Banking Complexity in the Global Economy

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Abstract

International lending flows are often intermediated through banking hubs and complex multi-national routing. We develop a dynamic stochastic general equilibrium model where global banks choose the path of direct or indirect lending through partner institutions in multiple countries. We show how conflating locational loan flows with ultimate lending biases results both by attributing ultimate lending to banking hubs, and by missing ultimate lending that occurs indirectly via third countries. We next study the effects of global banking complexity. Indirect lending allows countries to bypass shocked lending routes via alternative countries; however, it dilutes their ability to diversify sources of funds after shocks. The quantitative analysis reveals that banking complexity can exacerbate credit instability when countries feature heterogeneous banking efficiency.

Keywords: Indirect Lending, Banks, Locational Loan Flows, Financial Integration

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1 Introduction

Recovering from the Global Financial Crisis retrenchment, banks' global cross-border claims now amount to more than $35 trillion (Claessens, 2017). An unknown but potentially substantial share of lending flows are intermediated between source and destination countries, through a ramified network of bank affiliates and subsidiaries (Allen, Gu, and Kowalewski, 2013) and complex financial routes through third countries (Coppola, Maggiori, Neiman, and Schreger, 2021). These indirect flows obscure the ultimate source of lending supply and demand from official statistics on bilateral flows of funds by conflating lending between countries with lending moving through them. Further, little is known about the role of these indirect banking linkages in the global propagation of shocks. Given the growing importance of complex, multinational banking groups and of banking hubs, this can also distort the conclusions about the effects of major policy transformations, such as banking integration and banking unions (e.g., the European banking union).

We develop an N-country dynamic stochastic general equilibrium model where globally active banks choose the path of lending through an endogenously formed network of affiliates or partner institutions in multiple countries. Banking hubs arise endogenously in the financial intermediation network. The model provides a framework to reconcile observable international statistics that aggregate gross cross-border flows—which we refer to as *locational* flows—with notions of financial exposure. It generates a set of bilateral loan flows that conceptually matches the aggregate (observable) Bank of International Settlement (BIS) locational banking statistics (LBS), as distinct from the ultimate demand for and supply of liquidity from borrowers and savers—*ultimate* lending.[1] The model shows how conflating BIS LBS flows with ultimate loan demand and supply biases empirical results, and can even result in sign reversals. Moreover, it reveals that accounting for indirect lending is crucial for understanding the influence of global banking on the propagation of aggregate shocks.

In our economy, in each country banks produce loans using deposits and loan officer labor (e.g., as in Goodfriend and McCallum (2007)), and offer loan contracts internationally to firms. Extending loans internationally incurs costs in the form

[1] Banking statistics that consolidate international banking groups also do not capture our notion of ultimate lending (Brei and von Peter, 2018). By comparing gross LBS flows (inflows plus outflows) to World Bank data on the size of domestic bank loan production, we isolate a set of countries that are most likely acting as global bank intermediation hubs.

of regulatory, information, communication, and management frictions. Banks use their heterogeneous global networks to minimize these costs. They can either lend funds directly to firms in destination countries, or they can choose to lend indirectly through one or more third countries. Indirect lending can lower costs when, for example, subsidiaries or partners in third countries can more cheaply acquire information on and send liquidity to borrowers in destination countries. For instance, a US multinational bank may transfer funds to a subsidiary in the Netherlands whose loan officers can more effectively lend to firms in Belgium. Overall, global banks choose the cheapest option for their liquidity to reach final loan demand.

Following Allen and Arkolakis (2022), we model the choice of lending paths through intermediate countries by assuming that path costs are a product of all bilateral intermediation frictions—*edge costs*—incurred along the path as well as path-idiosyncratic costs. This allows us to aggregate the path choices of individual banks and to derive analytic expressions for the share of all bank lending from each origin country, to each destination country, using each intermediate country. The general equilibrium solution generates a gravity equation where the bilateral gravity friction is a non-geographic, endogenous outcome that corresponds to bilateral network proximity. It also yields a closed-form expression relating the ultimate origin-destination (supply-demand) lending, the cost structure of the network, and the locational flows of funds, equivalent of the BIS LBS.

We calibrate the model's parameters to the data using three blocs or regions: North America, Asia, and Europe. The calibration yields estimates of cross-region bilateral lending frictions, relative banking productivities, and the elasticity of bilateral lending with respect to lending frictions.[2] This elasticity governs the degree of *banking complexity* in our global economy: lower values of the elasticity imply a thicker tail of idiosyncratic draws, corresponding to a world where ramified banking networks are more active and, hence, indirect lending is more pervasive.

Our setting allows us to simulate not only the response of the global economy to permanent or transitory changes in countries' fundamentals, such as TFP or banking efficiency, but also the response to changes in the edge costs between nodes, e.g. reflecting permanent changes in financial regulations or temporary financial sanc-

[2]This elasticity can be thought of as corresponding to a trade elasticity in the context of global lending flows. Dordal i Carreras, Hoelzlein, and Orben (2023) estimate an elasticity of substitution for domestic interbank lending.

tions limiting cross-border lending. Such changes in edge costs are understudied but common: using the Barth, Caprio Jr, and Levine (2013) world regulation and supervision database, we document no fewer than 30 regulatory changes that potentially impacted cross-border lending between 1996 and 2012.[3] In the case of such node and edge shocks, we study how locational loan flows and ultimate origin-destination lending are affected and we contrast these effects with those obtained in a network-free setting (i.e., where all loans flow directly to the destination country).[4]

Using analytic results and simulations, we show how empirical specifications conflating the BIS LBS data with ultimate origin-destination lending bias results in two directions: first, by missing indirect loan flows between the countries, and second by counting funds not originated or destined for the countries as lending. First, we examine the effects of an exogenous change in the TFP of one country. Following a reduction in TFP, unaffected countries move lending away from the affected country and to other unaffected countries ("lending flight"), just as would be predicted in a model without indirect flows. However, locational loan flows tell a different story. Bilateral flows between unaffected countries *decrease*, picking up the reduction in loans to and from the affected country that flow (indirectly) through unaffected countries. Moreover, the drop in locational loan flows to the affected country significantly underestimates the reduction in ultimate loan flows. We then explore the impact of an exogenous change in a single connection (edge) cost in the network. Here, the qualitative predictions of our model for the effects on ultimate loan flows differ from a model without indirect lending. Further, locational flows can incorrectly confirm the no-network predictions. These results underscore the need to disentangle locational flows from ultimate lending and may help explain third-country effects as empirically documented in Hale, Kapan, and Minoiu (2020) and Kalemli-Ozcan, Papaioannou, and Perri (2013), for example.

Next, we operationalize our edge shocks to examine the influence of banking complexity on the international propagation of shocks. We consider complexity in the form of regulatory, policy, or technology transformations that foster denser in-

[3]This number refers to instances in which regulations on the activities of multinational banks were altered without a corresponding change in the regulations of domestic banks. In a significant number of additional instances, regulatory changes affected both domestic and multinational banks. See Appendix B.6 for details.

[4]In the last part of the paper, we also illustrate the consequences for salient macroeconomic variables, such as investment and output.

ternational networks supporting more indirect international lending.[5] The effects of banking complexity are multifaceted in our context: a complex banking network with more indirect lending paths can make countries more resilient to shocks to lending costs by offering alternative paths through third countries. However, third countries' usage of indirect lending exposes their lending routes to shocks as well, inhibiting their ability to act as substitute sources of liquidity to shock-affected countries. Put differently, global banking complexity can increase the scope for diversification of lending *pathways*, but can reduce the scope for diversification of lending *sources*: as more banks rely on subsidiaries and partners in more countries for cross-border lending, an increase in intermediation costs in one location is more likely to impact the ability of third country banks to move liquidity internationally.

To quantitatively evaluate the relative strengths of the above mechanisms, we repeat the edge shock experiments in a series of increasingly complex environments. As the banking network becomes more complex (more indirect linkages), the benefit of improved path diversification dominates the reduced ability of the network to offer lending source diversification. On balance, in our baseline calibration, banking complexity moderates the drop in bilateral lending flows caused by an edge shock, thereby stabilizing overall global lending as well. Importantly, here too the mere observation of location loan flows would bias conclusions: increasing banking complexity leads to a larger response of locational lending, belying its stabilizing influence.

However, we also find that the relative strengths of source and path diversification—hence the overall effect of banking complexity—can differ when countries feature highly heterogeneous banking efficiency or when their banking productivity responds endogenously to network connectivity. Intuitively, when the banking sectors of third countries are highly efficient, the dilution of source diversification induced by a more complex banking network is particularly harmful. In such scenarios, banking complexity, i.e. stronger indirect links, can have a destabilizing effect, amplifying rather than mitigating shocks.

Related literature Our first contribution is to the literature on the geography of banking and the determinants and aggregate implications of international lending flows. The BIS LBS is the most extensive source of international banking statistics.

[5] In our model, banking complexity corresponds to changes in the parameter governing the dispersion and relative importance of path productivity in loan intermediation.

This has prompted many studies on the macroeconomics of banking to use locational lending data. However, the proliferation of indirect lending, due to the expansion of large multinational banking conglomerates and global syndicated lending markets as well as the growing exploitation of offshore banking centers (Coppola, Maggiori, Neiman, and Schreger, 2021), has resulted in an increasing misalignment between these statistics and ultimate bilateral lending. This may lead to biased conclusions about the effects of global banking on the international transmission of shocks (see, e.g., Kalemli-Ozcan, Papaioannou, and Perri (2013) for more on this point). Our DSGE model of indirect lending provides a conceptual framework for the relationship between ultimate and locational flows. We analytically describe the nature of these biases and study quantitatively their direction and magnitude.[6]

Our second contribution is to the literature on the macroeconomic effects of global banking and banking integration. Kalemli-Ozcan, Papaioannou, and Perri (2013), Niepmann (2015), Cao, Minetti, Olivero, and Romanini (2021), and Morelli, Ottonello, and Perez (2022) stress that larger multinational banking groups can increase the exposure of countries to shocks hitting a common multinational lender. However, financial integration can also allow for better diversification of funding sources in the aftermath of shocks hitting individual countries. We highlight the consequences of financial complexity: the greater availability of alternative indirect lending paths and the possible dilution of the ability of countries to serve as alternative sources of funding. Our analysis is in spirit related to Fillat, Garetto, Götz, and Smith (2018), who investigate how the branches and subsidiaries composition of multinational banks affects the international transmission of shocks.[7] Our emphasis is not on the structure of branches and subsidiaries, however, but on the distinction between direct and indirect bank lending. In this respect, we provide a novel characterization of global banking complexity, encompassing both the organizational and geographical complexity (Cetorelli and Goldberg, 2014): the elasticity of bilateral lending with respect to international lending frictions relates country-level determinants of diversification and productivity, including tax arbitrage and regulation, to bank-level path optimiza-

[6] A related group of studies examine gravity in banking. Using BIS LBS data, Buch (2005) and Papaioannou (2009) find that distance is a relevant predictor of cross-border bank lending. See also Portes and Rey (2005) and Aviat and Coeurdacier (2007). However, Delatte, Capelle-blancard, and Bouvatier (2017) show that an empirical gravity equation for banking does a poor job of rationalizing the data.

[7] For empirical studies, see, e.g., Cetorelli and Goldberg (2012) and De Haas and Van Horen (2012).

tion and efficiency (Buch and Goldberg, 2022).

Finally, the paper broadly relates to the theoretical and empirical literature on financial and production networks. Studies explore the international transmission of the Lehman Brothers collapse via syndicated loans (De Haas and Van Horen, 2012), monetary policy transmission via production networks, business cycle synchronization via trade linkages (Juvenal and Monteiro, 2017), or the role of trade credit in amplifying financial shocks (Altinoglu, 2021). We embed an endogenously formed banking network in a DSGE multi-country model with banks and study the aggregate consequences of banking complexity through this framework. In this dimension, the analysis also speaks to a set of papers that explore financial contagion (Acemoglu, Ozdaglar, and Tahbaz-Salehi, 2015, Allen and Gale, 2000, Elliott, Golub, and Jackson, 2014). We define and focus on a different aspect of integration related to internal networks of global banking conglomerates exploiting indirect lending. Our framework allows us to study edge shocks, scenarios related to disruptions to international financial linkages, besides country (node) shocks. To our knowledge this approach and its application to a general equilibrium dynamic setting are novel to the literature.[8] This leads us to disentangle distinct mechanisms, path and source diversification, and the dispersion of indirect lending as driving forces of aggregate propagation.

The remainder of the paper is organized as follows. In Section 2 we set up the model and solve for agents' decisions. Section 3 studies the equilibrium. In Section 4, we present the model calibration and perform counterfactual exercises and simulations, assessing the biases resulting from conflating locational and ultimate loan flows. Section 5 examines the effects of global banking complexity. In Section 6 we consider extensions and further analysis. Section 7 concludes. Technical derivations, proofs and additional results are relegated to the Online Appendices.

2 Model Setup

In this section, we present a discrete-time dynamic general equilibrium model with $\mathcal{N} > 2$ countries and endogenous international banking linkages. We specify agents'

[8] Oberfield (2018) provides a partial equilibrium model where producers probabilistically match with upstream and downstream firms, giving rise to an endogenous input-output structure. Acemoglu and Azar (2020) allow for an endogenous choice of intermediate goods in an input-output framework; however they do not explicitly take into account network paths.

problems and study their decisions.

In each country $i \in \mathcal{N}$ there are four sectors: the household sector, the firm (goods production) sector, the capital production sector, and the banking sector (comprising banking consulting firms and banks). All agents are owned by households, who consume a single final good produced by competitive firms, and supply labor to the goods production and banking sectors. Labor and capital are immobile across countries. Firms hire labor from households, purchase physical capital from capital producers, and demand a diversified aggregate loan to finance their capital investment. Banking consulting firms acquire individual loan varieties $\omega \in \Omega$ in competitive international markets and produce the aggregate loan demanded by firms via CES bundling.[9] Banks produce loans using households' deposits and labor (e.g., as loan officers) and offer debt contracts to banking consulting firms internationally through cost-minimizing lending paths.

2.1 Households

Households in country i earn a wage rate $w_{i,t}^{H}$ on labor supplied to the goods production sector ($H_{i,t}$). They also earn a wage rate $w_{i,t}$ on labor supplied to the banking sector as loan production activity ($M_{i,t}$). Further, they earn a gross rate of return $(1+R_{i,t}^{D})$ on deposit holdings $D_{i,t}$. They use their funds for consumption $C_{i,t}$ and saving through deposit holdings, solving:

$$\begin{aligned} \max_{\{C_{i,t},D_{i,t},H_{i,t},M_{i,t}\}_{t\geq 0}} \quad & \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_{i,t} - k_H \frac{H_{i,t}^{1+\epsilon}}{1+\epsilon} - k_M \frac{M_{i,t}^{1+\varphi}}{1+\varphi} \right) \\ s.t. \quad & C_{i,t} + D_{i,t} = (1+R_{i,t-1}^{D}) D_{i,t-1} + w_{i,t}^{H} H_{i,t} + w_{i,t} M_{i,t} + \Pi_{i,t}, \end{aligned} \tag{1}$$

where ϵ is the inverse Frisch elasticity for labor supplied to the production of goods and φ is the inverse Frisch elasticity for labor supplied to banking activities. The parameters k_H and k_M govern the disutility from labor in the two sectors. The transfers $\Pi_{i,t}$ received by households comprise profits distributed by firms ($\Pi_{i,t}^{F}$), banks ($\Pi_{i,t}^{B}$) and capital producers ($\Pi_{i,t}^{K}$).

Households maximize their lifetime utility by choosing consumption $C_{i,t}$, de-

[9] The framework can capture the range of financial products that firms need from banks, e.g. credit lines and term financing, among others, or reflect sectoral specialization of banking institutions.

posits $D_{i,t}$, labor supply $H_{i,t}$ to firms, and labor supply $M_{i,t}$ to banks.[10]

2.2 Capital Producers and Firms

Capital producers Capital producers invest in $I_{i,t}$ units of capital goods at the cost of $I_{i,t}\left[1+f(I_{i,t}/I_{i,t-1})\right]$ units of consumption goods, where the continuous, convex function $f(\cdot)$, with $f(1)=0$, $f'(1)=0$, captures the adjustment cost in the capital-producing technology. They choose the amount of new capital $I_{i,t}$ to maximize the present discounted value of lifetime profits:

$$\max_{I_{i,t}} \qquad \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{i,0,t} \left\{ P^K_{i,t} I_{i,t} - \left[1 + f\left(\frac{I_{i,t}}{I_{i,t-1}}\right)\right] I_{i,t} \right\}, \tag{2}$$

where $P^K_{i,t}$ denotes the price of capital. $\Lambda_{i,t,t+j} = \beta^t \frac{u'_{C_{i,t+j}}}{u'_{C_{i,t}}}$ is the stochastic discount factor, since households own capital producers and are the recipients of any profits $\Pi^K_{i,t}$. The first order condition

$$P^K_{i,t} = \left\{1 + f\left(\frac{I_{i,t}}{I_{i,t-1}}\right) + \frac{I_{i,t}}{I_{i,t-1}} f'\left(\frac{I_{i,t}}{I_{i,t-1}}\right)\right\} - \mathbb{E}_t \Lambda_{i,t,t+1} \left(\frac{I_{i,t+1}}{I_{i,t}}\right)^2 f'\left(\frac{I_{i,t+1}}{I_{i,t}}\right) \tag{3}$$

implies that the marginal cost of capital production is equal to the price of capital.

Firms The representative firm in country i uses labor $H_{i,t}$ and capital $K_{i,t-1}$ to produce final good $Y_{i,t}$ via an increasing, concave, and constant returns to scale technology. Firms must obtain loans to finance purchases of capital. They do so by demanding bundled loans $X_{i,t}$ from banking consulting firms.[11]

Firms maximize the discounted sum of dividends distributed to households, subject to the budget constraint (4), the technological constraint (5), the law of accumu-

[10] Households' and firms' optimizing conditions are reported in the Appendix.

[11] This is similar to Craig and Ma (2020), where firms delegate their borrowing from lending banks to larger, diversified intermediary banks.

lation of the capital stock (6), and the financing constraint (7):

$$\max_{\{H_{i,t},K_{i,t},X_{i,t},I_{i,t}\}} \mathbb{E}_0 \sum_{j=0}^{\infty} \Lambda_{i,t,t+j+1} \Pi^F_{i,t}$$

$$\text{s.t.} \quad \Pi^F_{i,t} + P^K_{i,t} I_{i,t} + (1 + R^X_{i,t-1}) X_{i,t-1} = Y_{i,t} + X_{i,t} - w^H_{i,t} H_{i,t}, \tag{4}$$

$$Y_{i,t}(K_{i,t-1}, H_{i,t}) = A_{i,t} K^{\alpha}_{i,t-1} H^{1-\alpha}_{i,t}, \tag{5}$$

$$K_{i,t} = (1-\delta) K_{i,t-1} + I_{i,t}, \tag{6}$$

$$X_{i,t} = P^K_{i,t} I_{i,t}. \tag{7}$$

$R^X_{i,t}$ denotes the net interest rate on loan bundles, δ is the capital depreciation rate and $A_{i,t}$ captures the aggregate total factor productivity (TFP).

2.3 The Banking Sector

The banking sector comprises banking consulting firms and banks. Banks collect deposits from households domestically and lend to domestic and foreign consulting banks, which aggregate loans and extend them to firms. There are two facets of the bank lending technology. First, banks produce loans using deposits and labor. Second, loans can reach ultimate demand in a destination country directly (through subsidiaries in that country) or indirectly through lending paths, p, involving (subsidiaries in) third countries.

Consulting firms In each country, competitive consulting banks combine loans of type ω from the lowest-cost international suppliers to produce an aggregate non-traded loan $X_{j,t}$ using a Dixit-Stiglitz technology

$$X_{j,t} = \left(\sum_i \int_{\omega \in \Omega} x_{ij,t}(\omega)^{\frac{\sigma-1}{\sigma}} \, d\omega \right)^{\frac{\sigma}{\sigma-1}}, \tag{8}$$

where $\sigma > 1$ is the constant elasticity of substitution across loan varieties.

Banks For each loan variety ω, there is a set of risk-neutral, competitive banks in each country i.[12] We refer to banks by their loan variety index ω. To maintain

[12] ω banks could be differentiated in terms of maturity, industry, or other contract characteristics. As in Eaton and Kortum (2002), ω banks within countries are homogeneous, including their idiosyncratic path choices. This can be relaxed by considering a large-N number of banks of each ω type with

tractability, we posit that banks return dividends to households at the end of each period. This framework (combined with the i.i.d. assumption introduced below) is effectively isomorphic to a setting where banks exit in every period, as in Boissay, Collard, and Smets (2016).[13] We accordingly drop the time subscript from banks' problem.

Loan production Building on Goodfriend and McCallum (2007), banks produce loans by combining labor $M_i(\omega)$ and deposits $D_i(\omega)$ via a Leontief technology.[14] Labor tasks in banks can comprise deposit collection, information production, and headquarter services. Banks maximize dividends taking as given the banking sector wage w_i and the net interest rate on deposits R_i^D. A loan $x_{ij}(\omega)$ destined for a firm in country j entails a route-dependent intermediation cost $\tau_{ij}(\omega, p) \geq 1$, modeled as an interest rate markup.[15]

Since the choice of inputs does not affect the lending path optimality, and viceversa, we present the two subproblems (loan production and loan path selection) sequentially. Here, we describe banks' input choice problem in loan production given a lending path p. Substituting the usual asset and liabilities balance, a bank's problem reduces to maximizing its net cash flow subject to the loan production function:

$$\max_{M_i(\omega), D_i(\omega)} \sum_j \frac{r_{ij}(\omega)}{\tau_{ij}(\omega, p)} x_{ij}(\omega) - w_i M_i(\omega) - R_i^D D_i(\omega) \tag{9}$$

$$s.t. \quad \sum_j x_{ij}(\omega) = \min\{z_i M_i(\omega), D_i(\omega)\} \tag{10}$$

where $r_{ij}(\omega)$ is the net interest rate in j, and z_i is a country-specific labor productivity in the banking sector.[16] Competition implies that banks from i charge a net interest

heterogeneous networks available to them, i.e. heterogeneous path choices. The banking sector could be alternatively modeled via monopolistic competition, as in Gerali, Neri, Sessa, and Signoretti (2010). We provide a Melitz (2003) version of the banking partial equilibrium in Appendix D.

[13] In our model, their setting would imply that banks are born and collect deposits in $t-1$, hire workers in period t, and die at the end of period t, so that deposit rates, wages, and profits are payed to households in period t. Differently from Boissay, Collard, and Smets (2016) (BCS), the Eaton and Kortum (2002) structure implies that shocks are realized before banks choose inputs. This implies that individual banks do not face input mismatches, neither for liquidity (as in BCS) nor for labor. The model could also be augmented with an explicit interbank market, as shown in a supplement.

[14] Our model can be related to the two-tier Gerali, Neri, Sessa, and Signoretti (2010) banking structure, since the Leontief production function makes the two inputs (deposits and loan officers) complements and both necessary for the production of loans. A Cobb-Douglas loan production technology as in Goodfriend and McCallum (2007) would imply $c_i = a\,(w_i/z_i)^\zeta \left(R_i^D\right)^{1-\zeta}$ with a being a constant.

[15] This explicitly incorporates the cost into banks' optimization problem, without resorting to the notion of iceberg losses as in standard gravity models.

[16] In our main exposition we treat z_i as exogenous. In Section 6.1 we relax the exogeneity assumption

rate in j equal to their marginal cost:

$$r_{ij}(\omega, p) = c_i \tau_{ij}(\omega, p) \tag{11}$$

where the unit loan production cost, c_i, net of the bilateral intermediation cost, satisfies:[17]

$$c_i = \frac{w_i}{z_i} + R_i^D. \tag{12}$$

The ex-ante bilateral intermediation friction $\tau_{ij}(\omega, p)$ is both bank ω and path p specific. In what follows, we study banks' lending path decisions.

Loan path selection The decision facing banks of how to move funds internationally closely follows Allen and Arkolakis (2022). A path, or route, is a graph $p \in P$ which consists of an ordered sequence of nodes (countries) $\mathcal{N}(p)$ of length K_p and a set of edges $E(p)$ that connect nodes, following a sequence beginning from an "origin" node i and ending with a "destination" node j, i.e. $\mathcal{N}(p) = \{i, k_1, \ldots, j\}$, and $E(p) = \{\{i, k_1\}, \{k_1, k_2\}, \ldots, \{k_{N-1}, j\}\}$.

Banks have the option to move funds along any edge, from any country (node) k to any country (node) l. Moving liquidity along any path p is costly and incurs intermediation frictions. These frictions represent the cost of monitoring foreign subsidiary intermediaries, which entails informational frictions, frictions for using internal capital markets, and loan officer training efforts. For example, a US multinational bank interested in extending a loan to a Polish firm might choose to extend the loan directly through a (recently established) subsidiary in Poland, or instead choose to first transfer liquidity to a (well-established) subsidiary in the Czech Republic, which could then arrange a loan trough the Polish correspondent of the banking conglomerate. Monitoring and managing the relationship with the Czech subsidiary entails costs, and in turn the Czech subsidiary will face costs for monitoring the activity of the correspondent in Poland. Still, this might me cheaper than dealing with the Polish subsidiary directly, if the established Czech subsidiary can easily communicate with the US headquarters and is particularly familiar with the Polish market. In Appendix A, we microfound the "reduced form" intermediation costs of the model along these

by making it network-dependent.

[17] All banks have the same technology, hence $c_i(\omega) = c_i$.

lines, as intermediation and monitoring costs of intermediary agents at each node.[18]

To minimize a loan's intermediation cost $\tau_{ij}(\omega, p)$, a bank chooses the lowest-cost path through which to send the loan. Banks in i can extend a loan to j through the direct path $p_{direct} = \{i, j\}$ or indirectly through one or more intermediary locations k comprising a path of length greater than one. Specifically, a component of the intermediation costs, $e_{kl} > 1$, is shared by all banks wishing to move loans along a given edge. This corresponds to challenges facing all banking groups intermediating through the edge, and may include common regulatory, language or cultural barriers or other common, uniform informational frictions. Other frictions are instead specific to a bank's subsidiaries and a given arrangement. For example, such specific costs may capture the difficulty a given set of loan officers and report structures face in managing and monitoring loans of a specific type or industry.

A bank ω's cost $\tau_{ij}(p, \omega)$ of sending funds from i to j through path p can therefore be decomposed into the path-specific series of edge costs that are shared by all banks and the bank, path-specific cost:

$$\tau_{ij}(p, \omega) \equiv \frac{\tilde{\tau}_{ij}(p)}{\xi_{ij}(p, \omega)}. \tag{13}$$

$\tilde{\tau}_{ij}(p) \equiv \prod_{k=1}^{K_p} e_{k-1,k}$ is the (deterministic, shared) portion of costs related to bilateral liquidity transfers and $\xi_{ij}(p, \omega)$ is the intermediation cost of moving a loan of a given type ω from i to j that is specific to the organizational structure of affiliates associated with p.[19] We further assume $\xi_{ij}(p, \omega)$ is an i.i.d. realization of draws from a Fréchet distribution with shape parameter $\theta > \max\{1, \sigma - 1\}$: $F(\xi_{ij}(p, \omega)) = \exp\left\{-\xi^{-\theta}\right\}$.[20] The shape parameter θ governs the degree of heterogeneity in the productivity of affiliate groups and organizational structures. This can be thought of as a technological parameter, encompassing anything amplifying differences in loan officer group productivity, e.g. information communication technology or the regulatory environment. When θ is small, the bank-specific portion of intermediation costs dominates the path choice.[21]

[18] In the main text, intermediation wages are paid in the originating country. In Appendix A, we explore extensions where intermediation requires that labor wages are paid along the path as well, similar to Antràs and De Gortari (2020).

[19] An alternative would be to model the edge frictions as additive. We prefer the multiplicative form which is consistent with intermediary interest markups.

[20] The i.i.d. assumption allows to maintain tractability and obtain analytical results.

[21] This framework implies that each bank has a full network of intermediaries. An isomorphic alter-

ω-banks at i offering loans to j choose the least cost path to send loans, such that:

$$\tau_{ij}(\omega) \equiv \min_{p \in P} \tau_{ij}(p, \omega). \tag{14}$$

3 Equilibrium

We first derive the partial equilibrium probabilities of loan and route choices, then distinct equilibrium gravity equations for locational and ultimate loan flows, and finally close the model.

3.1 Path Probabilities

After banks identify least-cost paths, consulting firms in j choose the lowest-cost supplier of loan ω from all countries $i \in \mathcal{N}$. Using the standard Eaton and Kortum (2002) method, summing across loan types for each path, we obtain the following:

Lemma 1 (Gravity probability)**.** *The probability that borrowers in country j choose to obtain a loan from country i through a path p is:*

$$\lambda_{ijp\omega} = \frac{\left[c_i \tilde{\tau}_{ij}(p)\right]^{-\theta}}{\sum_l c_l^{-\theta} \sum_{p \in G} \left[\tilde{\tau}_{lj}(p)\right]^{-\theta}}. \tag{15}$$

Proof. See Appendix B.2.

Similar to Eaton and Kortum (2002), across all loan types, this is also the share of loans extended in country j that come from i and take path p, λ_{ijp}. Overall, countries with lower loan production costs and with paths incurring lower bilateral intermediation costs will account for a larger fraction of the loans extended in country j.

native is to model each bank as having an exogenous set of intermediaries (and thus path choices) at a subset of countries. Specifically, for a given set of idiosyncratic draws, the observed paths selected in equilibrium are identical.

3.2 Network Costs

We can define the term $\sum_{p \in G_{ij}} \tilde{\tau}_{ij}(p)^{-\theta}$ in the denominator of (15) as the *bilateral network cost*:

$$\tau_{ij} \equiv \sum_{p \in G_{ij}} \tilde{\tau}_{ij}(p)^{-\theta} \propto E(\tau_{ij}(p)). \tag{16}$$

τ_{ij} is proportional to the average or expected bilateral cost, summing over all the possible paths' costs conditional on selection. It is a single measure that summarizes direct and indirect frictions between country i and country j. Reordering paths by length K, we can consider this sum as capturing K-th order connections between i and j and, as such, it is inversely related to the (measure of the) network proximity between i and j:

Lemma 2 (Network Costs)**.** *Let A be the inverse cost matrix where the ijth element of A is $e_{ij}^{-\theta}$, and let b_{ij} denote an element of the matrix $B \equiv (\mathbf{I} - A)^{-1}$. For a constant γ*

$$\tau_{ij} = \gamma b_{ij}^{-1/\theta}. \tag{17}$$

Proof. See Appendix B.3.

In the remaining of the paper, we sometimes prefer working directly with the matrices A and B rather than with the edge costs e or the network costs τ. With a slight abuse of interpretation, we call these edge and network probabilities, respectively.

3.3 Ultimate and Locational Gravity

We now describe how the above network probabilities (and hence, the network costs) give rise to aggregate variables: ultimate (X_{ij}) and locational (Ξ_{ij}) bilateral loan flows, and the aggregate interest rate that firms face in a given country, R_j^X.

We first derive a closed-form expression for the composite loan interest rate $R_{j,t}^X$:

$$R_j^X = \vartheta \left(\sum_i \left(c_i \tau_{ij} \right)^{-\theta} \right)^{-\frac{1}{\theta}} \tag{18}$$

where $\vartheta = \Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)^{\frac{1}{1-\sigma}}$ is a constant.[22] The derivation is in Appendix B.5.

Ultimate gravity Starting from lemma 1, summing across routes and using the network probabilities, we obtain the share of total loans extended in country j obtained from country i:

$$\lambda_{ij} = \frac{\left(c_i\tau_{ij}\right)^{-\theta}}{\sum_l \left(c_l\tau_{lj}\right)^{-\theta}} = \frac{\left(c_i\tau_{ij}\right)^{-\theta}}{\vartheta^{\theta} R_j^{-\theta}}. \tag{19}$$

Defining the aggregate loans in country j obtained from i as $X_{ij} \equiv \lambda_{ij} X_j$, we recover a network gravity equation:

$$X_{ij} = \vartheta^{-\theta} R_j^{\theta} X_j c_i^{-\theta} \tau_{ij}^{-\theta}. \tag{20}$$

This gravity equation relates bilateral ultimate lending to loan demand in j, $R_j^{\theta} X_j$, loan production efficiency in i, $c_i^{-\theta}$, and a bilateral friction, $\tau_{ij}^{-\theta}$. However, recalling that $\tau_{ij}^{-\theta} = \left(\sum_{p\in G_{ij}} \prod_{k=1}^{K_p} e_{k-1,k}(p)^{-\theta}\right)$, rather than a primitive, this bilateral friction is the average cost of lending across paths of different length through the banking network. It accounts for the effect of the complexity of the entire banking network on ultimate bilateral lending, including the possibility of different path lengths and third country effects.

Locational gravity Bank loans can take a direct path from country i to country j, as well as an indirect path, through a series of countries $k, l, \ldots, K$. In this section, we derive a *locational* gravity equation, i.e. the amount of loans that go through an edge e_{kl}, without necessarily originating at k nor stopping at l. Let $\psi_{kl|ij}$ denote the conditional probability of a bank ω serving country j from county i, and going through countries k and l. We can prove the following:

Lemma 3. *The probability of any loan product ω going through a kl edge, conditional on*

[22] Note that in a one-country setup the aggregate interest rate would be equal - simplifying the weights - to $R_i^X = w_i + R_i^D$, and we would obtain a simple expression similar to the interest rate spreads in Goodfriend and McCallum (2007) or Gerali, Neri, Sessa, and Signoretti (2010).

being originated in i and ultimately extended in j, is

$$\psi_{kl|ij} = \frac{b_{ik} a_{kl} b_{lj}}{b_{ij}} = \left(\gamma \frac{\tau_{ij}}{\tau_{ik} e_{kl} \tau_{lj}}\right)^{\theta}. \tag{21}$$

Proof. See Appendix B.4.

The first expression for the conditional probability $\psi_{kl|ij}$ in (21) can be visualized in Figure 1. The link probability, a_{kl}, is the probability of going from k to l, conditional on the rest of the banking network. The network probabilities b, instead, capture all the possible paths from origin country i to the intermediate step k (upstream), and all the possible paths from the intermediate step l to the destination country j (downstream); where upstream and downstream are relative to the intermediate step kl. The second expression for $\psi_{kl|ij}$ in (21), written in terms of costs, relates the probability of using kl to the cost e_{kl} and the average network cost of sending loans from i to k and from l to j.

$\psi_{kl|ij}$ is a microfounded, probabilistic version of the edge betweeness centrality formula, such that the importance of an edge depends on the amount of shortest lending paths that go through it.[23]

[23]To express node betweeness centrality, we can present a triangular ikj version of the same, which is more intuitive: Ξ_{ikj} is the probability of a loan going from country origin i to destination country j through a third country k,

$$\Xi_{ikj} = \sum_{l} \psi_{kl|ij} X_{ij} = \sum_{l} \psi_{kl|ij} \lambda_{ij} X_j = \psi_{k|ij} \lambda_{ij} X_j,$$

where the last expression uses the definition of the bilateral loan flows, as the product of loan demand and the share λ. This is related to equation (7) in Arkolakis, Ramondo, Rodríguez-Clare, and Yeaple (2018) model of multinational production.

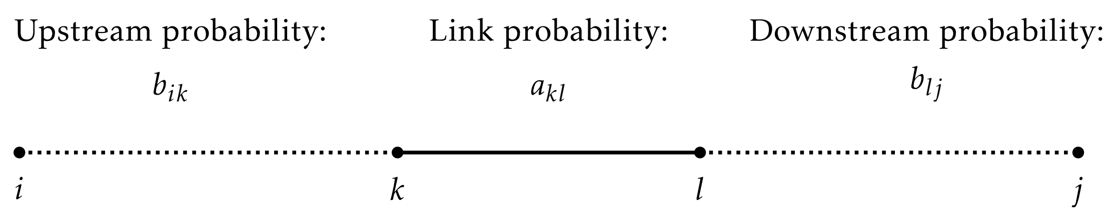


Figure 1: Locational Gravity: Probability Interpretation

Note: The figure draws a schematic representation of indirect lending. i k l and j are nodes or countries. The dotted lines between i and k and l and j represent the sets of possible paths between the respective nodes. The solid line represents the edge between k and l.

We can now obtain the total locational loan flows between k and l, Ξ_{kl}, summing over all the origin i and destination j countries:

$$\Xi_{kl} = \sum_i \sum_j X_{ij} \psi_{kl|ij} = \sum_i \sum_j X_{ij} \frac{b_{ik} a_{kl} b_{lj}}{b_{ij}}. \tag{22}$$

This locational loan volume includes loan flows bound for l and those continuing onward to other destination countries. Locational loan flows Ξ are a function of loan intermediation costs and ultimate loan flows X only. The effects on loan flows of country-specific features such as loan production efficiency and equilibrium loan rates, as well as shocks to these, are subsumed by X, and affect locational flows proportionately on all routes according to $\psi_{kl|ij}$.[24]

3.4 Closing the Model

For each country i, we obtain banks' aggregate demand for labor and deposits by aggregating across the individual loan varieties:

$$M_{i,t} = \int_{\Omega} M_{i,t}(\omega) d\omega, \qquad D_{i,t} = \int_{\Omega} D_{i,t}(\omega) d\omega. \tag{23}$$

[24]Since, following Allen and Arkolakis (2022), there is a unique set of ultimate loan flows X consistent with observed country characteristics, market clearing conditions, and banks' optimization, there exists a unique matrix Ξ of locational loan flows.

Banks' aggregate demand for labor and deposits is related to the total loans produced in the country (regardless of destination), $X_{ij,t}$:

$$M_{i,t} = \sum_j X_{ij,t}/z_i. \qquad D_{i,t} = \sum_j X_{ij,t}. \tag{24}$$

A competitive equilibrium is defined in the usual way: all agents optimize taking prices and interest rates as given, and the markets for both types of labor, capital, deposits, aggregate and individual loans, and final goods clear.

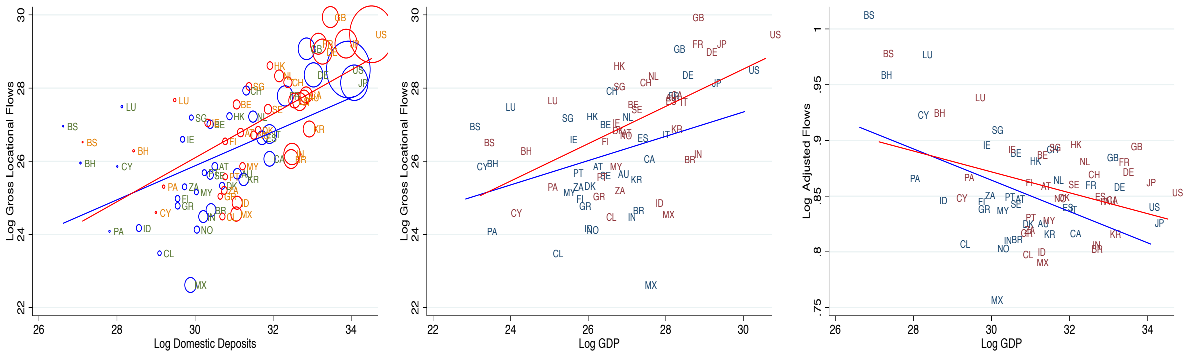
4 Model Analysis

In what follows, we detail the calibration of the model and then use the model to study the effects of changes in individual country fundamentals, in the form of changes in TFP, and changes in bilateral intermediation costs, in the form of changes in edge costs e_{ij} between country pairs. We focus on the impact on locational and ultimate loan flows but later (Section 6.2) also illustrate the consequences for investment, labor, and output.

In model counterfactuals and simulations, we derive then illustrate the bias that arises from observing locational loan flows in place of ultimate lending. Locational loan flows can distort the measure — or even reverse the sign — of the impact on ultimate lending. In the subsequent section, we investigate the implications of indirect lending for the global propagation of shocks and for aggregate lending stability. Before detailing the calibration, we first illustrate key data patterns that our model can help capture: the disconnect between country size and bilateral loan flows due to indirect network lending, and the deviation of bilateral flows from observed lending frictions due to network proximity of linkages to global banking.

4.1 From Model to Data

The model delivers a set of both ultimate and locational bilateral loan flows. A country i with a solid presence of internationally active banks would be characterized by sizeable ultimate loan flows $X_{i,j}$. Countries with a developed banking sector that also act as banking hubs would originate *and* intermediate loans, hence exhibiting high



(a) Flows v Deposits **(b)** Flows v GDP **(c)** Adjusted Flows v GDP

Figure 2: Gross Locational Loan Flows vs Deposits

Note: The figure plots the relationship between gross locational flows, GDP, and deposits across countries. Panel a shows the log of the sum of gross incoming and outgoing locational flows (BIS LBS) (y axis) against the log domestic deposits with circle sizes denoting national GDP (World Bank Global Financial Development Database) and fit lines in 2017 and 2001. Panel b plots the same y-axis against log of GDP on the X axis. Panel c adjusts locational flows (y-axis) by dividing by the log of total deposits, and plots the result against log of GDP. Red circles and fit line use 2017Q4 data. Blue circles and fit line represent 2001Q4 data. ISO country codes are plotted in green and orange, respectively. Estimated coefficients (robust SEs in parentheses) for the fitted line in Panels a, b and c are, respectively, 0.47 (0.15), 0.33 (0.16), and -0.02 (0.01) for 2001 data and 0.60 (0.15), 0.51 (0.13), and -0.01 (0.01) for 2017 data (regressions reported in the Appendix in Table A1). Where, for some countries, BIS or World Bank data was missing for 2001Q4, we take data from the earliest possible date after 2001Q4.

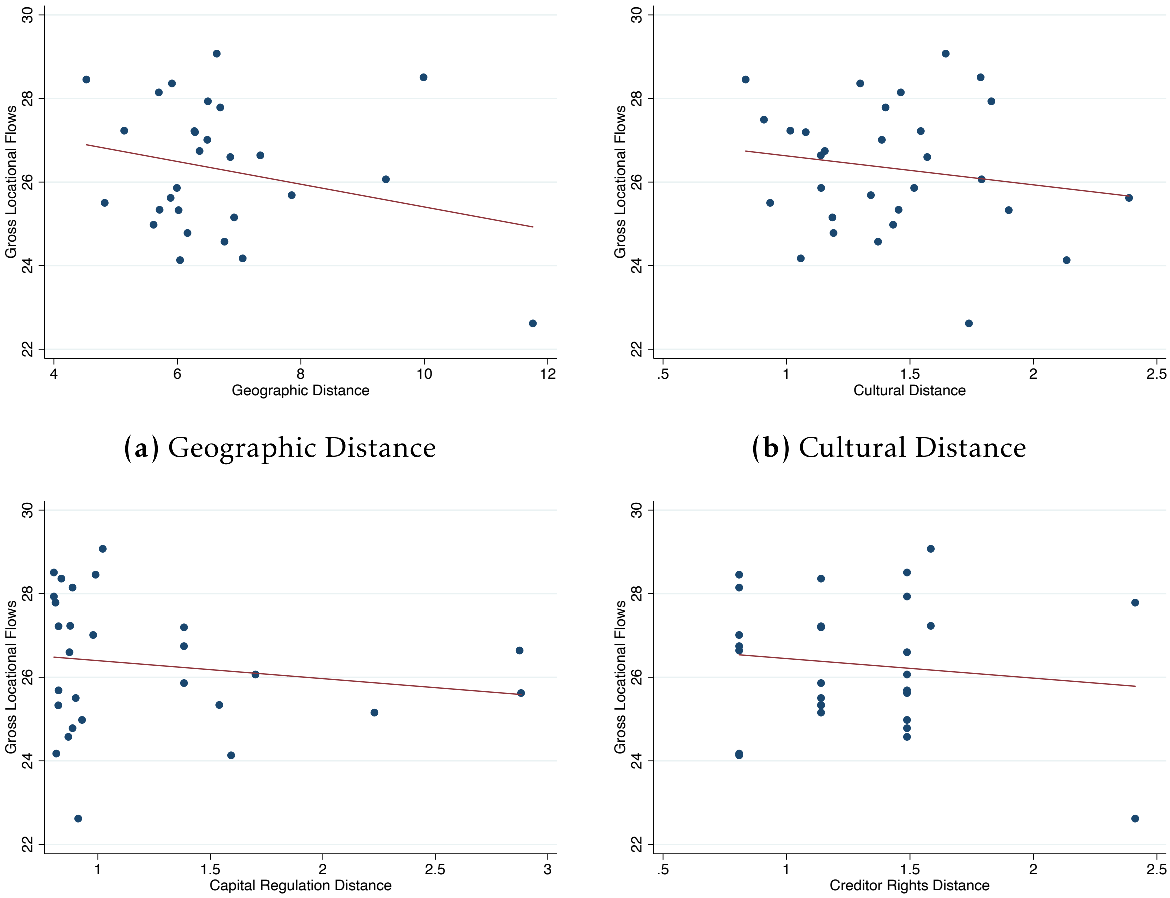
ultimate flows $X_{i,j}$ *and* locational flows, both outward $\Xi_{i,l}$ and inward $\Xi_{i,\mathrm{UK}}$. Offshore banking countries, instead, would be characterized by lower ultimate flows and high locational flows: they generate a small volume of loans, but they facilitate the intermediation of loans through their jurisdiction.

While our motivating empirical hurdle is the inability to observe bilateral ultimate flows, the model does suggest some observable statistics which can differentiate between these scenarios. For example, one could consider the statistic $(\Xi_{ik} + \Xi_{kj})/\sum_j X_{kj}$, which measures the total flow of locational loans in and out of k relative to the total loans originated in k (regardless of destination). Holding fixed the ratio of domestic to international loans, two countries could both have large locational loan flows going through them (i.e., a high value of $(\Xi_{ik} + \Xi_{kj})$) but exhibit a very different value of this statistic. For example, the Cayman Islands would have a high value of the above ratio, as they intermediate a large volume of international loans while producing very few; the United Kingdom would feature a relatively lower value of the ratio as it produces a substantial amount of loans, besides acting as an intermediary node in the global banking network.

Using information on locational loan inflows and outflows for all BIS reporting countries from the BIS Locational Banking Statistics together with data from the World Bank Financial Development Database on total domestic deposits in the same countries, we consider this ratio in two years: 2001, at the onset of the process of global expansion of multinational banking groups, and 2017, after the recovery of global lending flows from the Great Financial Crisis. Figure 2, Panel a, plots the gross locational loan flows (inflows plus outflows) of the countries against the volume of their domestic deposits (both expressed in log million dollars). The blue and red circles refer to 2001 and 2017, respectively, with the size of the circles reflecting the size of the economies (GDP). Fitted lines are also shown. The figure helps to distinguish between banking hub countries, plotted above the fitted line, and non-banking hub countries (e.g., Chile or Canada), which fall below it. Further, pure banking hubs with modest own loan production (e.g., the Bahamas and Cyprus) are plotted in the upper-left region while banking hubs also featuring large own loan production (e.g., the United Kingdom) are plotted in the upper-right region. The figure also hints at an increase in the complexity of global banking from 2001 to 2017: the upward shift of the fitted line suggests an overall rise in gross locational loan flows for any size of domestic bank loan production. More surprisingly (but in line with policy efforts to reduce the relevance of bank tax heavens), the increase in the slope of the fitted line from 2001 to 2017 suggests that such complexification was driven more by banking hubs with sizeable domestic bank loan production than by hubs with modest loan production.

Panel b of Figure 2 reveals a positive relationship across countries between gross locational loan flows and GDP, showing a strengthening relationship over time. This again suggests a disproportionate rise in locational flows through major economies. Panel c shows that locational flows normalized by total deposits negatively correlate with GDP, indicating that "excess" loan flows are differentially present in small offshore banking centers. Panel c also reveals a fall in such excess loan flows in those economies at the same time as their rise in larger economies. Taken together, the three panels illustrate a nuanced link between the size of originating countries and locational loan flows, and the potential rise of indirect lending through major economies in recent years.

The model further predicts that the tendency of a country to become a banking hub and intermediate international loan flows will be related to the intermediation frictions (cross-border edge costs) between the country and other countries in the global banking network. As suggested by equation (22), however, this relationship is



(a) Geographic Distance **(b)** Cultural Distance

(c) Capital Regulation Distance **(d)** Creditor Rights Distance

Figure 3: Gross Locational Flows and Cross-Border Lending Frictions

Note: The figure plots gross locational flows on (Panel a) the weighted physical distance between the capital of a country and the capitals of other countries (in thousand kilometers); (Panel b) the weighted Euclidean cultural distance between a country and other countries; (Panel c) the absolute value of the bank capital regulation tightness difference between a country and other countries; (Panel d) the absolute value of the creditor rights difference between a country and other countries. Pearson's coefficients for the relationships are -0.26, -0.13, -0.16, and -0.13, respectively.

complex, as it reflects the structure of edge costs along the global banking network. Probing these points in the data, we consider four fundamental drivers of international lending frictions studied in the banking literature: geographic distance, cultural distance, distance in creditor legal rights, and banking regulation distance (see, e.g. Gao and Jang, 2021, Giannetti and Yafeh, 2012).[25] For each country for which we have data on locational loan flows and on these distance measures, we compute the population-weighted bilateral distance (geographic, cultural, legal, or regulatory) from the other countries in the global network. Figure 3, Panels a-d, plot the gross locational loan flows (inflows plus outflows) of each country against its weighted bilateral distance from other countries in the global banking network, together with

[25]As we elaborate below, these studies use micro-level loan data to relate wedges in loan financing costs to these frictions.

fitted lines. The panels reveal a slight negative relationship between gross locational loan flows and the country's weighted bilateral distance from the global network. On the other hand, they suggest that a large portion of locational flows cannot be directly explained by bilateral frictions between countries. This echoes the mixed results on the relationship between observable frictions and international lending in the banking gravity literature (Buch, 2005, Delatte et al., 2017, Papaioannou, 2009) and points to the importance of accounting for the entire network structure of edge costs. For example, some countries may exhibit large locational flows despite high bilateral lending frictions because of low frictions on important second-order links. Appendix Table A2 confirms these patterns regressing bilateral LBS flows on bilateral frictions, adding controls for reporting and destination country GDPs and reporting and destination country-by-year fixed effects.

4.2 Calibration

In performing counterfactuals and simulations, we consider a framework with $\mathcal{N} = 3$ countries (regions). In particular, in line with a broad set of studies, we calibrate the model so as to match the North-American, Asian, and European regions (henceforth, also denoted as region 1, 2 and 3, respectively).[26] The model is calibrated to quarterly frequency and solved numerically by locally approximating around the non-stochastic steady state.

Table 1 presents calibrated values for the model parameters. A first set of parameters refer to the household sector and are set to common values across the three regions: the discount factor β, the inverse Frisch elasticities for labor supplied to the firm sector ϵ and to the banking sector φ, and the labor disutility parameters in the two sectors, k^H and k^M. A second set of parameters pertain to the firm sector. The capital share of output α, the depreciation rate δ, and the parameter governing the elasticity of the capital supply η are common across the firm sectors of the three regions. The steady-state TFP, A_i, is allowed to vary across regions. Finally, a third set of parameters refer to the banking sector. The elasticity of substitution σ across loan varieties and the Fréchet shape parameter θ are set to common values across regions. The loan officers' productivity z_i and the internal intermediation cost e_{ii} are allowed

[26]The North American bloc comprises 3 countries, the European bloc 25 countries, and the Asian bloc 17 countries. Details are provided in Appendix B.7.

to vary across regions; the cross-border edge costs e_{12}, e_{13}, and e_{23} are allowed to vary across region pairs.

We externally calibrate parameters that are fairly standard in the literature (β, ϵ, φ, α, δ, η, σ). We internally calibrate the remaining parameters (k^H, k^M, z_1, z_2, z_3, A_1, A_2, A_3, θ, e_{11}, e_{22}, e_{33}, e_{12}, e_{13}, e_{23}) by targeting data moments. Consider first the externally calibrated parameters. In the household sector, the discount factor is calibrated to $\beta = 0.9975$, implying a yearly steady state deposit rate (R^D) of 1%, as in Goodfriend and McCallum (2007) for example. The Frisch elasticity of labor supply is set to $\epsilon = \varphi = 4$ in both the final goods and the banking sectors, in line with the suggestion by Chetty, Guren, Manoli, and Weber (2011) for macro models. In the firm sector, the depreciation rate of capital is set to $\delta = 0.025$ implying an annual depreciation rate of 10%, in line with a broad class of models. We set the share of capital $\alpha = 0.3$, implying a wage bill of two thirds of total output. In the capital producing sector, we specify the investment adjustment function as $f(I) = -\eta/2\,(I_t/I_{t-1} - 1)^2$, with $\eta = 1.728$, as in Gertler, Kiyotaki, and Queralto (2012). In the banking sector, we set the elasticity of substitution across loan product varieties at $\sigma = 1.471$ as in Gerali, Neri, Sessa, and Signoretti (2010). This implies a limited degree of substitutability across loan varieties and, hence, across banks, in line with the observation that relational lending is pervasive in credit markets and firms cannot easily switch among lending banks (see, e.g., Chodorow-Reich (2014)).

Turning to the internally calibrated parameters (k^H, k^M, z_1, z_2, z_3, A_1, A_2, A_3, θ, e_{11}, e_{22}, e_{33}, e_{12}, e_{13}, e_{23}), we pick them so as to match the following targets: total hours worked ($M + H$), GDP ratios between region pairs, the ratio of the wage in the banking sector relative to the wage in the goods producing sector, the ratio of non-interest operating (labor) expenses in the banking sector over total (interest and non-interest) bank expenses, the ratio of cross-border lending to domestic lending, the spread between the domestic loan rate and the deposit rate, and the wedges between the financing cost of loans extended internationally between region i and region j and the financing cost of loans extended domestically. We pick the labor disutility parameters (k^H and k^M) and the loan officers' productivity z_i so that, in conjunction with the other parameters, we match total hours worked to 1/3, a ratio of the wage in the banking sector relative to the wage in the goods producing sector of four thirds, and a ratio of bank non-interest operating expenses over total bank expenses of 93.0%. In the US data the hourly wage is around \$40 in the financial sector and \$30 in manufacturing; similar ratios can be observed in the euro area (BLS, 2023, Eurostat, 2021). The targeted ratio of non-interest expenses over total bank expenses is drawn from the US FDIC Call reports. The steady state values of the TFP of the three regions are residuals set so that, in conjunction with the other parameters, the model can match the observed ratios between the respective GDPs of the three regions (accounting for labor force differences).

Table 1: Calibration of Selected Parameters

Description	Symbol	Value
(a) Externally Calibrated Parameters		
Preferences		
Household discount factor	β	0.9975
Inverse Frisch elasticity for H	ϵ	0.250
Inverse Frisch elasticity for M	φ	0.250
Firms		
Capital share of output	α	0.330
Capital depreciation	δ	0.025
Inverse elasticity of net investment to the price of capital	η	1.728
Banks		
Loans elasticity of substitution	σ	1.471
(b) Internally Calibrated Banking Parameters and Derived Moments		
Internally Calibrated Parameters		
Fréchet shape parameter	θ	2.61
Banking productivity North America/Asia	z_1/z_2	1.22
Banking productivity Europe/Asia	z_3/z_2	1.14
Cross-border edge cost North America-Asia	e_{12}	2.87
Cross-border edge cost North America-Europe	e_{13}	1.97
Cross-border edge cost Europe-Asia	e_{23}	1.91
Internal intermediation cost, North America	e_{11}	1.15
Internal intermediation cost, Asia	e_{22}	1.16
Internal intermediation cost, Europe	e_{33}	1.22
Derived Moments		
Cross-border network lending frictions North America-Asia	τ_{12}/τ_{ii}	1.21
Cross-border network lending frictions North America-Europe	τ_{13}/τ_{ii}	1.14
Cross-border network lending frictions Europe-Asia	τ_{23}/τ_{ii}	1.13

Note: This table presents the calibrated values of selected parameters of the model. Panel a displays selected externally calibrated parameters. Panel b shows selected internally calibrated parameters and derived moments.

We calibrate the Fréchet parameter to $\theta = 2.61$. The internal intermediation costs are $e_{ii} = \{1.15, 1.16, 1.22\}$ for North America, Asia, and Europe, respectively. The cross-border edge cost between North-America and Asia is calibrated to $e_{12} = 2.87$, that between North-America and Europe to $e_{13} = 1.97$, and the cross-border edge cost between Asia and Europe to $e_{23} = 1.91$. In conjunction with the other parameters, these values allow to match a ratio of cross-border lending to domestic lending of 1 to 4, a quarterly spread between the domestic loan rate and the deposit rate of 90 basis points (3.6% annually), and the following quarterly wedges between the financing costs of loan products extended internationally and domestically: 24.25 basis points for loans between North America and Asia (0.97% annually), 16.5 basis points for loans between North America and Europe (0.66% annually), and 15.5 basis points for loans between Europe and Asia (0.62% annually). The targeted ratio between cross-border and domestic lending of 1 to 4 is in line with the ratio (25%) reported in BIS data on foreign versus domestic loan claims for the set of BIS reporting countries.[27] The targeted spread between the domestic loan rate and the deposit rate is drawn from data for average loan spreads over recent decades provided by the IMF and the World Bank.[28] The targets for the bilateral financing cost wedges between region pairs are set so as to match the wedges predicted by established empirical studies on international lending (Giannetti and Yafeh (2012); Gao and Jang (2021)). These studies relate such wedges to geographic distance, cultural distance, differences in creditor rights protection, and differences in bank regulation between countries, highlighting that these components drive informational, managerial, contractual and coordination frictions. For each pair of countries belonging to two different regions (e.g., a country in the North American region and a country in the Asian region), we compute the values of the fundamental determinants of the financing cost spread, namely, geographic distance, euclidean cultural distance, creditor rights difference, and bank capital regulation stringency difference, and then obtain a target for the financing cost wedge based on the estimates in Giannetti and Yafeh (2012) and Gao and Jang (2021). We then compute population-weighted averages of these bilateral wedges across region pairs in order to obtain the target financing cost wedge between regions.[29]

We verified that the calibrated values of the Fréchet parameter and of the edge cost parameters, e_{12}, e_{13}, e_{23}, e_{11}, e_{22}, and e_{33} satisfy the condition that the spectral radius of the matrix A (defined in lemma 2) is less than 1.[30] In Sections 5.1-5.2, we

[27] This is also in the ballpark of the average for major euro area countries.

[28] Gao and Jang (2021) and Liu and Pogach (2016) document a similar spread.

[29] The resulting targeted financing cost wedges are of international loans to counterfactual loans made internationally without cross-border frictions, holding fixed selection.

[30] This is in order to apply the geometric sum that leads to matrix B. A sufficient condition for the

will investigate the role of the Fréchet parameter θ and the sensitivity of the results to its value. While our global economy comprises three regions, and hence caution should be exerted in drawing such conclusions, it is interesting to observe that there is a modest positive correlation (0.08) between the GDP of the regions and the gross locational flows in and out of the regions. In addition, there is a negative correlation (-0.27) between the GDP of the regions and the gross locational flows scaled by domestic deposits. These suggestive steady state patterns are broadly in line with the data patterns discussed in Section 4.1.[31]

4.3 Steady State Analysis and Counterfactuals

The data presented above suggest a material effect of banking regulations and legal restrictions on locational loan flows, as well as a potential disconnect between real-economy country fundamentals and banking flows due to indirect lending. The calibrated model allows us to explore these links by assessing the potential long-term impact on locational and ultimate loan flows of TFP growth in one region of the international banking network and lifting or introduction of financial regulations between regions. The empirical international finance literature has often preferred locational loan data for two reasons: cross-sectional and time-span availability, and the argument that locational loan flows better capture bilateral exposures, contagion, or synchronization. On the other hand, empirical studies (e.g., Hale, Kapan, and Minoiu, 2020) detect major puzzles when using such locational loan flows to assess the impact of structural transformations or temporary shocks. Our model with indirect lending can help address a number of puzzles uncovered in this literature.

With these goals in mind, we perform two model counterfactuals, with key results summarized in Table 2. In a first counterfactual exercise ("catch-up growth"), we study the impact on steady-state loan flows of TFP growth in Asia (e.g., capturing the process of development of the region). In a second counterfactual exercise ("financial fragmentation"), we examine the impact on steady-state loan flows of increased regulatory restrictions between two regions. In particular, we recalibrate the model economy to a scenario in which the regulatory distance between the North American

spectral radius being less than 1 is $\sum_j e_{ij}^{-\theta} < 1$ for all i, which is satisfied in the calibration.

[31] Appendix E reports an alternative edge cost calibration targeting "traffic," (i.e., locational loan flows), following the method described in the appendix of Allen and Arkolakis (2022). While we cannot adopt this approach because of severe data limitations, we highlight broad qualitative similarities.

regional bloc and the Asian regional bloc is increased symmetrically.

Catch-up growth (TFP) To better understand the underlying mechanisms in our TFP counterfactual, we first analytically illustrate the impact of TFP on loan flows with the help of differential calculus.

Proposition 1 (TFP Impact on Ultimate and Locational Flows)**.** *A higher TFP in country k has the following impact on ultimate and locational loan flows:*

$$\frac{\partial X_{ij}}{\partial TFP_k} = \frac{\partial X_j}{\partial TFP_k}\lambda_{ij} + X_j \frac{\partial \lambda_{ij}}{\partial TFP_k}, \qquad \frac{\partial \Xi_{k',l'}}{\partial TFP_k} = \sum_{i,j} \frac{\partial X_{ij}}{\partial TFP_k} \psi_{k'l'|ij}. \tag{25}$$

The expression in (25) for the impact of TFP on ultimate loan flows $\frac{\partial X_{ij}}{\partial TFP_k}$ would look the same in a standard gravity model without indirect lending—in our model the complexity of the banking network is captured via expected costs τ_{ij} which, in turn, affect the loan shares λ_{ij}. Put differently, effects of TFP on bilateral loan flows happen via general equilibrium effects on interest rates and wages, which affect ultimate and *then* locational loan flows; TFP does not affect the network structure (indeed, its effects on ultimate flows would be qualitatively similar in a model without indirect lending).[32] The effects of TFP on locational loan flows can be sharply different from the effects on ultimate loan flows, leading to biased conclusions. In particular, the expression $\frac{\partial \Xi_{k',l'}}{\partial TFP_k}$ in equation (25) makes clear that in our model the impact on the locational loan flows between k' and l' is the weighted average effect of the impact on the ultimate flows, with weights being the network relevance of the edge $k'l'$ in the paths starting in all origins i to all destinations j.

Recalling equation (22), we can write the bias when using locational loan flows Ξ_{kl} in place of ultimate loan flows X_{kl} to interpret the impact of TFP:

[32] The effects on ultimate loan flows would be quantitatively identical in a model without indirect lending in which the bilateral frictions are exactly equal to the bilateral network costs in our model. In Section 6.1, we develop an extension in which the effects of TFP on ultimate loan flows diverge between the two models.

$$\sum_{\{i,j\}\setminus\{k,l\}}\left(\underbrace{\frac{\partial X_j}{\partial TFP_{k'}}\lambda_{ij}}_{\substack{\text{GE effects on}\\ \text{indirect flows}}}+\underbrace{X_j\frac{\partial \lambda_{ij}}{\partial TFP_{k'}}}_{\substack{\text{Indirect}\\ \text{substitution lending}}}\right)\psi_{kl|ij}-\left(\underbrace{\frac{\partial X_l}{\partial TFP_{k'}}\lambda_{kl}+X_l\frac{\partial \lambda_{kl}}{\partial TFP_{k'}}}_{\substack{\text{Effect on flows not}\\ \text{transmitted through } kl}}\right)(1-\psi_{kl|kl}). \tag{26}$$

The first two terms represent the effect on loans from other sources i to other destinations j, through kl, either because of general equilibrium effects at destinations or because of substitution between origins induced by the TFP shock. They amount to an error that comes from attributing locational loan flows through kl to ultimate kl lending. The third and fourth terms represent a negative error stemming from the impact on ultimate loan flows that originate in k for destination l that already circumvented, or now circumvent, the edge kl by using other network nodes. Overall, the more a node k is used as a banking hub for l, the more empirical work using Ξ_{kl} will overstate the impact of TFP on ultimate loan flows from k to l; the more ultimate lending from k to l flows through alternative banking hubs, the more locational flows will understate the impact on ultimate lending. The direction of the bias arising from these errors will be a function of the correlation between any variable of interest and the net error, as determined by the network structure.

Table 2, Panel A, shows salient effects of a 10% permanent increase in the TFP of the Asian region (region 2), roughly the equivalent of 7 years of TFP growth in Asia (as calculated using the average TFP growth rate between 2010 and 2020). In our model economy, the impact of a higher TFP on the locational loan flows to the affected Asian region is consistently smaller than the impact on the ultimate loan flows to that region. This occurs because some fraction of the substituted ultimate lending between regions 1 (North America) and 3 (Europe) flows through 2 (Asia), as captured by the second term in equation (26). Our calibrated model suggests adjustment factors that could be used to recover the impact on ultimate loan flows following a 10% permanent rise in the TFP of the Asian regional bloc. The ratio between locational loan flows to Asia post- and pre-TFP rise should be scaled up by a factor of 1.08.[33]

[33]The results of this first counterfactual suggest that the observed empirical relationship between locational loan flows and GDP detected in Figure 2 (Section 4.1) understates the relationship between

Financial fragmentation While there is a large literature that explores the impact of TFP or other country fundamentals on lending flows, most theoretical works assume an exogenous network. Instead, we can allow any bilateral edge cost to change: recalling Lemma 2, a change in a single e_{ij} has an impact on the entire network cost τ_{ij}.[34] Table 2, Panel B, summarizes the impact on ultimate and locational loan flows in a second counterfactual experiment in which we permanently raise the regulatory barriers between the North American bloc and the Asian bloc. Proposition 2 decomposes analytically the impact on loan flows with the help of differential calculus:

Table 2: Counterfactual Steady State Loan Flows to Asia

	Locational Flows	Ultimate Flows	Adjustment Factor
	(1)	(2)	(3)
	(A) Counterfactual 1: Asia Catch-up Growth		
From North America	1.0668	1.1511	1.0790
From Europe	1.0591	1.1485	1.0844
	(B) Counterfactual 2: Financial Fragmentation		
From North America	0.6695	0.9348	1.3963
From Europe	0.8815	1.0007	1.1352

Note: This table presents the effects of a 10% higher TFP of the Asian region (Panel A) and a 10% higher edge cost between the North-American and Asian regions (Panel B) on steady state bilateral loan flows to Asia from North America and Europe. Column 1 reports the ratio of locational loan flows between steady states. Column 2 reports the same ratio for ultimate flows. Column 3 reports the ratio between column 2 and column 1.

Proposition 2 (Edge Cost Impact on Loan Flows)**.** *A higher edge cost e_{kl} results in the following impact on ultimate loan flows:*

$$\frac{\partial X_{ij}}{\partial e_{kl}} = \underbrace{\frac{\partial X_j}{\partial e_{kl}}\lambda_{ij} + X_j \frac{\partial c_i^{-\theta}}{\partial e_{kl}} \frac{\lambda_{ij}}{c_i^{-\theta}} + X_j \frac{\partial R_j^{-\theta}}{\partial e_{kl}} \frac{\lambda_{ij}}{R_j^{-\theta}}}_{\text{GE effects}} + \underbrace{X_j \frac{\partial \tau_{ij}^{-\theta}}{\partial e_{kl}} \frac{\lambda_{ij}}{\tau_{ij}^{-\theta}}}_{\text{network effects}} \tag{27}$$

and the following impact on locational flows:

$$\frac{\partial \Xi_{k',l'}}{\partial e_{kl}} = \underbrace{\sum_{i,j} \frac{\partial X_{ij}}{\partial e_{kl}}}_{\text{average effect}} \psi_{k'l'|ij} + \underbrace{\sum_{i,j} X_{ij} \frac{\partial \psi_{k'l'|ij}}{\partial e_{kl}}}_{\text{diversion}}. \tag{28}$$

Equation (27) separates the effect of the edge cost kl on the ultimate loan flows between i and j into four terms. The first is the effect of intermediation frictions on

ultimate loan flows and GDP.

[34] Computationally, this entails inverting the B matrix, a $\mathcal{N} \times \mathcal{N}$ matrix of endogenous variables.

total loan demand X_j. The second and third terms capture the effects through the marginal loan production cost and interest rates. The final term captures the effects through bilateral network costs. In an off-the-shelf gravity model without indirect lending, the bilateral network cost in the last term would be replaced with (direct) bilateral frictions, and be zero unless $i = k$, $j = l$. This would bias the first three terms, with the direction of bias depending on the shape of the network.

Equation (28) separates the effect of the edge cost kl on the locational loan flows along edge $k'l'$ into two terms: the average effect on ultimate loan flows for all bilateral pairs, weighted by the proportion of each flow using $k'l'$, and the effect on the proportion of ultimate loan flows using $k'l'$, weighted by the size of those ultimate flows. The first term, expanded in equation (27), is the total effect of the edge cost on all lending. The second term represents the extent to which the edge cost induces a diversion of loan flows through the network towards or away from $k'l'$.

Table 2, Panel B, summarizes the effects of the financial fragmentation experiment, in the form of a a 10% increase in the bilateral edge cost between the North American region and the Asian region (corresponding to a roughly 50% increase in the regulatory- and legal-driven lending frictions).[35] The panel confirms the importance of accounting for indirect lending when assessing the impact of regulatory and legal barriers. Following the increase in the bilateral edge cost between the North American region and the Asian region, the locational loan flows between North America and Asia drop significantly, largely overestimating the actual negative impact of the edge cost increase on the ultimate loan flows between the two regions. Thus, a policy maker interpreting the long-term effects of an increase of regulatory restrictions through the lens of locational loan flows would significantly overestimate such effects. The actual resilience of the ultimate loan flows between the two regions is explained by the European bloc playing an intermediation role between North America and Asia, which significantly dampens the impact on ultimate loan flows. An observer focusing on locational loan flows would neglect this diversification of lending paths (here, through the European region). Interestingly, a policy maker focusing on locational loan flows may also fail to grasp the substitution role that Europe can play for Asia as a source of funding. As column 2 in Panel B shows, there is some drop

[35]This can be thought of as a significant regulatory change. In the various regulatory shock episodes surveyed in the Appendix, the indicator for the stringency of regulations on foreign banks changed by about 35% on average.

in the locational flows between Europe and Asia. This happens because Europe effectively uses some Asian countries to ultimately reach destinations in North America. When the edge cost between Asia and North America rises, such loan flows tend to dry up, thus somewhat shrinking locational loan flows from Europe to Asia.

Panel B of Table 2 also displays implied adjustment factors that could be used to recover the impact on ultimate loan flows from the observed impact on locational flows. For the location loan flows from North America to Asia, the suggested upward adjustment is clearly larger than for the locational loan flows from Europe to Asia. When contrasted with the adjustment factors for the TFP counterfactual in Panel A, the adjustment factors for the edge cost counterfactual in Panel B additionally suggest that regulatory barriers can impact the role of a region as an intermediation hub significantly more than TFP: unlike in the TFP experiment, in fact, there is a pronounced change in the locational loan flows through regions relative to the ultimate loan flows originated from the regions.

Before proceeding, it is useful to clarify the scope and limits of our exercises. As we will see, the effects of (permanent or temporary) changes in country fundamentals, such as TFP, or of changes in financial regulations can be influenced by the relative efficiency of the banking sectors of the countries in the international network. The increasing availability of data that can inform precisely about the banking efficiency of individual countries in producing and monitoring loans will allow to fine-tune the choice of the banking efficiency parameters, leading to a more precise evaluation of the effects of shocks through the global network.

4.4 Shocks and Third-Country Effects

The model economy can help explain puzzling effects of shocks on third (non-shock affected) countries that have been uncovered by the empirical literature (when studying for example "lending flights;" see e.g. Hale et al. (2020)). We further investigate the importance of distinguishing between ultimate and locational loan flows, first in the context of a node (TFP) shock and then of an edge shock.[36] To ease the reading of this section, in both cases we consider contractionary shocks (respectively a tempo-

[36]In Appendix B, we provide examples of regulation-driven edge shocks identified by using the database "Banking Regulation and Supervision around the World" compiled by Barth, Caprio and Levine (2020).

rary TFP drop in the Asian region and a temporary increase in the edge cost between the North American and the Asian regions).

Figure 4 shows the impulse responses of ultimate loan flows (blue solid lines) and locational flows (blue dashed-dotted lines) to a temporary 1 percent negative TFP shock in the Asian region.[37] To facilitate the interpretation of third-country effects, in the figure we also compare the responses with those obtained in an alternative gravity model, i.e. an economy with the same bilateral frictions but without network paths and indirect lending (black dashed lines).

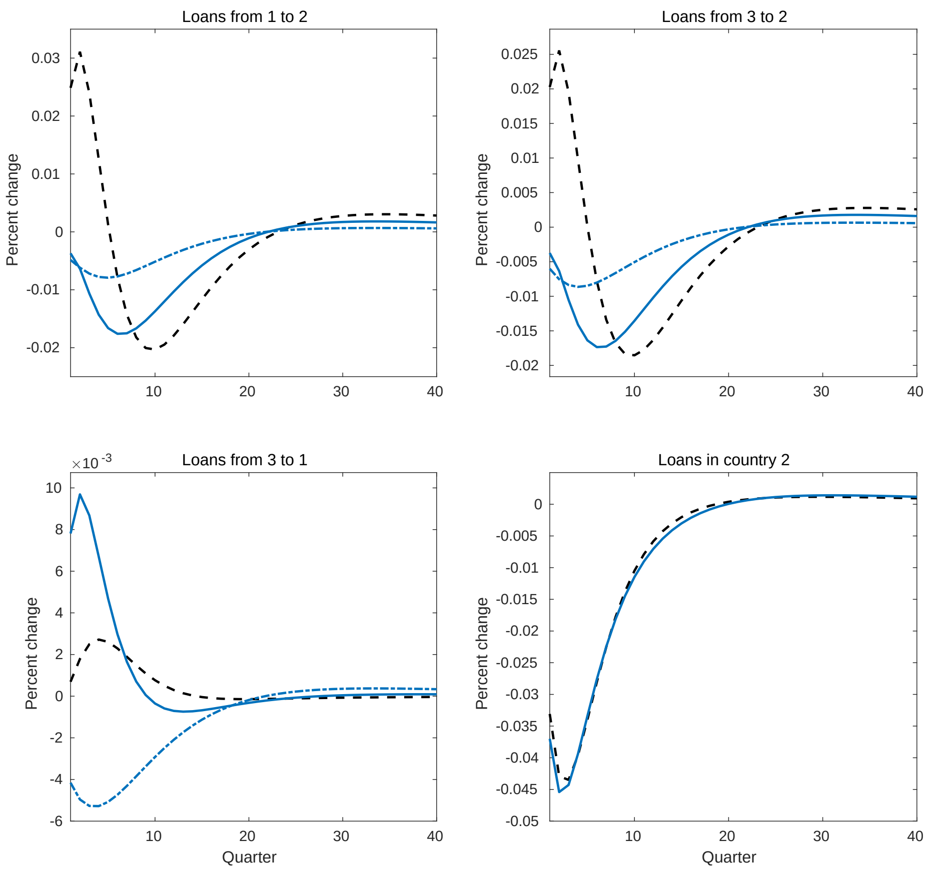


Figure 4: Bilateral Ultimate and Locational Lending, Node Shock

Note: The figure plots the impulse response functions of selected bilateral loan flows to a 1% decrease in the TFP of region 2. The solid blue line refers to ultimate flows in our baseline path economy, the dashed-dotted blue line refers to locational flows, while the dashed black line refer to bilateral lending in an Eaton and Kortum (2002) economy without paths.

As expected, both our model and the comparison economy agree on the direction of the shock's effect on the ultimate loan flows. As standard in the IRBC literature, a negative TFP shock reduces investment in the shock-affected Asian region, and hence the amount of its domestic credit, X_{22}. It also leads to a credit flight, that is, a decrease in X_{12} and X_{32}. The figure also demonstrates the bias in equation (26).[38] Remarkably,

[37] We set the persistence of the shock to 0.8. Appendix Figure A1 plots all 9 bilateral flows.

[38] Analogous to the steady-state TFP counterfactual results, locational loan flows largely underesti-

the direction of response of ultimate and locational loan flows between non-shocked regions (3 and 1) are reversed. Both models agree that ultimate loan flows increase: region 3 (Europe) diverts lending away from now-less-productive firms in 2 (Asia) towards firms in region 1 (North America). But, because part of the ultimate loans to and from 2 flow indirectly through the 1 to 2 link, the decrease in lending to and from 2 results in an observed drop in locational loan flows between 3 (Europe) and 1 (North America). Taken as ultimate flows, observed locational data would then suggest a decrease in lending from region 3 to 1, failing to corroborate the model's prediction. This may help explain the negative third-country effects of shocks documented empirically by Hale, Kapan, and Minoiu (2020), for example.

We next perturb our economy with an unexpected ten percent positive shock to the edge cost $e_{1,2}$, with impulse responses shown in Figure 5.[39] This could capture temporary financial sanctions imposed on lending from North America to Asian countries (e.g., Russia) or a temporary increase in regulatory restrictions on the operations of US and Canadian banks in Asia. As would be expected, the loan flows X_{12} decrease, with locational loan flows largely overestimating the actual drop in ultimate flows between North America and Asia.[40] The figure also shows the effects between regions 3 (Europe) and 1 (North America), between which there is no shock. Ultimate loans from the European bloc to the North American bloc are substantially unaffected (solid blue line). The comparison gravity model without indirect lending, though, predicts a decrease in lending due to the diversion of region 3 loan flows from 1 (North America) to 2 (Asia) (dashed black line), in substitution of the loan drop from North America to Asia. In a twist, locational loan flows from 3 to 1 (dashed-dotted blue line) confirm the comparison model with no indirect lending for the wrong reasons. While naive observers would attribute the drop in these observed locational flows to a reduction in ultimate loan flows, their drop is due to European banks being discouraged from reaching Asia through countries of the North American bloc post shock, and not to reduced lending to North America as substitution.

mate the drop in ultimate loan flows from North America and Europe to the Asian region.

[39]We set the persistence of the shock to 0.8.

[40]The figure also displays loan flows from 3 to 2. A theorist ignoring indirect lending would predict positive changes due to substitution effects. An empirical observer focusing on locational flows would see negative third-country effects. In reality, loan flows from 3 to 2 are essentially stable, with network and substitution effects washing each other out. Appendix Figure A2 plots all 9 bilateral flows.

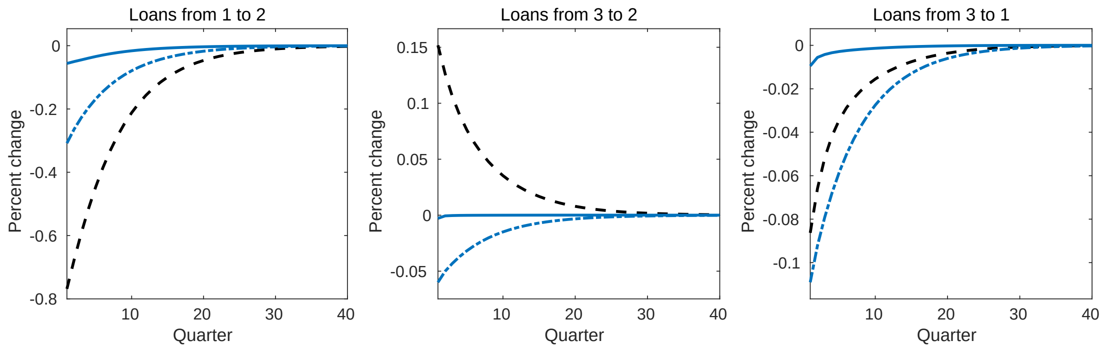


Figure 5: Ultimate and Locational Loans, Edge Shock

Note: The figure plots the impulse response functions of selected bilateral loan flows to a 10% increase in the edge cost e_{12}. The solid blue line refers to ultimate flows in our baseline path economy, the dashed-dotted blue line refers to locational flows, while the dashed black line refers to flows in a standard gravity model à la Eaton and Kortum (2002).

5 Banking Complexity

In this section, we explore how banking complexity (the prevalence of indirect lending) affects shock propagation. Banking complexity is a function of the dispersion of productivity of multinational banking activities across banks. When productivities of particular agent combinations (loan officer or branch) are heterogeneous, the set of cost-minimizing combinations, and thus loan paths, are different across banking groups. Regulatory and technology changes can affect this dispersion. For example, innovations in information communication technology affecting synergies and information sharing between loan officers, regulations affecting the training and mobility of human capital between countries, or regulations governing mergers with local banks (or affecting the degree of restrictions on global syndicated loan networks) could all make specific sets of loan officers or branches, and hence particular lending paths, more efficient for particular banks or loans.

In our model, this dispersion is determined by θ, the parameter governing the relative distribution of idiosyncratic draws and, hence, the prevalence of indirect lending. Lower values of θ imply a thicker tail of idiosyncratic draws, corresponding to a world where ramified banking networks are more active. Policies inducing greater dispersion reduce θ. To investigate the effect of increased dispersion, we therefore repeat the edge shock exercise considered in the previous section while gradually changing the value of θ.

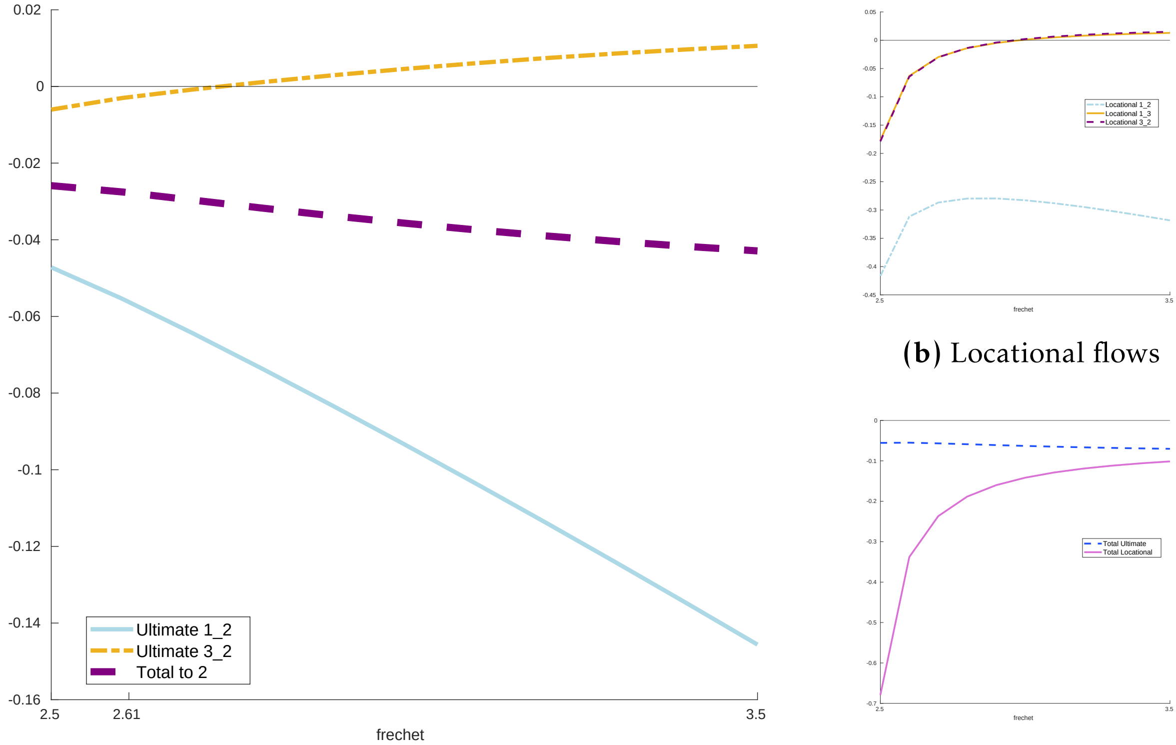
Greater banking complexity (more indirect lending) generates two competing forces. On the one hand, it allows for greater substitution of lending paths: bank lending can circumvent a shocked link between two countries, which mitigates the impact and cross-border transmission of the shock. On the other hand, banking complexity can lead to a lower substitutability of funding sources, as more lending relationships across more countries are exposed to the shock through the network. Importantly, as we will see, here too the mere observation of location loan flows would lead to biased conclusions about the relative strengths of these two competing forces.

We subsequently explore tweaks to our initial experiment, allowing for heterogeneity in the banking efficiency parameter z_i, or simultaneously shocking multiple edges at once.

5.1 Source and Path Diversification

Lending to region 2 In Figure 6a, we graph the immediate impact of the ten percent positive shock to the edge cost $e_{1,2}$ on ultimate lending flows to region 2 (the Asian bloc) using values of θ ranging from 2.5, which satisfies the spectral radius constraint, to 3.5, at which point nearly all locational flows are ultimate lending and the domestic lending share approaches 90%. In Appendix Figure A3, we show robustness to considering the average response over the first four periods after the shock. The solid blue line in Figure 6a represents $X_{1,2}$, ultimate lending from 1 (North America) to 2 (Asia), with 2 being more costly to reach following the edge shock. The dashed-dotted orange line represents $X_{3,2}$, ultimate lending from 3 (Europe) to 2 (Asia), with region 3 representing region 2's alternative source of credit. The dashed purple line represents total ultimate lending to region 2.

Consider first ultimate lending from region 1 to region 2 (solid blue line). Unsurprisingly, for any value of θ, loan flows shrink following the shock. Yet, this drop is less pronounced for lower values of the Fréchet parameter, that is, greater banking complexity (i.e., when the global banking network features larger indirect loan flows). To gain insights into this effect, we open up the last term in equation (27).



(a) Ultimate Flows

(b) Locational flows

(c) Total cross-border flows

Figure 6: Banking Complexity and the Response of Loan Flows to Edge Shocks

Note: The figure plots selected variables (y axis) in a scenario with a 10% shock to edge cost e_{12}, at different values of the Fréchet parameter θ (x axis). Panel 6a plots the impact response of ultimate flows from region 1 to region 2 (solid blue), region 3 to region 2 (dash-dotted orange), and total cross-border flows to region 2 (dashed purple line). Panel 6b plots locational flows from region 1 to region 2 (dot-dash blue), region 3 to region 2 (dash purple) and region 1 to 3 (solid orange). Panel 6c plots total ultimate (dashed blue) and locational (solid purple) cross-border flows.

Substituting for the effect on 1 to 2 lending, the network term becomes

$$\underbrace{X_2 \frac{\partial \tau_{12}^{-\theta}}{\partial e_{12}} \frac{\lambda_{12}}{\tau_{12}^{-\theta}}}_{\text{network effects}} = -X_{12} \left[\underbrace{\frac{\theta}{e_{12}} + \frac{\theta}{\tau_{11}} \frac{d\tau_{11}}{de_{12}} + \frac{\theta}{\tau_{22}} \frac{d\tau_{22}}{de_{12}}}_{\text{direct effect}} + \underbrace{\frac{1}{\psi_{12|12}} \frac{d\psi_{12|12}}{de_{12}}}_{\text{switching effect}} \right]. \tag{29}$$

Path diversification has two components: an ex-ante reduction in exposure to a shock, and the ability to divert lending ex-post. The first three terms capture the direct effect of the shock on the network-average cost of lending from 1 to 2.[41] Lower values of θ reduce the proportion of loans flowing through the shocked link, diversifying the initial (pre-shock) set of paths and reducing region 1's exposure to the heightened cost of the direct link. The fourth term captures the change in the probability that a given unit of loans uses a path with the direct link. The banking network will give banks in region 1 the ability to shift loans to paths which avoid the direct link, as captured

[41] The second and third terms account for loans that move internally or circuitously before being lent at 2.

by the fourth term. Lower values of θ increase such ability of banks to switch paths. Together these effects constitute path diversification.

If an interconnected world with large indirect loan flows can benefit from a higher diversification of lending paths, it can, however, lose along an alternative dimension: *source diversification*. Consider ultimate lending from region 3 to region 2 (dashed-dotted orange line in Figure 6a). At relatively high values of the Fréchet parameter (i.e., in a world with little indirect lending), such loan flow responds positively to the $e_{1,2}$ edge shock, reflecting a source-diversification mechanism: increased interest rates in region 2 induce 3 to act as an alternative source of credit, supplanting the drain of liquidity from region 1. However, in a financially complex economy with more indirect lending (i.e., low θ), this substitution effect is weakened. From equation (27), the network effect on ultimate lending from 3 to 2 is:

$$X_2 \frac{\partial \tau_{32}^{-\theta}}{\partial e_{12}} \frac{\lambda_{32}}{\tau_{32}^{-\theta}}. \tag{30}$$

The exposure of lending from region 3 to region 2 to the edge shock is proportional to the extent to which region 3 uses region 1 as a hub for lending to 2 ($\frac{\partial \tau_{32}^{-\theta}}{\partial e_{12}}$), which is decreasing in θ. That is, as θ decreases, we see more loans flowing (initially) indirectly, including from region 3 to region 2, and therefore more use of 1 as a hub for such transactions. This in turn leaves these substitution lending flows more exposed to the very shock which generates (through general equilibrium effects) their demand. As in equation (29), a path substitution effect exists for this network effect too, and some portion of these exposed lending flows can divert back to a direct path. However on net, the network effect must be negative (since $\tau_{32}^{-\theta}$ is decreasing in e_{12}) undermining the ability of region 3 to act as an alternative source of funding. Indeed, in Figure 6a, as we move left from $\theta = 3.5$ to $\theta = 2.5$ along the graph, ultimate lending from 3 to 2 shrinks, rather than increases, following the edge shock. Moreover, the size of the network effect is proportional to λ_{32}, so we should expect this negative network effect to be more important for third countries (regions) with bigger, more productive banking systems.

The overall effect of the shock on the ultimate loan flows to region 2 (dashed purple line in Figure 6a) depends on how the impact of path diversification compares with that of source diversification. For lower values of the Fréchet parameter, that is, when the global banking network features thicker indirect lending paths, the overall loan flow to region 2 drops less, suggesting that the strengthening of loan path diversification outweighs the weakening of loan source diversification. Below, however, we will see that this conclusion depends on the nature of the shock and on the relative efficiency of the banking sectors of the individual regions. In particular, the relative strengths of the above mechanisms can be reversed when considering scenarios where substitute lending sources are relatively more efficient in loan production.

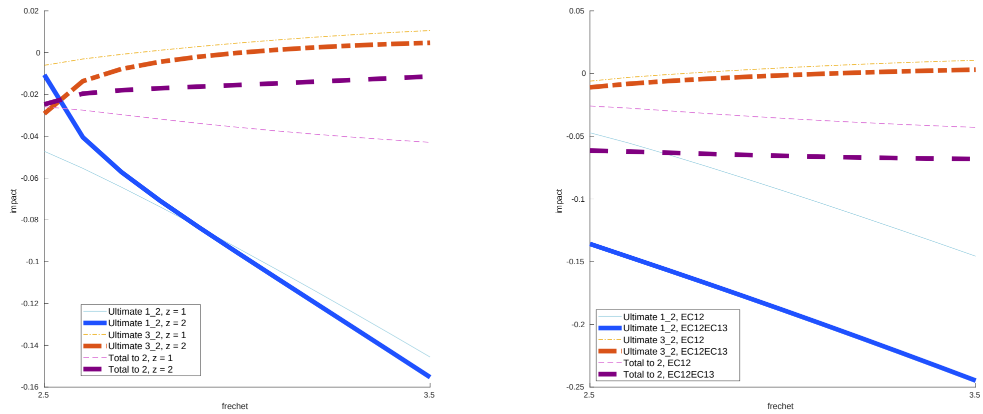
In Section 4, we found that the conventional approach of looking at locational loan flows can lead to distorted conclusions about the mechanisms of shock transmission. Similarly, observed locational flows can distort conclusions about the consequences of banking complexity. The hump-shaped curve of locational flows from 1 to 2 (blue dashed-dotted line) in Figure 6b appears to show that substantially increasing banking complexity relative to the current calibration of θ amplifies the impact of shocks on loans from 1 to 2, contrary to the actual effect.

Global loan flows Figure 6c shows that the effect of the $e_{1,2}$ edge shock on the global ultimate loan flows is negative, but less so for lower values of θ (higher banking complexity). This reflects the interaction of the aforementioned countervailing forces, and the overall prevalence of a stronger path diversification over the weakening in source diversification when indirect lending is more pervasive (i.e., θ is lower).

Belying the dampening effect of complexification on the impact of shocks to ultimate lending, locational flows (solid purple line in Figure 6c) once again incorrectly suggest a different story. Higher banking complexity amplifies the negative effect of shocks on locational flows, a product of a larger base share of indirect flows. Indeed, observers of locational loan flows would fail to identify the stabilizing effect of banking complexity, perceiving the proliferation of indirect lending as amplifying.

5.2 Can Banking Complexity be Destabilizing?

We further explore the race between the path and source diversification forces. We first modify our calibration then the nature of the shocks in order to see if the above conclusions on the consequences of banking complexity could be reversed.



(a) Influence of Banking Efficiency

(b) Multiple Edge Shocks

Figure 7: Banking Complexity and Loan Responses, Alternative Scenarios

Note: Both panels show the impact response (y axis) of selected ultimate loan flows to a 10% shock to edge cost e_{12}, at different values of the Fréchet parameter θ (x axis). The orange dashed-dotted lines refer to flows from region 3 to region 2, the blue solid lines refer to flows from region 1 to region 2, the purple dashed lines to total ultimate cross-border flows to region 2 (i.e. from both 1 and 3). Lighter lines refer to the baseline case (see figure 6a). In Panel 7a, darker lines refer to the corresponding flows in the case of double monitoring efficiency in country 3. In Panel 7b darker lines refer to a scenario with an additional 10% shock to edge cost e_{13}.

Banking efficiency Countries (regions) can differ significantly in the size and efficiency of their banking sectors. This can shift the relative strengths of the two competing forces, path and loan source diversification. Here, we depart from our baseline calibration and consider banking complexity in the presence of asymmetries in banking efficiency larger than in the baseline scenario. To this end, we allow for more pronounced cross-country differences in loan officers' productivity in producing loans, z_i. If third countries (regions) unaffected by a shock feature a highly productive banking sector, their diminished ability to act as alternative sources of liquidity can be particularly harmful and even outweigh the benefits of loan path diversification.

We replicate the previous section's exercise, altering region 3's bank loan officers to be twice as productive (i.e., higher z_i than in regions 1 and 2). Figure 7a overlays the previous results (thin lines) with these new ones (thick lines). The effects of the shock on the loan flows from 1 to 2 and from 3 to 2 are qualitatively similar to the baseline scenario. Indeed, the parameter of the Fréchet distribution, and hence the degree of indirectness of the banking flows, exerts a similar influence on the response to the shock of the ultimate loan flows from 1 to 2 and from 3 to 2. What is instead sharply different from the baseline is the way path diversification and source diversification are weighted against each other. When region 3 is highly efficient in producing loans, losing it as a source of credit exerts a large depressing impact on the total ultimate loans to region 2. While region 1 continues to be able to exploit region 3 as a tertiary node towards 2, this path-diversification effect is now dominated by the reduced ability of region 3 to act as an alternative source of credit.

As a result, banking complexity now leads to shock amplification: a global banking network with more indirect linkages (lower θ) exhibits a larger drop in the ultimate loan flows to region 2, as shown by the upward-sloping dashed purple line. This suggests that banking complexity can have a stabilizing influence for shocks between countries with similar degree of banking efficiency but can have a destabilizing effect where countries have significantly different banking efficiency.

To further grasp the relevance of banking efficiency, in the Appendix we also perform an alternative exercise in which we replicate the previous section's experiment, but this time altering the TFP of region 3 (Europe), rather than its banking efficiency. Appendix Figure A3 overlays the previous results (thin lines) with those obtained by letting the TFP of region 3 to be 10% larger than in our baseline calibration (thick lines). The effects of the edge shock on the loan flows from 1 to 2 and from 3 to 2 are similar to the baseline scenario, with region 3 exhibiting a slightly larger ability to act as an ultimate source of substitute funding (source diversification, upward sloping dashed orange line). On the other hand, there is very little influence on region's 3 ability to act as an alternative intermediation hub for loan flows between regions 1 and 2, and hence a very small influence on the degree of path diversification (downward sloping blue line). Overall, the consequences for the overall response of ultimate loan flows to the edge shock are small, in contrast with the significant influence of banking efficiency detected in Figure 7a.

Multiple edge shocks In Figure 7b we consider a shock that raises the costs of lending from region 1 (North America) to both regions 2 (Asia) and 3 (Europe).[42] We again plot these new results in thick lines with baseline results in corresponding thin lines. This double-edge shock can be thought as a tightening of banking regulation in region 1 that increases the cost of lending abroad for banks in 1. The negatively sloped solid blue line (the change in the ultimate loans from 1 to 2 under increasing values of θ) is shifted downward. Path diversification is now reduced. Due to the increased costs of lending along the 1 to 3 edge, banks in region 1 find it more difficult to circumvent

[42]We now increase both $e_{1,2}$ and $e_{1,3}$ by 10%. Again, we set the shock persistence to 0.8.

the higher costs of lending directly to 2. On the other hand, increasing complexity still reduces source diversification (observe the positively sloped orange line). While the nature of the shock reduces path diversification, the qualitative implications of the baseline scenario carry through.

6 Extensions and Further Analysis

In this section, we extend the analysis in two dimensions: revisiting the effects on loan flows when banks' productivities are endogenous and exploring implications for the responses of real sector variables, including investment and output, as well as implications for the aggregate effects of financial policies.

6.1 Endogenous Monitoring

In the main version of the model we assume banks' productivities z_i to be exogenous. However, banks' efficiency in loan production and extension may be affected by experience accumulated through the activity of liquidity intermediation across countries.[43] In this section, we endogenize loan officers' productivity, scaling it by an exponential factor corresponding to the sum of excess inward and outward locational loan flows with respect to the steady state value of the region:

$$z_{i,t} = z_i * \exp\left[1 + \psi\left(\tilde{\Xi}^{\text{IN}}_{i,t-1} + \tilde{\Xi}^{\text{OUT}}_{i,t-1}\right)\right], \tag{31}$$

In (31), z_i is the steady-state loan officers' productivity of the baseline economy, $\tilde{\Xi}$ are deviations of inward and outward locational flows from their respective steady-state values, and ψ is a positive parameter. This reduced-form approach can capture a learning process where loan officers acquire information and experience based on the number of transactions they process. To capture the persistence of the centrality, we posit that the scale affects the productivity of banks with a lag. Figure 8 plots loan responses following a ten percent shock to the edge cost $e_{1,2}$.

[43] In Appendix A, we explicitly model intermediation as a loan officer's task. Alternatively, scale could affect global banking if loan officers' experience in loan production and extension impacts their intermediation efficiency, which would further endogenize the process of hub formation. This is explored in the second part of Appendix A.

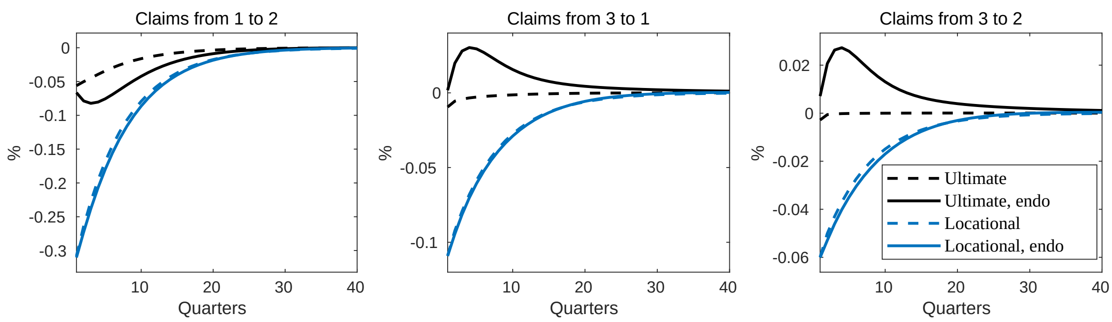


Figure 8: Complexity, Endogenous Banking Productivity

Note: The figure plots selected impulse response functions of cross-border loans to a 10% increase in the edge cost e_{12}. The dashed lines refer to ultimate (black) and locational (blue) flows in our baseline path economy, while the solid lines refer to the model with endogenous banking productivity. Appendix Figure A5 plots all bilateral flows and scales.

The response of the ultimate loan flows between regions 1 and 2 (solid black line) qualitatively mirrors that obtained in the baseline scenario with exogenous bank productivity (dashed black line). However, the drop in the endogenous banks' productivity triggered by the reduction in loan intermediation shifts that response downward. More surprisingly, the ultimate loan flows from region 3 to regions 1 and 2 increase following the shock. Intuitively, because region 3 becomes an intermediation hub for loan flows from 1 to 2 (path diversification), it rebounds to gain banking efficiency on net, and hence produces more loans, benefiting regions 1 and 2. Interestingly, this suggests that when learning effects are strong in the banking sector, path diversification could enhance third countries' ability to serve as alternative sources of funds. That is, path and source diversification could exhibit some degree of complementarity.

6.2 Additional Analysis

Real sector implications Our focus in this paper is on the implications of indirect lending and banking complexity for the behavior of global lending flows. It is however useful to examine the response of salient real sector variables (investment, consumption, labor employed in the final goods sector, and output) to verify whether their response aligns with what expected in an international real business cycle model with lending frictions. In Appendix Figure A6 we consider the one percent negative TFP shock in region 2, while in Figure A7 we study the ten percent positive $e_{1,2}$ edge shock. In line with expectations, the IRFs in Appendix Figure A6 show a drop in investment and output in region 2 following the TFP shock, accompanied by some investment and output increase in regions 1 and 3 (due to a lending flight). Turning to the $e_{1,2}$ edge shock, in line with expectations, the IRFs in Figure A7 show that this shock depresses investment and output in regions 1 and 2, now more costly for global banks to reach. Interestingly, it also has negative effects on investment and output in region 3, partly reflecting banks' reduced ability to reach that region through indirect lending paths.[44]

Policies As noted, the analysis can yield relevant insights about the effects of major policy transformations, such as banking integration and banking unions. In the context of the European banking union, for instance, there has been large policy uncertainty associated with the ring-fencing measures frequently enacted by host countries, aimed at restricting liquidity flows withing multinational banking groups and at introducing a geographic separation of the liquidity and capital of bank subsidiaries from their multinational groups. This has been compounded by informal communications of host-country supervisors, or bank-specific guidance under the "pillar II" process of banking supervision.[45] These policies have effectively restricted the flow of liquidity within cross-border banking groups, discouraged cross-border bank mergers in the euro area, and overall slowed down the development of ramified multinational banking conglomerates.[46] Further, the effects of this uncertainty in policy actions have been highly heterogeneous across lending paths, loan products and banking groups.[47] Our analysis suggests that these policies, rather than enhancing aggregate stability as in the intentions of host-countries policy makers, might dilute the potentially stabilizing role of banking complexification.

In a more short-term perspective, the results reveal that a relaxation or introduction of bilateral regulatory barriers or the imposition of temporary financial sanctions

[44]We computed output correlations across regions in response to the two shocks in our baseline economy and in economies with less intense indirect lending (with higher values of θ). In economies with more indirect lending, we observe lower output comovement following TFP shocks, and higher output comovement following edge shocks. We leave to future research the analysis of the implications of indirect lending for the debate on international output synchronization.

[45]In a survey, Lehmann and Nyberg (2014) found that ring-fencing measures became increasingly common in emerging Europe after 2011.

[46]Over the last two decades, an average of thirty to forty bank mergers occurred each year in the euro area, including a small number of cross-border ones.

[47]For an individual banking group, ring-fencing reduces the economies of scale and impedes the efficient allocation of capital and liquidity that can be attained in cross-border mergers and acquisitions.

can have very different consequences for international banking flows depending on the ramification of multinational banking groups. Thus, when assessing the financial and real effects of such actions, one cannot neglect how the two layers of banking regulation (bilateral entry barriers and the enactment of ring-fencing regulations and limitations of cross-border banking) may interact.

7 Conclusion

The expansion of complex multinational banking groups with broad networks of affiliates and correspondents is reshaping the global financial landscape. This paper presents a dynamic general equilibrium model with multi-country banking flows to account for the substantial fraction of international lending that is intermediated through banking hubs and complex multi-national routing. Our model rationalizes observable international statistics. It generates a set of bilateral *locational* flows of funds that conceptually matches aggregate (BIS LBS) statistics, as distinct from the *ultimate* demand and supply of bank credit. We show how empirical specifications conflating the BIS LBS data with ultimate origin-destination lending biases results and can distort or even reverse empirical patterns.

We further demonstrate that accounting for indirect banking linkages is crucial for understanding how shocks to international frictions (e.g., bank regulation changes or the introduction of financial sanctions) propagate through the network. Accounting for indirect banking links unveils new tradeoffs when considering banking complexity. While a more complex banking network characterized by thicker indirect links eases the use of alternative paths for reaching destination countries (path diversification), it can undermine countries' ability to diversify the sources of international liquidity (source diversification). Overall, the model yields nuanced implications for macroprudential and regulatory policies: the overall net effect of banking complexity on the propagation of shocks depends on the nature of the shocks and on the relative efficiency of the banking systems of the different countries.

The analysis leaves relevant questions open. While our framework captures a rich structure of network paths, it abstracts from complex general equilibrium interactions between banking intermediation costs and aggregate variables that may be relevant for international lending flows, such as the price of international collateral and financial assets. We leave this and other issues to future research.

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Online Appendices

Banking Complexity in the Global Economy

Online Appendices

Banking Complexity in the Global Economy

These Online Appendices contain further microfoundations for intermediation costs (Appendix A), derivations for the model and further details on the analysis (Appendix B), additional figures and tables (Appendix C), the case of a Melitz economy (Appendix D), and (Appendix E) an alternative approach to edge cost inference based on the method described in the appendix of Allen and Arkolakis (2022).

A Further Microfoundations

In Section 2.3, we modeled (deterministic) edge costs as e_{kl}. One interpretation of this cost is, as iceberg costs in the trade literature, an additional friction resulting in higher effective marginal cost of monitoring from origin i to destination j. In this section, we provide a microfoundation of this friction along these lines.

A.1 Bank Intermediation and Edge Costs along the Path

In this microfoundation, the banking sector of each country performs two functions: production of loans and intermediation of liquidity between countries. In line with the literature on multinational banks' internal capital markets, we specify liquidity intermediation as an inflow of transfers from loan-originating countries and an outflow of transfers towards destination countries. This mimics the case of the internal capital markets of multinational banking groups which use their own subsidiaries in third countries to reach final destination countries.

The problem of a representative bank is now augmented in two ways. On the constraints side, the bank faces N intermediation constraints (one for each destination country) which relate transfers inwards to transfers outwards, according to a 1:1 technology (i.e., each unit of transfers outwards must be matched by a unit of transfers inwards). This N-constraints specification embeds the idea that banks cannot divert funds committed for specific destinations to cheaper destinations (in order to receive higher edge cost payments and expend lower edge cost payments to such cheaper destinations). On the objective function side, the bank pays costs for operating the liquidity intermediation technology. These can comprise costs for monitoring and managing transfers in and out and for matching them with each other, costs for dealing with other subsidiaries of the banking conglomerate (including informational frictions), loan officer training efforts, and more broadly frictions for using internal capital markets. The bank also receives payments from loan-originating countries aimed at covering such expenses sustained in the intermediation process.

Formally the problem of a bank in node (country) country k reads:

$$\max_{M_k(\omega),D_k(\omega)} \sum_j \frac{r_{kj}(\omega)}{\tau_{kj}(\omega,p)} x_{kj}(\omega) - w_k M_k(\omega) - R_k^D D_k(\omega) - \sum_{j=1}^{N}\sum_{i=1}^{N} e_{ik}\tilde{\Xi}_{ik}^{j} r_{ij}(\omega) + \sum_{i=1}^{N} T_i$$

$$s.t. \quad \sum_j x_{kj}(\omega) = \min\{z_k M_k(\omega), D_k(\omega)\} \tag{A.1}$$

$$\sum_{i=1}^{N} \tilde{\Xi}_{ik}^{j} = \tilde{\Xi}_{kj} \qquad j = 1,...,N, \tag{A.2}$$

where $\tilde{\Xi}_{ik}^{j}$ denotes the transfers into country k from country i which are destined to country j; $\tilde{\Xi}_{kj}$ are the overall transfers from country k to country j; $e_{ik}\tilde{\Xi}_{ik}^{j} r_{ij}$ represents the edge costs sustained by the bank for intermediating the transfers $\tilde{\Xi}_{ik}^{j}$; and T_i is the total payment received from each origin country i for the purpose of covering the intermediation expenses sustained by this bank in k. Two observations are in order about the intermediation costs. First, in this specification the banks in k must sustain intermediation costs for managing transfers inwards (the analysis would be similar if costs had to be sustained for managing transfers outwards). Second, as implied by the main text analysis, the payments T_i received from the loan-originating countries effectively cover all the expenses sustained for intermediation costs.

Finally, note that the problem above rules out that transfers are used in the loan production technology, as this would effectively imply that transfers are seized by the intermediating bank of country k. In a similar vein, allowing for local deposits to be used in the intermediation activity would imply that ξ draws are no longer forced to be associated with origin banks and their specific source of funds.

A.2 Bank Labor and Edge Costs

Below, we lay out a slightly richer microfoundation where edge costs are costs paid to labor for monitoring and managing liquidity transfers at intermediate nodes. For notational simplicity, in what follows we drop the time subscript t.

In addition to labor costs for loan origination, banks choosing route p now pay monitoring costs for loan intermediation. As before, the deterministic elements of intermediation frictions are:

$$\tilde{\tau}_{ij}(p) = \prod_{k=1}^{K_p} e_{k-1,k}.$$

However, now $e_{k-1,k}$ reflects endogenous labor costs for loan intermediation:

$$e_{k-1,k} = \frac{w_k^I}{z_{k-1,k}^I} \tag{A.3}$$

where w_k^I is the wage paid in country k to workers engaged in (monitoring) loan intermediation activities, and z_k^I is the node's bilateral monitoring efficiency in intermediation activities involving transfers from country $k-1$.

The intermediation constraints faced by a bank at node k now become:

$$\sum_{i=1}^{N} \min\left\{z_{i,k}^I m_{ik}^I(\omega), \tilde{\Xi}_{ik}^j(\omega)\right\} = \tilde{\Xi}_{kj} \qquad j = 1, \ldots, N, \tag{A.4}$$

where m_{ik}^I is the amount of labor employed in monitoring transfers from i to k. Here, bilateral frictions are due to the need of paying for a loan's monitoring in its travel along p. Effectively, loan production is global, and the loan production function is only the domestic portion of loan production.

In a scenario in which labor for intermediation activities and for loan production activities are differentiated from each other, the total demand for labor in intermediation activities reads

$$M_k^I = \sum_i m_{ik}^I = \sum_i \sum_j \frac{\tilde{\Xi}_{ik}^j}{z_{i,k}^I}.$$

The supply of labor for intermediation activities comes from households, whose modified problem reads:

$$\max_{\{C_{k,t},H_{k,t},M_{k,t},M^I_{k,t}\}_{t\geq 0}} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C^M_{k,t} - k_H \frac{H_{k,t}^{1+\epsilon}}{1+\epsilon} - k_M \frac{M_{k,t}^{1+\varphi}}{1+\varphi} - k_I \frac{{M^I_{k,t}}^{1+\eta}}{1+\eta} \right)$$

$$s.t. \quad C_{k,t} + D_{k,t} = (1 + R^D_{k,t-1}) D_{k,t-1} + w^H_{k,t} H_{k,t} + w^M_{k,t} M_{k,t} + w^I_{k,t} M^I_{k,t} + \Pi_{k,t}.$$

Thus, households also derive disutility from a third type of labor (for bank intermediation tasks) and receive wages on such labor. In this setup, edge costs are endogenous to banking wages for intermediations tasks, $w^I_{k,t}$. Increased demand for using k as a node can raise banking wages for intermediation activities and affect edge costs, as long as $\eta > 0$. However, in a setting where $\eta = 0$ and households suffer from linear disutility in performing intermediation tasks, the wage rate $w^I_{k,t}$ for intermediation will be fixed (possibly normalized to a value consistent with the data), and the analysis would remain as in the main text.

B Derivations and Further Details

This Appendix gives more details on the model's derivations and analysis. In the Appendix, with some definitional abuse, we use price and interest rate interchangeably.

B.1 Details on Households and Firms

Households' first order conditions read

$$[C_{i,t}]: \quad 1 = \mathbb{E}_t \Lambda_{i,t,t+1} (1 + R^D_{i,t}), \tag{B.1}$$

$$[H_{i,t}]: \quad k_H H^{\epsilon}_{i,t} = \frac{w^H_{i,t}}{C_{i,t}}, \tag{B.2}$$

$$[M_{i,t}]: \quad k_M M^{\varphi}_{i,t} = \frac{w^M_{i,t}}{C_{i,t}}, \tag{B.3}$$

Firms' first order conditions, in turn, read:

$$[H^D_{i,t}]: \quad \frac{(1-\alpha) Y_{i,t}}{H_{i,t}} = w^H_{i,t}, \tag{B.4}$$

$$[K_{i,t}]: \quad -P^K_{i,t}(1 + R^X_{i,t}) + \mathbb{E}_t \left[\Lambda_{i,t,t+1} \left((1-\delta) P^K_{i,t+1} (1 + R^X_{i,t+1}) + \frac{\alpha Y_{i,t+1}}{K_{i,t}} \right) \right] = 0. \tag{B.5}$$

B.2 Proof of Lemma 1 - Gravity Path Probability

Firms receive bids for financing their capital investments. Banks are competitive and each bank from country i and industry ω makes firms face the same interest rate r_i^X. Hence, this is given by:

$$r_{ij}^X(\omega) = c_i^X \; \tau_{ij}(\omega). \tag{B.6}$$

The goal is to derive the probability that a route is the lowest-cost route from i to j for loan product ω and country i is the lowest-cost supplier of loan product ω to j. We want to know the probability that any given loan ω is sent from i to j on a specific route p. Firms choose the lowest-cost route from i to j for ω from all routes $p \in G$ and firms in j choose the lowest-cost supplier of loan ω from all countries $i \in I$. We will observe ω being sent on a route from i to j if the final cost of ω, including both the marginal cost of loan production and the intermediation cost on that route from i to j, is lower than all the other costs of loan ω from all the other country-route combinations.

Therefore, we will find i) the probability that a country i provides loans to country j at the lowest cost; ii) the price of the loan that a country i actually pays to country j is independent of j's characteristics.

B.2.1 Lenders

The *unconditional* probability that taking a route p to lend from country i to j for a given loan product ω costs less than a constant τ is:

$$\begin{aligned} H_{ijp\omega}(\tau) \equiv & \Pr\Big(\tau_{ij}(p,\omega) \le \tau\Big) \\ =& 1 - \exp\left\{ - \left[\frac{\tilde{\tau}_{ij}(p)}{\tau} \right]^{-\theta} \right\}. \end{aligned} \tag{B.7}$$

Because the technology is i.i.d across types, this probability will be the same for all loan products $\omega \in \Omega$.

So far we have considered the potential intermediation cost. However, we do not observe bilateral ex-ante costs, but the cost that each country applies ex-post, after choosing the cheapest path. The probability that, *conditional* on banks choosing the least cost route, the cost in ω is less than some constant τ is given by:

$$H_{ij\omega}(\tau) \equiv \Pr\left(\tau_{ij}(\omega) \leq \tau\right),$$

which, after some algebra, yields

$$1 - \exp\left\{ - \tau^{\theta} \sum_{p \in G} \left[\tilde{\tau}_{ij}(p) \right]^{-\theta} \right\}. \tag{B.8}$$

To summarize, this is the probability that, given that banks choose the lower cost route, the cost is below a certain value.

B.2.2 Borrowers

The probability that $r_{ij}(p,\omega)$ is below a certain constant is

$$\begin{aligned} G_{ijp\omega}(r) \equiv& \Pr\left(r_{ij}(p,\omega) \leq r\right) \\ =& 1 - \exp\left\{ - \left[c_i \frac{\tilde{\tau}_{ij}(p)}{r} \right]^{-\theta} \right\}. \end{aligned} \tag{B.9}$$

Firms minimize the price they pay across countries and routes:

$$\begin{aligned} G_{j\omega}(r) \equiv& \Pr\left(\min_{i \in I, p \in G} r_{ij}(p,\omega) \leq r \right) \\ =& 1 - \exp\left\{ - r^{\theta} \sum_{i \in I} c_i^{-\theta} \sum_{p \in G} \left[\tilde{\tau}_{ij}(p) \right]^{-\theta} \right\}. \end{aligned} \tag{B.10}$$

B.2.3 Market Making

Finally, we can combine the two sides of the market, i.e. the probability that a firm in country j chooses to borrow from a bank of country i, and that the route from country i to j is the minimal cost route. In other words, we compute the probability that, picking any other route-country pair, the loan cost will be higher than the optimal one.

$$\begin{aligned}\pi_{ijp\omega} \equiv &\Pr\left(r_{ij}(p,\omega) \leq \min_{k\neq i,\, s\neq p} r_{kj}(s,\omega)\right)\\ = &\frac{\left[c_i \tilde{\tau}_{ij}(p)\right]^{-\theta}}{\sum_{i'\in I} c_i'^{-\theta} \sum_{p\in G}\left[\tilde{\tau}_{i'j}(p)\right]^{-\theta}}.\end{aligned} \tag{B.11}$$

By the law of large numbers, given the continuum of loan products, this is also the share of all loans extended from i to j in industry ω and that take route p, $\lambda_{ijp\omega}$.

B.3 Proof of Lemma 2 - Expected Cost

Assume banks choose the route that minimizes the cost of sending a loan from country i to country j. Let A be the inverse cost matrix defined above, and denote by b_{ij} an element of the matrix $B \equiv (\mathbf{I} - A)^{-1}$. Then, the network cost τ_{ij} is:

$$\tau_{ij} = \gamma b_{ij}^{-1/\theta}$$

where

$$b_{ij} = \sum_{p\in G_{ij}} \tilde{\tau}_{ij}(p)^{-\theta} \equiv \sum_{p\in G_{ij}} \prod_{k=1}^{K_p} e_{k-1,k}(p)^{-\theta}.$$

B.3.1 Expected Cost

The cost between locations i and j is the expected intermediation cost τ_{ij} from i to j across all lenders. Using also the distribution in (B.8):

$$\begin{aligned}\tau_{ij} \equiv \mathbb{E}_\omega\left[\tau_{ij}(p)\right] = \int_{p\in G_{ij}} \tau_{ijp}(\omega)\, dp = \int_0^\infty \tau\, dH_{ij\omega}(\tau)\\ = \Gamma\left(\frac{1+\theta}{\theta}\right)\left[\sum_{p\in G_{ij}} \tilde{\tau}_{ijp}^{-\theta}\right]^{-1/\theta}.\end{aligned} \tag{B.12}$$

B.3.2 Expected Cost with Paths

Let $\gamma \equiv \Gamma\left(\frac{1+\theta}{\theta}\right)$. Following Allen and Arkolakis (2022) and taking into account the length of the path, and all possible lengths:

$$\begin{aligned}
\tau_{ij}^{-\theta} &= \gamma^{-\theta} \sum_{p \in G_{ij}} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta} = \gamma^{-\theta} \sum_{K=0}^{\infty} \sum_{p \in G_{ij}(K)} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta} \\
&= \gamma^{-\theta} \sum_{K=0}^{\infty} \sum_{p \in G_{ij}(K)} \prod_{k=1}^{K} a_{ij} = \gamma^{-\theta} \sum_{K=0}^{\infty} A_{ij}^{K},
\end{aligned}$$

where we have used the definition $e_{k-1,k}^{-\theta} \equiv a_{ij}$. As long as the spectral radius of A is less than one, then:[48]

$$\sum_{K=0}^{\infty} A^{K} = (\mathbf{I} - A)^{-1} \equiv B. \tag{B.13}$$

Hence:

$$\tau_{ij} = \gamma b_{ij}^{-1/\theta} \Leftrightarrow b_{ij} = \sum_{p \in G_{ij}} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta}. \tag{B.14}$$

B.4 Proof of Lemma 3 - Locational Gravity

The probability of going through an edge kl, conditional on origin i and destination j, is:

$$\begin{aligned}
\psi_{kl|ij} =& \sum_{K=0}^{\infty} \sum_{p \in G_{ij}^{kl}(K)} \frac{\tilde{\tau}_{ij}(p)^{-\theta}}{\sum_{K=0}^{\infty} \sum_{p \in G_{ij}(K)} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta}} \\
=& \frac{1}{b_{ij}} \sum_{K=0}^{\infty} \sum_{p \in G_{ij}^{kl}(K)} \tilde{\tau}_{ij}(p)^{-\theta} = \frac{1}{b_{ij}} \sum_{K=0}^{\infty} \sum_{p \in G_{ij}^{kl}(K)} \prod_{k=1}^{K} e_{k-1,k}(p)^{-\theta} \\
=& \frac{1}{b_{ij}} \left(b_{ik} a_{kl} b_{lj}\right),
\end{aligned} \tag{B.15}$$

where in the last step we isolate the kl step and follow the matrix algebra in Allen and Arkolakis (2022), such that $\sum_{K=0} \sum_{L=0}^{K-1} A^{L} A A^{K-L-1} = (I-A)^{-1} A (I-A)^{-1}$.

[48] A sufficient condition for the spectral radius being less than one is if $\sum_j e_{ij}^{-\theta} < 1$ for all i.

The conditional probability is:

$$\psi_{kl|ij} = \frac{b_{ik}a_{kl}b_{lj}}{b_{ij}} = \left(\gamma \frac{\tau_{ik}e_{kl}\tau_{lj}}{\tau_{ij}}\right)^{-\theta} \tag{B.16}$$

where the last step was obtained by plugging the expected cost definition in (B.14).

B.5 Aggregate Interest Rate

Following standard derivations in Eaton and Kortum (2002):

$$\begin{aligned} R_j^{1-\sigma} &= \int_{\Omega} r_{ij}(\omega)^{1-\sigma}\, d\omega = \int_0^{\infty} p^{1-\sigma}\, dG_j(p) = \int_0^{\infty} p^{1-\sigma} \frac{d}{dp}(1-\exp\{-p\Phi\})\, dp \\ &= \Phi^{-\frac{1-\sigma}{\theta}} \Gamma\left(\frac{\theta+1-\sigma}{\theta}\right), \end{aligned}$$

we can write the aggregate interest rate in j as:

$$R_j = \vartheta \left(\sum_i c_i^{-\theta} b_{ij}\right)^{-\frac{1}{\theta}} \tag{B.17}$$

where $\vartheta = \Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)^{\frac{1}{1-\sigma}}$.

B.6 Identification of Edge Shocks in the Data

To identify regulatory-driven edge shocks, we considered four waves of the database "Banking Regulation and Supervision around the World" compiled by Barth, Caprio and Levine (2020) through questionnaires sent to the banking regulatory and supervisory authorities of 180 countries. The database covers the years from 1996 to 2012. Although there are many cases of regulatory changes that impact national and multinational lending simultaneously, we focus on isolating those instances in which regulations on the activities of multinational banks were altered (temporarily or permanently) without a corresponding change in the regulations of domestic banks—a pure edge shock. Precisely, we used as indicator of domestic bank regulation the “entry into banking requirements” index and as indicator of multinational bank regulation the “limitations on foreign bank entry/ownership” index. We then computed the changes in these indicators across survey waves (whenever consecutive data across two survey waves were available). Finally, we identified all instances in which there was an increase or decrease of the index of regulation on multinational banks not accompanied by a corresponding change in the domestic bank regulation index. We counted 30 such episodes. In six of these episodes the index of regulation on multinational banks changed by two units or more, signalling the introduction or removal of at least two restrictions on multinational banks' operations.

B.7 More Details on Calibration

The countries used in the calibration (determined by data availability) comprise 25 countries for Europe, 3 countries for North America, and 17 countries for Asia. The full list is as follows: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, USA, Canada, Mexico, China, Hong Kong, India, Indonesia, Israel, Japan, Jordan, South Korea, Malaysia, Philippines, Russia, Saudi Arabia, Singapore, Taiwan, Thailand, Turkey, Ukraine.

Information for computing the values of the fundamental determinants of the financing cost spread, namely, euclidean cultural distance, geographic distance, creditor rights difference, and bank capital regulation stringency difference, comes from the following various sources. The physical distance between the capitals of two countries is drawn from the CEPII databases, while the Euclidean distance between the cultures of two countries is drawn from the World Values Survey data. The (absolute) value of the difference between the creditor rights in two countries is drawn from Djankov, McLiesh, and Shleifer (2007), while that of the capital regulation stringency difference between two countries is originally drawn from Barth et al. (2013) (see also Gao and Jang (2021) and Karolyi and Taboada (2015)). We next obtain a target financing cost spread based on the estimates in Giannetti and Yafeh (2012) and Gao and Jang (2021). We then compute population-weighted averages of these bilateral spreads across country pairs in order to obtain the target financing cost wedges between regions.

C Additional Figures and Tables

Table A1: Gross Locational and Excess Loan Flows vs Deposits and GDP

	(1)	(2)	(3)	(4)	(5)	(6)
	2001			2017		
	Locational Flows	Locational Flows	Excess Flows	Locational Flows	Locational Flows	Excess Flows
Deposits	0.47			0.60		
	(0.15)			(0.15)		
GDP		0.33	-0.02		0.51	-0.01
		(0.16)	(0.01)		(0.13)	(0.01)
N	35	35	35	35	35	35
R^2	0.26	0.10	0.33	0.38	0.26	0.16

Note: This table reports the relationship between total gross locational loan flows (inward plus outward, BIS), total deposits (IMF), and GDP, as depicted in Figure 2, for 35 countries. Excess flows are the ratio of locational flows over deposits. Columns 1-3 report univariate regression coefficients for data from 2001, columns 4-6 for 2017. Robust standard errors in parentheses.

Table A2: Bilateral Locational Loan Flows vs Lending Frictions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Credit Rights Distance	-0.799	-0.683	-0.408									
	(0.240)	(0.319)	(0.281)									
Capital Regulatory Distance				-0.187	-0.096	-0.028						
				(0.162)	(0.053)	(0.239)						
Cultural Distance							-1.233	-1.373	-0.608			
							(0.362)	(0.369)	(0.278)			
Geographic Distance										-1.214	-1.947	-1.624
										(0.407)	(0.294)	(0.307)
GDP Reporting		0.564			0.609			0.668			1.234	
		(0.305)			(0.216)			(0.222)			(0.173)	
GDP Destination		0.677			0.770			0.839			1.268	
		(0.195)			(0.152)			(0.162)			(0.203)	
Year Fixed Effects	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N
Year-Reporting and Year-Destination FEs	N	N	Y	N	N	Y	N	N	Y	N	N	Y
Adj. R-Squared	0.032	0.131	0.647	0.021	0.156	0.638	0.115	0.276	0.650	0.218	0.587	0.747
N	2029	2029	2018	2710	2710	2709	2710	2710	2709	2624	2624	2623

Note: This table reports the relationship between bilateral locational loan flows (claims plus deposits) and measures of bilateral frictions (see Figure 3 for definitions of the four frictions) for all years between 2001 and 2019. Columns 1,4,7, and 10 report coefficients with year fixed effects. Columns 2,5,8, and 11 add controls for GDP of reporting country and destination country. Columns 3, 6, 9, and 12 add year-by-reporting country and year-by-destination country fixed effects. Standard errors are clustered two ways by reporting country and destination country.

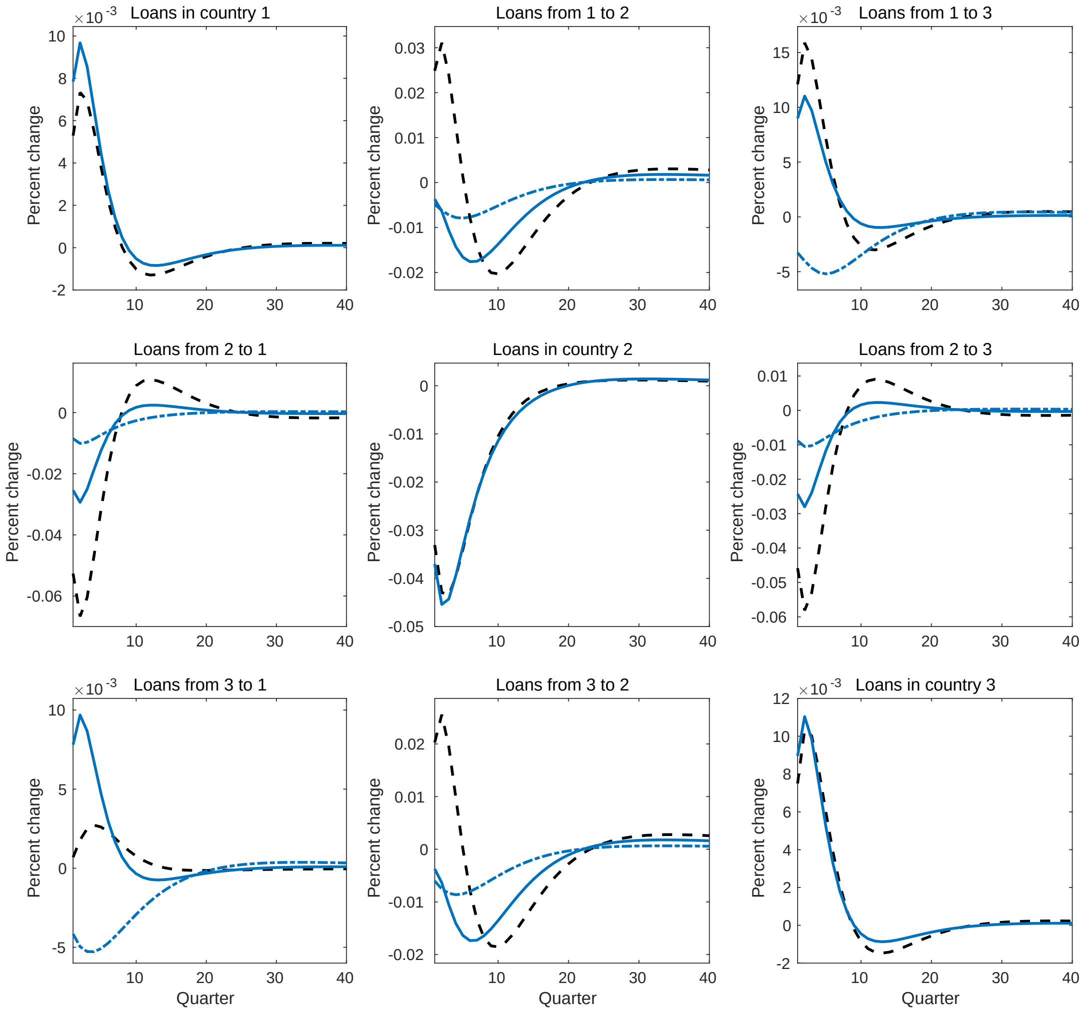

Figure A1: Node Shock, Full Set of Impulse Responses

Note: The figure plots the full set of impulse response functions of bilateral loan flows to a 1% decrease in the TFP of region 2. The solid blue line refers to ultimate flows in our baseline path economy, the dashed-dotted blue line refers to locational flows, while the dashed black line refer to bilateral lending in an Eaton and Kortum (2002) economy without paths.

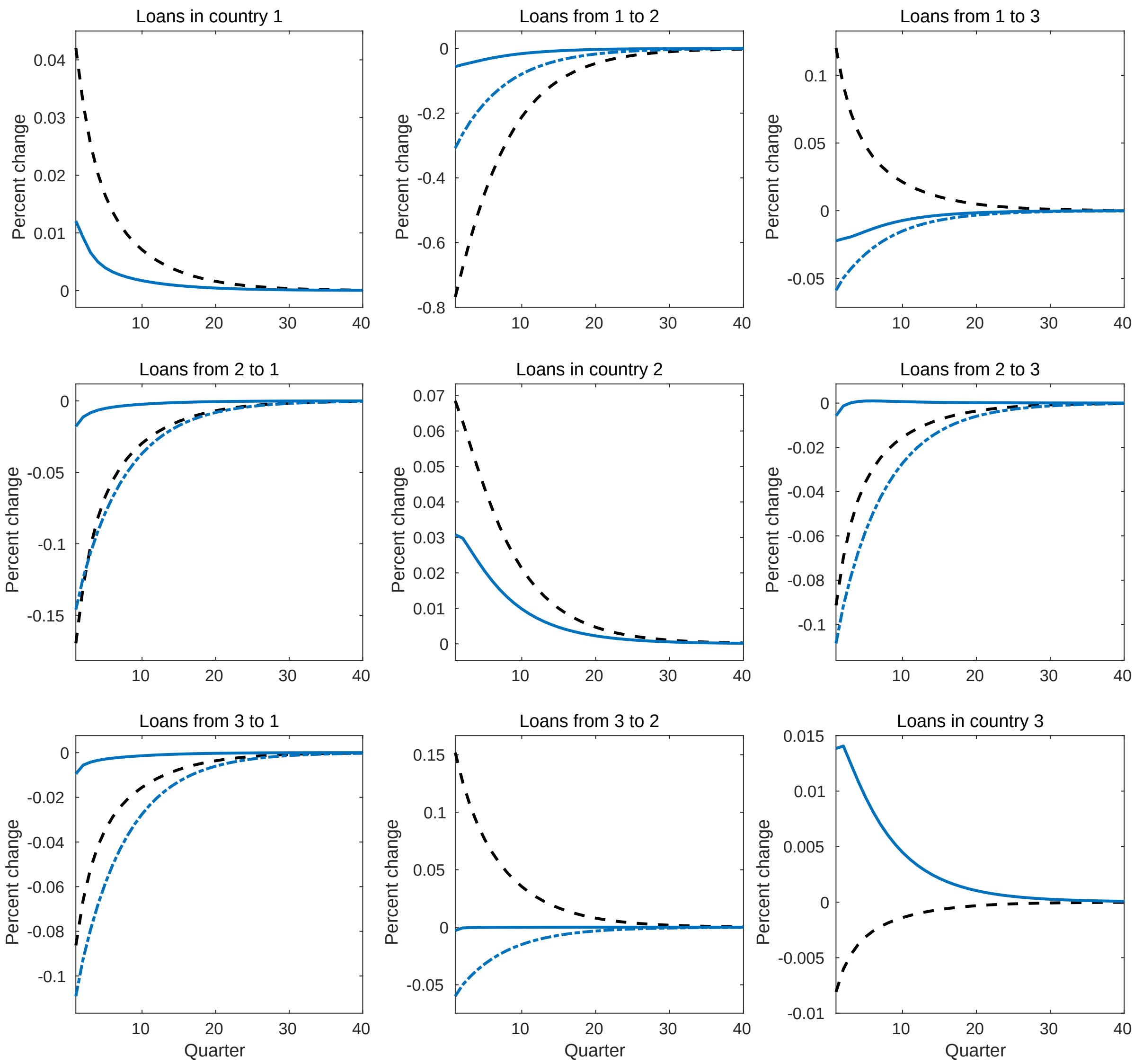

Figure A2: Edge Shock, Full Set of Impulse Responses

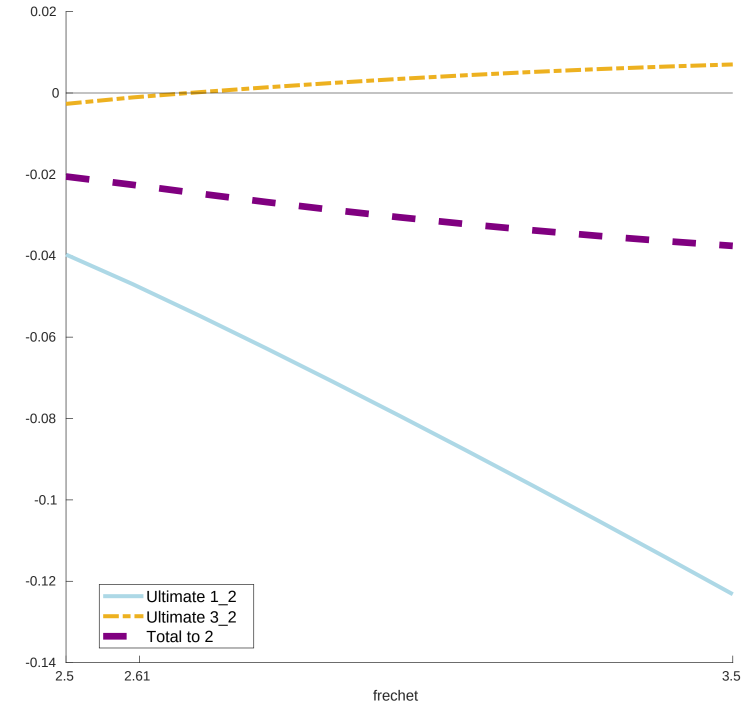

Figure A3: Complexity and Loan Responses to Edge Shock e_{12}, 4-Period Average

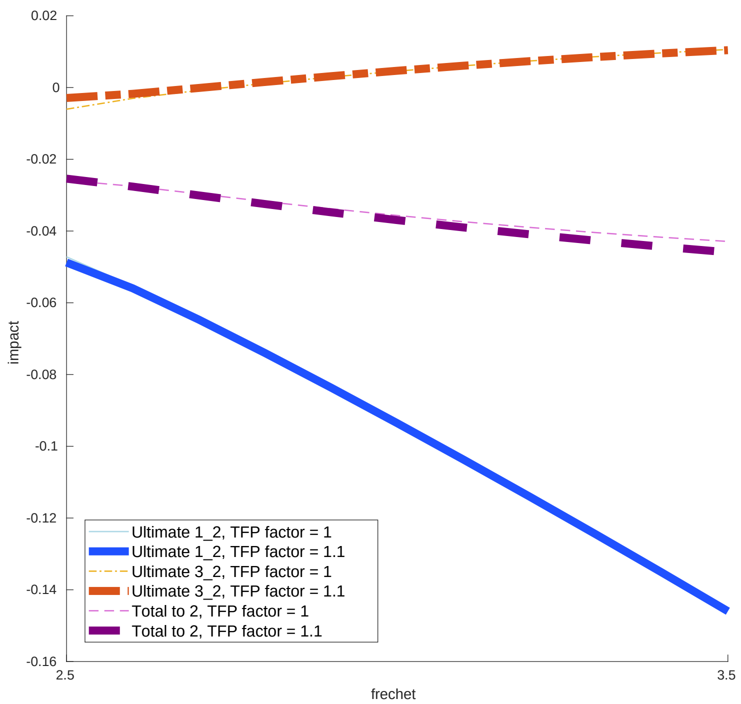

Figure A4: Complexity, Influence of TFP of Country 3

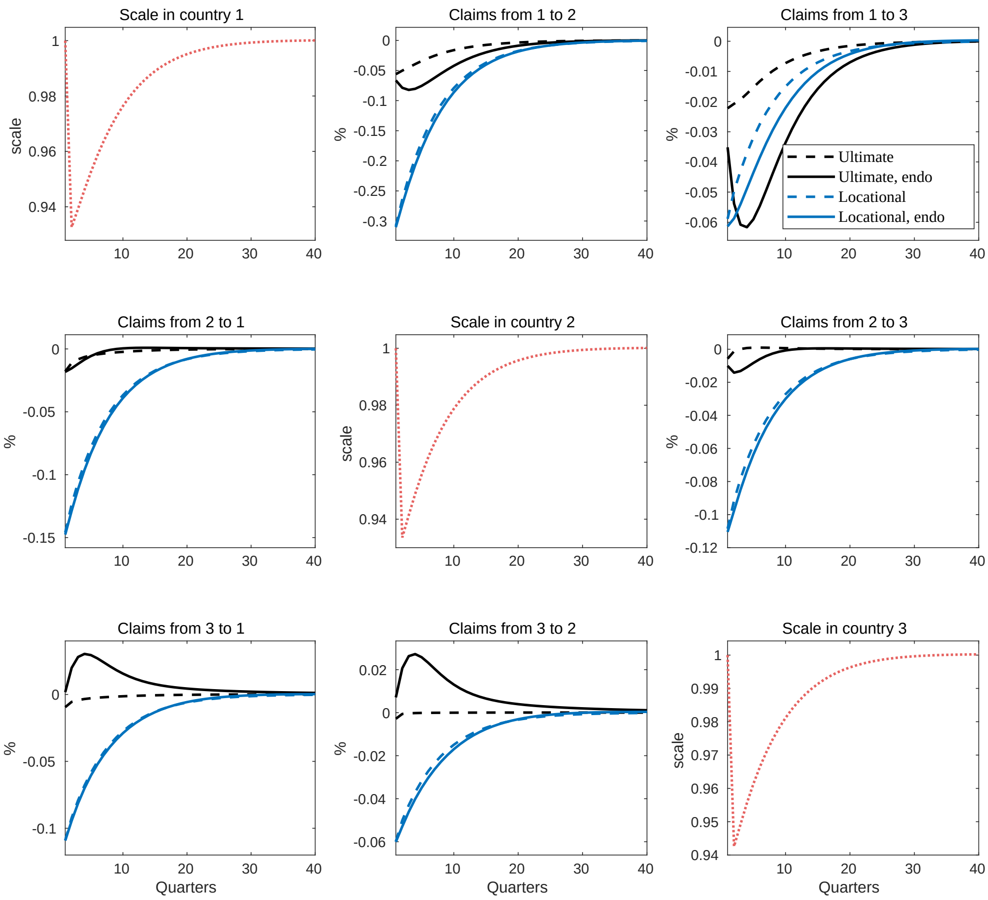

Figure A5: Complexity, Endogenous Banking Productivity

Note: The figure plots the full set of impulse response functions to a 10% increase in the edge cost e_{12}. The dashed lines refer to ultimate (black) and locational (blue) flows in our baseline path economy, while the solid lines refer to the model with endogenous banking productivity. The dotted red lines on the diagonal figures plot the endogenous scale of the banking productivity for the respective region.

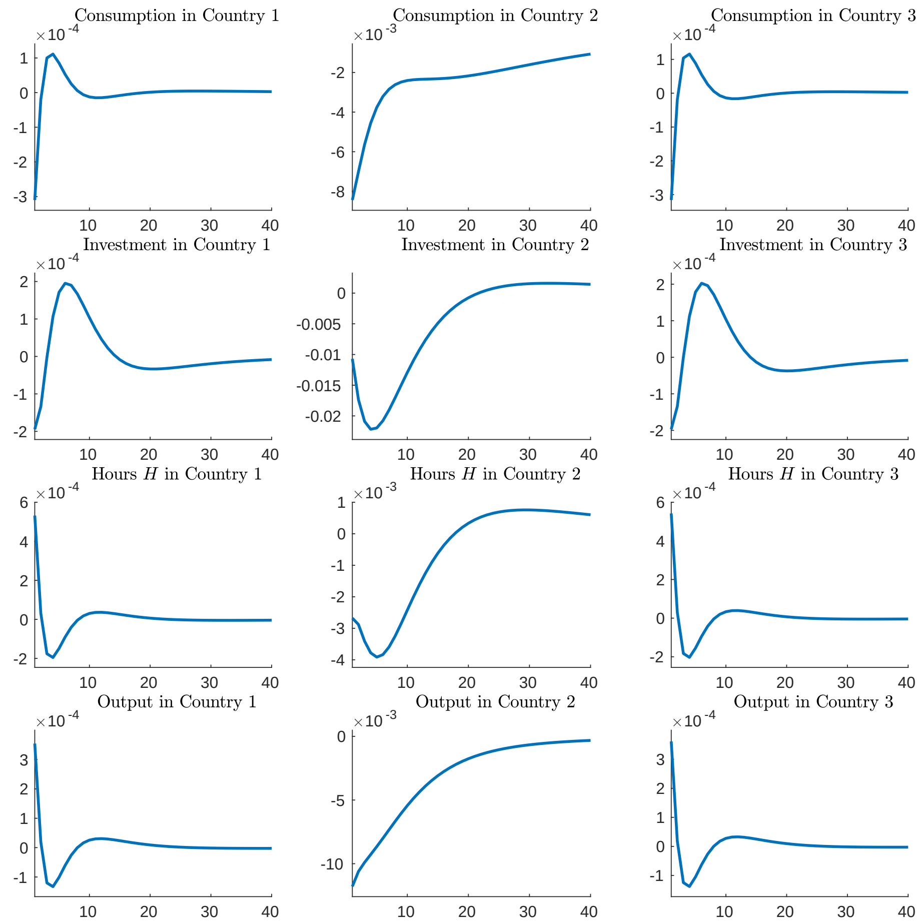

Figure A6: Responses of Real Sector Variables to Node Shock

Note: The figure plots the impulse response functions of selected real sector variables to a 1% decrease in the TFP of region 2.

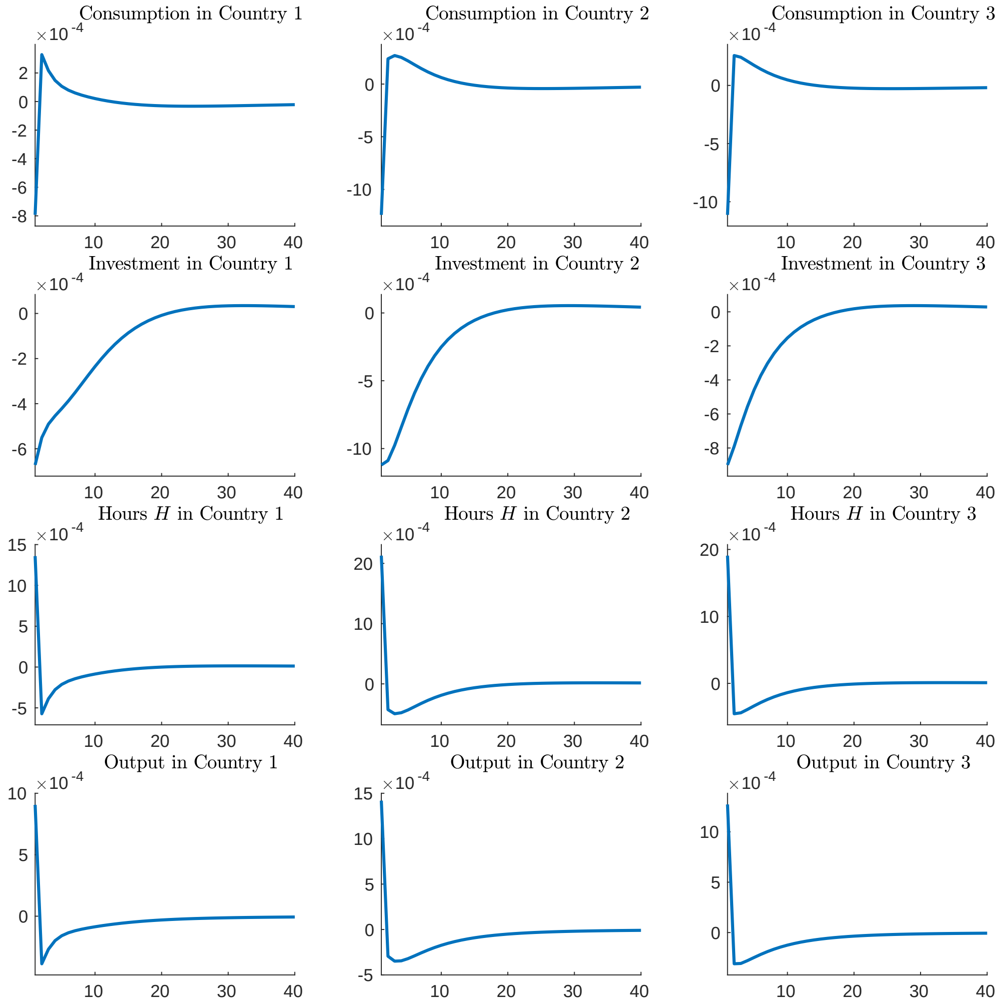

Figure A7: Responses of Real Sector Variables to Edge Shock

Note: The figure plots the impulse response functions of selected real sector variables to a 10% increase in the edge cost e_{12}.

D A Melitz-type Setting

In this Appendix, we consider a Melitz (2003) economy deviation from our main model, where bank productivity (formerly z) is heterogeneous across banks. For simplicity, we adopt sequential selection as in the appendix of Allen and Arkolakis (2022). Banks face entry costs creating Melitz-style selection, offering a product which is differentiated (across countries as well), then minimize costs creating Eaton-Kortum style selection on paths, then mark up over marginal cost. An alternative approach would consider cross-country oligopolistic competitive pressures.

As in Melitz (2003), dynamics are straightforward, with a stable i.i.d. Pareto distribution of productivity over time. The selection threshold is a function of within-period market access and competitive pressures.

The marginal cost of lending is:

$$r_{ij}(\omega,p) = \frac{\sigma}{\sigma-1}\frac{c_i}{\phi}\frac{\tilde{\tau}_{ij}(p)}{\xi_{ij}(p,\omega)} \tag{D.1}$$

where c_i is defined in equation (12), $\frac{\sigma}{\sigma-1}$ is the markup, ϕ is the Pareto-distributed productivity, and ξ is the Fréchet-distributed path (as in the baseline). We first derive the *unconditional* probability that taking a path p to lend from country i to j for a given loan product ω entails a value of $r_{ij}(p,\omega)$ less than a constant r:

$$G_{ijp\omega}(r) \equiv \Pr\Big(r_{ij}(p,\omega) \leq r\Big) = 1-\exp\left\{-\left[\frac{\sigma}{\sigma-1}\frac{c_i}{\phi}\frac{\tilde{\tau}_{ij}(p)}{r}\right]^{-\theta}\right\} \tag{D.2}$$

Hence, the conditional interest rate distribution is:

$$G_{ij\phi}(r) \equiv \Pr\left(\min_{p\in G} r_{ij}(p,\omega) \leq r\right) = 1-\exp\left\{-(r\phi)^{\theta}\left(\frac{\sigma}{\sigma-1}\right)^{-\theta} c_i^{-\theta}\sum_{p\in G}\Big[\tilde{\tau}_{ij}(p)\Big]^{-\theta}\right\} \tag{D.3}$$

Second, the probability that bank ω in i is able to offer country j loan $\omega\in\Omega$ for a cost less than τ reads:

$$H_{ijp\omega}(\tau,p) \equiv \Pr\Big(\tau_{ij}(p,\phi) \leq \tau\Big) = 1-\exp\left\{-\left[\frac{\tilde{\tau}_{ij}(p)}{\tau}\right]^{-\theta}\right\} \tag{D.4}$$

and therefore the conditional cost distribution is:

$$H_{ij\omega}(\tau) \equiv \Pr\left(\min_{p\in G} \tau_{ij}(p,\omega) \leq \tau\right) = 1 - \exp\left\{-\tau^{\theta} \sum_{p\in G} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta}\right\} \tag{D.5}$$

As a result, the equilibrium probability is:

$$\begin{aligned}
\psi_{ijp\omega} \equiv& \Pr\left(\operatorname*{argmin}_{s} \tau_{ij}(s,\omega) = p \cap \min_{s} \tau_{ij}(s,\omega) \leq \tau\right) \\
=& 1 - H_{ij\omega}\left(\tau_{ij}(p,\omega)\right) \\
=& \int_0^{\infty} \exp\left\{-\tau^{\theta} \sum_{p\in G} \left[\tilde{\tau}_{ij}(s)\right]^{-\theta}\right\} \tau^{\theta-1} \theta \left[\tilde{\tau}_{ij}(p)\right]^{-\theta} \, d\tau \\
=& \frac{\tilde{\tau}_{ij}(p)^{-\theta}}{\sum_{K=0}^{\infty} \sum_{p\in G_{ij}(K)} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta}}
\end{aligned}$$

D.1 Aggregate Interest Rate

Harmonic average productivity Next, we derive the average productivity post-selection:

$$\begin{aligned}
\int_{\phi^*_{ij}}^{\infty} \phi^{\sigma-1} \, dG_{ij}(\phi) =& \int_{\phi^*_{ij}}^{\infty} \phi^{\sigma-1} \, \frac{dG_{ij}(\phi)}{d\phi} d\phi \\
=& \frac{\kappa}{\kappa+1-\sigma} \left(\left[\frac{\sigma}{\varsigma} \frac{c_i f_j}{X_j R_j^{\sigma}}\right]^{\frac{1}{\sigma-1}} \frac{\sigma}{\sigma-1} c_i \left(\sum_{p\in G} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta}\right)^{-\frac{1}{\theta}} \right)^{\sigma-\kappa-1} \\
=& \varpi \left(\left[\frac{c_i f_j}{X_j R_j^{\sigma}}\right]^{\frac{1}{\sigma-1}} c_i \left(\sum_{p\in G} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta}\right)^{-\frac{1}{\theta}} \right)^{\sigma-\kappa-1}
\end{aligned} \tag{D.6}$$

where $\varpi = \frac{\kappa}{\kappa+1-\sigma} \left(\frac{\sigma}{\sigma-1}\right)^{\sigma-\kappa-1} \left(\frac{\sigma}{\varsigma}\right)^{\frac{\sigma-\kappa-1}{\sigma-1}}$.

Harmonic average interest rate, both paths and productivity

Let N_{ij} the mass of firms with $\phi \geq \phi^*$. We can derive the harmonic average interest rate:

$$\begin{aligned}
\mathbb{E}_{\phi,\xi}\left[r_{ij}(\omega)^{1-\sigma}\right] &= \int_{\Omega} r_{ij}(\omega)^{1-\sigma}\, d\omega \\
&= \vartheta c_i^{1-\sigma}\left(\sum_{p\in G}\left[\tilde{\tau}_{ij}(p)\right]^{-\theta}\right)^{\frac{\sigma-1}{\theta}} \frac{N_{ii}}{N_{ij}}\left(\left[\frac{c_i f_j}{X_j R_j^{\sigma}}\right]^{\frac{1}{\sigma-1}} c_i\left(\sum_{p\in G}\left[\tilde{\tau}_{ij}(p)\right]^{-\theta}\right)^{-\frac{1}{\theta}}\right)^{\sigma-\kappa-1} \\
&= \vartheta\frac{N_{ii}}{N_{ij}}\left(c_i\left(\sum_{p\in G}\left[\tilde{\tau}_{ij}(p)\right]^{-\theta}\right)^{-\frac{1}{\theta}}\right)^{\kappa}\left[\frac{c_i f_j}{X_j R_j^{\sigma}}\right]^{\frac{\sigma-\kappa-1}{\sigma-1}} \qquad \text{(D.7)}
\end{aligned}$$

where $\vartheta = \varsigma\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \varpi = \varsigma^{-\frac{\kappa}{1-\sigma}}\left(\frac{\kappa}{\kappa+1-\sigma}\right)\left(\frac{\sigma}{\sigma-1}\right)^{-\kappa}\sigma^{\frac{\sigma-\kappa-1}{1-\sigma}}$.
In the third line we used the density of banks sending loans from i to j:

$$N_{ij} = \left(1 - G_i(\phi_{ij}^*)\right)N_{ii} \qquad \text{(D.8)}$$

Corollary

With zero fixed costs, the threshold coincides with the lower bound of the support of the Pareto distribution, assumed here to be 1, hence:

$$\int_{\Omega} r_{ij}(\omega)^{1-\sigma}\, d\omega = \varsigma\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} c_i^{1-\sigma}\left(\sum_{p\in G}\left[\tilde{\tau}_{ij}(p)\right]^{-\theta}\right)^{\frac{\sigma-1}{\theta}} N_{ii}\frac{\kappa}{\kappa+1-\sigma} \qquad \text{(D.9)}$$

Interest rate *Let $G_{ij}(\phi)$ be the Pareto (equilibrium) probability density function of the productivities of banks from country i that send loans to country j such that the measure of banks from country i with productivity ϕ is $N_i\, dG_i(\phi)$. Then, we can write the aggregate interest rate in j as:*

$$R_j = \vartheta\left(\sum_i N_{ii} c_i^{1-\sigma} b_{ij}^{\frac{\sigma-1}{\theta}}\right)^{\frac{1}{1-\sigma}}$$

where $\vartheta = \frac{\kappa}{\kappa+1-\sigma}^{\frac{1}{1-\sigma}}\varsigma^{\frac{1}{1-\sigma}}\left(\frac{\sigma}{\sigma-1}\right)$.
Proof.

$$
\begin{aligned}
R_j^{1-\sigma} &= \sum_i N_{ii} \int_\Omega r_{ij}(\omega)^{1-\sigma} \, d\omega \\
&= \sum_i N_{ii} \varsigma \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} c_i^{1-\sigma} \left(\sum_{p\in G} \left[\tilde{\tau}_{ij}(p)\right]^{-\theta}\right)^{\frac{\sigma-1}{\theta}} \frac{\kappa}{\kappa+1-\sigma} \\
R_j &= \vartheta \left(\sum_i N_{ii} c_i^{1-\sigma} b_{ij}^{\frac{\sigma-1}{\theta}}\right)^{\frac{1}{1-\sigma}}
\end{aligned}
$$

where $\vartheta = \frac{\kappa}{\kappa+1-\sigma}^{\frac{1}{1-\sigma}} \varsigma^{\frac{1}{1-\sigma}} \left(\frac{\sigma}{\sigma-1}\right)$.

E Alternative Approch to Inference of Edge Costs

In this Appendix, we present an alternative estimation approach to our calibrated edge costs based off of the Supplementary Online Appendix of Allen and Arkolakis (2022). As we explain below, in our context this approach is severely limited by data availability.

Using IMF data on national deposits and credit in conjunction with LBS data, we estimate the following equation (equation B.8 in Allen and Arkolakis (2022)):

$$
e_{ij}^{-\theta} = \sqrt{\frac{\Xi_{ij} \times \Xi_{ji}}{\left(\frac{1}{2}\left(X_i^{\text{out}} + X_i^{\text{in}}\right) + \frac{1}{2}\left(\sum_{k=1}^N \Xi_{ik} + \sum_{k=1}^N \Xi_{ki}\right)\right) \times \left(\frac{1}{2}\left(X_j^{\text{out}} + X_j^{\text{in}}\right) + \frac{1}{2}\left(\sum_{k=1}^N \Xi_{jk} + \sum_{k=1}^N \Xi_{kj}\right)\right)}}
$$

where X_{in} is total credit to the non-financial sector from BIS, and X_{out} total deposits from IMF. These equations comprise a system relating edge costs across the entire network and total deposits in each country. Edge costs are assumed to be symmetric.

From the perspective of this estimation, a major limitation of the BIS LBS data is its incompleteness. Despite being the most comprehensive source on international banking positions, focusing on the "loans and deposits" component of cross-border exposures allows us to obtain a matrix of bilateral flows for only 22 countries scattered across 5 world regions (continents) with 191 bilateral pairs averaged between 2015 and 2019 (even considering a mirroring strategy from both claims and liabilities (Brei and von Peter, 2018)). These exclude major economies (e.g., China, Germany, Japan, the United Kingdom) as well as several smaller banking center countries. Without these economies, our exercise carried with it severe caveats. First, the network proximity of many of our 22 countries to missing nodes, through which a large number of banking flows move, will be mistaken by the estimation for network proximity to the existing major sources of deposits in our model (e.g., the United States and Western Europe), biasing our estimated costs. Furthermore, estimating over a highly incomplete set of economies excluding major countries potentially excludes major network links, making it impossible to invert the resulting estimated matrix of edge costs to obtain estimates of network proximity and the accompanying estimates of ultimate lending. Overcoming these obstacles is the subject of ongoing and future research.

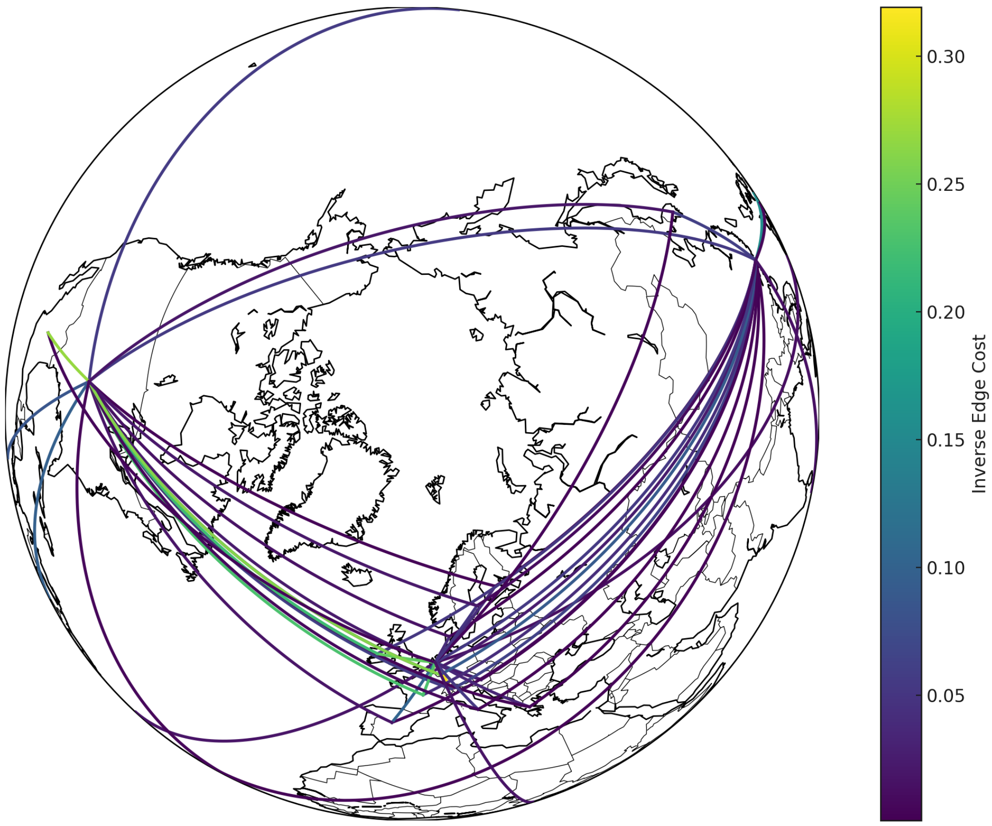

Figure A8: Edge Costs, Alternative Estimation

Note: The figure plots the inverse edge costs calculated using the estimation described in the text, for all bilateral links from the Hong Kong SAR, Netherlands, and United States. Lighter colors are higher inverse edge costs (lower frictions).

Figure A8 maps the inverse edge costs for 22 bilateral links to three countries: the United States, the Hong Kong SAR, and the Netherlands. Many of the intra-European connections to the Netherlands, which display high LBS flows despite the relatively low level of deposits in the Netherlands, are estimated to have low edge costs (lighter colors). This is consistent with the low intra-regional edge costs in our calibration in the main text, as are the relatively low estimated edge costs between the US and Mexico and the Hong Kong SAR and South Korea. Also consistent with our main text findings, where North American-Asian frictions are estimated to be high relative to European-Asian frictions, the inverse-edge costs between the US and Hong Kong SAR, a well-known Asian financial center, are also estimated to be about average despite high LBS flows. Indeed, while some of the lower-cost intra-region routes are EU-US, and the average costs between Europe and Asia are higher due to the data's omission of the low-friction Eastern Europe to Russia (Asia region) links, the lowest average cross-region frictions in these results are Europe-Asia, and the highest are North America-Asia. On the other hand, (not shown) Switzerland-Finland frictions appear to be half those of Switzerland-Sweden (also not shown). These may be the result of over-fitting and/or annual reporting fluctuations in the BIS LBS. While, given the small number of countries in this exercise and the above severe caveats to the direct estimation approach, we treat any direct comparison between this approach and the approch in the main text with extreme caution, we view their results as broadly consistent.