized at the 1st and 99th percentiles. Columns (1), (3), (5), and (7) include firm and fiscal-year fixed effects only. Columns (2), (4), (6), and (8) additionally control for firm size, leverage, cash holdings, tangibility, and trade credit. Cash holdings are omitted from the control set in column (6), where cash volatility is the dependent variable. Standard errors are clustered by firm and reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

### 5.2 Net Worth and the Price of External Finance

I next examine whether a stronger financial position lowers the price of external finance, the link captured by the decreasing credit schedule $R_{ik,\tau}(z)$ in equation (8). I estimate

$$BorrowingCost_{it} = \alpha_i + \delta_t + \beta\, NW_{i,t-1} + Z_{it}'\Gamma + \varepsilon_{it}, \tag{37}$$

where $BorrowingCost_{it}$ is total interest expense divided by total debt, and $NW_{i,t-1}$ is lagged net worth, measured either as book net worth relative to total assets or as market net worth relative to market-value assets. The terms $\alpha_i$ and $\delta_t$ are firm and fiscal-year fixed effects, and in the controlled specifications $Z_{it}$ contains firm size, leverage, tangibility, and trade credit. A negative $\beta$ means that firms entering the year with stronger net worth pay lower borrowing costs.

Table 3 shows that $\beta$ is negative for both measures of net worth and significant at the 1 percent level in every specification. With controls, an increase in lagged book net worth of 10 percentage points of assets is associated with a borrowing cost that is 0.46 percentage points lower, and the same increase in lagged market net worth with a borrowing cost that is 1.7 percentage points lower. The coefficients are larger in absolute value after conditioning on firm characteristics, and the relationship is consistent with the decreasing credit schedule in the model.

Table 3: Net Worth and Borrowing Costs

| Dep. var.: | Borrowing cost | | | |
|---|---|---|---|---|
| | Book Net Worth | | Market Net Worth | |
| | (1) | (2) | (3) | (4) |
| Lagged net worth / assets | -0.019*** | -0.046*** | -0.096*** | -0.168*** |
| | (0.005) | (0.006) | (0.019) | (0.021) |
| Log assets | | -0.067*** | | -0.072*** |
| | | (0.005) | | (0.006) |
| Leverage | | -0.185*** | | -0.155*** |
| | | (0.011) | | (0.011) |
| Tangibility | | -0.132*** | | -0.164*** |
| | | (0.032) | | (0.033) |
| Trade credit | | -0.001 | | 0.001 |
| | | (0.002) | | (0.002) |
| Observations | 58,459 | 58,268 | 51,509 | 51,330 |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Controls | No | Yes | No | Yes |

*Notes:* This table reports estimates of equation (37), firm-level fixed-effects regressions relating lagged net worth to subsequent borrowing costs. The dependent variable is total interest expense divided by total debt. Book net worth is shareholders' equity divided by total assets. Market net worth is constructed using the market value of equity and scaled by market-value assets. All continuous variables are winsorized at the 1st and 99th percentiles. Columns (1) and (3) include firm and fiscal-year fixed effects only. Columns (2) and (4) additionally control for firm size, leverage, tangibility, and trade credit. Standard errors are clustered by firm and reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

### 5.3 Interpretation

The evidence in this section supports the two links on which the model's borrowing-cost channel rests. Firms that hedge more have more stable financial positions, and firms with stronger financial positions pay lower borrowing costs. These patterns indicate that hedging can stabilize the price at which a firm borrows, which in the model enters its marginal cost and is transmitted to connected firms through prices and input purchases. Appendix I provides further evidence on external financing. Borrowing rises strongly with

operating financing needs, consistent with the working-capital financing in the model, and firms with weak balance sheets borrow less when these needs rise.

## 6 Quantitative Model and Aggregate Implications

The evidence so far shows that hedging by a firm's customers and suppliers is followed by lower operating volatility. This pattern is consistent with a mechanism in which hedging stabilizes a firm's net worth and therefore the rate at which it borrows, which in turn stabilizes its prices and production and passes through to connected firms via the costs of their inputs and the demand for their output. These findings raise three questions. How much does foreign exchange hedging stabilize the economy as a whole? How much of a firm's stabilization comes from its own hedge, and how much from the hedging of other firms in the network? And does it matter where in the network hedging takes place? To answer these questions, I first document how firms' hedging varies with their position in the production network and then quantify the model on the 60-industry U.S. production network, calibrated to the aggregate notional value of reported foreign exchange derivatives.

Three results stand out. First, hedging stabilizes firms' financial positions much more than their operations. It lowers the exchange-rate-driven volatility of terminal net worth by 31 to 48 percent and that of sales, COGS, and output by 1 to 6 percent. Second, the two forms of stabilization have different sources. An industry's own hedge accounts for almost all of the stabilization of its net worth, whereas the hedging of other industries accounts for one-third to three-fifths of the stabilization of its operations. Third, an industry's hedge matters more for other industries when the industry is a central supplier, although no single industry accounts for much of the aggregate stabilization. In the aggregate, hedging smooths production across exchange-rate states with a negligible effect on expected production, and it offsets one-quarter to two-fifths of the volatility amplification generated by the dependence of borrowing rates on net worth. Table 4 summarizes these results.

Table 4: Quantitative results at a glance

| | Import price | Foreign demand |
|---|---|---|
| *A. Access to hedging: optimal hedge relative to no hedge* | | |
| Reduction in terminal-net-worth volatility (%) | 47.5 | 30.8 |
| Reduction in output volatility (%) | 3.0 | 2.8 |
| Reduction in aggregate value-added volatility (%) | 3.9 | 2.5 |
| Change in expected aggregate value added (%) | 0.00002 | 0.0001 |
| *B. Share of stabilization due to other industries' hedging* | | |
| Terminal net worth (%) | 3.0 | 3.1 |
| Sales (%) | 60.1 | 60.0 |
| COGS (%) | 37.6 | 34.3 |
| Output (%) | 50.5 | 51.0 |
| *C. Removing one industry's hedge: 60 interventions per economy* | | |
| Median absolute value-added response outside the source ($m) | 0.006 | 1.49 |
| Rank correlation of this response with supplier centrality | 0.72 | 0.83 |
| Partial rank correlation, with controls | 0.91 | 0.59 |
| Median increase in aggregate value-added volatility (%) | 0.03 | 0.02 |
| *D. Borrowing-cost channel: relative to a matched constant rate* | | |
| Amplification of value-added volatility without hedging (%) | 10.2 | 10.5 |
| Amplification of value-added volatility with optimal hedging (%) | 5.9 | 7.8 |
| Share of the amplification offset by hedging (%) | 42 | 26 |

*Notes:* This table summarizes the key results from Section 6. Volatility is the standard deviation of log outcomes across the five exchange-rate states. Net-worth and output volatility are BEA-output-weighted means of industry standard deviations (Table 7); value-added volatility refers to aggregate real value added of the 60 modeled industries. Panel B reports the output-weighted Shapley share of stabilization attributed to the hedging of the other 59 industries (equation (44)). Panel C sets each industry's hedge to zero in turn while the other industries reoptimize; supplier centrality is forward Leontief centrality, correlations are Spearman's, the partial correlation controls for the removed notional, the source's gross output, and its direct exchange-rate exposure, and volatility increases are relative to the baseline standard deviation. Panel D compares the no-hedge and optimal-hedge economies with an economy in which each industry's borrowing rate is fixed at its baseline expected value.

### 6.1 Hedging Allocation Across the Production Network

Before turning to the quantitative model, I document how firms' own foreign exchange hedging varies with their position in the production network. I measure a firm's connectedness by the numbers of its observed downstream customers and upstream suppliers in FactSet Revere, whose coverage, unlike that of the Compustat Segment data, is not limited to major customers. Figure 7 shows that hedge participation rises strongly with both: it is below 10 percent among firms with no observed customers or suppliers, but about 37 percent among firms with at least ten observed customers and 45 percent among firms with at least ten observed suppliers.

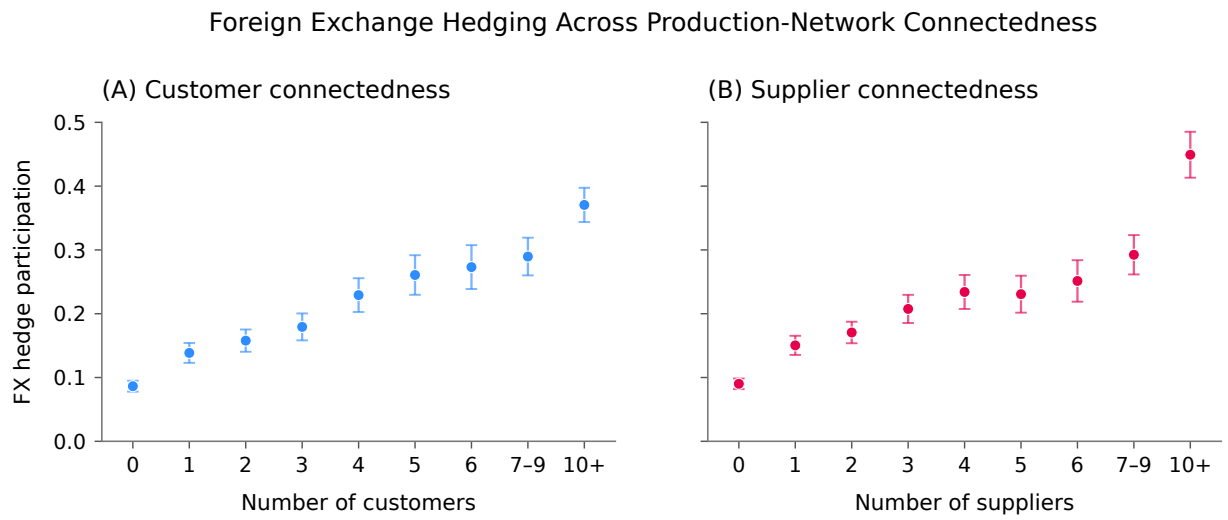



Figure 7: Foreign Exchange Hedging Across Production-Network Connectedness

*Notes:* This figure plots mean foreign exchange hedge participation by the number of observed downstream customers (Panel A) and upstream suppliers (Panel B) in FactSet Revere, grouped as 0, 1, . . . , 6, 7–9, and 10 or more. Hedge participation equals one when the firm's reported FX derivative notional is positive. Vertical bars are 95% confidence intervals clustered by firm. The sample is the 63,259 firm-year observations from 8,005 firms in columns (1)–(2) of Table 5; firm-years with missing network data are excluded rather than assigned zero counterparties.

Firms with more customers and suppliers may also trade more directly with foreign markets or differ in size and financial structure. To account for these differences, I estimate

$$Hedge_{it} = \beta_D \log(1 + Customers_{it}) + \beta_U \log(1 + Suppliers_{it}) + \theta_O \log(1 + OutputExposure_{it}) + \theta_I \log(1 + InputExposure_{it}) + X'_{it}\boldsymbol{\phi} + \mu_k + \delta_t + \varepsilon_{it}, \tag{38}$$

where $Hedge_{it}$ is either an indicator for positive FX hedging or FX derivative notional scaled by total assets, and $Customers_{it}$ and $Suppliers_{it}$ are the numbers of observed customers and suppliers. $OutputExposure_{it}$ and $InputExposure_{it}$ measure direct foreign operating exposure by the numbers of output- and input-side country mentions in the firm's 10-K filing (Section 3.5). $X_{it}$ contains firm size, leverage, cash holdings, tangibility, and trade credit, $\mu_k$ denotes industry or firm fixed effects, and $\delta_t$ denotes fiscal-year fixed effects.

Table 5 shows that the relationship holds after conditioning on direct foreign exposure and firm characteristics. With two-digit SIC and fiscal-year fixed effects, doubling $1 + Customers$ is associated with a 1.2 percentage point higher probability of hedging, and doubling $1 + Suppliers$ with a 2.1 percentage point higher probability. Both coefficients

remain positive and significant with firm fixed effects. Foreign exchange hedging is therefore associated with production-network connectedness as well as with direct foreign exposure.

Table 5: FX Hedging and Production-Network Connectedness

| | SIC2 and Year FE | | Firm and Year FE | |
|---|---|---|---|---|
| | Hedge participation | Hedge intensity | Hedge participation | Hedge intensity |
| Log(1+Customers) | 0.017*** | 0.002*** | 0.010*** | 0.001*** |
| | (0.004) | (0.000) | (0.003) | (0.000) |
| Log(1+Suppliers) | 0.031*** | 0.004*** | 0.010*** | 0.001** |
| | (0.005) | (0.001) | (0.004) | (0.000) |
| Log(1+Output exposure) | 0.026*** | 0.002*** | 0.017*** | 0.002*** |
| | (0.004) | (0.000) | (0.003) | (0.000) |
| Log(1+Input exposure) | 0.027*** | 0.002*** | 0.007** | -0.001* |
| | (0.004) | (0.000) | (0.003) | (0.000) |
| Log assets | 0.045*** | 0.003*** | 0.025*** | 0.001** |
| | (0.002) | (0.000) | (0.003) | (0.000) |
| Leverage | 0.036*** | 0.002*** | 0.009*** | -0.000 |
| | (0.003) | (0.000) | (0.002) | (0.000) |
| Cash / Assets | -0.108*** | -0.010*** | -0.011 | -0.002 |
| | (0.014) | (0.002) | (0.011) | (0.001) |
| Tangibility | -0.121*** | -0.008*** | -0.031* | -0.005*** |
| | (0.018) | (0.002) | (0.018) | (0.002) |
| Trade credit | 0.002*** | 0.000*** | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Observations | 63,259 | 63,259 | 62,967 | 62,967 |
| Adjusted $R^2$ | 0.287 | 0.167 | 0.695 | 0.647 |
| SIC2 FE | Yes | Yes | No | No |
| Firm FE | No | No | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

*Notes:* This table reports estimates of equation (38). Customers and Suppliers are the numbers of observed downstream customers and upstream suppliers in FactSet Revere; output and input exposure are the numbers of output- and input-side country mentions in the firm's 10-K filing. Hedge participation equals one when the firm's reported FX derivative notional is positive. Hedge intensity is FX derivative notional divided by total assets, winsorized at the 1st and 99th percentiles. Standard errors clustered by firm are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

Figure 8 provides a complementary sector-level view of these allocation patterns. Foreign exchange hedging is heterogeneous across sectors and is observed throughout the production network rather than being confined to a single part of the network. The figure also highlights the dense supplier-customer relationships linking sectors with substantially different hedging participation rates. Appendix Figures A7 and A8 report hedge participation and intensity by sector and the prevalence of hedging among firms' customers and suppliers.

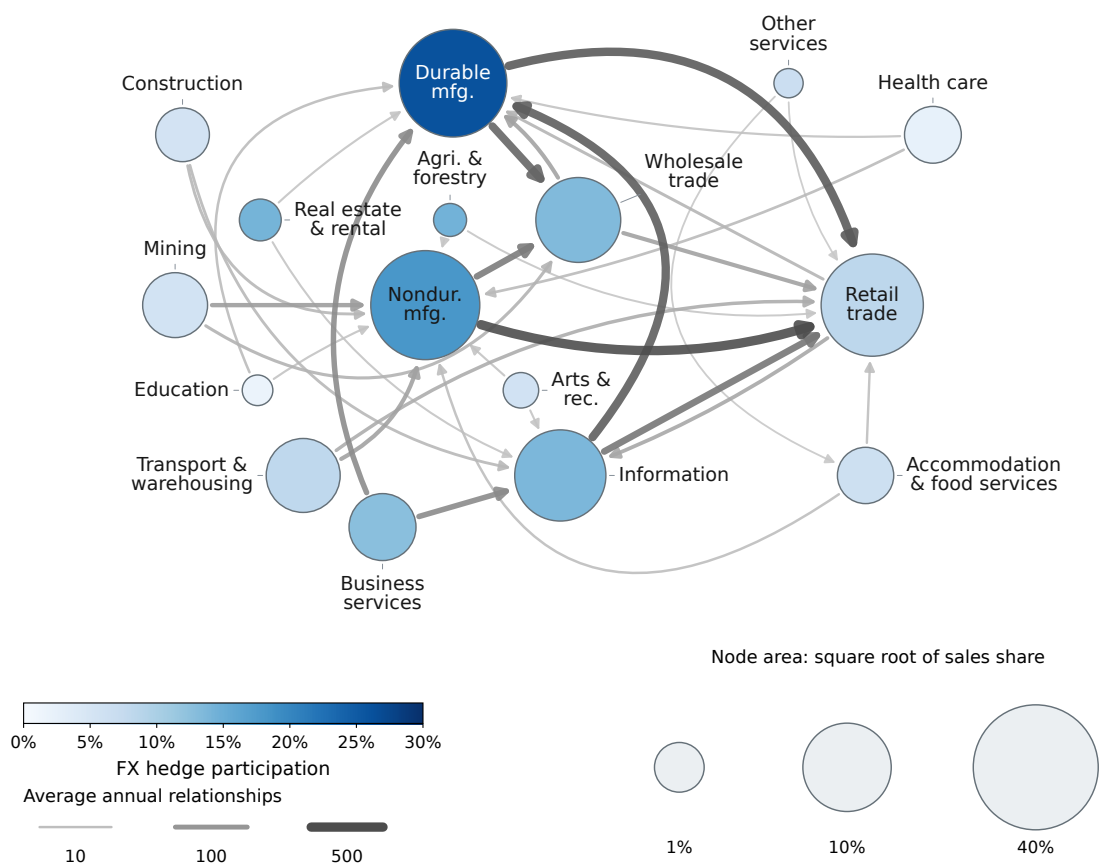



Figure 8: Foreign Exchange Hedging Across Broad Production Sectors

*Notes:* This figure provides a sector-level representation of foreign exchange hedging across the production network. Nodes are broad production sectors constructed from the BEA industry classification. Node color is the share of firm-year observations in the sector with positive foreign exchange hedging, and node area is proportional to the square root of the sector's average annual share of sample sales. Arrows run from supplier to customer sectors, with thickness proportional to the average annual number of observed supplier-customer relationships; for readability, only the two strongest outgoing links of each sector are shown. Relationships combine Compustat Segment and FactSet Revere links over fiscal years 2003–2022.

## 6.2 Calibration

**Production network.** The quantitative economy is the multi-input version of the model in Appendix A.8, applied to 60 industries. Gross output, intermediate-input purchases, imports, and exports are taken from the 2022 Bureau of Economic Analysis (BEA) input-output accounts. The 60-industry network excludes utilities, housing, four finance and insurance industries, and five government industries. Inputs supplied by these excluded

domestic industries remain in firms' production costs and external-financing requirements, but their prices are held fixed at one rather than determined endogenously within the network. Let $G_i$ denote industry $i$'s gross output and $X_i$ its exports. Each modeled industry can face both imported-input costs and foreign demand, directly and through its suppliers and customers, and its position in the network does not determine the direction of its hedge.

**Exchange-rate states.** One model period is a year. I construct five equally likely exchange-rate states from fifteen December-to-December changes in the Federal Reserve H.10 broad U.S. dollar index, inverted so that an increase corresponds to dollar depreciation. I sort these observations into five equal-frequency bins and normalize the middle state from its empirical value of 0.98772 to one. This normalization is a modeling choice. The resulting states are $e_s = 0.908$, 0.959, 1.000, 1.021, and 1.073, yielding a fair forward rate of $e_f = \sum_s \pi_s e_s = 0.9922$.[5] I interpret $e_s$ as a common dollar depreciation factor, consistent with evidence that a common dollar factor accounts for a substantial share of bilateral exchange-rate movements (Lustig et al., 2011; Verdelhan, 2018).

**Price rigidity.** I set the quarterly probability of not resetting prices to 0.65, motivated by the median monthly producer-price change frequency of 13.1% reported by Goldberg and Hellerstein (2009). Under a constant monthly adjustment hazard, this corresponds to a quarterly survival probability of approximately $(1 - 0.131)^3 = 0.656$. I use 0.65 as a benchmark rather than a directly estimated quarterly probability, implying an annual preset-price share of $\lambda = 0.65^4 = 0.179$.

**Transmission channels.** As in Section 2.1, I study the import-price and foreign-demand channels in separate economies. In the *import-price economy*, the exchange rate moves the price of imported inputs, and foreign demand responds only to industries' dollar prices. In the *foreign-demand economy*, imported-input prices are fixed, and foreign demand for industry $i$ is

$$Y_{is}^f = X_i \left[ \frac{e_s/e_0}{P_{is}/P_i^0} \right]^{\chi_i}, \qquad e_0 = P_i^0 = 1, \tag{39}$$

which is equation (10) with $\beta_f^X = \chi_f = \chi_i$; the import-price economy sets $\beta_f^X = 0$. The two economies isolate transmission channels rather than types of industries, so their effects are reported separately.

[5] Pricing the forward at the expected spot rate abstracts from currency risk premia (Lustig and Verdelhan, 2007; Verdelhan, 2010; Lustig et al., 2011) and from deviations from covered interest parity (Du et al., 2018); the resource cost $\Gamma_i$ in equation (41) captures hedging costs in reduced form.

**Foreign-demand elasticities.** For 15 industries with a direct counterpart in GTAP, the foreign-demand elasticities follow the relative profile of the import-source substitution parameters in Hertel and van der Mensbrugghe (2024), normalized to an export-weighted mean of four within that group; the remaining 45 industries have $\chi_i = 4$. The matched industries account for 33 percent of exports, and the export-weighted mean elasticity across all 60 industries is four. The GTAP parameters provide relative variation across industries rather than direct estimates of each industry's demand response to the dollar.

**Imported-input prices.** The import-price economy replaces the linear schedule in equation (9) with an annual schedule whose local elasticity with respect to the exchange rate is 0.20, in line with the response of the U.S. import price index in Appendix B.2. Appendix J.3 gives both specifications.

**Borrowing rates.** The credit schedule for borrowing rates is equation (8) with $R_{\min} = 1.0311$ and $\Delta R = 0.0175$,

$$R_{i\tau}(z) = 1.0311 + 0.0175 \exp\left[-\gamma \frac{z - z^0_{i\tau}}{\text{Rev}^0_i}\right], \tag{40}$$

so the net borrowing rate at the reference position is 4.86 percent. The reference revenue $\text{Rev}^0_i$ and the reference positions $z^0_{i\tau}$ are held fixed across all counterfactuals.

**Hedging cost.** The hedging cost is equation (12) with $D_{H,i} = G_i$,

$$\Gamma_i(q_i) = \frac{\kappa (e_f q_i)^2}{2G_i}, \qquad \kappa = 0.002. \tag{41}$$

I fix $\kappa$ as a low-friction benchmark. Because the cost is quadratic, its average charge per dollar of notional rises with the size of the position; at the calibrated positions it is 0.04 basis points in the import-price economy and 0.71 basis points in the foreign-demand economy.[6]

**Calibration target.** Given these values, $\gamma$ is chosen to match a single moment. Let $q^P_i(\gamma)$ and $q^D_i(\gamma)$ denote the optimal positions in the import-price and foreign-demand

[6]The convexity is consistent with the balance-sheet costs of the intermediaries that supply currency hedges, which drive deviations from covered interest parity (Du et al., 2018).

economies. The model counterpart of aggregate notional relative to gross output is

$$\mathcal{H}(\gamma) = \frac{e_f \sum_i \left( |q_i^P(\gamma)| + |q_i^D(\gamma)| \right)}{\sum_i G_i}. \tag{42}$$

Because firms report gross notional summed across contracts, I sum the absolute positions from the two channel economies. The data counterpart is reported fiscal-year 2022 foreign exchange derivative notional divided by BEA gross output, 3.56 percent. The calibrated value $\gamma = 7.65$ matches this target; the foreign-demand economy accounts for 3.35 percentage points and the import-price economy for 0.20 (Table 6). Reported derivatives can also hedge exposures outside the model, such as financing or translation exposure, so the target is an upper bound on operating hedges.

**Untargeted moments.** The model also captures much of the cross-industry variation in hedging. Across 16 broad sectors, model-implied and reported hedging intensities have a Spearman rank correlation of 0.83 and an output-weighted Pearson correlation of 0.88 (Table 6, Panel E), neither of which is targeted. Because the hedging cost is common across industries, the model spreads hedging more evenly across sectors than the data do (Appendix Figure A17).

Table 6: Quantitative Model Calibration and Untargeted Moments

| Parameter or moment | Value | Source or discipline |
|---|---|---|
| *A. Fixed parameters and model inputs* | | |
| Quadratic hedging-cost parameter, $\kappa$ | 0.002 | Low-friction benchmark |
| Foreign-demand elasticity, $\chi_i$ (export-weighted mean) | 4.00 | GTAP-based profile; Hertel and van der Mensbrugghe (2024) |
| Import-price exchange-rate pass-through | 0.20 | Appendix B.2 |
| Annual preset-price share, $\lambda$ | 0.179 | Quarterly survival rate: $0.65^4$ |
| Annual exchange-rate states | 5 | Five-state FX discretization |
| State probabilities, $\pi_s$ | 0.20 | Equal probabilities |
| Actuarially fair forward rate, $e_f$ | 0.9922 | $\sum_s \pi_s e_s$ |
| Credit schedule: $R_{\min}$ | 1.0311 | Reference borrowing-rate specification |
| Credit schedule: $\Delta R$ | 0.0175 | Reference net rate of 4.86% |
| *B. Internally calibrated parameter* | | |
| Financial-friction sensitivity, $\gamma$ | 7.6533 | Aggregate FX hedging moment |
| *C. Targeted moment* | | |
| FX derivative notional / gross output (%), data | 3.5555 | FY2022 10-K filings and BEA |
| FX hedging notional / gross output (%), model | 3.5555 | Calibrated equilibrium |
| *D. Model decomposition of the targeted moment* | | |
| Import-price channel (%) | 0.2038 | Model-implied |
| Foreign-demand channel (%) | 3.3517 | Model-implied |
| *E. Untargeted sectoral moments* | | |
| Model–data hedging intensity correlation: Spearman | 0.831 | 16 broad industry groups |
| Model–data hedging intensity correlation: weighted Pearson | 0.878 | BEA-output-weighted; 16 groups |

*Notes:* This table summarizes the calibration of the annual 60-industry production-network model. The hedging-cost parameter is fixed at a low effective quadratic-friction benchmark. Foreign-demand elasticities use GTAP-based relative heterogeneity for 15 directly matched industries; the remaining industries have $\chi_i = 4$. The annual preset-price share corresponds to a quarterly non-reset probability of 0.65. The financial-friction parameter $\gamma$ is calibrated to match aggregate reported FX derivative notional relative to BEA gross output. The model moment sums absolute hedge notionals from separately solved import-price and foreign-demand economies for measurement purposes; these positions are not jointly optimized. Panel E reports untargeted correlations between model-implied and reported FX hedging intensities across 16 broad industry groups. Each intensity is calculated as aggregate FX notional divided by the corresponding group's BEA gross output. The weighted Pearson correlation uses group BEA gross output as weights. Although the model captures the broad cross-industry ranking, its hedging allocation is less concentrated than in the data. Operating stabilization, output, prices, and network spillovers are not targeted.

### 6.3 The Stabilizing Effects of Foreign Exchange Hedging

The main counterfactual removes financial hedging while keeping the credit schedule for borrowing rates and the production network. In each channel economy, I set every $q_i$ to

zero and let prices, production, and financing re-equilibrate. The comparison with the optimal-hedging baseline measures the total equilibrium effect of access to hedging.

For a positive industry outcome $V$, let $\sigma^c_{i,V}(a) = \mathrm{SD}_\pi(\log V^c_{is}(a))$ denote its standard deviation across the five states, where $c \in \{P, D\}$ indexes the channel and $a \in \{H, 0\}$ denotes optimal hedging or no hedging. With output weights $w_i = G_i / \sum_j G_j$, the stabilization measure is

$$\mathcal{S}^c_V = 100\left[1 - \frac{\sum_i w_i \sigma^c_{i,V}(H)}{\sum_i w_i \sigma^c_{i,V}(0)}\right], \tag{43}$$

which is the percentage reduction in the weighted mean standard deviation.

Table 7 shows that the largest reductions concern terminal net worth. In the import-price economy, hedging lowers its weighted standard deviation by 47.5 percent, compared with 4.4 percent for sales, 6.0 percent for COGS, and 3.0 percent for output. In the foreign-demand economy, the corresponding reductions are 30.8, 1.3, 2.0, and 2.8 percent. Hedging thus absorbs a large share of the exchange-rate-driven variation in financial resources while leaving most of the variation in demand and production costs in place.

Net-worth and output volatility fall in all 60 industries in both economies, so at the calibrated parameters optimal hedging stabilizes net worth in every industry, the case discussed after Proposition 4. Operating outcomes respond less, as the model anticipates: a resource transfer changes a flexible firm's price and output but leaves a rigid firm's output unchanged. COGS volatility rises in some industries, mostly in the import-price economy, because hedging raises output in the states in which imported inputs are expensive, so lower input-price sensitivity need not reduce the volatility of input expenditure.

Table 7: Volatility stabilization from foreign exchange hedging

| | Weighted log SD | | | Industries | |
|---|---|---|---|---|---|
| Outcome | No hedge | Optimal hedge | Reduction (%) | Lower | Higher |
| *Panel A. Import-price economy* | | | | | |
| Sales | 0.000428 | 0.000409 | 4.43 | 54 | 5 |
| COGS | 0.000351 | 0.000330 | 6.02 | 34 | 26 |
| Output | 0.001438 | 0.001395 | 3.01 | 60 | 0 |
| Terminal net worth | 0.000662 | 0.000347 | 47.54 | 60 | 0 |
| *Panel B. Foreign-demand economy* | | | | | |
| Sales | 0.025453 | 0.025111 | 1.34 | 59 | 1 |
| COGS | 0.026051 | 0.025541 | 1.96 | 54 | 6 |
| Output | 0.026935 | 0.026180 | 2.80 | 60 | 0 |
| Terminal net worth | 0.016744 | 0.011593 | 30.76 | 60 | 0 |

*Notes:* Weighted log SD is the BEA-output-weighted mean of industry standard deviations of log outcomes across the five exchange-rate states. Reduction is equation (43). The last two columns count industries whose standard deviation is lower or higher with optimal hedging; one import-price industry with a near-zero no-hedge sales standard deviation is excluded from the count.

### 6.4 Own and Other Industries' Hedging

The comparison in Section 6.3 combines each industry's own hedging with the hedging of its suppliers, its customers, and the rest of the network. To separate the two, I compare the four economies in Table 8 for each industry $i$ in each channel: no industry hedges, only industry $i$ hedges, every industry except $i$ hedges, and every industry hedges. In every economy, the industries allowed to hedge choose their positions optimally, and prices, production, and credit re-clear.

Table 8: Separating own and other industries' hedging

| | Other 59 industries do not hedge | Other 59 industries hedge |
|---|---|---|
| Industry $i$ does not hedge | $\sigma_{i,V}(0)$<br>No-hedge economy | $\sigma_{i,V}(H_{-i})$<br>Single-industry intervention |
| Industry $i$ hedges | $\sigma_{i,V}(H_i)$<br>Only $i$ hedges | $\sigma_{i,V}(H)$<br>Baseline |

*Notes:* Each cell is industry $i$'s standard deviation of log outcome $V$ across exchange-rate states in the indicated economy. Moving from the left to the right column adds the other industries' hedging, and moving from the top to the bottom row adds industry $i$'s own hedging. Total stabilization is $\sigma_{i,V}(0) - \sigma_{i,V}(H)$. The contribution of other industries' hedging, $\Phi^N_{i,V}$ in equation (44), averages the two horizontal differences, and the contribution of industry $i$'s own hedging, $\Phi^O_{i,V}$, averages the two vertical differences.

The horizontal difference in the top row of Table 8, $\sigma_{i,V}(0) - \sigma_{i,V}(H_{-i})$, measures how much the hedging of the other 59 industries stabilizes industry $i$ when $i$ itself cannot hedge, and the difference in the bottom row measures the same contribution when $i$ hedges. The two can differ because the value of an industry's own hedge depends on whether the rest of the network hedges. I therefore average them, and likewise the two vertical differences,

$$\begin{aligned} \Phi^{N}_{i,V} &= \tfrac{1}{2}\left[\sigma_{i,V}(0) - \sigma_{i,V}(H_{-i})\right] + \tfrac{1}{2}\left[\sigma_{i,V}(H_i) - \sigma_{i,V}(H)\right], \\ \Phi^{O}_{i,V} &= \tfrac{1}{2}\left[\sigma_{i,V}(0) - \sigma_{i,V}(H_i)\right] + \tfrac{1}{2}\left[\sigma_{i,V}(H_{-i}) - \sigma_{i,V}(H)\right], \end{aligned} \tag{44}$$

so that $\Phi^{N}_{i,V} + \Phi^{O}_{i,V} = \sigma_{i,V}(0) - \sigma_{i,V}(H)$. This is the Shapley value of a two-player game between industry $i$ and the rest of the network. The share of stabilization attributed to other industries' hedging is $\sum_i w_i \Phi^{N}_{i,V} / \sum_i w_i [\sigma_{i,V}(0) - \sigma_{i,V}(H)]$. The decomposition treats the other 59 industries as a single player, so it does not attribute stabilization to each of them separately, and the own component includes the feedback of an industry's hedge on itself through its suppliers and customers.

Figure 9 shows a sharp contrast. Other industries' hedging accounts for only 3 percent of the stabilization of an industry's terminal net worth in both economies, but for about half of the stabilization of its output, 60 percent of the stabilization of its sales, and 34 to 38 percent of the stabilization of its COGS. Even when an industry cannot hedge, the hedging of the other 59 industries lowers its output volatility by 1.5 and 1.4 percent of the no-hedge level, about half of the total reductions, so the result does not depend on the order in which own and other industries' hedging is introduced. Appendix Table A15 and Appendix Figure A18 report the decomposition and its distribution across industries.

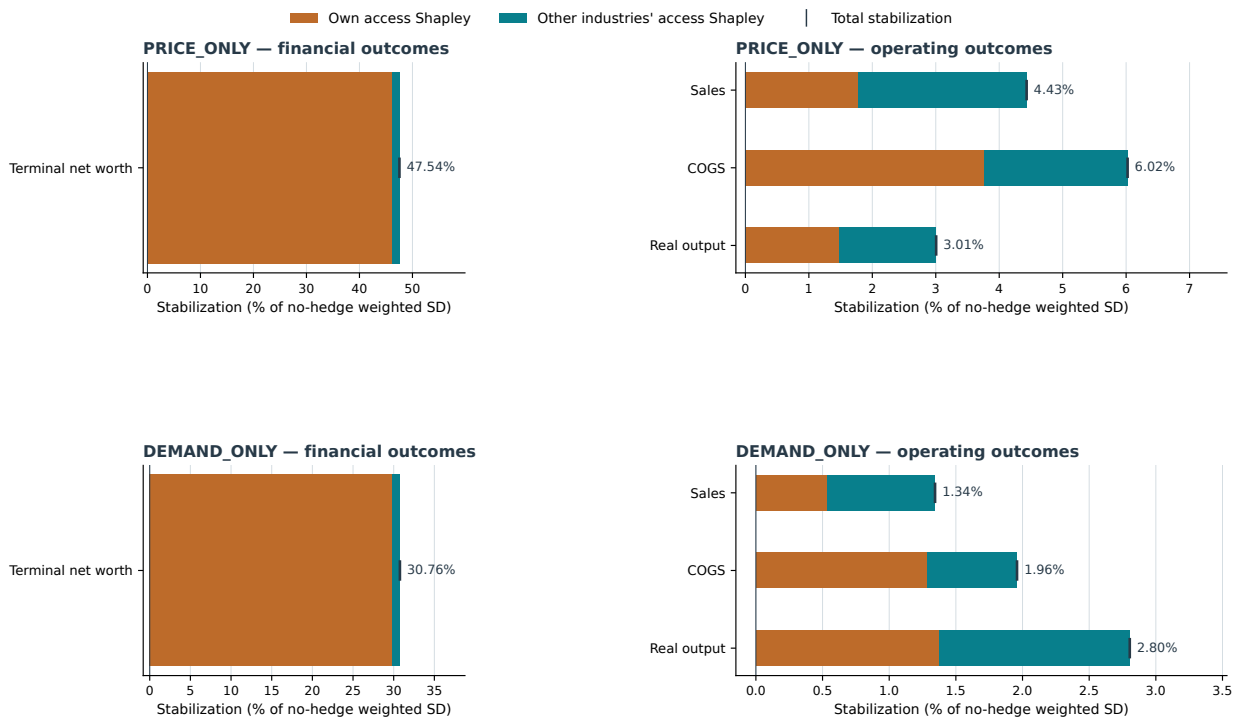



Figure 9: Stabilization from own and other industries' hedging

*Notes:* Each bar splits the total stabilization of the output-weighted industry volatility of an outcome, equation (43), into the Shapley contributions of each industry's own hedging and of the other 59 industries' hedging, equation (44). Left panels show terminal net worth and right panels the operating outcomes. Top panels show the import-price economy and bottom panels the foreign-demand economy; horizontal scales differ.

The pattern follows from the model. A firm's own hedge transfers resources across exchange-rate states and therefore acts directly on its net worth and borrowing rate (Propositions 3 and 4), but it changes the firm's operations only through the response of its flexible price, and not at all for a rigid-price firm that meets demand. The hedges of other industries instead reach the firm through the prices of its inputs and the demand of its customers (Propositions 5 and 6), which act directly on its sales, costs, and output. Hedging is therefore mainly a private stabilizer of financial positions and, to a substantial degree, a network stabilizer of operations. The second margin is the one the event-study evidence in Section 4 measures.

### 6.5 Propagation of Individual Industries' Hedges

Section 6.4 takes the perspective of the industry that benefits from hedging. This section takes the perspective of the industry that hedges: how much does one industry's hedge affect activity in the rest of the economy, and which industries' hedges matter most for

others? I remove the hedge of one industry at a time, for each of the 60 industries in each channel economy, while the other 59 industries reoptimize their hedges and prices, production, and credit re-clear. I measure the outside response by the sum of absolute changes in the other 59 industries' expected real value added.[7]

The outside responses vary widely across sources, with medians of $0.006 million in the import-price economy and $1.49 million in the foreign-demand economy (Appendix Figure A10). For most sources, industries other than the source account for more than half of the absolute response.[8]

Figure 10 shows that the outside response rises with the source's forward Leontief centrality as a supplier, with Spearman rank correlations of 0.72 in the import-price economy and 0.83 in the foreign-demand economy. The association does not reflect hedge size or industry scale alone: after controlling for the removed notional, the source's gross output, and its direct exchange-rate exposure, the partial rank correlations are 0.91 and 0.59, and the association also holds per dollar of removed notional and when influential sources are excluded (Appendix Table A13 and Figure A11). In the foreign-demand economy, however, hedge size and industry scale account for most of the cross-source variation. The volatility responses of other industries show a similar pattern (Appendix Figure A19). A given hedge therefore reaches more of the network when a central supplier holds it.

[7] I use absolute rather than signed changes because, in the foreign-demand economy, the responses of different industries often have opposite signs: the total response has the opposite sign of the source industry's own response for 25 of the 54 sources with a measurable own response, so conventional multipliers are not well defined (Appendix Figures A12 and A13).

[8] For example, removing the hedge of chemical products (BEA 325), which generates the largest outside response in both economies, lowers expected value added by $40.1 million in the foreign-demand economy, 73 percent of it outside chemicals; relative to each industry's size, the response declines with distance from chemicals in the supplier-to-buyer network (Appendix Figure A16).

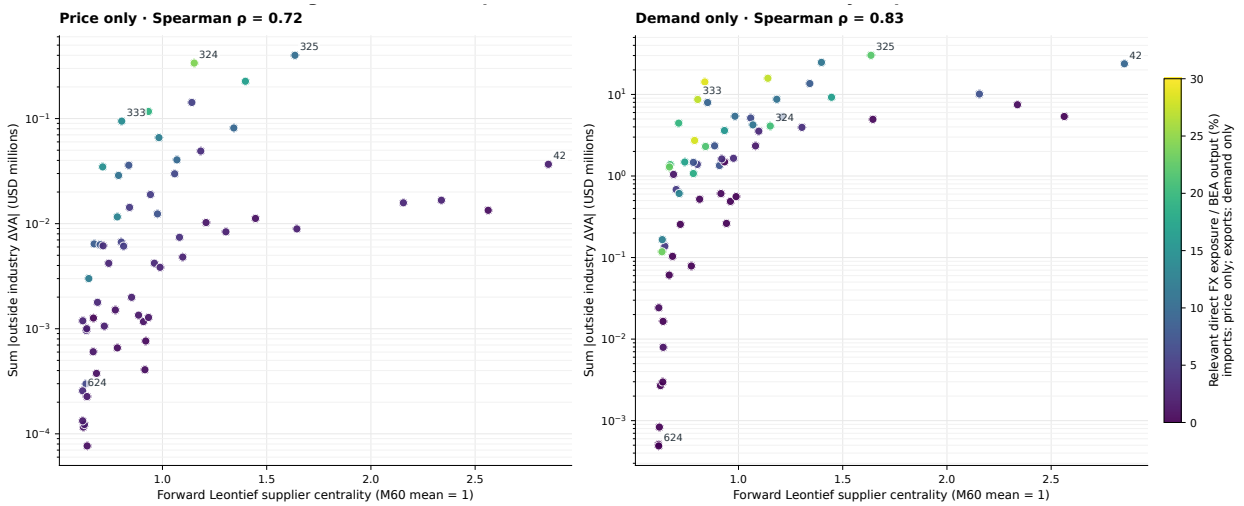



Figure 10: Network position and the response outside the source industry

*Notes:* Each point is one of 60 interventions that sets the hedge of the indicated source industry to zero while the other 59 industries reoptimize. The vertical axis is the sum of absolute changes in expected real value added outside the source industry, in millions of dollars (log scale). The horizontal axis is the source's forward Leontief centrality as a supplier, normalized to a mean of one across the 60 industries. Color is the source's direct exposure relative to BEA gross output: imports in the import-price economy and exports in the foreign-demand economy. Labels mark selected BEA industries. Appendix Figure A11 reports the relationship after controls and per dollar of removed notional.

The aggregate effects of any single industry's hedge are small. Removing one industry's hedge raises the volatility of aggregate value added in all 120 interventions, but the median increase is 0.03 percent of the baseline standard deviation in the import-price economy and 0.02 percent in the foreign-demand economy, compared with 4.1 and 2.5 percent when all hedges are removed (Appendix Figure A14). The aggregate stabilization from hedging therefore reflects hedging by many industries across the network rather than by a few.

### 6.6 State-Contingent Effects on Production, Prices, and Borrowing Costs

I measure aggregate activity by real gross output and real value added, both at common model reference prices. Value added subtracts all intermediate inputs, including imported inputs and purchases from outside the network, and refers to the 60 modeled industries rather than national GDP. The aggregate output-price index weights industry prices by 2022 BEA gross output and is a producer price index rather than a consumer price index. Appendix J.4 gives the definitions.

Figure 11 shows that hedging mainly redistributes production across exchange-rate states. A dollar depreciation lowers production in the import-price economy, by raising

imported-input costs, and raises it in the foreign-demand economy, by raising foreign demand. In both economies, removing hedging raises value added in the states in which production is high and lowers it in the states in which production is low, by about 0.005 percent in the extreme states of the import-price economy and 0.08 to 0.09 percent in those of the foreign-demand economy. Hedging thus flattens the response of production to the exchange rate.

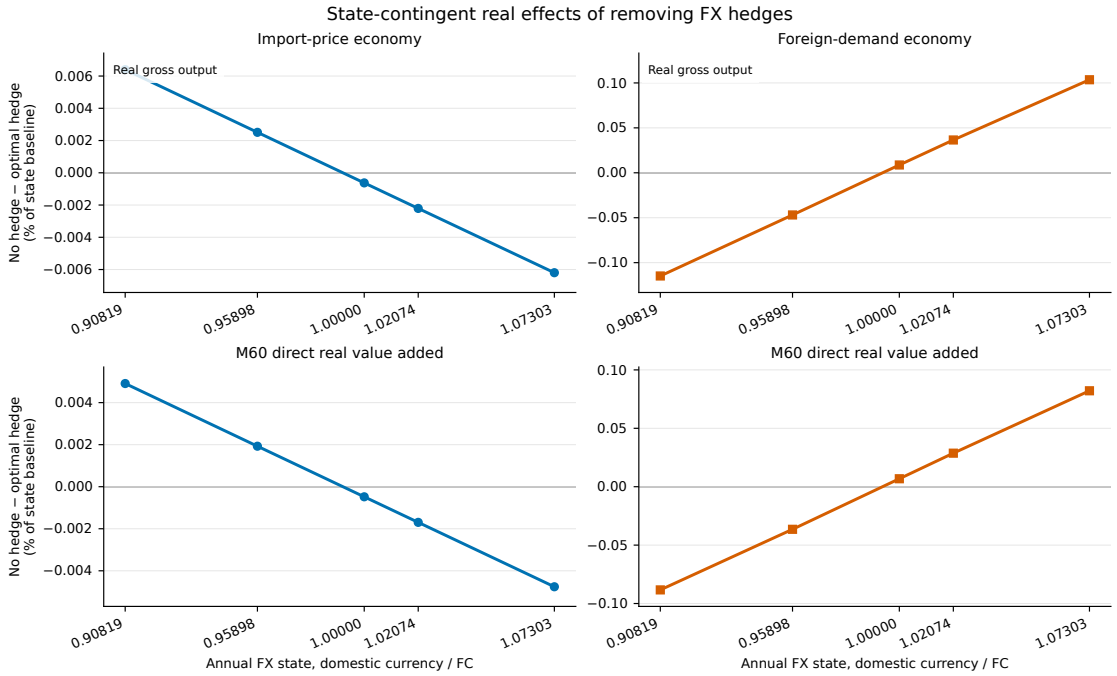



Figure 11: Effect of removing hedging on real production, by exchange-rate state

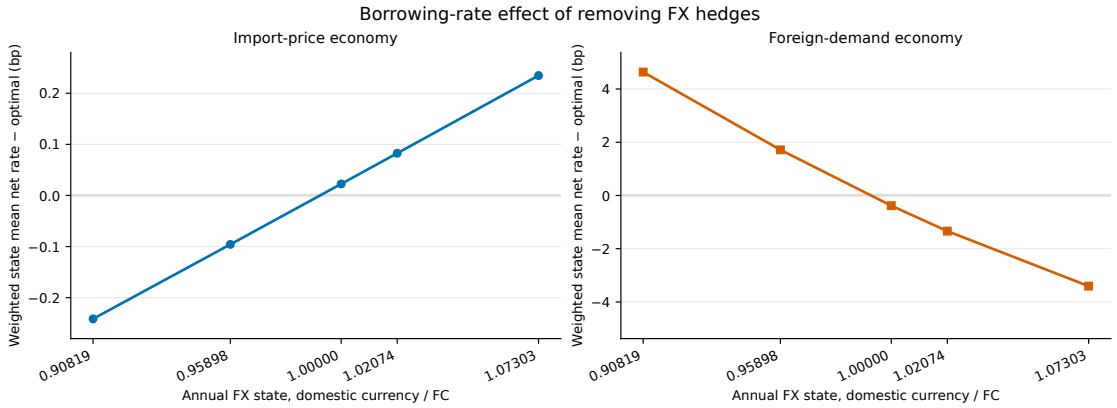
*Notes:* Each point is real gross output (top) or real value added (bottom) of the 60 modeled industries in the no-hedge economy minus the optimal-hedge baseline, in percent of the baseline in the same state. Both aggregates are evaluated at common model reference prices. The left panels show the import-price economy and the right panels the foreign-demand economy; vertical scales differ. The horizontal axis indexes exchange-rate states, not time.

The effects on expected production are much smaller. Hedging raises expected real value added by 0.00002 percent in the import-price economy and 0.0001 percent in the foreign-demand economy (Appendix Table A9), whereas it lowers the standard deviation of log aggregate value added across states by 3.9 and 2.5 percent. Because the forward is fairly priced, a given position transfers resources across states without changing their expected value, $\mathbb{E}_\pi[(e_s - e_f)q_i] = 0$. Production, credit, and pricing respond nonlinearly, so this identity does not pin down the expected output effect, but in the computed equilibria the gains in weak states and the losses in strong states nearly offset.

Figure 12 shows the corresponding responses of borrowing rates and prices. With-

out hedging, borrowing rates rise in the states in which firms' financial positions are weak: depreciation states in the import-price economy and appreciation states in the foreign-demand economy. Hedging lowers the output-weighted within-industry standard deviation of borrowing rates from 0.35 to 0.19 basis points in the import-price economy and from 9.67 to 6.95 basis points in the foreign-demand economy, leaving the expected rate essentially unchanged (Appendix Table A11). Through marginal costs, it also lowers the standard deviation of the price index across states by 2 percent in the import-price economy and 28 percent in the foreign-demand economy, with a negligible effect on its expected level (Appendix Table A10).

*(i) Borrowing rates*




*(ii) Output-price index*

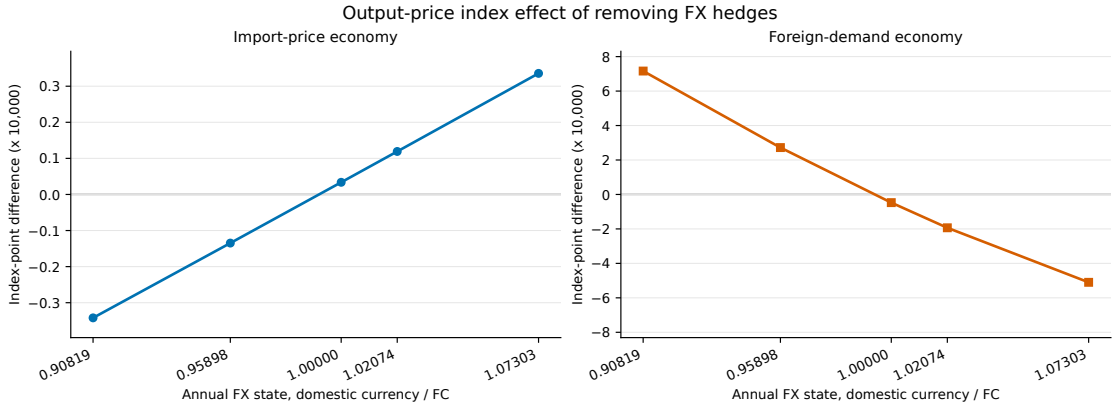



Figure 12: Effect of removing hedging on borrowing rates and prices, by exchange-rate state

*Notes:* Row (i) shows the BEA-output-weighted mean net annual borrowing rate in the no-hedge economy minus the optimal-hedge baseline, in basis points. Row (ii) shows the corresponding difference in the 2022-BEA-gross-output-weighted price index, in index points multiplied by $10^4$. Left panels show the import-price economy and right panels the foreign-demand economy; vertical scales differ. Index levels and expected values are reported in Appendix Tables A10 and A11.

### 6.7 Financial Amplification

To isolate the role of the credit contract, I replace the credit schedule in equation (40) with a *matched quote* that fixes each industry's borrowing rate at its own expected rate in the baseline, averaged over states and pricing types (equation (A27)). Each industry then pays the same average rate as in the baseline, but its rate no longer varies across states or with its financial position. Hedges and all other choices are reoptimized, and optimal hedges are then economically zero: once the rate no longer depends on the financial position, a fairly priced forward has no private benefit, while its cost remains positive, as Proposition 3 implies.

Because hedges are zero in both the no-hedge and the matched-quote economies, comparing them isolates the credit contract. Figure 13 normalizes the standard deviation of log aggregate activity across states to 100 under the matched quote. Without hedging, the dependence of the borrowing rate on net worth raises the volatility of aggregate value added by 10.2 percent in the import-price economy and 10.5 percent in the foreign-demand economy. With optimal hedging, the excess falls to 5.9 and 7.8 percent, so hedging offsets 42 and 26 percent of the volatility amplification generated by the borrowing-cost channel. Gross output and industry sales and COGS show the same pattern (Appendix Figure A9).[9]

[9]Expected value added is 0.20 and 0.22 percent higher in the baseline than under the matched quote, and similarly higher than under a uniform quote of 4.86 percent for every industry (Appendix Table A9). Because the matched quote preserves each industry's average rate, this gap does not reflect the average level of borrowing costs but the other features of the credit contract: the rate's sensitivity to the financial position, its state dependence, and its variation across pricing types. It is not an estimate of the output gain from hedging, which is the much smaller difference reported in Section 6.6.

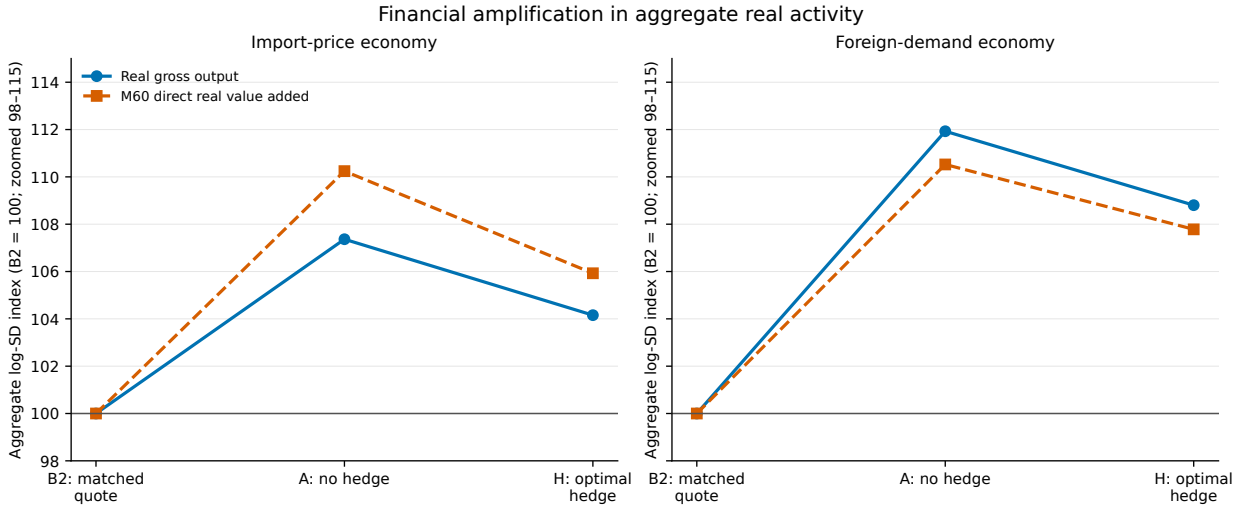



Figure 13: Financial amplification of exchange-rate-driven volatility

*Notes:* Standard deviation of log real gross output and log real value added of the 60 modeled industries across the five exchange-rate states, normalized to 100 in the economy with a matched constant borrowing rate. "No hedge" and "Optimal hedge" use the credit schedule in equation (40). Hedges are zero in the no-hedge economy and economically zero under the matched rate, so the difference between these two economies reflects the credit contract alone. The vertical axis is truncated.

**Summary.** An industry's own hedge stabilizes mainly its own net worth, whereas the hedging of other industries accounts for about half of the stabilization of its operations, and an industry's hedge reaches more of the network when the industry is a central supplier. In the aggregate, hedging smooths production across exchange-rate states with little effect on expected production and offsets part of the volatility that the borrowing-cost channel generates. These results show how hedging decisions made privately by individual industries shape the transmission of exchange-rate risk through the production network.

## 7 Conclusion

This paper shows that the effects of foreign exchange risk management extend beyond the hedging firm. In a production network with financial frictions, a hedge changes the firm's borrowing costs across exchange-rate states and, through its prices and input purchases, the costs and demand of its suppliers and customers. Using new hand-collected data on the foreign exchange derivatives of U.S. firms, linked to their supply-chain relationships, I find that the first adoption of hedging by a firm's customers or suppliers is followed by lower volatility of its sales or production costs. Evidence on net worth and borrowing costs supports the financial mechanism. In a model calibrated to the U.S. production network, an industry's own hedge accounts for almost all of the stabilization of its net

worth, whereas the hedging of other industries accounts for about half of the stabilization of its output and a large share of the stabilization of its sales and costs. Hedging affects other industries most when undertaken by central suppliers, and in the aggregate it offsets part of the volatility amplification generated by borrowing costs.

Two implications follow. For firms, the stability of operations depends not only on their own trade and risk management but also on the exposures and hedging of their suppliers and customers, so assessments of exchange-rate risk that stop at the firm's own transactions understate the role of hedging. For policymakers, the dominance of the dollar in trade invoicing does not insulate U.S. firms from exchange-rate risk, and disruptions to the supply of hedging instruments, such as those studied by Jung (2025), may propagate beyond the firms that lose access to them, with the largest effects when central suppliers are affected.

These results also raise questions for future work. Because a firm's hedge stabilizes its suppliers and customers through prices and demand, private hedging decisions need not account for all of their effects, and whether the resulting allocation of hedging across the network is efficient, and how policies that affect the supply of hedging instruments should take the network into account, remain open questions. The analysis also focuses on U.S. firms. Firms in other dominant-currency economies, such as the euro area, face the same question of why they hedge when much of their trade is invoiced in their own currency. The spillovers may matter even more for firms in emerging market economies, for which hedging is costly and which may therefore rely in part on the hedging of their trading partners in advanced economies. Through cross-border production links, hedging by firms in dollar and other safe-haven currency economies may thus serve as a channel of international risk sharing. Measuring these spillovers across countries and firm characteristics with more granular data on trade and hedging is a natural next step.

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# Part I: Theory

## A Proofs

Throughout this appendix, derivatives with respect to a firm's own choices hold fixed the aggregate environment, other firms' choices, and the reference centers and scales of the credit schedule. At date 1, the firm takes its rate as given. At date 0, a change in the hedge or preset changes the firm's subsequent rate and operating plan, and derivatives account for these responses. All derivatives are evaluated at allocations that satisfy Assumption 2.

### A.1 Interiority and Stability Conditions

Condition (iii) of Assumption 2 holds automatically for a rigid-price firm. Its price is fixed at the preset, so additional resources leave its output and production cost unchanged and raise projected net worth one for one, $\zeta_{ik,R} = 1$. For a flexible-price firm, the rate and the price affect each other. A lower rate lowers the price $p_{ik,F} = M_i r_{ik,F} C_i$ toward $M_i C_i$, the price that maximizes operating profit before interest, which raises projected net worth and lowers the rate further. The proof of Proposition 3 shows that

$$\zeta_{ik,F} = \frac{1}{1-\varphi_{ik}}, \qquad \varphi_{ik} = \frac{\epsilon_i(r_{ik,F}-1)}{r_{ik,F}}\, b_{ik,F}\left[-R'_{ik,F}\left(z_{ik,F}\right)\right] \geq 0. \tag{A1}$$

The term $\varphi_{ik}$ measures the strength of the feedback. A one-unit increase in the rate the firm faces lowers its projected net worth by $\epsilon_i(r_{ik,F}-1)b_{ik,F}/r_{ik,F}$, and each dollar of lower projected net worth raises the rate assigned by the credit schedule by $-R'_{ik,F}(z_{ik,F})$. The first factor is zero at $r_{ik,F} = 1$, where the flexible price maximizes operating profit before interest, and rises as the rate moves the price further above that level. Because $\varphi_{ik} \geq 0$, $\zeta_{ik,F}$ is at least one when $\varphi_{ik} < 1$ and negative when $\varphi_{ik} > 1$. Condition (iii) is therefore equivalent to $\phi_{ik} < 1$: the feedback between the rate and the price converges, amplifying the direct effect of resources by the finite factor $1/(1-\phi_{ik})$, rather than diverging. In that case, the implicit function theorem implies that the rate and the operating plan that satisfy $r_{ik,F} = R_{ik,F}(z_{ik,F})$ are locally unique and differentiable in the firm's resources and in the prices and demand it faces, so a small change in the hedge or preset moves them continuously.

### A.2 Proof of Proposition 1: Operating Costs and Sector Prices

*Proof.* Fix a state and suppress firm and state indices. Conditional on output $y > 0$, the firm minimizes $P_j x + W\ell$ subject to $x^\alpha \ell^{1-\alpha} \geq y$. The constraint binds, and the first-order conditions give $P_j x/(W\ell) = \alpha/(1-\alpha)$, so

$$x(y) = \left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha}\left(\frac{W}{P_j}\right)^{1-\alpha} y, \qquad \ell(y) = \left(\frac{\alpha}{1-\alpha}\right)^{-\alpha}\left(\frac{W}{P_j}\right)^{-\alpha} y. \tag{A2}$$

The minimized production cost is $C_i y$, with $C_i$ given in equation (17). Since the loan finances this bill, $b = C_i y$.

For a flexible firm, demand at fixed aggregate conditions is $y(p) = \mathcal{A} p^{-\epsilon_i}$ with $\mathcal{A} = P_i^{\epsilon_i} Y_i > 0$. At a given rate $r$, the firm maximizes $v + (p - rC_i)y(p)$, and

$$\frac{d}{dp}\Big[(p - rC_i)y(p)\Big] = y(p)\left[1 - \epsilon_i \frac{p - rC_i}{p}\right] = 0 \quad \Longleftrightarrow \quad p = M_i r C_i.$$

This is the unique maximizer because, in terms of output, revenue $\mathcal{A}^{1/\epsilon_i} y^{1-1/\epsilon_i}$ is strictly concave while the financing cost $rC_i y$ is linear. The rate then satisfies $r = R(z)$ at the resulting plan.

With symmetry within pricing types, the CES price index satisfies $P_i^{1-\epsilon_i} = \lambda_i \bar{p}_i^{1-\epsilon_i} + (1 - \lambda_i) p_{i,F}^{1-\epsilon_i}$. Because the preset does not vary with the state, and because $d \log p_{i,F} = d \log r_{i,F} + \alpha_{ij}\, d \log P_j$ at a fixed wage,

$$\frac{d \log P_i}{d \log e} = \frac{(1 - \lambda_i) p_{i,F}^{1-\epsilon_i}}{P_i^{1-\epsilon_i}} \frac{d \log p_{i,F}}{d \log e} = \vartheta_i \left(\alpha_{ij} \varepsilon_{P_j,e} + \varepsilon_{r_{i,F},e}\right).$$

When $\lambda_i = 1$, $\vartheta_i = 0$ and the sector price does not respond. The credit schedule gives

$$\frac{d \log r_{i,F}}{d \log e} = \frac{R'_{i,F}(z_{i,F})}{r_{i,F}} e \frac{dz_{i,F}}{de} = -\frac{\gamma(r_{i,F} - R_{\min})}{\mathrm{Rev}_i^0\, r_{i,F}} e \frac{dz_{i,F}}{de}.$$

Since $z = v + py - b$ and $dv/de = q$ at fixed date-0 choices, $dz/de = q + d(py - b)/de$. Finally, differentiating equation (9) gives $\varepsilon_{P_f,e} = \eta P_x e / P_f$. ■

**The preset-price condition.** At a fixed hedge and fixed aggregate environments, let $y_s(\bar{p}) = \mathcal{A}_s \bar{p}^{-\epsilon_i}$ and let $C_s$ be the state unit cost. The rigid type's projected net worth is $z_s = v_s + (\bar{p} - C_s) y_s$ and its rate is $r_s = R_s(z_s)$. Differentiating $\mathcal{V}_{R,s}$ with respect to the preset, including the response of the rate, gives

$$\mathcal{V}_{R,s,\bar{p}} = y_s + (\bar{p} - r_s C_s) y'_s - b_s R'_s(z_s)\,[y_s + (\bar{p} - C_s) y'_s], \qquad y'_s = -\frac{\epsilon_i y_s}{\bar{p}}, \tag{A3}$$

where the last term is the effect of the preset on the firm's own rate. For $\lambda_i > 0$, an interior preset satisfies $\sum_s \pi(s) \mathcal{V}_{R,s,\bar{p}} = 0$ at the same hedge as the hedge first-order condition; for $\lambda_i = 0$, the preset is immaterial. These necessary conditions do not by themselves certify a joint maximum in $(q, \bar{p})$.

### A.3 Proof of Proposition 2: Sectoral Demand

*Proof.* By equation (A2), each downstream variety $k$ purchases $x_{di,k} = a_{di}(P_i) y_{dk}$, where

$$a_{di}(P_i) = \left(\frac{\alpha_{di}}{1 - \alpha_{di}}\right)^{1-\alpha_{di}} \left(\frac{W}{P_i}\right)^{1-\alpha_{di}}.$$

If sector $i$ has no other destination, market clearing gives $Y_i = \int_0^1 x_{di,k}\,dk = a_{di}(P_i)\int_0^1 y_{dk}\,dk = a_{di}(P_i)\Delta_d Y_d$, which is equation (20). Because the variety mass is one and $(\epsilon_d - 1)/\epsilon_d \in (0,1)$, Jensen's inequality gives $\int y_{dk}^{(\epsilon_d-1)/\epsilon_d}dk \le (\int y_{dk}\,dk)^{(\epsilon_d-1)/\epsilon_d}$, so $Y_d \le \widetilde{Y}_d$ and $\Delta_d \ge 1$, with equality only when variety output is equal almost everywhere. Under CES demand, an equivalent expression is

$$\Delta_d = \int_0^1 \left(\frac{p_{dk}}{P_d}\right)^{-\epsilon_d} dk = \lambda_d \left(\frac{\bar{p}_d}{P_d}\right)^{-\epsilon_d} + (1-\lambda_d)\left(\frac{p_{d,F}}{P_d}\right)^{-\epsilon_d}, \tag{A4}$$

which generally differs from one when rigid and flexible prices differ.

Taking logarithms of $Y_i = a_{di}(P_i)\Delta_d Y_d$ gives equation (21), and multiplying by $P_i$ gives the expenditure elasticity $\varepsilon_{P_i Y_i,e} = \varepsilon_{Y_d,e} + \alpha_{di}\varepsilon_{P_i,e} + \varepsilon_{\Delta_d,e}$. For foreign demand, $\log Y_{3f} = \log \bar{Y}_{3f} + \beta_f^X(\log e - \log e_0) - \chi_f(\log P_3 - \log P_3^0)$, so its elasticity is $\beta_f^X - \chi_f \varepsilon_{P_3,e}$. With several destinations, the elasticity of total sectoral demand is the quantity-share-weighted average of the destination elasticities. ■

### A.4 Proof of Proposition 3: The Private Hedge Decision

*Proof.* At a given rate, the optimized operating value is $V(v,r) = v + \max\{py - rb\}$, with the preset fixed for the rigid type. Under Assumption 2, the operating feasible set does not depend on $v$ or $r$, so the envelope theorem gives $V_v = 1$ and $V_r = -b$. Accounting for the response of the rate, $\mathcal{V}(v) = V\big(v, R(z(v))\big)$, so

$$m = \mathcal{V}'(v) = V_v + V_r R'(z)\, z_v = 1 + b\psi\zeta,$$

which is equation (23).

For a rigid-price firm that meets demand, a change in $v$ leaves its preset, demand, and unit cost unchanged, so its output and bill are locally constant, $z = v + (\bar{p} - C)y$, and $\zeta_R = 1$. For a flexible firm at fixed demand shifter and unit cost, $p(r) = M_i r C$, $y(r) = \mathcal{A}(M_i r C)^{-\epsilon_i}$, and $y_r = -\epsilon_i y/r$. Let $G(y) = \mathcal{A}^{1/\epsilon_i} y^{1-1/\epsilon_i}$ denote sales revenue, so that $G'(y) = rC$ at the optimum given the rate. Since $z = v + G(y) - Cy$, differentiating and accounting for the response of the rate gives

$$\zeta = 1 + [G'(y) - C]\, y_r\, R'(z)\,\zeta = 1 + (r-1)Cy_r R'(z)\,\zeta,$$

and therefore

$$\zeta_F = \frac{1}{1 - (r-1)Cy_r R'(z)} = \frac{1}{1 - \epsilon_i(r-1)b\psi/r},$$

which is equation (24). Condition (iii) of Assumption 2 gives $\zeta \ge 1$ for both types; Appendix A.1 shows that, for a flexible-price firm, this is equivalent to $\epsilon_i(r-1)b\psi/r < 1$. Hence $m = 1 + b\psi\zeta > 1$ for both types.

Now fix the preset and the aggregate environments, and let $\nu_{iR} = \lambda_i$ and $\nu_{iF} = 1 - \lambda_i$.

The date-0 objective as a function of the hedge is

$$J(q) = \sum_{s,\tau} \pi(s)\nu_{i\tau}\mathcal{V}_{\tau,s}\Big(a^0 + [e(s) - e_f]q - \Gamma(q)\Big).$$

Because $v_s'(q) = e(s) - e_f - \Gamma'(q)$,

$$J'(q) = \sum_{s} \pi(s) m_s(q)\,[e(s) - e_f - \Gamma'(q)]. \tag{A5}$$

Since $\mathbb{E}_\pi[e - e_f] = 0$, $\mathbb{E}_\pi[m_s(e - e_f)] = \mathrm{Cov}_\pi(m_s, e)$. Setting $J'(q^*) = 0$ and dividing by $\mathbb{E}_\pi[m_s] > 0$ gives equation (25); the factor $\mathbb{E}_\pi[m_s]$ appears because the hedging cost reduces resources in every state.

At $q = 0$, $\Gamma'(0) = 0$, so $J'(0) = \mathrm{Cov}_\pi(m_s(0), e_s)$. Under strict concavity and an attained interior optimum, the maximizer lies on the same side of zero as $J'(0)$, and $J'(0) = 0$ makes zero the unique maximizer. With two states, fair pricing implies

$$\Omega \equiv \pi_H(e_H - e_f) = \pi_L(e_f - e_L) = \pi_H\pi_L(e_H - e_L) > 0,$$

so $J'(0) = \Omega[m_H(0) - m_L(0)]$.

Finally, if the borrowing rate is constant, $\mathcal{V}_s(v) = v + \Phi_s$ and $m_s = 1$, so $J(q)$ equals a constant minus $\Gamma(q)$ and $q = 0$ is the unique optimum. Because the operating policy then does not depend on resources, the same conclusion holds after optimizing the preset. ■

### A.4.1 Concavity Conditions

Convexity of the credit schedule and the quadratic hedge cost do not by themselves guarantee joint concavity of problem (15) or uniqueness of equilibrium. This subsection gives sufficient conditions for concavity in the hedge.

For a rigid-price firm at fixed aggregate conditions and preset, the continuation value is

$$\mathcal{V}_R(v) = v + \bar{p}y - R\Big(v + (\bar{p} - C)y\Big)Cy, \tag{A6}$$

so $\mathcal{V}_{R,v} = 1 - CyR'(z) > 0$ and $\mathcal{V}_{R,vv} = -CyR''(z) < 0$.

For a flexible-price firm, let $a = \gamma/\mathrm{Rev}_i^0$, so that $\psi = a(r - R_{\min})$, and define $L = b\psi$, $\varsigma(r) = \epsilon_i(r-1)/r$, and $\mathcal{D} = 1 - \varsigma(r)L$, which equals $1 - \varphi_{ik} > 0$ in equation (A1). The proof above gives $m = 1 + L/\mathcal{D}$ and $r_v = R'(z)\zeta = -\psi/\mathcal{D}$. Because the flexible price adjusts with the rate, $b(r) = Br^{-\epsilon_i}$ for a constant $B > 0$, so

$$L_r = ab\left[1 - \frac{\epsilon_i(r - R_{\min})}{r}\right], \qquad \varsigma'(r) = \frac{\epsilon_i}{r^2}.$$

Differentiating $m$ with respect to $r$ and multiplying by $r_v$ gives

$$\mathcal{V}_{F,vv} = -\frac{\psi}{\mathcal{D}^3}\left[L_r + \frac{\epsilon_i L^2}{r^2}\right]. \tag{A7}$$

A sufficient condition for $\mathcal{V}_{F,vv} < 0$ is $L_r \geq 0$, which holds when $r \leq M_i R_{\min}$.

When each continuation value is increasing and concave in resources over the relevant range of hedges,

$$J''(q) = \sum_{s,\tau} \pi(s)\nu_{i\tau}\left\{\mathcal{V}_{\tau,s,vv}[e(s) - e_f - \Gamma'(q)]^2 - \mathcal{V}_{\tau,s,v}\Gamma''(q)\right\} < 0, \tag{A8}$$

so the hedge objective is strictly concave. This establishes concavity in the hedge at a given preset; it does not establish joint concavity in the hedge and preset, existence of equilibrium, or uniqueness of the rate that satisfies $r = R(z)$.

### A.4.2 Sufficient Conditions for Importer and Exporter Hedges

The following examples use the baseline credit schedule and operating problem without additional restrictions. They give sufficient conditions for the conventional positions while leaving signs endogenous in general.

**An importer.** Consider a rigid-price firm with the same demand $y$ and preset $p$ in both states and unit costs $C_H > C_L > 0$, with positive margins in both states at $q = 0$. Then $b_H = C_H y > b_L = C_L y$ and $z_H = a^0 + (p - C_H)y < z_L = a^0 + (p - C_L)y$. Because $\psi(z) = -R'(z)$ is positive and decreasing in $z$, $b_H\psi(z_H) > b_L\psi(z_L)$, so $m_H > m_L$ and the optimal hedge is long under the conditions of Proposition 3. The larger financed bill and the weaker financial position both raise the value of resources in the depreciation state. Since $r_H > r_L$ and $C_H > C_L$, terminal net worth is also lower in that state, $\omega_H < \omega_L$, so the optimal long position stabilizes net worth in the sense of Proposition 4.

**An exporter.** Consider a rigid-price firm with demand $y_H > y_L > 0$, common unit cost $C$, common preset $p$, common opening resources, a common credit schedule, and positive margins $p - r_s C > 0$. At $q = 0$,

$$b_s = Cy_s, \qquad z_s = a^0 + (p - C)y_s, \qquad m_s = 1 + Cy_s\psi(z_s),$$

so $z_H > z_L$, and the exponential credit schedule gives

$$\frac{m_H - 1}{m_L - 1} = \frac{y_H}{y_L}\exp\left[-\frac{\gamma}{\text{Rev}_i^0}(p - C)(y_H - y_L)\right].$$

The exporter therefore chooses a short hedge if and only if

$$\frac{\gamma}{\text{Rev}_i^0}(p - C)(y_H - y_L) > \log\left(\frac{y_H}{y_L}\right), \tag{A9}$$

a long hedge if the inequality is reversed, and no hedge under equality. The condition compares two forces. The larger financed bill in the high-demand state raises the marginal value of resources there, which favors a long position. The stronger financial position in that state lowers the slope of the credit schedule, which favors a short position. The

exporter goes short when the credit schedule is steep enough, relative to the scale $\text{Rev}_i^0$, for the second force to dominate. Because $r_H \le r_L$, terminal net worth satisfies $\omega_H - \omega_L \ge (p - r_L C)(y_H - y_L) > 0$, so the short position is the stabilizing one; when condition (A9) fails, the firm's optimal hedge raises the dispersion of net worth.

For a firm that faces both pricing realizations, the sign depends on the probability-weighted marginal values in Proposition 3. The ordering $m_{\tau,H} < m_{\tau,L}$ for every type with positive weight is sufficient for a short position, but an ordering for the rigid type alone does not determine the hedge of a firm that may be either type.

### A.5 Proof of Proposition 4: Local Stabilization

*Proof.* For fixed probabilities, let $\mu_X(t) = \sum_s \pi_s X_s(t)$. Then

$$\begin{aligned}\frac{d}{dt}\operatorname{Var}_\pi(X_s(t)) &= \frac{d}{dt}\left[\sum_s \pi_s X_s(t)^2 - \mu_X(t)^2\right] \\ &= 2\left[\sum_s \pi_s X_s(t) X_s'(t) - \mu_X(t)\sum_s \pi_s X_s'(t)\right] = 2\operatorname{Cov}_\pi\Big(X_s(t), X_s'(t)\Big),\end{aligned}$$

which is equation (27). For a positive outcome, the same argument applies to $\log X_s$.

Fix a pricing type and the aggregate environment, and let $q = \sigma t$ with $t \ge 0$. Because $\Gamma'(0) = 0$,

$$\left.\frac{dv_s}{dt}\right|_0 = \sigma(e_s - e_f), \qquad \left.\frac{d\omega_s}{dt}\right|_0 = \sigma m_s(0)(e_s - e_f).$$

Since $e_L < e_f < e_H$,

$$\left.\frac{d(\omega_H - \omega_L)}{dt}\right|_0 = \sigma\Big[m_H(e_H - e_f) + m_L(e_f - e_L)\Big],$$

which has the sign of $\sigma$ because both marginal values are positive. Two-state variance equals $\pi_H \pi_L (\omega_H - \omega_L)^2$, so a long position reduces it when $\omega_H < \omega_L$ and a short position reduces it when $\omega_H > \omega_L$. The log spread has the same ordering and directional derivative sign, so the result also applies to log net worth.

For the borrowing rate, $dr_s/dt|_0 = \sigma R_s'(z_s)\zeta_s(e_s - e_f)$, so

$$\left.\frac{d(r_H - r_L)}{dt}\right|_0 = -\sigma\Big[\psi_H \zeta_H(e_H - e_f) + \psi_L \zeta_L(e_f - e_L)\Big],$$

which has the sign of $-\sigma$ because $\psi_s > 0$ and $\zeta_s \ge 1$. With a common decreasing credit schedule, $z_H < z_L$ implies $r_H > r_L$, so a long position narrows the rate spread; $z_H > z_L$ implies $r_H < r_L$, so a short position narrows it. ∎

These conclusions are local. For a finite hedge, the marginal cost of hedging enters, response coefficients change, and the initial ordering can reverse; in a network-wide comparison, aggregate environments and presets also respond. The covariance identity remains valid, but its sign must be evaluated for each outcome.

**Exchange-rate derivatives of terminal net worth.** Along a differentiable state path,

$$\frac{d\omega_{ik,\tau}}{de} = m_{ik,\tau} q_{ik} + \nabla_{\mathcal{E}} \mathcal{V}_{ik,\tau} \cdot \frac{d\mathcal{E}}{de}, \tag{A10}$$

where the environment derivative includes the induced response of the firm's own rate. In a price-only comparison for a direct importer, this becomes $d\omega/de = mq + \mathcal{V}_{P_f} \eta P_x$; in a demand-only comparison with demand shifter $D(e)$, it becomes $d\omega/de = mq + \mathcal{V}_D D'(e)$.

**Resource transfers and real activity.** For a flexible firm at fixed aggregate conditions, $r_v = R'(z)\zeta < 0$, and therefore

$$p_v = M_i C r_v < 0, \qquad y_v = -\frac{\epsilon_i y}{r} r_v > 0, \qquad (py)_v = (1-\epsilon_i)\frac{py}{r} r_v > 0, \tag{A11}$$

so a resource transfer lowers its price and raises its output, revenue, and production expenditure. For a rigid-price firm that meets demand, $p_v = y_v = b_v = 0$ at fixed demand, although $\omega_v > 0$ and $r_v < 0$. Financial stabilization can therefore be large when operating stabilization is small.

### A.6 Proof of Proposition 5: Supplier-Price Transmission

*Proof.* Applying Proposition 1 to sectors 1 and 2,

$$\varepsilon_{P_1,e} = \vartheta_1 \left( \alpha_{1f} \varepsilon_{P_f,e} + \varepsilon_{r_{1,F},e} \right), \qquad \varepsilon_{P_2,e} = \vartheta_2 \left( \alpha_{21} \varepsilon_{P_1,e} + \varepsilon_{r_{2,F},e} \right).$$

Substituting the first expression into the second gives equation (28). The expenditure shares $\vartheta_i$ are the derivative weights of the CES log price index, so no separate derivative of $\vartheta_i$ enters this first-order identity; comparisons across hedging equilibria must allow the shares to change.

The supplier financing term equals $\vartheta_2 \alpha_{21} \vartheta_1 (R_1'/r_{1,F}) e\, dz_{1,F}/de$. Its settlement component contains $q_1$, and the full derivative also includes the supplier's price, revenue, and input-bill responses. Holding the other terms fixed, a smaller positive supplier financing elasticity lowers the downstream price elasticity.

Aggregate production expenditure in sector 2 is $\mathcal{B}_2 = \int_0^1 C_2 y_{2k}\, dk = C_2 \Delta_2 Y_2$. Since $d \log C_2 = \alpha_{21}\, d \log P_1$ at a fixed wage, $\varepsilon_{\mathcal{B}_2,e} = \alpha_{21} \varepsilon_{P_1,e} + \varepsilon_{Y_2,e} + \varepsilon_{\Delta_2,e}$. ∎

### A.7 Proof of Proposition 6: Customer-Demand Transmission

*Proof.* By Proposition 2, $\varepsilon_{Y_2,e} = \varepsilon_{Y_3,e} - (1-\alpha_{32})\varepsilon_{P_2,e} + \varepsilon_{\Delta_3,e}$. Substituting $\varepsilon_{Y_3,e} = \beta_f^X - \chi_f \varepsilon_{P_3,e}$ gives equation (29). Using $\varepsilon_{P_3,e} = \vartheta_3(\alpha_{32}\varepsilon_{P_2,e} + \varepsilon_{r_{3,F},e})$ and collecting terms in $\varepsilon_{P_2,e}$,

$$\varepsilon_{Y_2,e} = \beta_f^X - \chi_f \vartheta_3 \varepsilon_{r_{3,F},e} - \left[ \chi_f \vartheta_3 \alpha_{32} + 1 - \alpha_{32} \right] \varepsilon_{P_2,e} + \varepsilon_{\Delta_3,e}.$$

Substituting $\varepsilon_{P_2,e} = \vartheta_2(\alpha_{21}\varepsilon_{P_1,e} + \varepsilon_{r_{2,F},e})$ gives equation (30). The coefficient $K_3$ combines the pass-through of $P_2$ into the customer's price, which lowers foreign demand, and the

customer's conditional input demand.

The supplier's revenue elasticity adds $\varepsilon_{P_2,e}$:

$$\varepsilon_{P_2 Y_2,e} = \beta_f^X - \chi_f \varepsilon_{P_3,e} + \alpha_{32}\varepsilon_{P_2,e} + \varepsilon_{\Delta_3,e}. \tag{A12}$$

■

### A.8 Normalization and the General Network

**Reference scales.** Replacing the denominator of the credit schedule by $\widetilde{D}$ while scaling $\gamma$ to $\widetilde{\gamma} = \gamma\widetilde{D}/\mathrm{Rev}_i^0$ leaves the credit schedule unchanged, and the hedge-cost curve is unchanged when $D_H$ is replaced by $\widetilde{D}_H$ and $\kappa$ by $\kappa\widetilde{D}_H/D_H$. Because these rescalings are sector specific, a common change in $\gamma$ or $\kappa$ cannot undo sector-specific differences in the scales.

**Projected versus terminal net worth.** The rate is indexed to projected net worth $z$ rather than terminal net worth $\omega$. Under the alternative contract $r = R(\omega)$, the implicit equation $\omega = v + py - R(\omega)b$ gives $\omega_v = [1 + bR'(\omega)]^{-1}$ for a rigid firm, so the marginal value of resources would take a different form and require a separate regularity condition.

**CES accounting.** For $y_{ik} = (p_{ik}/P_i)^{-\epsilon_i} Y_i$, the price-index identity implies $\int_0^1 p_{ik} y_{ik}\, dk = Y_i P_i^{\epsilon_i} \int_0^1 p_{ik}^{1-\epsilon_i} dk = P_i Y_i$, whereas the arithmetic sum of variety output is $\int_0^1 y_{ik}\, dk = \Delta_i Y_i$.

**Multiple inputs.** Consider a constant-returns technology with labor share $\alpha_{iL} > 0$, domestic-input shares $\alpha_{ij} \geq 0$, and foreign-input shares $\alpha_{if} \geq 0$ that sum to one,

$$y_{ik} = A_i \ell_{ik}^{\alpha_{iL}} \prod_{j \in \mathcal{S}(i)} x_{ij,k}^{\alpha_{ij}} \prod_f x_{if,k}^{\alpha_{if}},$$

with unit cost

$$C_i = A_i^{-1} \left(\frac{W}{\alpha_{iL}}\right)^{\alpha_{iL}} \prod_{j \in \mathcal{S}(i)} \left(\frac{P_j}{\alpha_{ij}}\right)^{\alpha_{ij}} \prod_f \left(\frac{P_f}{\alpha_{if}}\right)^{\alpha_{if}}, \tag{A13}$$

where zero-share factors are omitted. Conditional input spending is $P_j x_{ij,k} = \alpha_{ij} C_i y_{ik}$, so aggregate purchases on a domestic link are $X_{ij} = \alpha_{ij} C_i \Delta_i Y_i / P_j$, and the credit and hedge results apply with $b_{ik} = C_i y_{ik}$. Let $\mathsf{A} = (\alpha_{ij})$ be the domestic input-share matrix with buyers in rows, $\Theta = \mathrm{diag}(\vartheta_i)$, $u_i = \sum_f \alpha_{if} \varepsilon_{P_f,e}$, and $r_i^e = \varepsilon_{r_{i,F},e}$. Then

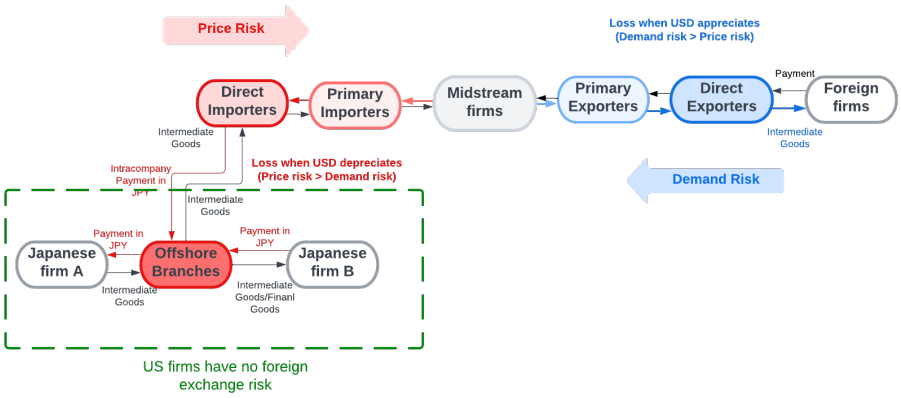
$$(I - \Theta\mathsf{A})\, \varepsilon_P = \Theta(u + r^e). \tag{A14}$$

Because labor shares are strictly positive, each row sum of $\Theta\mathsf{A}$ is below one, so $(I - \Theta\mathsf{A})^{-1} = \sum_{n \geq 0} (\Theta\mathsf{A})^n$ exists and has nonnegative entries. This gives the propagation of price responses through the network conditional on the financing responses $r^e$; because $r^e$ is endogenous, it does not establish existence or uniqueness of the full equilibrium.

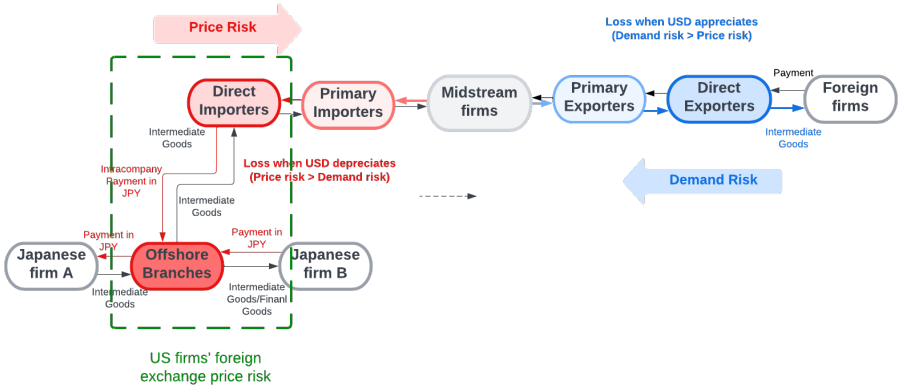
# B Additional Figures and Diagrams to Support the Theory

## B.1 U.S. Firms Foreign Exchange Risk Exposure: Additional Cases

(A) FX Risk by Offshore Branches




(B) FX Risk by U.S. Headquarters




(C) Additional FX Risk in Offshore Branches

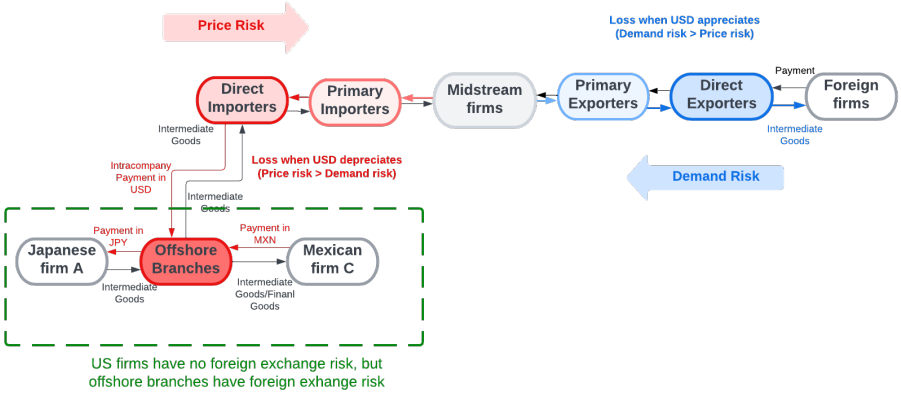



Figure A1: FX Risk: U.S. Headquarters vs. Offshore Branches

*Notes:* This figure illustrates scenarios where U.S. firms with offshore branches encounter foreign exchange risks.

Figure A1 illustrates additional ways U.S. firms are exposed to foreign exchange risk through international trade when offshoring is an option. Panel (A) shows that when U.S. firms' offshore branches conduct purchases and sales in local foreign markets using the local currency (e.g., purchasing and selling in Japanese Yen in Japan), these branches do not face foreign exchange risks. Panel (B) demonstrates that if offshore branches make sales back to U.S. headquarters in foreign currencies, the U.S. headquarters still bear foreign exchange risk. Panel (C) indicates that if offshore branches engage in international transactions–such as purchasing from a Japanese firm invoiced in Yen and selling to a Mexican firm invoiced in Pesos–U.S. firms are exposed to foreign exchange risk through these activities. However, as long as intrafirm transactions between offshore branches and U.S. headquarters are conducted in U.S. dollars, the headquarters do not directly face foreign exchange risk from these offshore activities.

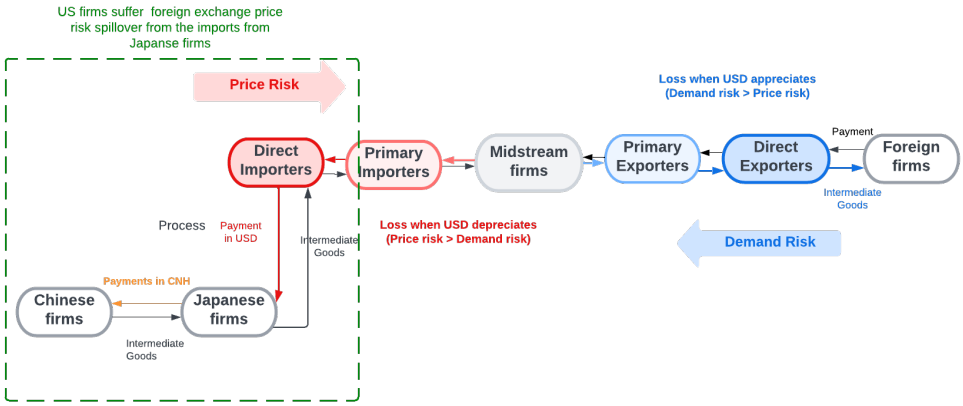



Figure A2: FX Risk: Indirect Exposures of U.S. Firms

*Notes:* This figure illustrates the indirect foreign exchange price risk exposures faced by U.S. firms.

Additionally, U.S. firms, as direct importers, face foreign exchange risk exposures through indirect channels. Figure A2 illustrates a scenario where a U.S. firm imports goods from Japanese suppliers that experience foreign exchange price risk due to input purchases from Chinese firms. Even when these imports are invoiced in U.S. dollars, U.S. firms remain indirectly exposed to foreign exchange risk, as their suppliers–the Japanese firms–may adjust their prices in response to fluctuations in the cost of intermediate inputs priced in Chinese Yuan.

## B.2 Impulse Response Functions

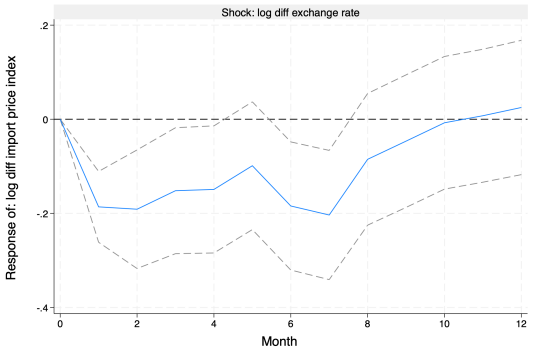
Figure A3 and Figure A4 show that a 10% appreciation of the U.S. dollar index results in approximately a 2% reduction in the import price index and a 1.3% decrease in the export price index after one month.[10]

[10] Gopinath and Itskhoki (2010) demonstrates that exchange rate pass-through to the import price index conditional on price adjustment is 0.24 for dollar-priced goods and 0.96 for non-dollar priced goods, while the pass-through to export prices is 0.84 for dollar-priced goods and 0.25 for goods priced in the importing country's currency. This study uses an aggregate price index; the import price index response aligns with

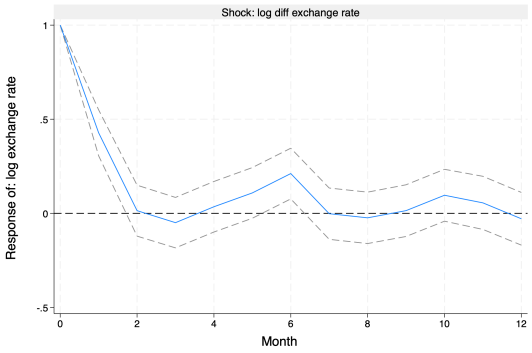
granular findings, but the export price response appears lower. This difference could be due to time horizon variations, as Gopinath and Itskhoki (2010) covers 1994–2005, whereas my analysis spans 1997–2022, potentially capturing shifts in dollar pricing shares. Moreover, U.S. exporters' pricing flexibility may have been constrained by pricing-to-market practices and increased global economic uncertainty in recent years, limiting their responses to exchange rate changes.

(A) Import Price Index & Exchange Rate

(A.1) Response: Import Price Index

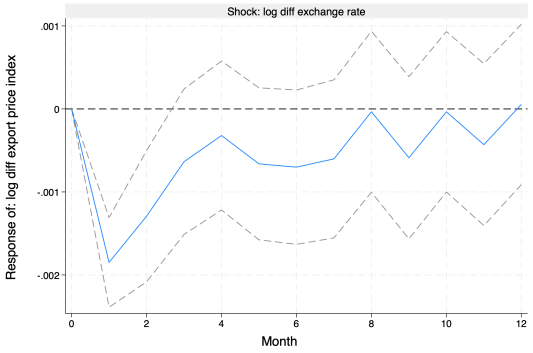



(A.2) Response: Exchange Rate




(B) Export Price Index & Exchange Rate

(B.1) Response: Export Price Index




(B.2) Response: Exchange Rate

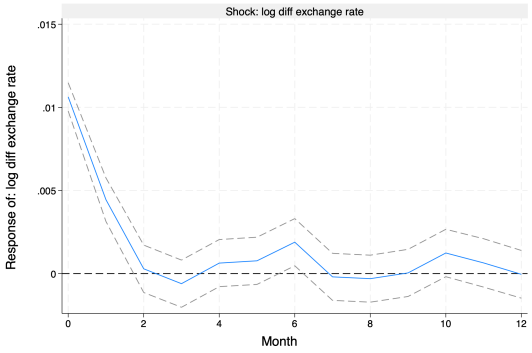
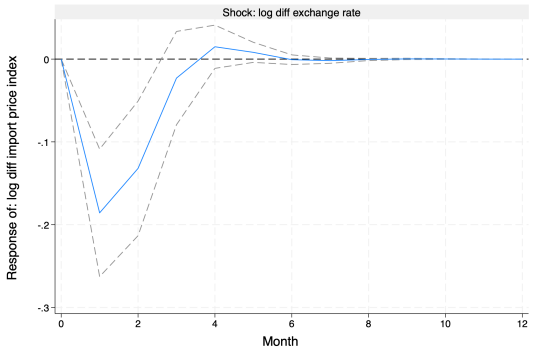



Figure A3: Local Projection: IRF to the Exchange Rate Shock

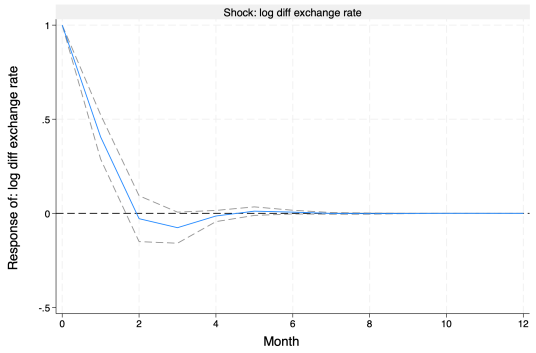
*Notes:* This figure presents the impulse response functions (IRFs) for a one standard deviation exchange rate shock, using local projection models. Panel (A) displays the IRF for the model with the import price index and exchange rate index, incorporating 4 lags and controlling for the U.S. Consumer Price Index (CPI), U.S. Industrial Production (IP) index, and the Harmonized Index of Consumer Prices (HICP) in the Euro area. Subpanel (A.1) shows the response of the log difference of the import price index to a one standard deviation shock in the log difference of the exchange rate, while subpanel (A.2) shows the response of the log difference of the exchange rate itself to this same shock. Panel (B) presents the IRF for the model with the export price index and exchange rate index, also with 4 lags. Subpanel (B.1) illustrates the response of the log difference of the export price index to a one standard deviation shock in the log difference of the exchange rate, and subpanel (B.2) shows the response of the log difference of the exchange rate. All data used are monthly.

(A) Import Price Index & Exchange Rate

(A.1) Response: Import Price Index

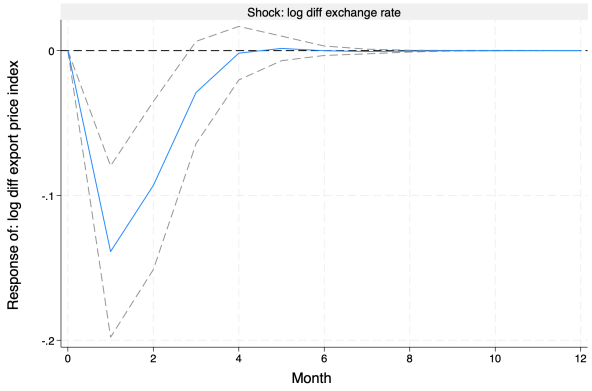



(A.2) Response: Exchange Rate




(B) Export Price Index & Exchange Rate

(B.1) Response: Export Price Index




(B.2) Response: Exchange Rate

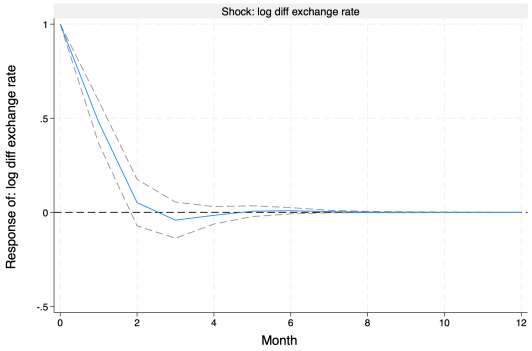



Figure A4: Structural Vector Autoregressive (SVAR): IRF to the Exchange Rate Shock

*Notes:* This figure presents the impulse response functions (IRFs) for a one standard deviation exchange rate shock, using Structural Vector Autoregressive (SVAR) model with Cholesky decomposition. Panel (A) displays the IRF for the model with the import price index and exchange rate index, incorporating 4 lags and controlling for the U.S. Consumer Price Index (CPI), U.S. Industrial Production (IP) index, and the Harmonized Index of Consumer Prices (HICP) in the Euro area. Subpanel (A.1) shows the response of the log difference of the import price index to a one standard deviation shock in the log difference of the exchange rate, while subpanel (A.2) shows the response of the log difference of the exchange rate itself to this same shock. Panel (B) presents the IRF for the model with the export price index and exchange rate index, also with 4 lags. Subpanel (B.1) illustrates the response of the log difference of the export price index to a one standard deviation shock in the log difference of the exchange rate, and subpanel (B.2) shows the response of the log difference of the exchange rate. All data used are monthly.

# Part II: Data Construction

## C Foreign Exchange Hedging Data Collection

I construct a firm-level panel of foreign exchange derivative positions by combining text-based screening of firms' 10-K filings with manual data collection. The resulting dataset covers fiscal years 2000–2022 and records the notional amount of firms' outstanding foreign exchange derivatives. I first identify firms likely to use foreign exchange derivatives following the text-based procedure in Hoberg and Moon (2017). I then manually collect and standardize the notional amounts reported in firms' annual filings.

### C.1 Text-based identification of foreign exchange derivative users

I follow the foreign exchange derivatives mention procedure in Hoberg and Moon (2017) to identify firms that potentially use foreign exchange derivatives. Their procedure searches 10-K filings for terms from three groups: (i) *Currency* or *Foreign Exchange*; (ii) *Forward*, *Future*, *Option*, *Swap*, *Spot*, *Derivative*, *Hedge*, *Hedging*, or *Hedged*; and (iii) *Contract*, *Position*, *Instrument*, *Agreement*, *Obligation*, *Transaction*, or *Strategy*. A qualifying foreign exchange derivative mention requires at least one term from each of the three groups to occur within the same paragraph and within 25 words of one another.

I aggregate qualifying mentions across filings and rank firms by their total number of foreign exchange derivative mentions. Manual collection proceeds from firms with the largest number of mentions to those with fewer mentions. Firms with no qualifying foreign exchange derivative mentions are excluded from the manual collection sample.

### C.2 Source documents

The primary source for the manual collection is firms' Form 10-K filings obtained from the SEC's Electronic Data Gathering, Analysis, and Retrieval (EDGAR) system. When the corresponding filing is unavailable through EDGAR, I use the firm's annual report obtained from the company's investor-relations website or from AnnualReports.com.

For each firm-year, I examine the sections of the filing discussing derivatives, hedging activities, financial instruments, market risk, and foreign currency exposure and record the outstanding notional amount of foreign exchange derivatives reported for the fiscal year end.

### C.3 Measurement of foreign exchange hedging

My primary measure is the total notional amount of outstanding foreign exchange derivatives. I use notional amounts rather than derivative fair values because the notional amount measures the scale of the contractual position underlying the derivative, whereas fair value reflects the current market value of the derivative contract and can vary substantially with market conditions even for positions with similar underlying exposure.

I collect foreign exchange derivatives regardless of their accounting designation. In particular, the measure includes both derivatives designated for hedge-accounting pur-

poses and derivatives that are not designated as accounting hedges. Designated derivatives include, among others, cash-flow and fair-value hedges whose accounting treatment satisfies the relevant hedge-accounting requirements. Non-designated derivatives are instruments for which changes in fair value are generally recognized directly in earnings. Hedge-accounting designation affects the accounting treatment of changes in derivative fair values but does not determine whether the contract economically provides foreign exchange exposure. I therefore aggregate qualifying foreign exchange positions across accounting-designation categories.

For firm $i$ in fiscal year $t$, I define

$$\text{FXNotional}_{it} = \sum_{j \in \mathcal{H}_{it}} \text{Notional}_{ijt},$$

where $\mathcal{H}_{it}$ denotes the set of outstanding derivative positions that hedge or otherwise offset foreign exchange exposure and $\text{Notional}_{ijt}$ is the U.S.-dollar notional amount of contract $j$.

### C.4 Foreign exchange contract coverage

I include derivative contracts whose underlying exposure is explicitly related to foreign exchange rates. These contracts include foreign exchange forwards, currency futures, foreign exchange options, foreign exchange swaps, and cross-currency swaps. I exclude interest-rate derivatives that do not contain an identifiable foreign exchange component.

When a firm reports several types of foreign exchange derivatives, or reports separate positions by hedge-accounting designation, currency, maturity, or business purpose, I sum the relevant outstanding notional amounts to obtain the firm's total foreign exchange derivative position.

### C.5 Currency conversion

I express all notional amounts in U.S. dollars. When the filing reports both a foreign-currency notional amount and the corresponding U.S.-dollar amount or contract exchange rate, I use the information reported in the filing. When the filing reports only a foreign-currency amount, I convert the position into U.S. dollars using the spot exchange rate corresponding to the fiscal reporting period. My primary exchange-rate source is the OECD; when the required exchange rate is unavailable from the OECD, I use Bloomberg.

This procedure produces a common U.S.-dollar measure of foreign exchange derivative notionals across firms and years.

### C.6 Fiscal-year alignment and identifiers

I align the manually collected hedging observations with Compustat fiscal years using the same fiscal-period assignment procedure used for the text-based country and currency exposure measures. I preserve the firm's CIK, filing date, SEC report-period date, and other filing metadata separately from the assigned fiscal year.

I first map each filing's CIK to GVKEY using the project identifier crosswalk. For each mapped filing, I compare the SEC report-period date with the same firm's Compustat

annual reporting dates and assign the filing to a fiscal period when there is a unique Compustat annual observation within seven calendar days of the SEC report-period date. I then inherit the matched Compustat `fyear`. This procedure ensures that foreign exchange hedging, accounting variables, and text-based foreign exposure measures are aligned to the same firm–fiscal-year observations.

### C.7 Example: Apple Inc.

Apple Inc. provides an example of the manual collection procedure. In its fiscal-year 2022 Form 10-K, Apple reports the notional amounts of outstanding derivative instruments separately for instruments designated as accounting hedges and instruments not designated as accounting hedges. The notional amount of foreign exchange contracts designated as accounting hedges is $102,670 million, while the notional amount of foreign exchange contracts not designated as accounting hedges is $185,381 million.

I therefore record Apple's total foreign exchange derivative notional amount for fiscal year 2022 as

$$\$102{,}670 \text{ million} + \$185{,}381 \text{ million} = \$288{,}051 \text{ million}.$$

The notional amounts of the Company's outstanding derivative instruments as of September 24, 2022 and September 25, 2021 were as follows (in millions):

| | 2022 | 2021 |
|---|---|---|
| Derivative instruments designated as accounting hedges: | | |
| Foreign exchange contracts | $ 102,670 | $ 76,475 |
| Interest rate contracts | $ 20,125 | $ 16,875 |
| Derivative instruments not designated as accounting hedges: | | |
| Foreign exchange contracts | $ 185,381 | $ 126,918 |

Figure A5: Foreign Exchange Hedging Data Collection: Apple Inc. (AAPL)

*Notes:* The figure shows the table reporting outstanding derivative notional amounts in Apple Inc.'s fiscal-year 2022 Form 10-K. The filing is obtained from the SEC's EDGAR system. The foreign exchange hedging measure includes both foreign exchange contracts designated as accounting hedges and foreign exchange contracts not designated as accounting hedges.

## D Country- and Currency-Level Import and Export Exposure from 10-K Filings

I construct firm–country measures of offshore output and input activity from firms' 10-K filings following the text-based procedure in Hoberg and Moon (2017). Their approach identifies country names and country adjectives in 10-K text and classifies nearby text into offshore output, external input, internal input, and indeterminate input activity. I apply the same economic classification and proximity logic to my cleaned 10-K corpus using a transparent and auditable implementation. I then aggregate the country-level measures to the currency level for the foreign-exchange analysis.

### D.1 Country identification

For each 10-K filing, I identify mentions of foreign countries using a dictionary of official country names, common alternative names, and country adjectives or demonyms. All aliases are mapped to a canonical country identifier. Matching is case-insensitive and token based, and ambiguous short forms are excluded when they generate obvious false positives.

Because my goal is to measure foreign operating exposure, I exclude the United States and all U.S.-related aliases from the baseline foreign-country dictionary, including "United States," "United States of America," "U.S.," "U.S.A.," "USA," "America," "American," and "Americans."

### D.2 Activity classification

Following Hoberg and Moon (2017), I classify text surrounding country mentions into four activity categories. The baseline dictionaries are taken directly from their Appendix A.

**Offshore output / export words.**

> SALES, MARKETS, CUSTOMERS, DISTRIBUTION, MARKETING, REVENUES, DISTRIBUTORS, REVENUE, EXPORT, CUSTOMER, DISTRIBUTOR, DEMAND, STORES, CONSUMER, MARKETED, DISTRIBUTE, DISTRIBUTES, DISTRIBUTED, SHIPMENTS, DEALERS, CLIENTS, WHOLESALE, EXPORTS, STORE, MARKETPLACE, CONSUMERS, DEALER, EXPORTED, CLIENT, DISTRIBUTING, DISTRIBUTIONS, DEMANDS, DISTRIBUTORSHIP, EXPORTING, WHOLESALERS, RECEIVABLE, RECEIVABLES.

**Offshore external input / import words.**

> SUPPLIERS, IMPORT, SUPPLIER, IMPORTS, IMPORTED, IMPORTATION, VENDORS, SUBCONTRACTORS, SUBCONTRACTOR, VENDOR, IMPORTING, SUBCONTRACT, PURCHASE & FROM, PURCHASED & FROM, PURCHASES & FROM.

**Offshore internal input words.**

> SUBSIDIARIES, SUBSIDIARY, FACILITIES, FACILITY, VENTURE, PLANT, EXPLORATION, PLANTS, VENTURES, WAREHOUSE, STORAGE, FACTORY, WAREHOUSES, WAREHOUSING, FACTORIES.

**Offshore indeterminate input words.**

> MANUFACTURING, PRODUCTION, MANUFACTURED, MANUFACTURE, MANUFACTURES, PRODUCED, PRODUCING, PRODUCE, PRODUCES, PRODUCTIONS.

The "PURCHASE & FROM" entries are implemented as directed purchase-from constructions rather than by treating the generic word "purchase" as sufficient evidence of external input activity.

### D.3 Paragraph and proximity rule

I follow the proximity rule in Hoberg and Moon (2017). A country mention and an activity term must occur within the same textual paragraph or recovered text block, and the country and activity terms must be separated by no more than 25 intervening words. I preserve paragraph boundaries from the cleaned 10-K files where available; when the original cleaning process has removed some paragraph breaks, surviving line structure is used as a conservative fallback.

My preferred implementation counts qualifying country occurrences rather than country–activity-word pairs. For OUTPUT, each occurrence of country $c$ contributes at most one output hit if at least one qualifying output term appears within its 25-word neighborhood. For INPUT, I pool external, internal, and indeterminate input activity and count each country occurrence at most once if it is associated with any qualifying input term. Thus, multiple qualifying activity words—or multiple input categories—around the same country occurrence do not generate additional counts. The same country occurrence may, however, contribute once to OUTPUT and once to INPUT if both types of activity evidence are present. A second occurrence of the same country elsewhere in the filing may generate an additional hit if it independently satisfies the proximity rule.

For robustness, I also retain a more granular pair-count measure that counts distinct qualifying country–activity-word occurrence pairs.

### D.4 Firm–country–year measures

I first construct filing-level counts and then aggregate to the firm–country–year level. For firm $i$, country $c$, and fiscal observation $t$, let

$$\text{OutputCount}_{ict}$$

denote the number of distinct qualifying country occurrences associated with offshore output activity, and let

$$\text{InputCount}_{ict}$$

denote the number of distinct qualifying country occurrences associated with any external, internal, or indeterminate input activity, pooled and deduplicated across input categories.

I also construct extensive-margin indicators,

$$\text{OutputDummy}_{ict} = \mathbf{1}\{\text{OutputCount}_{ict} > 0\}, \qquad \text{InputDummy}_{ict} = \mathbf{1}\{\text{InputCount}_{ict} > 0\}.$$

I construct country shares analogous to the intensity measures in Hoberg and Moon (2017):

$$\text{OutputShare}_{ict} = \frac{\text{OutputCount}_{ict}}{\sum_{c'} \text{OutputCount}_{ic't}}, \qquad \text{InputShare}_{ict} = \frac{\text{InputCount}_{ict}}{\sum_{c'} \text{InputCount}_{ic't}}.$$

When the corresponding denominator is zero, the share is set to zero.

The denominator is defined over all emitted foreign countries and territories for the firm-year. In particular, it is not restricted to countries that can subsequently be mapped

to one of the currencies used in the FX analysis.

### D.5 Currency-level exposure

For the FX analysis, I aggregate the country-level measures to the currency level. Let $m(c,t)$ denote the currency associated with country $c$ in year $t$, whenever such a mapping is available. For firm $i$, currency $k$, and fiscal observation $t$, I define

$$\text{OutputCount}^{FX}_{ikt} = \sum_{c:m(c,t)=k} \text{OutputCount}_{ict},$$

and

$$\text{InputCount}^{FX}_{ikt} = \sum_{c:m(c,t)=k} \text{InputCount}_{ict}.$$

The corresponding currency exposure shares are

$$\text{OutputShare}^{FX}_{ikt} = \frac{\text{OutputCount}^{FX}_{ikt}}{\sum_{c'} \text{OutputCount}_{ic't}}, \qquad \text{InputShare}^{FX}_{ikt} = \frac{\text{InputCount}^{FX}_{ikt}}{\sum_{c'} \text{InputCount}_{ic't}}.$$

Importantly, the denominator is the firm's total qualifying foreign-country exposure, not total exposure only among the currencies included in the FX sample. Countries that cannot be mapped to one of the supported currencies therefore remain in the denominator. As a result, the currency exposure shares need not sum to one across the observed currency buckets.

The baseline currency mapping covers CAD, CNY, EUR, GBP, INR, JPY, KRW, MXN, and TWD. Euro exposure is constructed using year-specific euro-area membership. A country enters the EUR bucket only from its euro-adoption year onward. The first eleven euro-area members enter in 1999; Greece enters in 2001; Slovenia in 2007; Cyprus and Malta in 2008; Slovakia in 2009; Estonia in 2011; Latvia in 2014; Lithuania in 2015; and Croatia in 2023. There is no EUR bucket before 1999. Before adoption, a country's exposure remains in the all-country denominator but does not contribute to the EUR numerator.

### D.6 Year alignment and identifiers

I preserve CIK, accession number, source-folder year, filing date, SEC report period, and related filing metadata separately. Because the source-folder year is not necessarily the Compustat fiscal year, I assign filings to Compustat fiscal periods before constructing the fiscal-year exposure measures.

I first map each filing's CIK to GVKEY using the project identifier crosswalk. For each mapped filing, I compare the SEC report-period date with the same firm's Compustat annual reporting dates and assign the filing to a fiscal period when there is a unique Compustat annual observation within seven calendar days of the SEC report-period date. I then inherit the matched Compustat `fyear` and aggregate filing-level country occurrence counts to the firm–fiscal-year–country level. Country and currency shares are recomputed

only after this fiscal-period assignment and aggregation.

### D.7 Validation against Hoberg–Moon

I validate my independently reconstructed measures against the public Hoberg–Moon country database over 2012–2017. At the positive firm–country–year level, the output measure has precision of 81.0%, recall of 96.7%, and a Jaccard index of 0.788 relative to the public data. The corresponding figures for the input measure are 81.4%, 96.9%, and 0.794. Country-level ranking correlations exceed 0.95 for both output and input activity.

Raw counts depend more strongly on the exact counting convention. Counting every qualifying country–activity-word pair yields aggregate counts roughly twice those in the public database. Collapsing repeated activity-word matches so that each country occurrence contributes at most once to OUTPUT and at most once to pooled INPUT reduces the ratio of my total counts to the public data from 2.123 to 1.099 for output and from 2.136 to 1.149 for input; the median ratio among observations positive in both datasets falls to one. Because the proprietary implementation details of the original text engine are not fully observed, I use this comparison as an external validation of economic content rather than as a claim of exact software replication.

## E Constructing Production-Network Relationships

I combine the foreign exchange hedging data with firm-to-firm supplier–customer relationships from two complementary sources: the Compustat Segment customer data available through WRDS and FactSet Revere Supply Chain Relationships. The Compustat Segment data identify major customer relationships reported by suppliers and provide supplier-reported sales to named customers, while FactSet Revere provides a substantially broader set of direct supplier–customer relationships together with relationship histories and, when available, the percentage of a supplier's revenue derived from a particular customer. I combine the two sources to increase coverage of publicly traded firms while preserving the economic direction, timing, and source provenance of each relationship.

Throughout the construction, a directed relationship runs from supplier $s$ to customer $c$. For a focal firm $i$, I define its *upstream* network as the set of suppliers that sell to firm $i$, and its *downstream* network as the set of customers to which firm $i$ sells. This distinction is central to both the model and the empirical analysis. Supplier hedging can stabilize the input costs faced by the focal firm, whereas customer hedging can stabilize demand for the focal firm's products. I therefore construct upstream and downstream network-hedging measures separately throughout the paper rather than combining them into a single measure of connected-firm hedging.

I first construct annual direct, or first-layer, relationships separately within the two data sources. For the Compustat Segment data, I use the canonical supplier-reported relationship architecture and retain the direction of the original supplier–customer link. For a downstream observation, the focal firm is the supplier and the reported customer is the downstream neighbor. For an upstream observation, the focal firm is the customer and the reporting supplier is the upstream neighbor. I exclude supplier–customer self-links.

The annual mapping preserves the accounting-period timing rules used in the underlying Segment construction rather than assigning relationships mechanically by calendar year.

For FactSet Revere, I use direct first-layer supplier and customer relationships that are active at the focal firm's fiscal-year-end date. Specifically, relationship membership is evaluated at the focal firm's accounting date, *datadate*. For each connected firm, I attach the latest completed accounting state dated on or before the focal firm's fiscal year-end date, provided that the accounting date is no more than 365 calendar days earlier. I first select the accounting state and then evaluate whether the corresponding hedging information is observed; I do not search farther backward merely to obtain a nonmissing hedging observation. This procedure prevents future accounting endpoints from entering the baseline network exposure while accommodating differences in fiscal-year-end dates across connected firms.

I then combine the two relationship sources at the unique focal-firm-year, direction, and connected-firm level. A relationship observed only in the Compustat Segment data enters as a Segment-only link, a relationship observed only in FactSet Revere enters as a Revere-only link, and a relationship appearing in both sources enters once as a common link rather than being duplicated. Thus, the hybrid network uses the union of economically distinct supplier–customer links across the two sources while retaining the source of each link and the information used to construct its economic weight.

### E.1 Constructing Network Hedging Measures

For each focal firm-year, I combine the hybrid production network with the foreign exchange hedging positions of its connected firms. The own-hedging measure for a connected firm is its total foreign exchange derivative notional scaled by positive total assets,

$$FXHedge_{jt} = \frac{FXNotional_{jt}}{Assets_{jt}}.$$

The hedging state attached to a network link corresponds to the same latest completed connected-firm accounting state selected under the timing rule described above. Observed zero hedging is retained as an observed zero, whereas missing hedging information remains missing. I do not replace an unobserved connected-firm hedge with zero, and I do not search backward for an older nonmissing hedge after selecting the relevant accounting state.

**Extensive-margin network hedging.** My primary event-study variables indicate whether foreign exchange hedging is observed among a firm's upstream or downstream counterparties. I define

$$UpAnyHedge_{it} = \mathbf{1}\{\text{at least one observed upstream counterparty of firm } i \text{ hedges in year } t\}, \tag{A15}$$

$$DownAnyHedge_{it} = \mathbf{1}\{\text{at least one observed downstream counterparty of firm } i \text{ hedges in year } t\}. \tag{A16}$$

A value of zero requires an observed production-network state in which the relevant connected firms have observed hedging states and none is observed to hedge. Missing network or hedging information is retained as missing and is never mechanically recoded to zero.

I define the first observed adoption of upstream hedging as the first consecutive-year transition

$$UpAnyHedge_{i,t-1} = 0, \qquad UpAnyHedge_{it} = 1, \tag{A17}$$

and define downstream adoption analogously:

$$DownAnyHedge_{i,t-1} = 0, \qquad DownAnyHedge_{it} = 1. \tag{A18}$$

These transitions form the treatment events in the baseline matched event-study analysis described in Section 4.1.

# F Construction of Network Variables

This appendix defines the production-network variables used in the empirical analysis. The directed network is oriented from supplier to customer, and a network state is indexed by the focal firm's accounting state $(i, t)$. Because firms have different fiscal calendars, linked firms may have different fiscal-year labels; I preserve the exact time-aligned supplier–customer links rather than forcing both endpoints to share the same fiscal-year label. Let $E_t$ denote the directed production network for fiscal year $t$.

## F.1 Degree

The numbers of distinct customers and suppliers of firm $i$ are

$$Customers_{i,t} = \sum_j \mathbf{1}\{(i,j) \in E_t\}, \qquad Suppliers_{i,t} = \sum_j \mathbf{1}\{(j,i) \in E_t\}. \tag{A19}$$

Section 6.1 computes these counts from FactSet Revere relationships and uses $\log(1 + Customers_{i,t})$ and $\log(1 + Suppliers_{i,t})$. An observed zero degree remains zero, and a missing network state is never recoded to zero.

## F.2 Full Leontief Centrality

The full Leontief inverse is

$$L_t = (I - A_t)^{-1} = I + A_t + A_t^2 + A_t^3 + \cdots, \tag{A20}$$

whenever the inverse exists and passes the numerical-stability checks. I retain both the full measure

$$C_t^{L,\text{full}} = \beta_t' L_t \tag{A21}$$

and the network-only component

$$C_t^{L,\text{network}} = \beta_t'(L_t - I). \tag{A22}$$

## G Summary Statistics

Table A1 reports descriptive statistics for the main firm-level variables used in the empirical analysis. Panels A and B describe the eligible firm-year population, while Panel C uses the sample underlying the production-network connectedness regressions in Section 6.1.

Table A1: Summary Statistics of Firm-Level Empirical Variables

| Variable | N | Mean | SD | P25 | Median | P75 |
|---|---|---|---|---|---|---|
| *Panel A. FX Hedging and Operating Outcomes* | | | | | | |
| Own FX hedging participation (0/1) | 83,686 | 0.147 | 0.354 | 0.000 | 0.000 | 0.000 |
| Own FX hedging intensity (all observed firms) | 83,686 | 0.011 | 0.040 | 0.000 | 0.000 | 0.000 |
| Own FX hedging intensity (hedgers only) | 12,284 | 0.077 | 0.076 | 0.018 | 0.048 | 0.111 |
| Absolute annual log Sales growth | 95,638 | 0.307 | 0.480 | 0.061 | 0.145 | 0.327 |
| Absolute annual log COGS growth | 95,448 | 0.308 | 0.490 | 0.064 | 0.149 | 0.326 |
| Absolute annual log Cash growth | 95,610 | 0.705 | 0.812 | 0.177 | 0.421 | 0.907 |
| Absolute annual log Market Net Worth growth | 80,595 | 0.557 | 0.591 | 0.160 | 0.364 | 0.734 |
| *Panel B. Financial Conditions and Firm Characteristics* | | | | | | |
| Book net worth / assets | 102,320 | 0.138 | 1.673 | 0.198 | 0.448 | 0.669 |
| Market net worth / market-value assets | 86,405 | 0.643 | 0.257 | 0.471 | 0.695 | 0.859 |
| Borrowing cost (interest expense/total debt) | 79,314 | 0.168 | 0.473 | 0.044 | 0.069 | 0.106 |
| Operating financing need | 95,736 | 0.016 | 0.150 | -0.020 | 0.006 | 0.041 |
| Change in total debt / lagged assets | 96,772 | 0.066 | 0.370 | -0.023 | 0.000 | 0.052 |
| Change in current debt / lagged assets | 97,236 | 0.024 | 0.223 | -0.004 | 0.000 | 0.010 |
| Log assets | 102,324 | 5.282 | 2.682 | 3.603 | 5.495 | 7.123 |
| Leverage | 101,937 | 0.369 | 0.719 | 0.029 | 0.206 | 0.420 |
| Cash / assets | 102,312 | 0.216 | 0.243 | 0.034 | 0.114 | 0.320 |
| Tangibility | 102,220 | 0.235 | 0.236 | 0.054 | 0.145 | 0.345 |
| Trade credit (accounts payable/COGS) | 101,794 | 1.178 | 5.070 | 0.067 | 0.119 | 0.216 |
| *Panel C. Production-Network Characteristics* | | | | | | |
| Number of downstream customers | 63,259 | 4.529 | 13.565 | 0 | 1 | 4 |
| Number of upstream suppliers | 63,259 | 4.248 | 15.622 | 0 | 0 | 3 |
| Log(1 + Customers) | 63,259 | 0.906 | 1.103 | 0.000 | 0.693 | 1.609 |
| Log(1 + Suppliers) | 63,259 | 0.793 | 1.042 | 0.000 | 0.000 | 1.386 |
| Log(1 + Foreign output exposure) | 63,259 | 2.269 | 1.433 | 1.099 | 2.485 | 3.401 |
| Log(1 + Foreign input exposure) | 63,259 | 2.155 | 1.482 | 0.693 | 2.303 | 3.367 |

*Notes:* Panels A and B use 102,324 eligible U.S.-incorporated firm-years in fiscal years 2000–2022 with positive assets and sales, excluding utilities (SIC 4900–4999) and financial firms (SIC 6000–6999). Each row uses its available nonmissing observations, so N differs across variables and is not a common regression sample. Panel C uses the exact 63,259 distinct firm-years in the Section 6.1 Table 5 SIC2-and-year-FE columns (1)–(2). Own-hedging participation is one for observed positive FX derivative notional and zero for observed zero; unavailable reports remain missing. Intensity is reported USD notional divided by USD assets. The hedgers-only intensity row includes firm-years with strictly positive observed FX derivative notional and uses the same full-sample winsorization as the unconditional intensity measure. Absolute annual log changes require positive current and consecutive-prior-year values. Borrowing cost is interest expense divided by positive total debt. Operating financing need is the annual change in receivables plus inventories minus payables, divided by lagged assets; debt changes use the same lagged-assets denominator. Trade credit is accounts payable divided by COGS. Network degrees are Revere counts; foreign exposure is the log of one plus fiscal-period 10-K country-mention counts.

# Part III: Additional Empirical Results

## H Additional Results for Section 4.1

### H.1 Distribution of Baseline Matched Adoption Events

Figure A6 describes the composition of the treated events entering the baseline matched first-adoption analysis. Panel (A) reports the distribution of matched treatment events across fiscal years, while Panel (B) reports their distribution across broad production sectors using the treated firm's industry classification immediately before adoption.

The baseline matched sample contains 1,351 downstream and 1,321 upstream first-adoption events. In both directions, matched transitions span fiscal years 2003 through 2019 rather than being concentrated in a single episode. The events also occur across a broad set of production sectors.

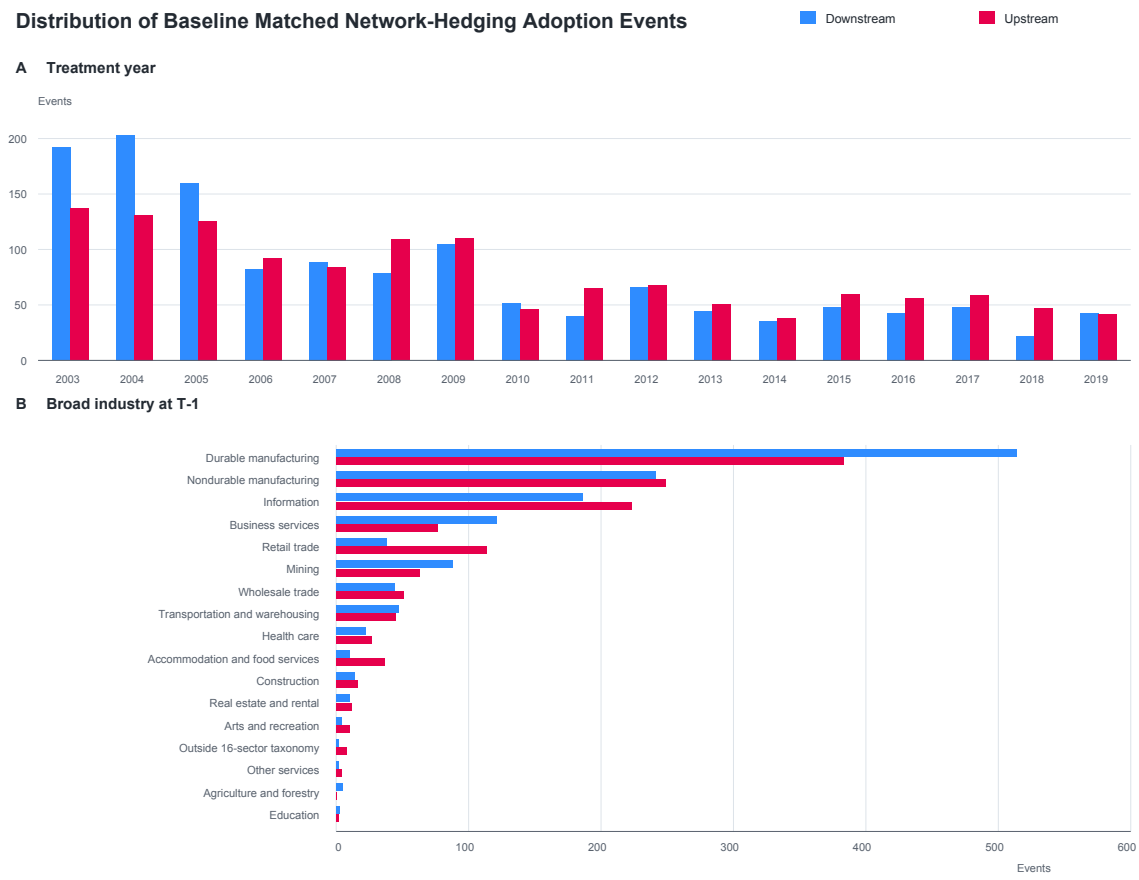



Figure A6: Distribution of Baseline Matched Network-Hedging Adoption Events

*Notes:* This figure reports the distribution of treated firms entering the baseline matched first-adoption analysis. Panel (A) plots the number of matched first observed $0 \rightarrow 1$ network-hedging transitions by treatment year. Panel (B) reports the corresponding distribution across broad production sectors, measured using the treated firm's industry classification in event year $-1$. Blue bars denote downstream transitions and magenta bars denote upstream transitions. The sector classification follows the refined 16-sector aggregation used elsewhere in the paper; matched events that do not map into one of these sectors are retained in the "Outside 16-sector taxonomy" category rather than dropped. The figure contains 1,351 downstream and 1,321 upstream matched treatment events.

## H.2 Matching Diagnostics

Table A2 reports pre-treatment characteristics of treated firms, eligible comparison firms, and the selected matched controls. Because the matching procedure is designed to prioritize similarity in pre-treatment outcome dynamics rather than exact equality in outcome levels, I report both the levels and adjacent pre-treatment changes of the primary outcome. The matched samples exhibit particularly small differences in the pre-treatment outcome changes that govern the local trajectory into treatment. Persistent treated-control differences in outcome levels are absorbed by the treated-firm indicator in the event-study specification, so identification rests on the parallel evolution of the treated-control gap

rather than on equal outcome levels.

Table A2: Pre-Treatment Matching Balance

| Variable | Treated | Eligible candidates | Matched controls | SMD before | SMD after |
|---|---|---|---|---|---|
| *Panel A. Downstream (Sales growth)* | | | | | |
| Firm size (log assets) | 6.158 | 5.823 | 6.243 | +0.154 | -0.039 |
| Leverage | 0.235 | 0.206 | 0.202 | +0.066 | +0.076 |
| Cash/assets | 0.237 | 0.239 | 0.201 | -0.011 | +0.150 |
| Tangibility | 0.243 | 0.245 | 0.255 | -0.009 | -0.051 |
| Trade credit | 0.244 | 0.217 | 0.140 | +0.018 | +0.069 |
| Own FX hedging intensity | 0.0183 | 0.0414 | 0.0106 | -0.064 | +0.016 |
| Primary outcome at −3 | 0.277 | 0.309 | 0.208 | -0.080 | +0.175 |
| Primary outcome at −2 | 0.255 | 0.264 | 0.194 | -0.026 | +0.179 |
| Primary outcome at −1 | 0.251 | 0.255 | 0.186 | -0.011 | +0.185 |
| Outcome change −3 to −2 | -0.022 | -0.045 | -0.014 | +0.054 | -0.020 |
| Outcome change −2 to −1 | -0.004 | -0.009 | -0.008 | +0.013 | +0.011 |
| *Panel B. Upstream (COGS growth)* | | | | | |
| Firm size (log assets) | 6.916 | 6.528 | 7.063 | +0.222 | -0.084 |
| Leverage | 0.242 | 0.220 | 0.215 | +0.083 | +0.103 |
| Cash/assets | 0.207 | 0.271 | 0.194 | -0.266 | +0.050 |
| Tangibility | 0.253 | 0.203 | 0.251 | +0.232 | +0.012 |
| Trade credit | 0.164 | 0.164 | 0.128 | -0.003 | +0.130 |
| Own FX hedging intensity | 0.0334 | 0.0214 | 0.0118 | +0.036 | +0.020 |
| Primary outcome at −3 | 0.254 | 0.263 | 0.199 | -0.024 | +0.147 |
| Primary outcome at −2 | 0.232 | 0.235 | 0.168 | -0.010 | +0.199 |
| Primary outcome at −1 | 0.219 | 0.215 | 0.164 | +0.013 | +0.182 |
| Outcome change −3 to −2 | -0.022 | -0.028 | -0.031 | +0.015 | +0.021 |
| Outcome change −2 to −1 | -0.013 | -0.020 | -0.004 | +0.021 | -0.026 |

*Notes:* This table reports pre-treatment characteristics of treated firms, eligible candidate controls, and selected matched controls. The treated group consists of the matched first-transition events. The eligible-candidate column pools all eligible control observations at each matched event's selected year-by-industry tier, so a control firm may appear in multiple candidate sets. Both standardized mean differences (SMDs) divide the treated-minus-control difference by the pooled pre-match sample standard deviation. Trade credit is accounts payable relative to COGS. Own FX hedging intensity is foreign exchange derivative notional relative to total assets and enters the matching distance only when observed for both members of a potential pair; its post-match SMD uses only pairs with both values observed (1,191 downstream and 1,202 upstream), while the displayed means use all observed values. Primary outcomes are winsorized absolute annual log changes in sales (Panel A) and COGS (Panel B). Matching is one-to-one with replacement.

### H.3 Estimates Across Specifications

Table A3 reports the average post-transition effects, standard errors, pre-trend tests, and sample sizes for all specifications discussed in Sections 4.3 and 4.4. Across specifications, the average effect over event years 0 through +3 ranges from −0.027 to −0.048 and is statistically significant at the 5 percent level in every case, and the joint pre-trend test does not reject at conventional levels in any specification. Within each alternative-explanation comparison, adding the control changes the average effect by no more than 0.002 in absolute value.

Table A3: Average Post-Transition Effects Across Specifications

| Specification | Avg. effect, 0 to +3 | Avg. effect, +1 to +3 | Pre-trend $p$ | Obs. | Pairs |
|---|---|---|---|---|---|
| **Panel A. Downstream hedging and sales volatility** | | | | | |
| Baseline | −0.031 (0.011) | −0.035 (0.012) | 0.978 | 18,388 | 1,351 |
| *Own hedging* | | | | | |
| Common sample, contemporaneous | −0.029 (0.011) | −0.032 (0.012) | 0.904 | 17,284 | 1,347 |
| + Contemporaneous own hedging | −0.029 (0.011) | −0.032 (0.012) | 0.904 | 17,284 | 1,347 |
| Common sample, lagged | −0.029 (0.011) | −0.032 (0.012) | 0.320 | 17,057 | 1,346 |
| + Lagged own hedging | −0.029 (0.011) | −0.032 (0.012) | 0.326 | 17,057 | 1,346 |
| *Realized FX volatility* | | | | | |
| Common sample | −0.036 (0.011) | −0.040 (0.012) | 0.914 | 16,682 | 1,336 |
| + Realized FX volatility | −0.036 (0.011) | −0.040 (0.012) | 0.916 | 16,682 | 1,336 |
| *Network reorganization* | | | | | |
| + New relationships | −0.032 (0.011) | −0.036 (0.012) | 0.985 | 18,388 | 1,351 |
| + New and exited relationships | −0.031 (0.011) | −0.035 (0.012) | 0.983 | 18,388 | 1,351 |
| *Persistence of network hedging* | | | | | |
| Through +1 | −0.039 (0.012) | −0.042 (0.014) | 0.714 | 13,504 | 978 |
| Through +2 | −0.033 (0.013) | −0.037 (0.015) | 0.860 | 10,292 | 739 |
| Through +3 | −0.047 (0.015) | −0.050 (0.017) | 0.462 | 8,078 | 577 |
| *Matching-distance weights* | | | | | |
| Outcome-history weight = 1 | −0.031 (0.011) | −0.035 (0.012) | 0.967 | 18,306 | 1,345 |
| Outcome-history weight = 4 | −0.029 (0.011) | −0.033 (0.012) | 0.926 | 18,306 | 1,345 |
| **Panel B. Upstream hedging and COGS volatility** | | | | | |
| Baseline | −0.031 (0.010) | −0.037 (0.012) | 0.122 | 17,956 | 1,321 |
| *Own hedging* | | | | | |
| Common sample, contemporaneous | −0.031 (0.011) | −0.037 (0.012) | 0.365 | 17,061 | 1,319 |
| + Contemporaneous own hedging | −0.031 (0.011) | −0.037 (0.012) | 0.374 | 17,061 | 1,319 |
| Common sample, lagged | −0.030 (0.011) | −0.035 (0.012) | 0.468 | 16,879 | 1,318 |
| + Lagged own hedging | −0.030 (0.011) | −0.035 (0.012) | 0.469 | 16,879 | 1,318 |
| *Realized FX volatility* | | | | | |
| Common sample | −0.027 (0.011) | −0.032 (0.012) | 0.120 | 16,489 | 1,311 |
| + Realized FX volatility | −0.027 (0.011) | −0.032 (0.012) | 0.120 | 16,489 | 1,311 |
| *Network reorganization* | | | | | |
| + New relationships | −0.032 (0.010) | −0.037 (0.012) | 0.106 | 17,956 | 1,321 |
| + New and exited relationships | −0.030 (0.011) | −0.035 (0.012) | 0.105 | 17,956 | 1,321 |
| *Persistence of network hedging* | | | | | |
| Through +1 | −0.027 (0.011) | −0.033 (0.013) | 0.113 | 12,186 | 883 |
| Through +2 | −0.037 (0.013) | −0.045 (0.015) | 0.228 | 8,989 | 645 |
| Through +3 | −0.048 (0.015) | −0.055 (0.016) | 0.419 | 7,196 | 514 |
| *Matching-distance weights* | | | | | |
| Outcome-history weight = 1 | −0.031 (0.011) | −0.036 (0.012) | 0.149 | 17,956 | 1,321 |
| Outcome-history weight = 4 | −0.028 (0.010) | −0.033 (0.011) | 0.153 | 17,956 | 1,321 |

*Notes:* This table reports average post-transition effects from the matched-pair event-study specification in equation (34). "Avg. effect, 0 to +3" averages the event-time coefficients $\beta_0$ through $\beta_3$, and "Avg. effect, +1 to +3" averages $\beta_1$ through $\beta_3$. Standard errors, in parentheses, are computed from the full variance–covariance matrix and clustered by the underlying firm. "Pre-trend $p$" is the $p$-value of the joint test $\beta_{-3} = \beta_{-2} = 0$. All regressions include a treated-firm indicator and matched-pair and fiscal-year fixed effects, and omit event year −1. The own-hedging, realized FX-volatility, and network-reorganization rows retain the baseline matched pairs without rematching; each augmented row is estimated on the same observations as the common-sample row immediately above it. The network-reorganization controls are observed for the full baseline sample, so these rows are compared directly with the baseline row. The persistence rows require the network hedging indicator to remain equal to one through the indicated event year, retaining the original transition year, and the matched sample is reconstructed for each requirement. The matching-weight rows vary the weight on the standardized pre-treatment outcome levels and slopes relative to the remaining matching covariates; the baseline weight is two. The baseline sample includes 20 downstream and 10 upstream pairs matched outside the treated firm's broad SIC division when no eligible control is available within it; the matching-weight specifications restrict all matches to the treated firm's broad SIC division.

# I Additional Results for Section 5

This appendix reports evidence on the quantity of external finance, a margin from which the model abstracts. Section 5 examines whether hedging stabilizes firms' financial positions and whether stronger financial positions lower borrowing costs. Here I examine whether firms with different financial positions borrow different amounts when their operating financing needs rise. Appendix I.1 reports the baseline estimates, and the remaining subsections show that they are robust to industry-by-year shocks, appear on the extensive margin of borrowing and for both current and long-term debt, and are clearest for receivables among the components of financing need.

## I.1 Net Worth, Operating Financing Needs, and Realized Borrowing

I measure operating financing need as the change in noncash operating working capital,

$$Need_{it} = \frac{\Delta\left(Receivables_{it} + Inventories_{it} - AccountsPayable_{it}\right)}{Assets_{i,t-1}}.$$

A positive value means that more resources are tied up in receivables and inventories, net of supplier credit. I use this measure rather than Compustat working capital because current liabilities include current debt, which would overlap mechanically with the borrowing outcomes.

The primary outcome is the annual change in total debt scaled by lagged assets, and the secondary outcome is the corresponding change in current debt. I estimate

$$\frac{\Delta Debt_{it}}{Assets_{i,t-1}} = \alpha_i + \delta_t + \beta_1 Need_{it} + \beta_2 NW_{i,t-1} + \beta_3\left(Need_{it} \times NW_{i,t-1}\right) + X'_{i,t-1}\Gamma + \varepsilon_{it},$$

where $NW_{i,t-1}$ is lagged book net worth relative to assets and $X_{i,t-1}$ contains lagged firm size, cash holdings, tangibility, and trade credit. All specifications include firm and fiscal-year fixed effects and cluster standard errors by firm, and accounting ratios and changes are winsorized at the 1st and 99th percentiles.

Columns (1) and (2) of Table A4 show that borrowing rises strongly with operating financing need, consistent with the working-capital financing in the model, and that the response is larger for firms with stronger net worth. The interaction is 0.0537 for total debt and 0.0229 for current debt, both significant at the 1 percent level.

The difference is concentrated among the weakest firms. I define low-net-worth firms as those in the bottom quartile of lagged net worth within the fiscal year and restrict the sample to firm-years with positive financing need. In columns (3) and (4), the interaction between financing need and the low-net-worth indicator is −0.2531 for total debt, significant at the 1 percent level, and −0.0644 for current debt, which is imprecisely estimated. For total debt, the slope on financing need is 0.822 above the bottom quartile and 0.569 within it, a borrowing response roughly 31 percent smaller. Estimating the slope separately by quartile gives 0.562 in the bottom quartile and 0.832, 0.843, and 0.800 in quartiles two through four, so the difference reflects the bottom tail rather than a gradient

across the whole distribution. Firms with weak balance sheets therefore meet increases in operating financing needs with less additional borrowing.

Table A4: Net Worth, Operating Financing Needs, and Realized Borrowing

| | Continuous Financial Condition | | Bottom-Tail Threshold | |
|---|---|---|---|---|
| | Total Debt | Current Debt | Total Debt | Current Debt |
| Operating financing need | 0.3024*** | 0.0539*** | 0.8217*** | 0.2083*** |
| | (0.0242) | (0.0147) | (0.0433) | (0.0214) |
| Lagged net worth / assets | -0.0112** | -0.0106*** | 0.0128 | -0.0016 |
| | (0.0049) | (0.0034) | (0.0088) | (0.0060) |
| Need × Lagged net worth | 0.0537*** | 0.0229*** | | |
| | (0.0073) | (0.0051) | | |
| Low lagged net worth | | | -0.0914*** | -0.0200*** |
| | | | (0.0081) | (0.0051) |
| Need × Low net worth | | | -0.2531*** | -0.0644 |
| | | | (0.0776) | (0.0491) |
| Observations | 84,557 | 84,991 | 47,072 | 47,317 |
| Adjusted $R^2$ | 0.193 | 0.136 | 0.205 | 0.161 |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes |
| Positive financing need only | No | No | Yes | Yes |

*Notes:* This table examines whether firms with stronger predetermined balance sheets expand realized borrowing more when operating financing needs rise. Operating financing need is the annual change in receivables plus inventories minus accounts payable, scaled by lagged total assets. Total debt is current debt plus long-term debt; the borrowing outcomes are annual changes scaled by lagged total assets. Lagged net worth is shareholders' equity relative to total assets. "Low lagged net worth" equals one for firms in the bottom quartile of the lagged net-worth distribution within fiscal year. Columns (1)–(2) use the full baseline sample and interact financing need with continuous lagged net worth. Columns (3)–(4) restrict the sample to observations with positive financing need and interact financing need with the low-net-worth indicator. Controls include lagged log assets, cash relative to assets, tangibility, and trade credit. All specifications absorb firm and fiscal-year fixed effects. Standard errors are clustered by firm and reported in parentheses. Continuous accounting variables are winsorized at the 1st and 99th percentiles. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

Table A5 replaces the fiscal-year fixed effects with two-digit-SIC-by-year fixed effects, in addition to firm fixed effects, to test whether the results reflect industry-specific annual conditions. The interaction between financing need and lagged net worth is almost unchanged, at 0.0535 for total debt and 0.0226 for current debt. In the bottom-tail specification, the interaction for total debt remains −0.2460, so low-net-worth firms continue to borrow substantially less when financing needs are positive.

Table A5: Operating Financing Needs and Realized Borrowing: Industry-by-Year Robustness

| | Continuous financial condition | | Bottom-tail threshold | |
|---|---|---|---|---|
| | (1) Total debt | (2) Current debt | (3) Total debt | (4) Current debt |
| Operating financing need | 0.2980*** | 0.0530*** | 0.8145*** | 0.2064*** |
| | (0.0246) | (0.0150) | (0.0433) | (0.0216) |
| Lagged net worth / assets | -0.0104** | -0.0103*** | 0.0150* | -0.0007 |
| | (0.0049) | (0.0034) | (0.0088) | (0.0061) |
| Need × Lagged net worth | 0.0535*** | 0.0226*** | | |
| | (0.0074) | (0.0051) | | |
| Low lagged net worth | | | -0.0947*** | -0.0212*** |
| | | | (0.0083) | (0.0053) |
| Need × Low net worth | | | -0.2460*** | -0.0587 |
| | | | (0.0777) | (0.0496) |
| Observations | 82,107 | 82,538 | 46,159 | 46,403 |
| Adjusted $R^2$ | 0.201 | 0.138 | 0.208 | 0.156 |

*Notes:* This table repeats the specifications in Table A4 with two-digit-SIC-by-year fixed effects. Operating financing need is the annual change in receivables plus inventories minus accounts payable, scaled by lagged total assets. The dependent variables are annual changes in total debt or current debt, also scaled by lagged total assets. Lagged net worth is shareholders' equity relative to total assets. Columns (1)–(2) interact operating financing need with continuous lagged net worth in the full sample. Columns (3)–(4) restrict the sample to observations with positive operating financing need and define low lagged net worth as the bottom quartile of the lagged net-worth distribution within fiscal year. All specifications absorb firm fixed effects and two-digit-SIC-by-year fixed effects. Controls include lagged log assets, cash relative to assets, tangibility, and trade credit. Standard errors are clustered by firm and reported in parentheses. Continuous accounting ratios and changes are winsorized at the 1st and 99th percentiles. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

Table A6 examines whether the same pattern appears on the extensive margin. The dependent variable is an indicator for whether total debt or current debt increases from the previous fiscal year, so a positive interaction between financing need and lagged net worth means that financially stronger firms are more likely to increase borrowing when financing needs rise. The interaction is positive and significant at the 1 percent level for both outcomes.

Table A6: Operating Financing Needs and the Extensive Margin of Borrowing

| | (1)<br>Pr(Total debt rises) | (2)<br>Pr(Current debt rises) |
|---|---|---|
| Operating financing need | 0.4740*** | 0.2768*** |
| | (0.0193) | (0.0175) |
| Lagged net worth / assets | 0.0202*** | 0.0055** |
| | (0.0023) | (0.0022) |
| Need × Lagged net worth | 0.0543*** | 0.0348*** |
| | (0.0032) | (0.0031) |
| Observations | 84,557 | 84,991 |
| Adjusted $R^2$ | 0.133 | 0.094 |

*Notes:* This table reports firm-level linear-probability regressions for the extensive margin of realized borrowing. The dependent variable in column (1) equals one when total debt increases relative to the previous fiscal year, and the dependent variable in column (2) equals one when current debt increases. Operating financing need is the annual change in receivables plus inventories minus accounts payable, scaled by lagged total assets. Lagged net worth is shareholders' equity relative to total assets. All specifications include firm and fiscal-year fixed effects and control for lagged log assets, cash relative to assets, tangibility, and trade credit. Standard errors are clustered by firm and reported in parentheses. Continuous accounting ratios and changes are winsorized at the 1st and 99th percentiles. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

### I.2 Components of Operating Financing Need

The baseline financing-need measure combines changes in receivables, inventories, and accounts payable. Table A7 estimates the baseline specification separately for each component. The interaction with lagged net worth is clearest for receivables and imprecisely estimated for inventories and accounts payable.

Table A7: Components of Operating Financing Need

| | (1) Receivables | (2) Inventories | (3) Less trade-credit supply |
|---|---|---|---|
| Receivables financing need | 0.6472*** | | |
| | (0.0304) | | |
| Lagged net worth / assets | -0.0111** | -0.0096* | -0.0069 |
| | (0.0051) | (0.0050) | (0.0051) |
| Receivables need × Lagged net worth | 0.0307** | | |
| | (0.0142) | | |
| Inventory financing need | | 0.8154*** | |
| | | (0.0415) | |
| Inventory need × Lagged net worth | | 0.0175 | |
| | | (0.0345) | |
| Reduced trade-credit supply | | | -0.7353*** |
| | | | (0.0407) |
| Reduced trade-credit supply × Lagged net worth | | | -0.0115 |
| | | | (0.0093) |
| Observations | 85,492 | 84,890 | 85,822 |
| Adjusted $R^2$ | 0.204 | 0.195 | 0.216 |

*Notes:* This table decomposes the operating-financing-need measure used in Table A4. In column (1), receivables need is the annual change in accounts receivable divided by lagged total assets. In column (2), inventory need is the annual change in inventories divided by lagged total assets. In column (3), the accounts-payable component is coded as the negative annual change in accounts payable divided by lagged total assets, so that a higher value corresponds to less trade-credit financing and therefore greater external financing need. The dependent variable in all columns is the annual change in total debt divided by lagged total assets. Lagged net worth is shareholders' equity relative to total assets. Each specification includes the component itself, lagged net worth, and their interaction, together with firm and fiscal-year fixed effects and controls for lagged log assets, cash relative to assets, tangibility, and trade credit. Standard errors are clustered by firm and reported in parentheses. Continuous accounting ratios and changes are winsorized at the 1st and 99th percentiles. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

### I.3 Debt Maturity

Table A8 separates the borrowing response into current and long-term debt. The interaction between financing need and lagged net worth is positive for both maturities. The baseline result therefore reflects a broad external-financing margin rather than a particular short-term credit line or revolver.

Table A8: Operating Financing Needs and Borrowing by Debt Maturity

| | (1) Current debt | (2) Long-term debt |
|---|---|---|
| Operating financing need | 0.0539*** | 0.2329*** |
| | (0.0147) | (0.0137) |
| Lagged net worth / assets | -0.0106*** | 0.0081*** |
| | (0.0034) | (0.0023) |
| Need × Lagged net worth | 0.0229*** | 0.0200*** |
| | (0.0051) | (0.0036) |
| Observations | 84,991 | 84,577 |
| Adjusted $R^2$ | 0.136 | 0.063 |

*Notes:* This table examines the maturity composition of the realized-borrowing response. Column (1) reproduces column (2) of Table A4. The dependent variable in column (1) is the annual change in current debt divided by lagged total assets, and the dependent variable in column (2) is the annual change in long-term debt divided by lagged total assets. Operating financing need is the annual change in receivables plus inventories minus accounts payable, scaled by lagged total assets. Lagged net worth is shareholders' equity relative to total assets. Both specifications include firm and fiscal-year fixed effects and controls for lagged log assets, cash relative to assets, tangibility, and trade credit. Standard errors are clustered by firm and reported in parentheses. Continuous accounting ratios and changes are winsorized at the 1st and 99th percentiles. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

# J Additional Results for Section 6

## J.1 Foreign Exchange Hedging Across Broad Production Sectors

Figure A7 provides a descriptive view of how firms' own foreign exchange hedging varies across broad production sectors. Hedge participation and hedge intensity display broadly similar cross-sector rankings, with durable and nondurable manufacturing among the sectors with the highest observed hedging activity. The figure uses the same refined BEA-based sector aggregation as the production-network visualization in the main text, allowing the sector-level hedging patterns to be compared directly across the two figures.

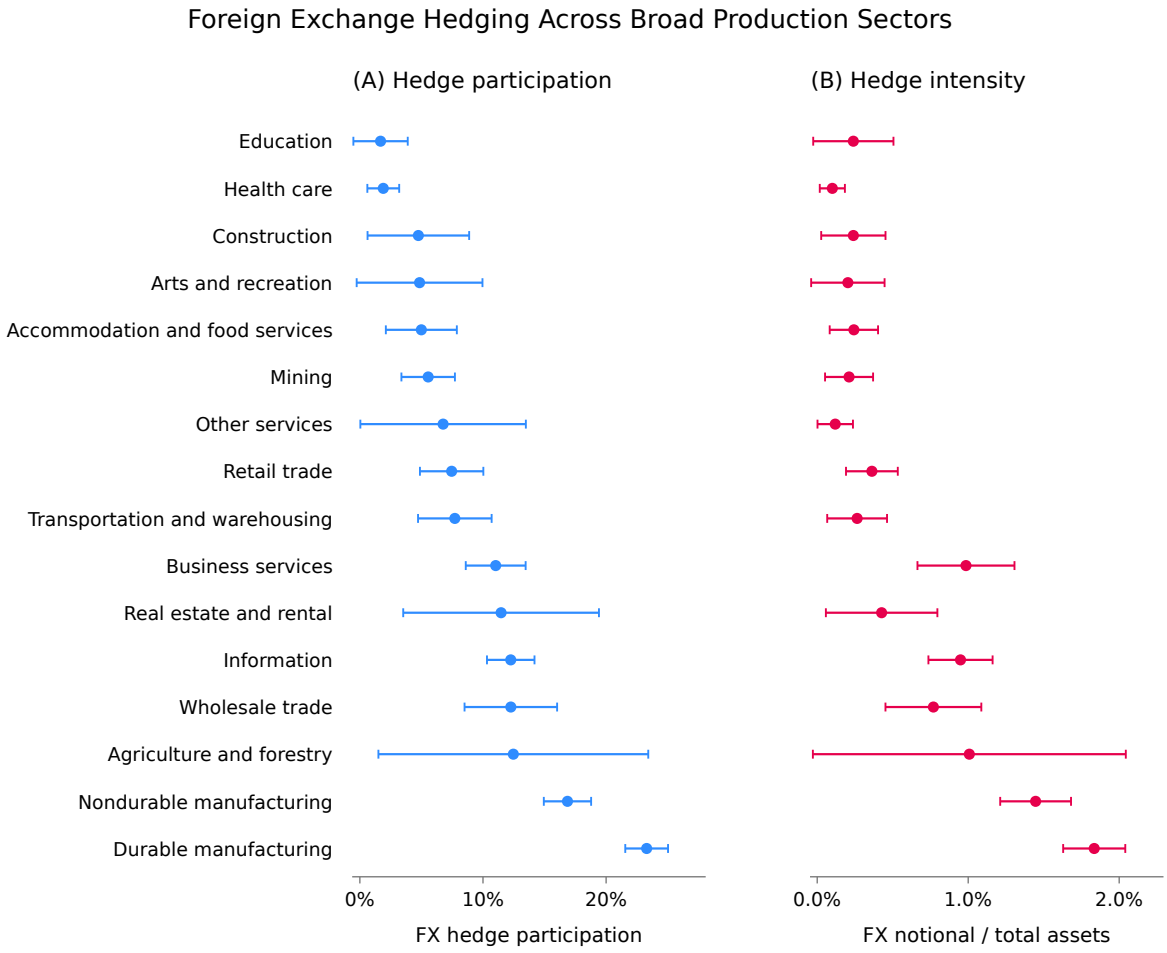



Figure A7: Foreign Exchange Hedging Across Broad Production Sectors

*Notes:* This figure reports cross-sector variation in firms' own foreign exchange hedging. The sector classification is the same refined BEA-based aggregation used in Figure 8. Panel (A) reports the share of observed firm-year observations with positive foreign exchange derivative notional amounts. Panel (B) reports mean foreign exchange derivative notional relative to total assets, including observed zero hedging observations. Points denote sector means and horizontal bars report 95% confidence intervals clustered by firm. The panels use a common ordering based on hedge participation in Panel (A). Missing hedging observations remain missing and are not recoded as zero. The figure uses 81,115 observed firm-year observations across the 16 displayed sectors.

## J.2 Upstream and Downstream Network Hedging Across Production Sectors

Figure A8 provides a descriptive comparison of where foreign exchange hedging is observed around firms in the production network. For each broad production sector, I report the share of firm-year observations with at least one hedging downstream customer and the share with at least one hedging upstream supplier. The relative prevalence of customer-side and supplier-side hedging varies substantially across sectors: customer-side prevalence is higher in seven sectors, while supplier-side prevalence is higher in nine. The figure therefore does not reveal a uniform directional ordering of network hedging

across industries. Instead, it highlights substantial cross-sector heterogeneity in whether observed FX risk management is concentrated among firms' customers or suppliers. The sector classification is the same refined BEA-based aggregation used in Figure 8 and Appendix Figure A7.

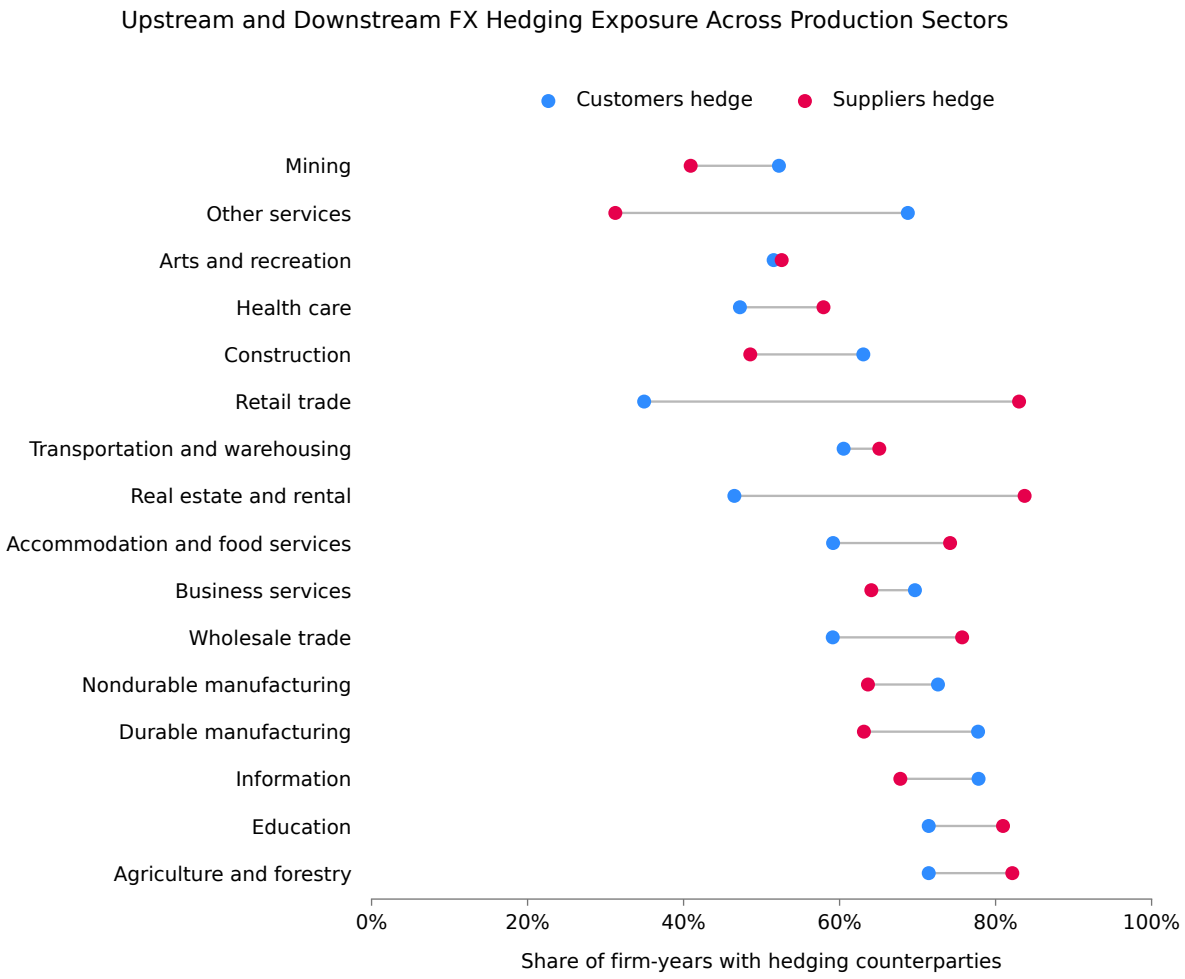



Figure A8: Upstream and Downstream FX Hedging Exposure Across Production Sectors

*Notes:* This figure compares the prevalence of foreign exchange hedging among firms' downstream customers and upstream suppliers across broad production sectors. The sector classification is the same refined BEA-based aggregation used in Figure 8. The blue dot for each sector reports the share of firm-year observations with at least one observed hedging downstream customer, while the magenta dot reports the share with at least one observed hedging upstream supplier. A zero requires an observed network state in the corresponding direction in which no observed counterparty hedges; missing network or hedging information remains missing and is not recoded as zero. Thin gray lines connect the two sector-level means to facilitate within-sector comparison. The figure uses 19,302 paired firm-year observations from 3,440 firms over fiscal years 2003–2022. The plotted relationships are descriptive and do not imply that customer-side or supplier-side hedging systematically dominates across sectors.

### J.3 Parameters

**Calibration target.** Aggregate gross output of the 60 modeled industries in the 2022 BEA accounts is $35.08 trillion; this fixed empirical scale is the denominator of both the data and model moments. The calibrated $\gamma = 7.6533$ reproduces the target of 3.5555 percent to within 0.00002 percent of its value. All baseline and counterfactual equilibria use this value of $\gamma$.

**Foreign-demand elasticities.** Let $\mathcal{M}$ be the set of 15 industries with a direct GTAP counterpart, and let $\sigma_{M,i}$ be the published import-source substitution parameter assigned to industry $i \in \mathcal{M}$. The elasticities are

$$\chi_i = \begin{cases} 4\,\sigma_{M,i}/\overline{\sigma}_M, & i \in \mathcal{M}, \\ 4, & i \notin \mathcal{M}, \end{cases} \qquad \overline{\sigma}_M = \frac{\sum_{i\in\mathcal{M}} X_i \sigma_{M,i}}{\sum_{i\in\mathcal{M}} X_i} = 6.558. \tag{A23}$$

The matched industries are BEA 23, 313TT, 321, 324, 326, 327, 332, 333, 334, 335, 3361MV, 3364OT, 481, 483, and 61, which account for 33.4 percent of exports. The resulting elasticities range from 2.32 to 5.37, and the export-weighted mean is four both within the matched group and across all 60 industries. Industries without an unambiguous GTAP counterpart, such as oil and gas extraction and several broad service industries, keep $\chi_i = 4$.

**Imported-input prices.** In the import-price economy, the normalized price of imported inputs is

$$\frac{P_f(u)}{P_f(1)} = 0.949\,u^{0.157} + 0.051\,u, \qquad u = e/e_0, \tag{A24}$$

whose elasticity at $u = 1$ is $0.949 \times 0.157 + 0.051 = 0.20$. The second term has full pass-through, while the first allows dollar-invoiced prices to adjust partially over the year. In the foreign-demand economy, $P_f(u) = P_f(1)$.

**Hedging cost.** With notional $N_i = e_f|q_i|$ and $h_i = N_i/G_i$, the average and marginal costs of equation (41) are $5{,}000\,\kappa h_i$ and $10{,}000\,\kappa h_i$ basis points per dollar of notional. At $\kappa = 0.002$ and $h_i = 0.05$, they are 0.5 and 1.0 basis points. Estimates of forward bid-ask spreads, such as Burnside et al. (2006) and Nozaki (2010), refer to linear transaction costs in market quotes and do not directly discipline this convex coefficient; $\kappa$ is therefore a benchmark rather than an estimate.

**Credit schedule.** At the calibrated $\gamma$, equation (40) implies that a decline in $z/\text{Rev}^0$ of one percentage point from the reference position raises the annual borrowing rate by 13.4 basis points locally, or by $175[\exp(0.01\gamma) - 1] = 13.9$ basis points exactly.

### J.4 Aggregation and Counterfactual Definitions

**Aggregates.** Let $a$ index an economy and $c$ a channel. At reference prices $P_i^0 = 1$, real gross output is $\mathcal{Q}_s^{c,a} = \sum_i P_i^0 Q_{is}^{c,a}$, and real value added is $VA_s^{c,a} = \sum_i \left[P_i^0 Q_{is}^{c,a} - \sum_{j \in \mathcal{I}_i} P_j^0 x_{ijs}^{c,a}\right]$, where $\mathcal{I}_i$ includes inputs from modeled industries, inputs from outside the network, and imported inputs. The output-price index is $\mathcal{P}_s^{c,a} = \sum_i w_i P_{is}^{c,a}$, with the same BEA weights $w_i$ in every economy. Expected values are probability-weighted levels, $\mathbb{E}_\pi[VA^{c,a}] = \sum_s \pi_s VA_s^{c,a}$.

**Mean and state comparisons.** The expected-level advantage of the hedged baseline $H$ over economy $a$ is

$$\Delta_a^{\text{mean}}(VA) = 100\left[\frac{\mathbb{E}_\pi VA^{c,H}}{\mathbb{E}_\pi VA^{c,a}} - 1\right], \tag{A25}$$

whereas state-level differences are reported relative to the baseline,

$$\Delta_a^{\text{state}}(VA_s) = 100\left[\frac{VA_s^{c,a}}{VA_s^{c,H}} - 1\right]. \tag{A26}$$

The two conventions have opposite signs. Price-index differences are reported in index points.

**Volatility.** Industry standard deviations in equation (43) use the five-state population variance. Industry sales equal $P_i Q_i$, and COGS and terminal net worth are the rigid- and flexible-type mixtures of production bills and terminal net worth. The standard deviation of $\log \mathcal{Q}_s$ or $\log VA_s$ is computed after aggregation and differs from the weighted mean of industry standard deviations. The amplification figures in Section 6.7 combine the value-added volatility reductions in Table A9: for the import-price economy, the ratio of the no-hedge to the matched-quote standard deviation is $(1 + 0.05926)/(1 - 0.03916) = 1.102$, and the share of this excess removed by hedging is $(1.102 - 1.059)/(1.102 - 1) = 0.42$. The increase from removing all hedges reported in Section 6.5 is $1/(1-0.03916)-1 = 4.1$ percent in the import-price economy and $1/(1 - 0.02481) - 1 = 2.5$ percent in the foreign-demand economy.

**Counterfactuals.** The no-hedge economy sets every hedge to zero and keeps the endogenous credit schedule. The uniform-quote economy sets the gross rate to 1.0486 for every industry, pricing type, and state. The matched-quote economy fixes industry $i$'s rate at

$$\overline{R}_i = \sum_s \pi_s \left[\lambda R_{iR,s}^H + (1 - \lambda) R_{iF,s}^H\right] \tag{A27}$$

for both pricing types and all states; it matches the industry's expected rate but not type-specific rates or interest payments. Hedges and prices are reoptimized in both constant-quote economies. The single-industry interventions set one industry's hedge to zero at a time and let the other 59 hedges reoptimize; for chemicals, a companion

experiment holds the other hedges fixed. Goods, prices, production, and credit re-clear in every counterfactual.

Table A9: Real production: expected and state effects

| | Baseline vs. comparator, mean (%) | | | Comparator vs. baseline, VA by state (%) | | |
|---|---|---|---|---|---|---|
| Comparator | Gross output | Value added | VA log-SD reduction (%) | Lowest $e$ | $e = 1$ | Highest $e$ |
| *Panel A. Import-price economy* | | | | | | |
| No hedge | 0.000019 | 0.000017 | 3.916 | 0.00491 | −0.00048 | −0.00476 |
| Uniform quote | 0.246288 | 0.199677 | −5.933 | −0.20628 | −0.19844 | −0.19304 |
| Matched quote | 0.244050 | 0.197962 | −5.926 | −0.20456 | −0.19673 | −0.19134 |
| *Panel B. Foreign-demand economy* | | | | | | |
| No hedge | 0.000702 | 0.000121 | 2.481 | −0.08833 | 0.00681 | 0.08212 |
| Uniform quote | 0.236771 | 0.193813 | −7.666 | 0.01898 | −0.18450 | −0.45579 |
| Matched quote | 0.269448 | 0.218910 | −7.783 | −0.00279 | −0.20960 | −0.48415 |

*Notes:* Mean effects follow equation (A25); state effects follow equation (A26) and have the opposite sign convention. The VA log-SD reduction is $100[1 - \mathrm{SD}(\log VA^H)/\mathrm{SD}(\log VA^a)]$ across the five states; negative values mean that the baseline is more volatile than the comparator. Value added refers to the 60 modeled industries at common reference prices.

Table A10: Output prices

| | Aggregate index | | | Industries | |
|---|---|---|---|---|---|
| Comparator | Baseline − comparator | SD reduction (%) | Median change (%) | Higher | Lower |
| *Panel A. Import-price economy* | | | | | |
| No hedge | −0.00000023 | 2.269 | 0.000012 | 60 | 0 |
| Uniform quote | −0.00152283 | −2.735 | 0.148356 | 60 | 0 |
| Matched quote | −0.00151092 | −2.737 | 0.147496 | 60 | 0 |
| *Panel B. Foreign-demand economy* | | | | | |
| No hedge | −0.00004749 | 27.919 | 0.003886 | 60 | 0 |
| Uniform quote | −0.00135819 | – | 0.129651 | 60 | 0 |
| Matched quote | −0.00153553 | – | 0.149680 | 60 | 0 |

*Notes:* The aggregate index uses 2022 BEA gross-output weights. The first column is the difference in expected index levels, in index points; the SD reduction is $100[1 - \mathrm{SD}(\mathcal{P}^H)/\mathrm{SD}(\mathcal{P}^a)]$. The last three columns compare each industry's expected price in the comparator economy with the baseline. In the foreign-demand economy, the price index is constant across states under either constant quote, so the SD reduction is undefined.

Table A11: Borrowing rates, working capital, and hedging costs

| Economy | Mean net rate (%) | State SD (bp) | Working capital ($tn) | Hedging cost ($m) | Average cost (bp) |
|---|---|---|---|---|---|
| *Panel A. Import-price economy* | | | | | |
| Optimal hedge | 4.85944 | 0.1859 | 23.10390 | 0.2955 | 0.0413 |
| No hedge | 4.85944 | 0.3470 | 23.10390 | 0.0000 | – |
| Uniform quote | 4.86000 | 0.0000 | 23.06486 | 0.0000 | – |
| Matched quote | 4.85944 | 0.0000 | 23.06523 | 0.0000 | – |
| *Panel B. Foreign-demand economy* | | | | | |
| Optimal hedge | 4.86771 | 6.9542 | 23.07137 | 83.5459 | 0.7105 |
| No hedge | 4.87016 | 9.6712 | 23.07164 | 0.0000 | – |
| Uniform quote | 4.86000 | 0.0000 | 23.03285 | 0.0000 | – |
| Matched quote | 4.86771 | 0.0000 | 23.02765 | 0.0000 | – |

*Notes:* The mean rate and the within-industry state standard deviation use BEA gross-output weights. Working capital is the expected aggregate loan. Hedging cost is the quadratic cost at the optimal positions; average cost is per dollar of notional.

Table A12: Constant-quote economies relative to the baseline

| Constant quote | Mean rate (%) | Rate SD (bp) | Value added (%) | Gross output (%) | Notional ($bn) |
|---|---|---|---|---|---|
| *Panel A. Import-price economy* | | | | | |
| Uniform | 4.860000 | 0 | −0.199279 | −0.245683 | 0.0 |
| Matched | 4.859436 | 0 | −0.197571 | −0.243456 | 0.0 |
| *Panel B. Foreign-demand economy* | | | | | |
| Uniform | 4.860000 | 0 | −0.193439 | −0.236211 | 0.0 |
| Matched | 4.867715 | 0 | −0.218432 | −0.268724 | 0.0 |

*Notes:* Value added and gross output are expected levels relative to the baseline, divided by the baseline. Hedges and all equilibrium objects are reoptimized; optimal notional is below $0.001 million in every case. The matched quote equals each industry's baseline expected rate averaged over states and pricing types.

### J.5 Industry Volatility Under Alternative Economies

Figure A9 compares industry volatility in the baseline with three comparators. A positive bar means that the baseline has a lower weighted standard deviation than the comparator. The no-hedge bars measure the effect of access to hedging under the endogenous credit schedule; the constant-quote bars compare different credit contracts and are negative for sales and COGS, indicating that the endogenous schedule amplifies operating volatility even with optimal hedging.

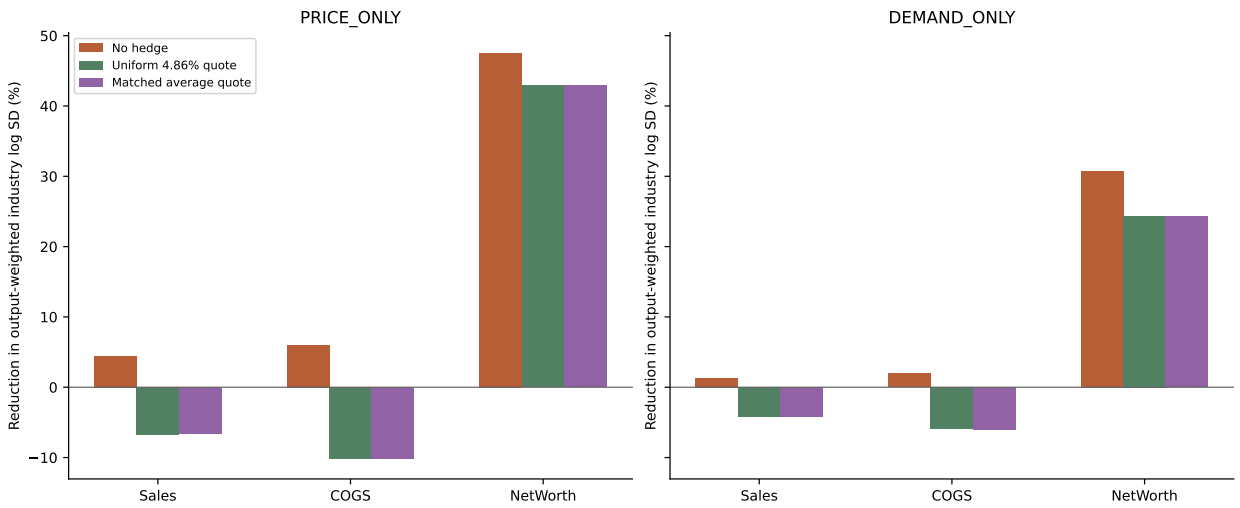



Figure A9: Industry volatility relative to alternative economies

*Notes:* Each bar is $100[1 - \sum_i w_i \sigma_{i,V}(H) / \sum_i w_i \sigma_{i,V}(a)]$, where the legend names the comparator $a$. Constant-quote economies replace the endogenous credit schedule and reoptimize hedges.

## J.6 Single-Industry Interventions

Each intervention sets one source industry's hedge to zero, lets the other 59 industries reoptimize, and re-solves the equilibrium in each channel economy, for 120 equilibria in total. The outside response of a source is the sum of absolute changes in expected real value added across the other 59 industries. This subsection reports the distribution of these responses, their relationship with network position, the sign of the expected effects, the size of the volatility effects, and the chemicals intervention in detail.

**Distribution.** Figure A10 shows the distribution of signed and absolute outside responses across the 60 sources in each economy. Signed responses are negative for most sources in the import-price economy but take both signs in the foreign-demand economy, and absolute responses span several orders of magnitude in both.

**Network position.** Table A13 summarizes the relationship between the outside response and the source's forward Leontief centrality. The controlled specification regresses the log outside response on log centrality, the log removed notional, log BEA gross output, and the source's direct exposure, measured by imports relative to gross output in the import-price economy and exports relative to gross output in the foreign-demand economy. Figure A11 shows the partial relationship and the response per dollar of removed notional. The controlled association is positive in both economies and remains positive when chemicals, wholesale trade, and other sources flagged as influential are excluded. Its strength depends on the channel and on the response measure: in the foreign-demand economy, centrality adds less than one percentage point to the explained variance once hedge size, scale, and exposure are controlled for.

Table A13: Network centrality and the response outside the source industry

| | Import-price economy | Foreign-demand economy |
|---|---|---|
| Rank correlation with centrality | 0.716 | 0.827 |
| Partial rank correlation, with controls | 0.906 | 0.585 |
| Elasticity with respect to centrality, with controls | 2.168 | 1.181 |
| Incremental $R^2$ of centrality (percentage points) | 8.55 | 0.91 |
| Rank correlation per dollar of removed notional | 0.51 | 0.61 |

*Notes:* Each economy has 60 source interventions. The response is the sum of absolute changes in expected real value added outside the source industry. Centrality is forward Leontief centrality as a supplier. Controls are the log removed notional, log 2022 BEA gross output, and direct exposure (imports or exports relative to gross output). The elasticity is the coefficient on log centrality in a regression of the log response on log centrality and the controls; the incremental $R^2$ is the increase in $R^2$ from adding log centrality to a regression on the controls alone. The partial rank correlation is computed after removing the controls from both variables. The last row is the Spearman correlation between centrality and the response divided by the removed notional. These are descriptive statistics across model counterfactuals.

**Multipliers and signs.** Figure A12 compares conventional multipliers, defined as the ratio of the total to the source industry's own change in expected value added, with the share of the absolute response that occurs outside the source. In the import-price economy, the multiplier exceeds one for every source with a measurable own response. In the foreign-demand economy, it changes sign for 25 sources and is undefined for 6 whose own response is near zero; the absolute share avoids both problems. Figure A13 shows that the reversals arise because the change in other industries' expected value added has the opposite sign from, and is larger than, the source industry's own change. In the foreign-demand economy, removing a single industry's hedge raises expected aggregate value added for 46 sources and lowers it for 14.

**Volatility.** Figure A14 reports the increase in the standard deviation of log aggregate real value added across states for each intervention. The computed increase is positive in all 120 cases. Its median is 0.032 percent of the baseline standard deviation in the import-price economy and 0.016 percent in the foreign-demand economy; it exceeds 0.1 percent for 14 and 8 sources, and its minimum is 0.0029 and 0.0002 percent. The 0.1 percent threshold is a descriptive magnitude screen rather than a test. For the five smallest changes in each economy, which are of order $10^{-8}$ in log points, goods-market residuals are below $2 \times 10^{-15}$ and hedge first-order-condition residuals are below $10^{-10}$. These residuals are not an end-to-end error bound for the change in the standard deviation, so the sign of the smallest changes should be read as computed rather than certified.

**State-contingent responses.** Figure A15 shows the outside response by exchange-rate state for five sources. In all 120 interventions, the change in expected aggregate value added is small relative to the largest change in any single state.

**The chemicals intervention.** Chemicals generates the largest outside response in both economies. To describe where its response occurs, let $Z_{ij}$ denote purchases by industry

$i$ from industry $j$, and record a directed link $j \to i$ when $Z_{ij}/G_i \geq 0.01$; the threshold is used only for this classification, and all links remain active in the equilibrium. Chemicals has 18 direct downstream buyers, 41 industries at longer downstream distances, and 4 direct upstream suppliers; because of cycles, 43 non-chemicals industries are reachable both upstream and downstream, so only the partition into chemicals, direct downstream, and indirect downstream industries is additive. Table A14 compares the intervention with the other hedges fixed and reoptimized, and Figure A16 scales each group's response by its own value added. Relative to their size, the 18 direct downstream buyers respond by about one-eighth as much as chemicals itself in the foreign-demand economy, and the response declines monotonically with distance. The results are similar whether the other industries' hedges are fixed or reoptimized, so the propagation operates through prices, input demand, and borrowing costs rather than through other industries' hedging responses.

Table A14: Removing the chemicals hedge

| | Change in expected value (%) | | | Change in value added ($m) | |
|---|---|---|---|---|---|
| Other industries' hedges | Gross output | Value added | Price index | Chemicals | Other industries |
| *Panel A. Import-price economy* | | | | | |
| Fixed | −0.000004095 | −0.000003435 | +0.000004286 | −0.250 | −0.403 |
| Reoptimized | −0.000004079 | −0.000003419 | +0.000004258 | −0.250 | −0.400 |
| *Panel B. Foreign-demand economy* | | | | | |
| Fixed | −0.000357014 | −0.000209069 | +0.000727478 | −10.859 | −28.843 |
| Reoptimized | −0.000358857 | −0.000210910 | +0.000723394 | −10.887 | −29.165 |

*Notes:* Each row compares the economy with the chemicals (BEA 325) hedge set to zero with the calibrated baseline of the same channel. "Fixed" holds the other 59 industries' hedges at baseline values; "Reoptimized" lets them adjust. Goods, prices, and credit re-clear in both. The chemicals and other-industry columns add up to the total change in expected value added. In the foreign-demand economy, the non-chemicals response of $29.2 million splits into $13.5 million for the 18 direct downstream buyers and $15.6 million for the 41 industries further downstream.

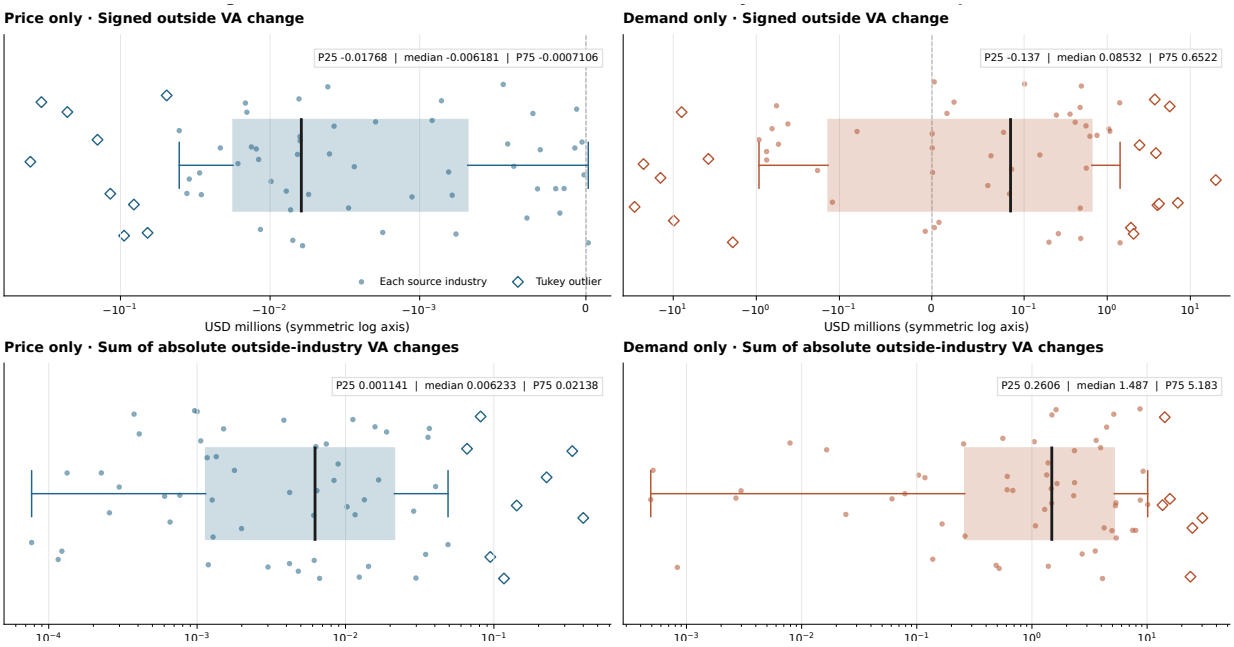
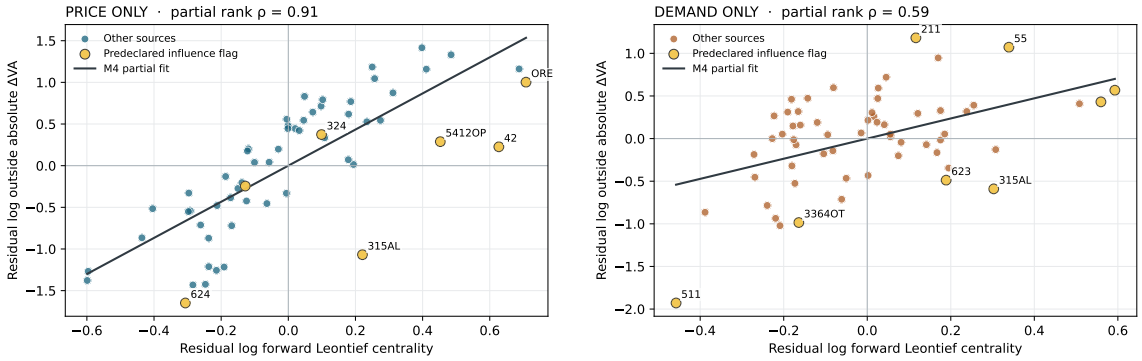



Figure A10: Distribution of outside-industry responses across the 60 source industries

*Notes:* Each point is one source industry whose hedge is set to zero while the other 59 industries reoptimize. Top panels show the signed change in expected real value added outside the source (symmetric log scale); bottom panels show the sum of absolute changes (log scale). Values are in millions of dollars.

*(i) Partial relationship after controls*




*(ii) Response per dollar of removed notional*

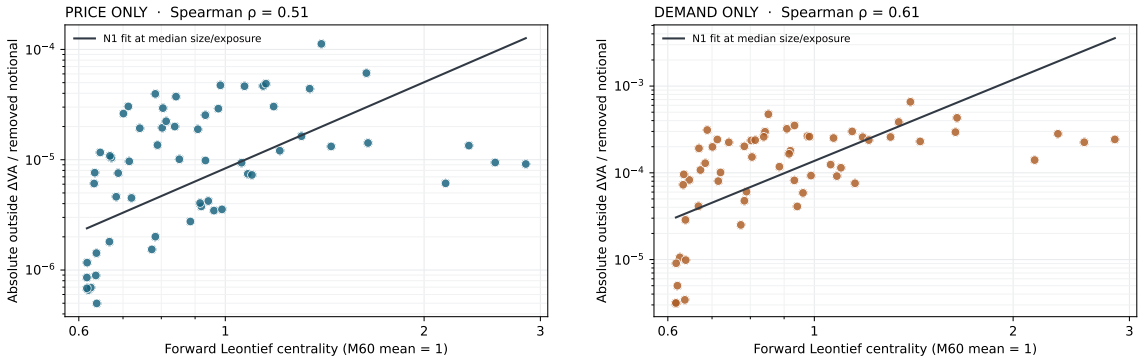



Figure A11: Network centrality and the outside response: controls and normalization

*Notes:* Row (i) plots the residual of the log outside response against the residual of log forward Leontief centrality, both after regressing on the log removed notional, log 2022 BEA gross output, and direct exposure (imports or exports relative to gross output); the line is the fitted slope, and labeled points are sources flagged as influential. Row (ii) plots the absolute outside response divided by the removed notional against centrality, both on log scales; the line is the fitted relationship at the median gross output and exposure. Left panels show the import-price economy and right panels the foreign-demand economy.

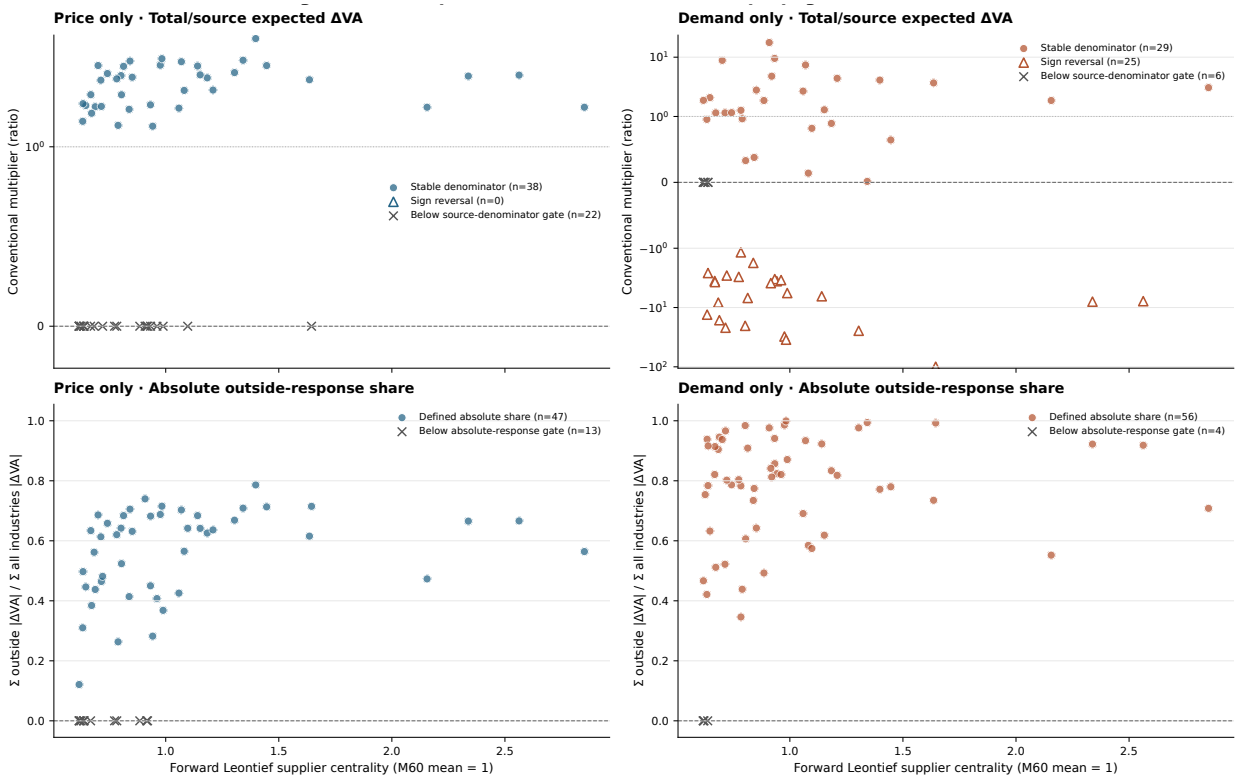



Figure A12: Conventional multipliers and the outside share of the absolute response

*Notes:* Top panels show the ratio of the total change in expected real value added to the source industry's own change; crosses mark sources whose own change is too small for the ratio to be meaningful, and triangles mark sources for which the total and own changes have opposite signs. Bottom panels show the share of the sum of absolute value-added changes that occurs outside the source. The horizontal axis is the source's forward Leontief centrality as a supplier, normalized to a mean of one.

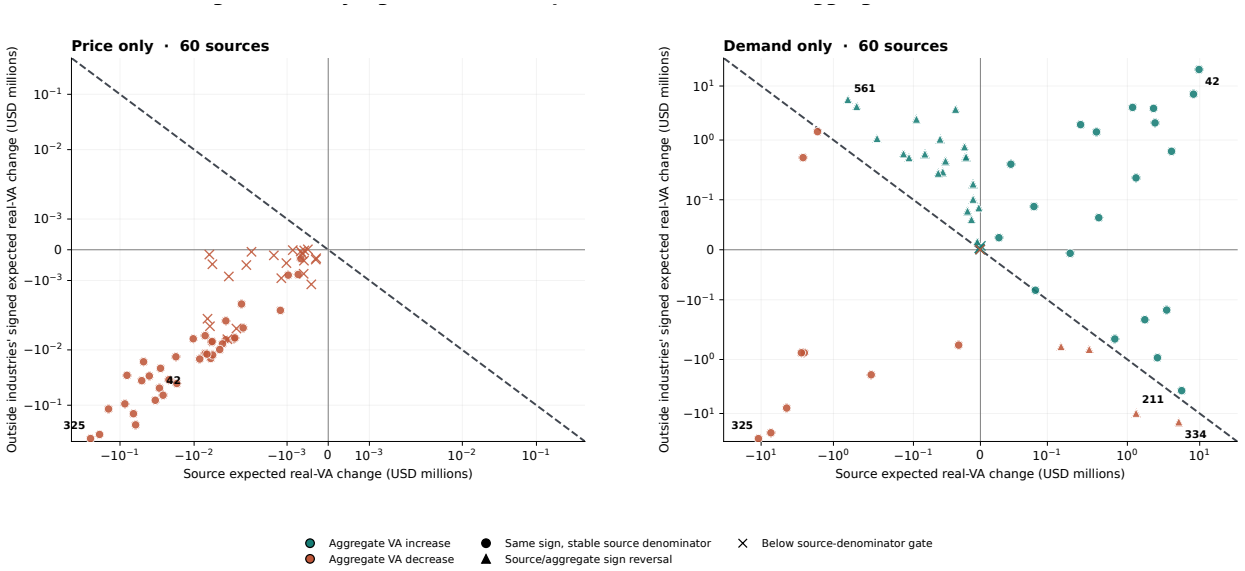
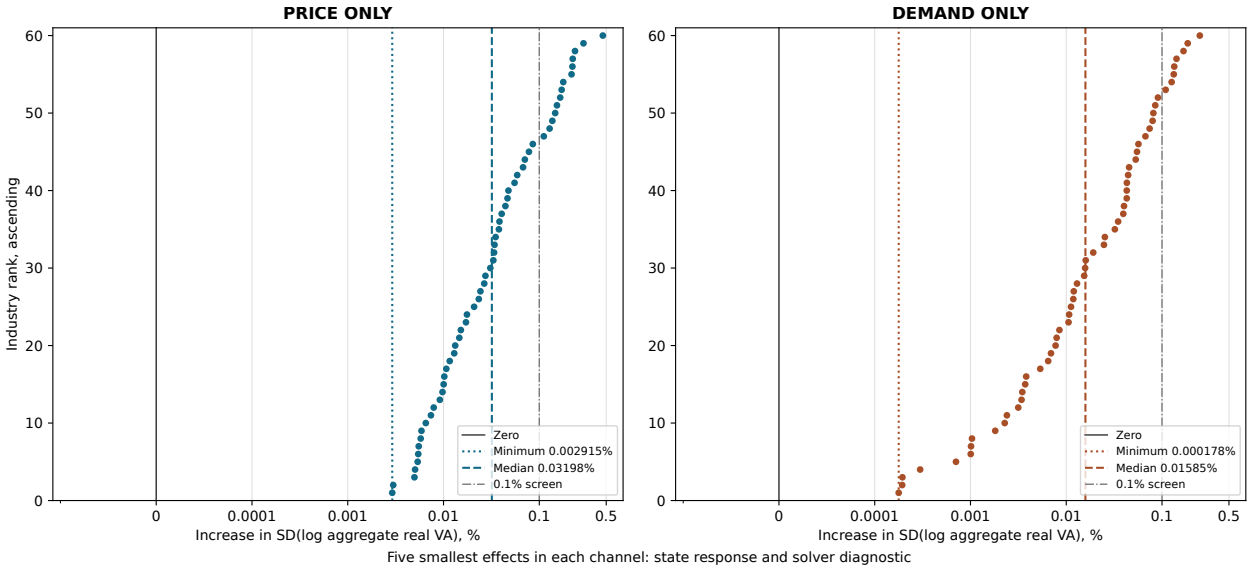



Figure A13: Source and outside-industry changes in expected value added

*Notes:* Each point is one source intervention. The horizontal axis is the change in the source industry's expected real value added and the vertical axis the change in the other 59 industries' expected real value added, in millions of dollars on symmetric log scales. Points above the dashed line raise expected aggregate value added. Triangles mark sources for which the source and aggregate changes have opposite signs; crosses mark sources whose own change is too small for a meaningful sign comparison.




Five smallest effects in each channel: state response and solver diagnostic

| Channel | BEA | ΔSD(log VA) | ΔSD / baseline | Max \|state ΔVA\| | Goods residual | Free-q FOC |
|---|---|---|---|---|---|---|
| Price | 485 | 2.34e-08 | 0.002915% | 0.67 | 1.2e-15 | 1.5e-11 |
| Price | 315AL | 2.4e-08 | 0.002985% | 0.686 | 1.1e-15 | 1e-11 |
| Price | 483 | 3.99e-08 | 0.004969% | 1.14 | 1e-15 | 5.9e-12 |
| Price | 113FF | 4.05e-08 | 0.005049% | 1.16 | 1.3e-15 | 4.6e-14 |
| Price | 711AS | 4.31e-08 | 0.005372% | 1.24 | 1.5e-15 | 2.2e-14 |
| Demand | 624 | 4.04e-08 | 0.000178% | 1.16 | 1.2e-15 | 9.7e-11 |
| Demand | 445 | 4.39e-08 | 0.0001935% | 1.26 | 1.2e-15 | 9.7e-11 |
| Demand | 623 | 4.41e-08 | 0.0001946% | 1.27 | 1e-15 | 6.9e-11 |
| Demand | 452 | 6.76e-08 | 0.0002981% | 1.94 | 1.7e-15 | 2.9e-11 |
| Demand | 713 | 1.6e-07 | 0.0007055% | 4.56 | 1.2e-15 | 6.9e-12 |

VA and max state ΔVA in USD millions. Goods residual is dimensionless; it is not an error bound for ΔSD. Five equal FX probabilities; M60 direct real VA at fixed reference prices.

Figure A14: Increase in aggregate value-added volatility from removing one industry's hedge

*Notes:* Each point is one source intervention, ranked by the increase in the standard deviation of log aggregate real value added across the five exchange-rate states, in percent of the baseline standard deviation (log scale). Vertical lines mark the minimum, the median, and a descriptive 0.1 percent screen. Left panel: import-price economy; right panel: foreign-demand economy.

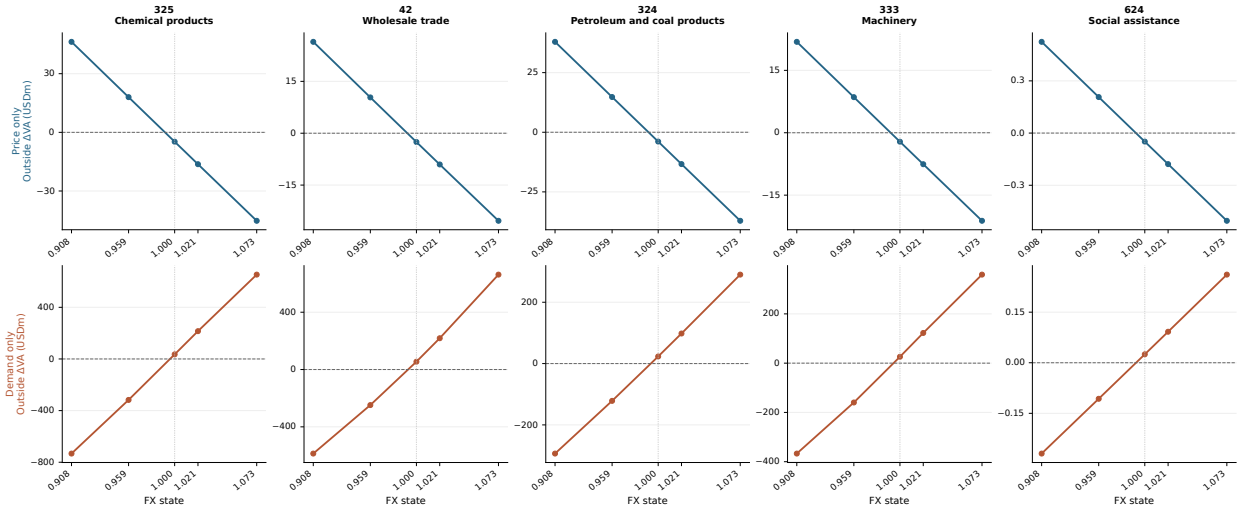



Figure A15: Outside-industry responses by exchange-rate state for selected sources

*Notes:* Change in real value added outside the source industry, in millions of dollars, in each exchange-rate state after the source's hedge is set to zero. Top panels show the import-price economy and bottom panels the foreign-demand economy; vertical scales differ across panels.

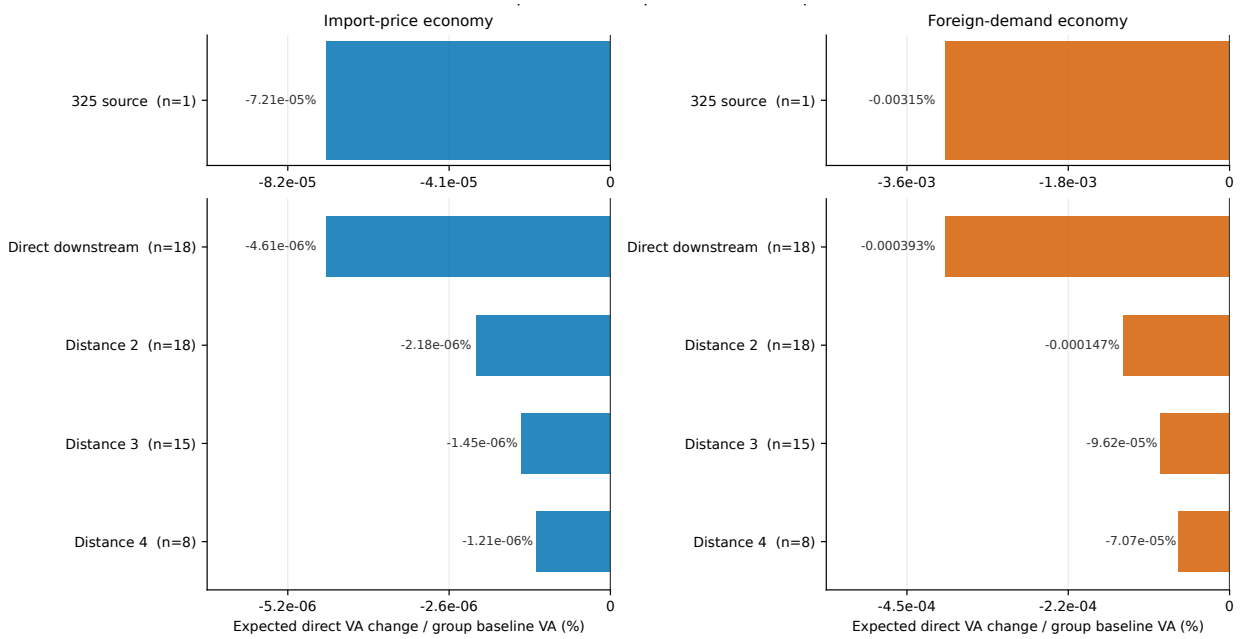



Figure A16: Value-added response to removing the chemicals hedge, by network distance

*Notes:* The chemicals (BEA 325) hedge is set to zero and the other 59 industries reoptimize. Each bar is the change in expected real value added of chemicals or of the industries at the indicated directed downstream distance, divided by that group's baseline value added. Group sizes are in parentheses. The source and non-source panels have separate scales.

### J.7 Sectoral Allocation of Foreign Exchange Hedging

This appendix evaluates the model's untargeted implications for the sectoral allocation of foreign exchange hedging. The calibration targets only aggregate reported FX derivative notional relative to gross output, leaving the distribution of hedging across industries unrestricted. I aggregate the 60 BEA industries into 16 broad industry groups and compare model-implied hedging intensity with its empirical counterpart using FY2022 BEA gross output as a common denominator.

Figure A17 presents the comparison. The model captures the broad cross-industry ranking of hedging intensity, with a Spearman rank correlation of 0.831 between model-implied and reported intensities. In particular, manufacturing and information industries exhibit relatively high hedging intensity in both the model and the data. However, the model generates a less concentrated distribution of hedging, underpredicting reported positions in manufacturing while assigning relatively greater hedging intensity to several nonmanufacturing industries. These discrepancies highlight an important limitation of the homogeneous hedging-cost specification, which abstracts from sectoral differences in derivative-market access, currency composition, and hedging costs.

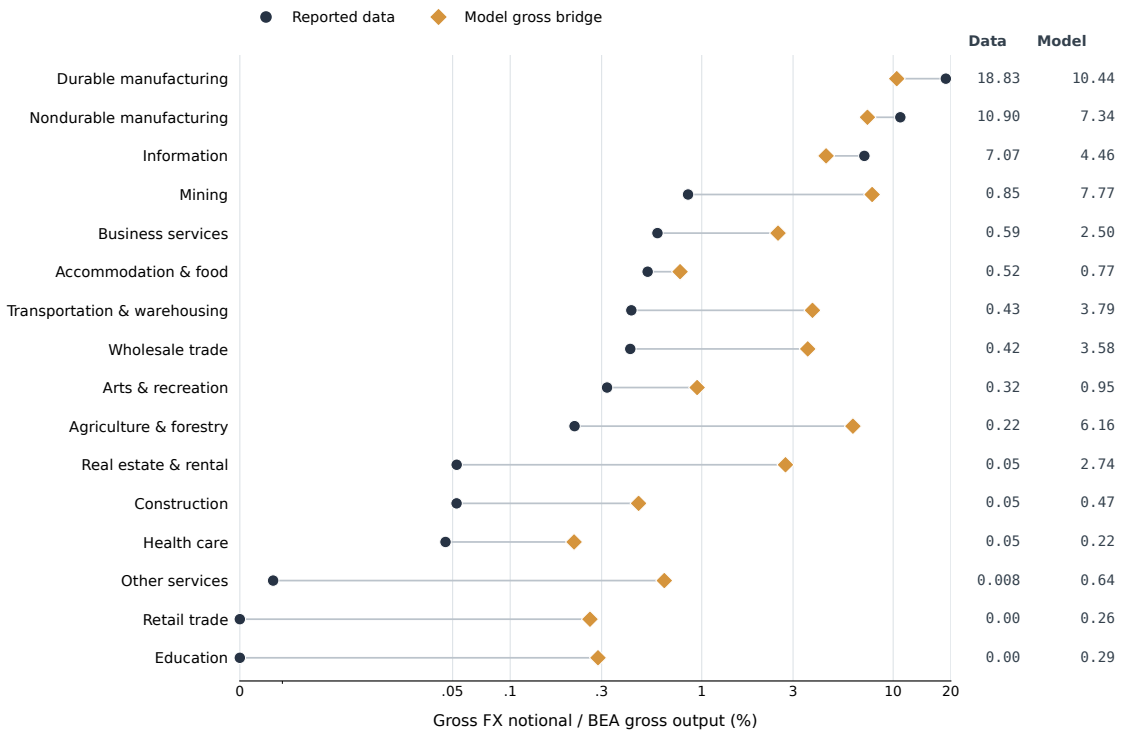



Figure A17: Model-Implied and Reported Foreign Exchange Hedging Across Industries

*Notes:* This figure compares reported and model-implied foreign exchange hedging intensity across 16 broad industry groups in FY2022. Reported intensity is the sum of firm-level gross FX derivative notionals divided by the corresponding group's BEA gross output. Model intensity is the sum of absolute optimal FX hedge notionals from the separately solved import-price and foreign-demand economies, divided by the same BEA gross output. The model combines the two channel-specific notionals for aggregate measurement purposes only; they are not jointly optimized positions. Group intensities are calculated as ratios of aggregate notionals to aggregate output, not averages of firm-level or industry-level ratios. Only aggregate FX hedging intensity is targeted in calibration. The Spearman rank correlation between model and reported industry intensities is 0.831. The empirical numerator reflects observed public-firm derivative disclosures, which may differ from the operating exposures represented in the model.

## J.8 Own and Other Industries' Hedging

Section 6.4 compares four economies for each industry $i$ and channel. The no-hedge economy and the full-hedging baseline are those of Section 6.3, and the economy in which every industry except $i$ hedges is the single-industry intervention of Section 6.5. The economy in which only industry $i$ hedges sets the other 59 hedges to zero and lets industry $i$ choose its hedge and its preset price; all other industries keep their technologies, pricing decisions, and financing, and prices, production, and credit re-clear. This adds 60 equilibria in each channel. The one-sided measure in the second column of Appendix Table A15 and the Shapley attribution in equation (44) use the same industry volatilities and output weights as Table 7, and the identity $\Phi^{N}_{i,V} + \Phi^{O}_{i,V} = \sigma_{i,V}(0) - \sigma_{i,V}(H)$ holds for every industry, outcome, and channel.

Table A15 reports the decomposition shown in Figure 9, and Figure A18 shows its distribution across industries.

Figure A19 relates the volatility responses of other industries to the source industry's centrality, using the single-industry interventions of Section 6.5. For each source $j$ and recipient $i \neq j$, the response is $\sigma_{i,V}(H_{-j}) - \sigma_{i,V}(H)$, positive when the source's hedge lowers the recipient's volatility. Figure A20 shows the full source-by-recipient matrix for COGS. Most entries are positive, but some recipients' COGS volatility falls when a source's hedge is removed, particularly in the import-price economy, and most individual responses are small.

Table A15: Stabilization from own and other industries' hedging

| | Total stabilization (%) | Other industries' hedging, own hedge off (%) | Other industries' share (%) |
|---|---|---|---|
| *Panel A. Import-price economy* | | | |
| Terminal net worth | 47.54 | 1.75 | 2.98 |
| Sales | 4.43 | 2.68 | 60.09 |
| COGS | 6.02 | 2.29 | 37.64 |
| Output | 3.01 | 1.53 | 50.53 |
| *Panel B. Foreign-demand economy* | | | |
| Terminal net worth | 30.76 | 1.19 | 3.11 |
| Sales | 1.34 | 0.81 | 60.04 |
| COGS | 1.96 | 0.68 | 34.25 |
| Output | 2.80 | 1.44 | 50.98 |

*Notes:* Total stabilization is equation (43) and equals the corresponding entry in Table 7. The second column is $100 \sum_i w_i [\sigma_{i,V}(0) - \sigma_{i,V}(H_{-i})] / \sum_i w_i \sigma_{i,V}(0)$, the reduction in the output-weighted industry volatility when each industry cannot hedge but the other 59 industries can, relative to the no-hedge level. The last column is the share of total stabilization attributed to other industries' hedging by the Shapley decomposition in equation (44); the remainder is attributed to each industry's own hedging. The decomposition applies to output-weighted industry volatilities, not to aggregate value-added volatility.

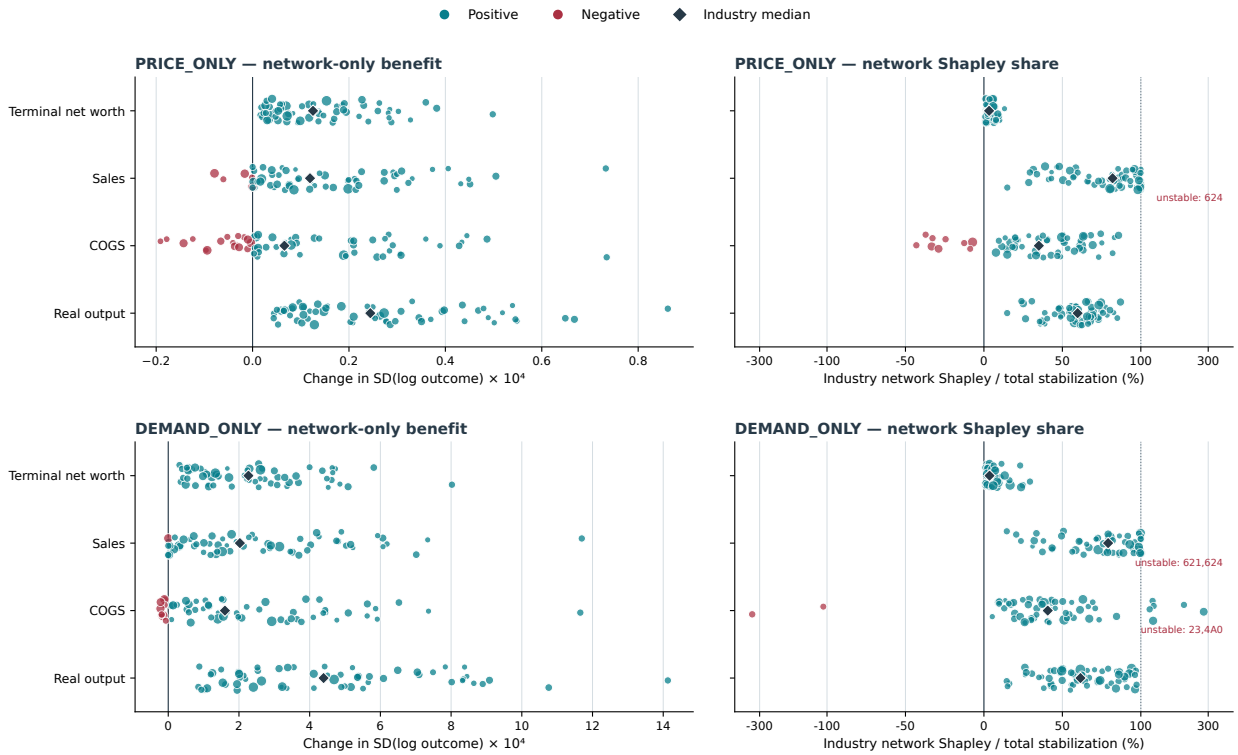



Figure A18: Distribution of other industries' contributions across industries

*Notes:* Left panels show, for each industry, the reduction in the standard deviation of the log outcome across exchange-rate states when the industry cannot hedge but the other 59 industries can, $\sigma_{i,V}(0) - \sigma_{i,V}(H_{-i})$, multiplied by $10^4$. Right panels show each industry's Shapley share $\Phi^N_{i,V}/[\sigma_{i,V}(0) - \sigma_{i,V}(H)]$ in percent; industries whose total stabilization is close to zero are flagged and omitted. Red points are negative, and diamonds mark medians. Top panels show the import-price economy and bottom panels the foreign-demand economy.

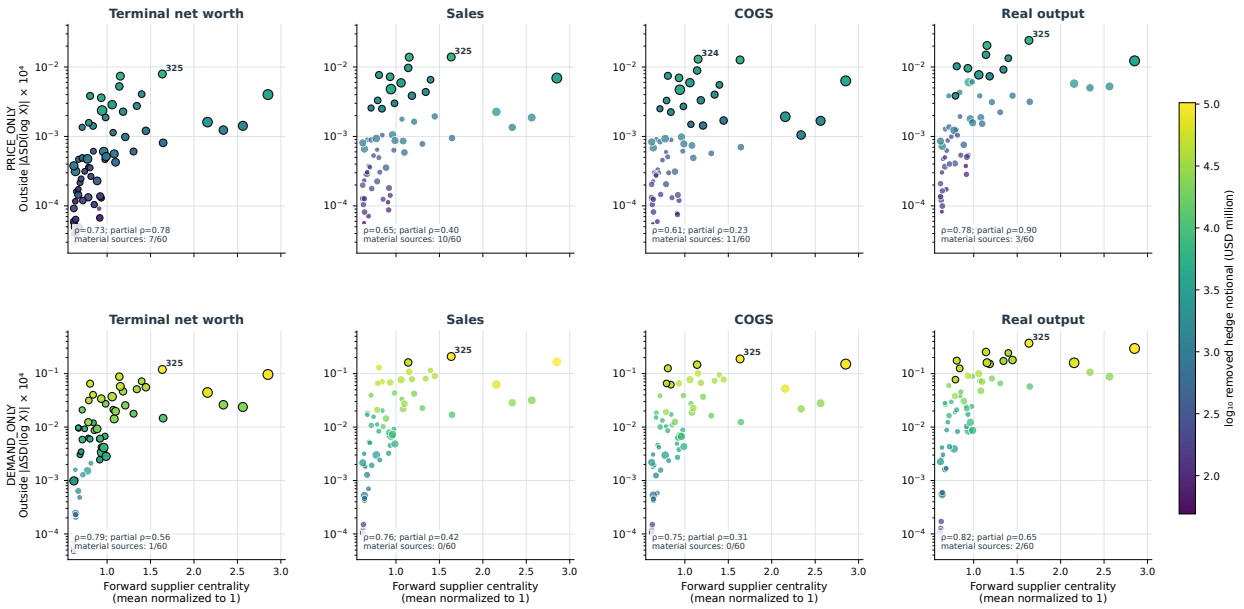



Figure A19: Network centrality and the volatility response outside the source industry

*Notes:* Each point is one source industry whose hedge is set to zero while the other 59 industries reoptimize. The vertical axis is the output-weighted sum of absolute changes in the other industries' standard deviation of the log outcome, multiplied by $10^4$ (log scale). The horizontal axis is the source's forward Leontief centrality as a supplier, normalized to a mean of one. Color is the log of the removed notional and marker area is proportional to the source's gross output. Each panel reports the Spearman correlation and the partial rank correlation controlling for the removed notional, gross output, and direct exchange-rate exposure. Top panels show the import-price economy and bottom panels the foreign-demand economy.

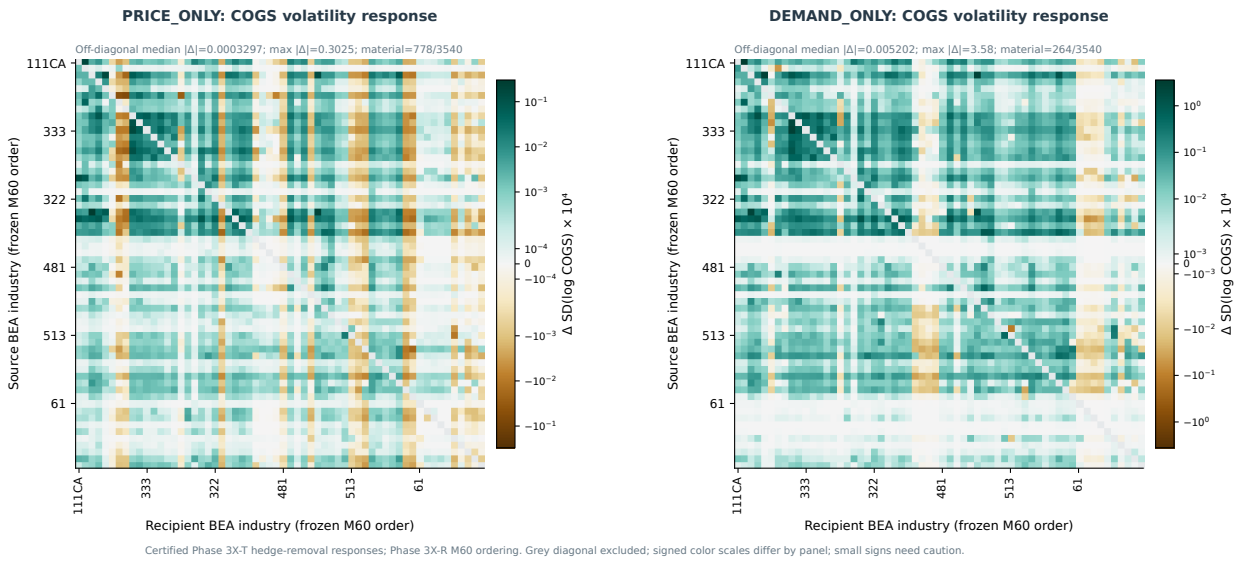



Figure A20: Source-to-recipient responses of COGS volatility

*Notes:* Each cell is the change in the recipient industry's standard deviation of log COGS across exchange-rate states, multiplied by $10^4$, when the source industry's hedge is set to zero and the other industries reoptimize. Positive values mean that the source's hedge lowers the recipient's volatility. Industries are in BEA order, and the diagonal is omitted. The median absolute off-diagonal response is 0.0003 in the import-price economy and 0.005 in the foreign-demand economy, and the largest is 0.30 and 3.58. Color scales differ across panels and are symmetric logarithmic.