

International Coordination of Macroprudential Policies with Capital Flows and Financial Asymmetries

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Abstract

Lack of coordination for prudential regulation hurts developing economies but benefits advanced economies. We consider a two-country macro model in which countries have limited ability to issue state-contingent contracts in international markets, and equilibrium is constrained inefficient. Both countries have incentives to stabilize their economy by using prudential limits, but the emerging economy depends on the advanced economy to bear global risk. Intermediating global risk requires bearing systemic risk, which financially developed economies are unwilling to bear, preferring financial stability over credit flows. Advanced economies prefer tighter prudential limits than would occur with coordination, to the harm of emerging economies.

Keywords: International Capital Flows, Capital Controls, Macroeconomic Instability, Macroprudential Regulation, Policy Coordination, Spillovers, Financial Crises.

JEL classification: E44, F36, F38, F42, G15.

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1 Introduction

Following the Great Recession, economists and policy makers have debated the appropriate uses of prudential regulations to promote financial and macroeconomic stability.¹ Many hope that limiting risk-taking can decrease the frequency and duration of times of economic or financial stress. The effectiveness and implementation of these policies are complicated by interactions through international capital markets as well as the degree of international coordination. For these reasons, international coordination of prudential regulations have garnered renewed interest (Basel III was created in response to the financial crisis). This paper considers how the asymmetric nature of the global financial system is likely to affect policy coordination.

Economists have long recognized the crucial role of financial development to facilitate global intermediation.² Advanced economies (AEs) like the U.S. act as the “world’s global banker,” providing safe debt to emerging market economies (EMEs) and investing in risky foreign assets. For AEs to bear global risk on behalf of EMEs requires not only bearing fundamental risk but also exposing themselves to long-run financial instability; the frequency or duration of crises for AEs may be higher than would occur if AEs did not have leveraged aggregate balance sheets. While fundamental risk is generally compensated by excess returns ([Gourinchas et al., 2010](#)), with financial frictions or incomplete markets, sources of long-run instability need not be correctly compensated by returns (i.e., pecuniary externalities). Stability necessitates prudential policies.

In light of these concerns, our paper theoretically considers how systemic risk and global spillovers through international capital markets can affect countries’ capital account policy choices. To provide a meaningful analysis of systemic risk, we globally solve a stochastic macroeconomic model based off [Brunnermeier and Sannikov \(2015\)](#). Equilibrium features substantial nonlinearities caused by financial crises and is constrained inefficient due to a pecuniary externality. We deliberately maintain a parsimonious setup instead of including additional quantitative features to ensure theoretical clarity about the mechanisms driving our results. A global solution method is

¹Common prudential policies include bank capital requirements, counterparty concentration limits, interbank exposure limits, loan-to-value ratios, and reserve requirements, as well as limitations on capital inflows.

²See for example [Gourinchas and Rey \(2007\)](#), [Gourinchas et al. \(2010\)](#), [Lane and Milesi-Ferretti \(2007\)](#), and [Maggiori \(2017\)](#).

necessary because the economy spends significant lengths of time far from the steady state, so a perturbation around a deterministic steady state would poorly approximate dynamics. The infinite horizon setup also allows a meaningful analysis of recurring crises and long-run instability.

The model comprises two countries (AE and EME), which produce two goods and have limited ability to issue equity in international markets. The financial asymmetry is that the AE country has lower risk aversion than the EME country (see [Mendoza et al., 2009](#); [Gourinchas et al., 2010](#); [Stepanchuk and Tsyrennikov, 2015](#), for motivations). There are no trade frictions other than (potentially) regulations imposed by each country limiting capital inflows or domestic leverage. Because international financial markets are imperfect, financial crises occur in equilibrium and are inefficient due to the pecuniary externality arising from limited equity issuance. Because individual agents do not internalize their impact on asset prices, they borrow too much during booms and sell too quickly during busts, which amplifies shocks. As a result, global output depends endogenously on the relative share of wealth in each country, and debt imbalances (i.e., capital inflows or leverage) create volatility that increases the fraction of the time the global economy spends with misallocated capital. Higher leverage and capital inflows lead to a better *static* allocation of capital and higher growth at the cost of increased volatility that hurts *dynamic* global stability. A social planner would impose prudential controls in both the AE and the EME because countries use too much leverage in the laissez-faire competitive equilibrium. This result is consistent with the evidence in [Boar et al. \(2017\)](#) that countries that more frequently use macroprudential tools, all else equal, experience stronger and less volatile GDP growth.

The asymmetric role of bearing global financial instability creates different incentives for AEs and EMEs to use prudential policies. Because markets are incomplete and agents do not internalize the pecuniary externality, the so-called “exorbitant privilege” (excess return) from intermediating global risk does not sufficiently compensate AEs for the so-called “exorbitant duty” (losses in crises) of being the primary bearer of financial instability. Therefore, AEs have incentives to impose marginally tighter prudential regulations to “regulate away” sources of long-run financial instability (decreasing the frequency and duration of crises), which benefits AEs at the expense of EMEs. In contrast, EMEs want AEs to provide intermediation because AEs have superior risk-

bearing capacities. Policy coordination must balance these opposing incentives. We show that it is unlikely that advanced economies are willing to expose themselves to long-run financial instability on behalf of EMEs.

We first consider how regulation in one country positively affects outcomes and aggregate dynamics in the other (what we call “macro-level spillovers”). We find that tighter prudential regulations in the AE will decrease global volatility *when the AE is relatively poor* and improve the terms of trade for the AE *when the AE is relatively poor*. As a result, tighter regulations will decrease the frequency with which the AE is relatively poor. However, prudential controls by the AE increase the frequency with which the EME is relatively poor. Accordingly, the EME has strategic incentives to also tighten its policy in order to increase the frequency of being relatively rich. Incomplete markets due to limited equity issuance are crucial for this result. [Costinot et al. \(2014\)](#) show that countries have incentives to manipulate their terms of trade through taxes on capital flows only when their share of world output fluctuates over time. In the symmetric case of our model, if countries could freely issue equity, then their share of world output would be constant because of (perfect) risk sharing; with complete markets, there would be no reason to manipulate the terms of trade. We numerically solve for coordinated policies chosen by a global social planner and for uncoordinated policies chosen in Nash equilibrium and find that, due to these strategic incentives, Nash policies are tighter than would be chosen by a social planner. A global social planner would (for most Pareto weights) choose some degree of financial openness in the AE, allowing limited leverage and credit inflows to provide better international risk sharing because the AE has a higher risk tolerance. However, in Nash equilibrium the macro-level spillovers and strategic incentives lead both countries to close credit inflows completely (maximally regulate).

Crucially, the differences between Nash and optimal coordinated policies have asymmetric impacts on the AE and EME. When the AE does not use prudential controls but allows credit inflows and domestic leverage, the more risk averse EME benefits from better international risk sharing since the AE acts as a global intermediary, borrowing with safe debt to invest in risky capital. In Nash equilibrium, however, the AE is unwilling to act as a global intermediary, recognizing that credit flows create financial instability (longer and more frequent crises) that mostly harms

its own agents to the benefit of the EME. Relative to the laissez-faire competitive equilibrium and to coordinated outcomes that place less than 75% Pareto weight on the AE, the AE prefers the Nash equilibrium because it mitigates exposure to long-run financial instability. In contrast, the EME's welfare outcomes are worse under Nash policies. In principle, policy coordination leads to outcomes at least as good as the uncoordinated equilibrium, but achieving successful coordination is nontrivial, and the benefits may accrue unequally to participants. Understanding the incentives for coordination and the incentives that cause Nash equilibrium to differ from the coordinated equilibrium offer important insight for the conduct and creation of new international regulations.

Related Literature. Two other papers study similar questions as ours. [Agénor et al. \(2021\)](#) consider a linearized core-periphery model when financial intermediation is subject to frictions and show that policies trade off mitigating the short-run consequences of the financial accelerator (and spillovers) and the long-run effects of higher costs of capital. Our result that tighter policy provides strategic incentives for another country to tighten is consistent with the evidence in [Agénor et al. \(2021\)](#) who find that countries tend to set macroprudential policy more actively if their “neighbors” are more active. [Davis and Devereux \(2019\)](#) analyze an asymmetric two-country economy where one country faces domestic financial frictions and the other does not. Strategic interactions emerge because capital controls influence the severity of financial frictions through the terms of trade.

While we also find strategic interactions, our contribution is significantly distinct from these two papers because our model meaningfully incorporates the impact of systemic risk yet remains minimal in scale. Since [Agénor et al. \(2021\)](#) solve their model's dynamics with a first-order perturbation around a deterministic steady state, their analysis cannot comment about asset pricing nor systemic risk. The presence of financial frictions in a model does not necessarily imply a reasonable model of financial crises. Their model also requires bells and whistles that impose stronger assumptions about the structure of the global economy. In contrast, questions of systemic risk are fundamental to our paper. A global solution method allows us to meaningfully investigate the relationship between financial stability and strategic interactions with macroprudential policy. The continuous-time setup delivers exact expressions for important quantities like time-varying asset price volatility that would be difficult to calculate in a discrete-time approach. At the same time,

our model is comparatively parsimonious, which gives us greater confidence that the mechanisms in our paper would generalize to more complex models.

Unlike [Davis and Devereux \(2019\)](#), our paper does not permit analytical formulas, but by sacrificing analytical tractability, we can answer questions that [Davis and Devereux \(2019\)](#) cannot while maintaining a comparable level of theoretical clarity. Although the probability of a financial crisis is endogenous in [Davis and Devereux \(2019\)](#), they consider a three-period model, so the economy must return to “normal” in the final period. In contrast, the length of a financial crisis is endogenous in our model, so we can examine the degree to which strategic interactions with macroprudential tools influence not only the likelihood of a crisis but also the expected duration. Furthermore, we can study the economic impact of endogenously time-varying risk premia and long-run instability caused by repeated crises (see [Cochrane, 2017](#)). These additional dimensions are all crucial to discussions of systemic risk. We can also link nonlinear asset price volatility from fire sales to movements in the terms-of-trade due to capital controls, a feature absent from [Davis and Devereux \(2019\)](#).

Methodologically, our paper follows the stochastic continuous-time macro literature, pioneered by [Brunnermeier and Sannikov \(2014, 2015, 2016\)](#) and [He and Krishnamurthy \(2012, 2013, 2014\)](#), who apply continuous-time methods to analyze the non-linear global dynamics of economies with financial frictions. Most closely related, [Brunnermeier and Sannikov \(2015\)](#) demonstrate that closed capital accounts can improve welfare relative to open accounts because closing capital accounts reduce global instability arising from incomplete markets. We extend the analysis of [Brunnermeier and Sannikov \(2015\)](#) in two main ways: first, we allow each country to choose occasionally binding limits on capital inflows, with countries choosing potentially different policies; second, we use recursive preferences to disentangle effects driven by risk aversion from intertemporal substitution. By giving countries more flexibility in their policy choices, our model admits interesting policy spillovers and strategic considerations.

Our paper connects the literatures on the impact of capital controls on terms of trade and on macroprudential policy coordination (see below). In [Costinot et al. \(2014\)](#), for example, countries optimally “manipulate” the terms of trade by differentially taxing capital inflows (outflows) when

growth is higher (lower) than the rest of the world. We show that manipulating the terms of trade with simple leverage constraints on capital outflows proves an effective *macroprudential tool* in an economy with long-run financial instability due to incomplete markets. As in [Costinot et al. \(2014\)](#), the terms of trade creates individual incentives that are not necessarily aligned with social incentives. The literature on macroprudential policy coordination has studied several cases in which countries' policy choices create spillovers. Our novel insight and main contribution is that in a financially asymmetric world with systemic risk, this terms-of-trade mechanism has different normative implications for the welfare of AEs and EMEs. Incentives to manipulate the terms of trade complicates macroprudential policy coordination between AEs and EMEs because it misaligns their objectives. Both countries want to mitigate exposure to systemic risk, but EMEs want AEs to provide intermediation, which requires bearing some systemic risk.

Economists have tended to focus on the use of capital controls by EMEs to induce favorable terms of trade (see e.g. [Costinot et al., 2014](#); [Farhi and Werning, 2014](#)) or to mitigate the adverse consequences of fickle capital flows (see e.g. [Caballero and Simsek, 2016](#)). Similar to [Costinot et al. \(2014\)](#), [Farhi and Werning \(2014\)](#), and [Heathcote and Perri \(2016\)](#), in our model capital controls work by changing a country's terms of trade. However, the mechanism in our model is quite different. Rather than manipulating the risk-free interest rate and consumption behavior, capital controls primarily affect the terms of trade hedge identified by [Brunnermeier and Sannikov \(2015\)](#), which has a meaningful impact because of incomplete international markets. Limiting inflows alone is sufficient to benefit a country because the terms of trade hedge changes the stationary distribution of an economy, dynamically benefiting the financial position of the country in the long-run. An advantage of this approach is the simplicity of the policy instrument, as opposed to dynamically adjusting taxes on capital inflows/outflows.

The literature on macroprudential policy and pecuniary externalities includes [Caballero and Krishnamurthy \(2001, 2004\)](#), [Aoki et al. \(2009, 2010\)](#), [Bianchi \(2010, 2011\)](#), [Mendoza \(2010\)](#), and [Bianchi and Mendoza \(2010\)](#). [Korinek \(2016\)](#) provides a “first welfare theorem” when international markets lack frictions; there is role for coordination in our setting because international financial markets are imperfect. Within the continuous-time literature, [Caballero and Simsek \(2017\)](#)

consider how macroprudential policy can mitigate damage arising from belief heterogeneity, and [Phelan \(2016\)](#) illustrates that leverage limits improve macroeconomic stability by endogenously increasing the frequency with which the banking sector is well-capitalized. These results contrast with [Gârleanu et al. \(2015\)](#), where limits on leverage reduce agents' incentives to diversify and result in more correlated investments, increasing financial fragility. In our model, the effects of deteriorated terms of trade are larger when the country is more indebted and debt is non-contingent. Similarly, [Cao and Nie \(2017\)](#) highlight how incomplete markets alone without collateral constraints can generate significant amplification effects.

Our model also contributes to the literature on coordinated policy in international settings due to spillovers. [Banerjee et al. \(2016\)](#) explore the impact of spillovers from the macroeconomic policies of advanced economies to emerging market economies. [Acharya and Bengui \(2018\)](#) study capital flow management when AEs are at the ZLB. [Jin and Shen \(2019\)](#) studies macroprudential policy coordination spillovers among EMEs, who over-accumulate liquid assets, thus pushing down global rates. [Sergeyev \(2014\)](#) studies policy coordination in response to bank funding shocks, and global coordination works through affecting interest rate.

Outline. The remainder of the paper is organized as follows. Section 2 presents the model and the equilibrium conditions. Section 3 numerically solves for equilibrium in a calibrated economy and illustrates the effects of regulations. Section 4 discusses welfare and inefficiencies. Section 5 solves for optimal coordinated and uncoordinated policies (constant, fixed leverage limits). Section 6 concludes.

2 The Model

This section presents a modified version of the two-country model in [Brunnermeier and Sannikov \(2015\)](#). The global economy is populated by agents who live in two different countries, the AE and the EME. Variables related to the AE and the EME will be denoted by a subscript of A and E , respectively. Agents use capital to produce the two intermediate consumption goods a and b , and agents in the AE have productive advantages at producing good a (vice versa the EME and

b). Capital trades in a competitive market, but agents in each country may be subject to leverage constraints owing to capital account policies in each country. Financial frictions limit international credit flows to risk-free debt (non-state contingent contracts), hence markets are incomplete.

2.1 Setup

Technology. The production side of our economy is parsimonious and deliberately simple to ensure that the mechanisms behind our results are not driven by the particular details of our model's specification. Time is infinite and continuous. Capital can be used to produce either good a or good b , which are then combined into an aggregate (final) consumption good y_t , given by

$$y_t = (y_{a,t})^\alpha (y_{b,t})^{1-\alpha}, \quad (1)$$

where $y_{a,t}$ is the supply of good a and $y_{b,t}$ is the supply of good b .

Agents can produce goods a and b using linear production technologies. Agents in the AE have a superior technology for good a while agents in the EME have a superior technology for good b . Given k_t units of a capital, agents in the AE produce good a at rate $\bar{a}k_t$ and good b at rate $\underline{a}k_t$, where $\bar{a} > \underline{a} > 0$. The EME agents face the reverse situation, with good a produced at rate $\underline{a}k_t$ and good b at rate $\bar{a}k_t$. Output, therefore, depends endogenously on agents' risk-taking decisions.³

Denote the aggregate amount of world capital available at time t by K_t , and denote the share of world capital held by agents in the AE and in the EME by $\psi_{A,t}$ and $\psi_{E,t}$, respectively. Denote the fraction of world capital devoted to production of goods a and b by $\psi_{Aa,t}$, $\psi_{Ab,t}$, $\psi_{Ea,t}$, and $\psi_{Eb,t}$,

³Our main insights hold if output followed an endowment process and countries traded claims to endowments, because the incentive to manipulate terms of trade would remain (see Costinot et al. (2014)). However, we prefer a model with endogenous output for two reasons. First, a stationary distribution generally will not exist unless multiple trees and asymmetric consumption baskets are introduced, at which point the consequent model would be more complicated, not less. For intuition, suppose final output followed a single endowment process. The model would be the same as the case of no productivity differences in Brunnermeier and Sannikov (2015), who show that the stationary distribution would be degenerate. There would be no forces in the model that cause mean reversion in the share of global wealth. Multiple endowment processes with a symmetric consumption basket would not change this problem. Second, in the real world countries do face incomplete international markets and must manage a fundamental trade-off between static efficiency of capital allocation and dynamic stability. We want to better understand how countries behave when financial crises have consequences for real economic activity.

where the first superscript denotes the country employing the capital. By definition,

$$\psi_{Aa,t} + \psi_{Ab,t} + \psi_{Ea,t} + \psi_{Eb,t} = 1.$$

The supply of goods a and b per unit of capital then are given by

$$Y_{a,t} = \bar{a}\psi_{Aa,t} + \underline{a}\psi_{Ea,t}, \quad Y_{b,t} = \underline{a}\psi_{Ab,t} + \bar{a}\psi_{Eb,t},$$

yielding the total supply of the aggregate good

$$Y_t K_t = (Y_{a,t})^\alpha (Y_{b,t})^{1-\alpha} K_t. \quad (2)$$

Let the final good be the numeraire. Then the prices of a and b can be written as

$$P_{a,t} = \alpha \left(\frac{Y_{b,t}}{Y_{a,t}} \right)^{1-\alpha}, \quad P_{b,t} = (1-\alpha) \left(\frac{Y_{a,t}}{Y_{b,t}} \right)^\alpha. \quad (3)$$

There is a single type of physical capital. We model productivity shocks as shocks to “effective capital.” Capital owned by agents in Country i evolves according to

$$\frac{dk_t}{k_t} = (\Phi(\iota_t) - \delta) dt + \sigma dW_{i,t}, \quad (4)$$

where $\Phi(\cdot)$ is a standard investment technology, $\delta > 0$ is the rate of depreciation, σ is the volatility of capital growth, and $W_{i,t}$ is a standard Brownian motion. The two Brownian motions, $W_{A,t}$ and $W_{E,t}$, are independent and exogenous.

This specification is tractable and admits the interpretation of global aggregate shocks with idiosyncratic (negatively correlated) country specific shocks, which can capture country-specific productivity gains as well as redistributive shocks (e.g., international law suits). The reader may interpret these shocks as either shocks to capital located in a specific country (as in [Brunnermeier and Sannikov \(2015\)](#)) or productivity shocks based on the owner’s identity. Natural disasters are an example of the former while changes in a country’s technical knowledge are an example of

the latter. The latter interpretation does not require physical capital to cross borders when reallocated between countries: an agent in country i buys capital, wherever it is physically located, but the productivity of capital, and shocks to productivity, are determined by the owner's country of residence. (This assumption implies that if Apple runs a factory in China, the productivity of the factory is determined by Apple, and changes in productivity are driven by changes in Apple's characteristics.) The reader should choose whichever interpretation they prefer. As long as the shocks are either only to capital physically located in country i or only to capital owned by country i , the model is mathematically identical.⁴ It follows that aggregate capital follows the law of motion

$$\frac{dK_t}{K_t} = (\Phi(\iota_t) - \delta) dt + \psi_{A,t} \sigma dW_{A,t} + \psi_{E,t} \sigma dW_{E,t}. \quad (5)$$

To economize on notation, we will write $\mu_{K,t} = \Phi(\iota_t) - \delta$, $\Sigma_{K,t} = [\psi_{A,t} \sigma, \psi_{E,t} \sigma]^T$, and $d\mathbf{W}_t = [dW_{A,t}, dW_{E,t}]^T$.

Preferences. Agents have recursive preferences as in [Duffie and Epstein \(1992\)](#). Let γ_i be the risk aversion of agents in Country i . Consistent with the literature, we suppose agents in the AE have lower risk aversion ($\gamma_A \leq \gamma_E$), which implies that in equilibrium the AE will generally act as the “global intermediary” (use leverage). We assume asymmetric risk aversion because it focuses on the AE's role as a global intermediary rather than a particular micro-foundation for why the AE has a superior risk-bearing capacity.⁵ To focus our results on the role of the AE as the global

⁴In reality shocks may depend on both the country location and the country of ownership. For tractability in our paper we assume that only one of these matters. The specification of shocks in our model is therefore mathematically identical to the specification in [Brunnermeier and Sannikov \(2015\)](#). Appendix G shows that risk premia in our baseline model are similar to risk premia in a model which includes shocks dependent on both country location and the owner's country of residence. In the case of unit elasticity of substitution and risk aversion, there exists parametrizations such that risk premia are the same. Finally, we acknowledge that location-specific and owner-specific shocks are nontrivially different. The interpretation of the shocks matters for a quantitative estimation, but our purposes are theoretical. The actual equations are not changed, only the mapping to data.

⁵[Mendoza et al. \(2009\)](#) show that financial depth for AEs (greater contract enforcement) provides behavior similar to lower risk aversion and leads to negative average debt positions (global imbalances). [Gourinchas et al. \(2010\)](#) show that the debt positions of the US, generating so-called exorbitant privilege and exorbitant duty, are generated when the US has greater risk tolerance. [Stepanchuk and Tsyrennikov \(2015\)](#) also feature a model in which a less risk averse AE generates the global imbalance. An alternative modeling approach is asymmetry in the volatility of capital growth ($\sigma_A < \sigma_E$, see Appendix E.4). This approach delivers the same qualitative results regarding global risk bearing. Intuitively, a lower σ_A causes agents in the AE to price capital as if their risk aversion was lower than the EME's. See Footnote 9 for the exact equation. [Phelan and Toda \(2019\)](#) show that greater risk sharing by AEs through financial

intermediary, we assume a common discount rate ρ and unit elasticity of intertemporal substitution (EIS); however, our results also hold under CRRA preferences. The lifetime utility $V_{i,0}$ of Country i agents is given by

$$V_{i,0} = \mathbb{E} \left[\int_0^\infty f^i(c_{i,t}, V_{i,t}) dt \right], \quad (6)$$

where $f^i(\cdot)$ is the aggregator

$$f^i(c_{i,t}, V_{i,t}) = \rho(1 - \gamma_i)V_{i,t} \left(\log(c_{i,t}) - \frac{1}{1 - \gamma_i} \log((1 - \gamma_i)V_{i,t}) \right). \quad (7)$$

Markets for Physical Capital and Risk-free Bonds. Agents can trade ownership of capital in a competitive international market. We denote the equilibrium market price of capital per unit by q_t . Hence, capital k_t has market value $q_t k_t$. We postulate that q_t evolves endogenously according to

$$\frac{dq_t}{q_t} = \mu_{q,t} dt + \sigma_{qA,t} dW_{A,t} + \sigma_{qE,t} dW_{E,t}, \quad (8)$$

where $\mu_{q,t}$, $\sigma_{qA,t}$, and $\sigma_{qE,t}$ will be determined in equilibrium. The capital price determines the rate of internal investment according to Tobin's q :

$$\Phi'(\iota_t) = \frac{1}{q_t}. \quad (9)$$

Agents can also trade a risk-free bond that is in zero net supply. We denote the endogenously determined risk-free return by dr_t^F (we implicitly assume that the risk-free interest rate has absolutely continuous paths). Agents can borrow or save in the risk-free asset, but they may face borrowing limits imposed by regulation in their country. Agents cannot sell short capital.

Returns from Capital. The return from holding capital can be written as a diffusion process by summing capital gains $d(q_t k_t)/(q_t k_t)$ and the dividend yield from using capital to produce good a or b . We denote the return from an agent in Country i buying physical capital and using it to

innovations in securitized markets leads to global imbalances.

produce good j by dr_t^{ij} . Given equations (4) and (8) for the laws of motion for capital and the capital price and using Ito's Lemma, returns for the AE when producing good a are given by

$$dr_t^{Aa} = \left(\frac{\bar{a}P_{a,t}}{q_t} + \mu_{q,t} + \Phi(\iota_t) - \delta + \sigma\sigma_{qA,t} \right) dt + (\sigma + \sigma_{qA,t})dW_{A,t} + \sigma_{qE,t}dW_{E,t}, \quad (10)$$

and analogously for the other country-goods pairs.⁶ Notably, the AE shocks affect the returns to capital used in the AE directly (k_t changes) and indirectly through the effect on the capital price q_t ; however, the EME's shocks affect returns indirectly through the effect on the capital price (analogously for how shocks affect the EME's returns). To economize on notation, we will let $\Sigma_{ij,t}$ denote the volatility vector for Country i when producing good j . For example, the volatility vector of investing in good a for the AE is $\Sigma_{Aa,t} = [\sigma + \sigma_{qA,t}, \sigma_{qE,t}]^T$. Note that $\Sigma_{ia,t} = \Sigma_{ib,t}$.

Incomplete Markets, Financial Frictions, and Prudential Regulations. The single financial friction is the inability of countries to issue equity to each other. Agents can trade only risk-free bonds to purchase capital ownership, and as a result, markets are incomplete because they are limited to non-contingent financial contracts and cannot sell short capital. Reliance on risk-free debt generates financial instability that would be attenuated if agents could purchase equity in the other country. With free issuance of equity, countries could perfectly share aggregate risk and, when risk aversion is symmetric, consume constant shares of world output. The strategic interactions in our model would disappear in the symmetric case because, as [Costinot et al. \(2014\)](#) show, countries only have an incentive to manipulate capital flows only when their share of world output fluctuates over time.⁷ Finally, agents cannot sell short investment in the production of goods a and b . Incomplete international markets can be motivated by home bias in equity holdings,

⁶e.g., $dr_t^{Eb} = \left(\frac{\bar{a}P_{b,t}}{q_t} + \mu_{q,t} + \Phi(\iota_t) - \delta + \sigma\sigma_{qE,t} \right) dt + \sigma_{qA,t}dW_{A,t} + (\sigma + \sigma_{qE,t})dW_{E,t}$.

⁷Consider the example in Section IIIC of [Costinot et al. \(2014\)](#). When there are aggregate fluctuations, countries have incentives to tax capital *inflows* when they expect to earn a larger share of world output tomorrow and tax capital *outflows* in the opposite case. If they expect to earn the same share of world output tomorrow, however, then they have no incentive to manipulate the terms of trade. This example is the proper mapping of their paper to our model, where output is effectively exogenous under perfect risk sharing but becomes endogenous with incomplete markets. Note that the strategic interactions in our benchmark model with asymmetric risk aversion are essentially the same as those in the case of symmetric risk aversion. The primary differences are the welfare consequences.

micro-founded by agency problems and asymmetric information.⁸

The heart of our analysis involves prudential regulations in each country. We model prudential regulations as borrowing limits requiring that leverage from capital inflows not exceed a country-specific threshold. Within the context of our model, leverage constraints have the effect of limiting aggregate borrowing and therefore aggregate inflows. Maintaining the interpretation that capital ownership could be across borders, leverage constraints would therefore apply to total balance sheets (holdings of domestic and foreign capital assets), and so limits on borrowing via debt will limit total asset holdings. In reality, macroprudential policies such as leverage constraints are typically designed to target domestic excesses, not to address capital flow imbalances, and capital controls are envisioned as separate sets of tools. But the distinction is not always so clear. One example in which macroprudential policies were used to affect capital inflows is the case of Peru, which limited banks' derivatives positions as a way of stemming capital flows (see [Keller, 2018](#)). If the reader prefers a single interpretation of prudential limits in our model, then limits on capital inflows is the more robust interpretation, since heterogeneity within each country would imply that domestic leverage constraints could have different effects from limits on aggregate inflows. However, we recommend the reader interpret leverage constraints as a parsimonious way to capture the general effects of prudential tools that restrict capital inflows.

Consumption and Portfolio Choice. Each agent in Country i decides her consumption rate $c_{i,t}$ as well as how to allocate remaining wealth. Agents face a portfolio choice problem of how much capital to invest in the production of goods a and b , and how much to invest in the risk-free bond. For Country i , we denote the portfolio weights by $(x_{ia,t}, x_{ib,t}, 1 - x_{ia,t} - x_{ib,t})$, where $x_{ia,t}$ is the fraction of wealth invested in capital used to produce good a , $x_{ib,t}$ is the fraction of wealth invested in capital used to produce good b , and $1 - x_{ia,t} - x_{ib,t}$ is the fraction of wealth invested in the

⁸[Heathcote and Perri \(2013\)](#) provide an explanation for the empirically observed bias toward domestic asset holdings. See [Jensen and Meckling \(1976\)](#), [Bolton and Scharfstein \(1990\)](#), and [Holmström and Tirole \(1997\)](#) for theories of agency problems and asymmetric information limiting state-contingent contracts. More broadly, a home equity bias can be rooted in a fundamental trade-off between the diversification benefits and participation costs of investing in international markets. [Gârleanu et al. \(2015\)](#) show that limited market integration endogenously arises because of this trade-off, and since portfolios comprise more correlated securities, risk premia are higher relative to the frictionless benchmark.

risk-free asset. Portfolio weights $x_{ia,t}$ and $x_{ib,t}$ must be non-negative.

Denote $L_{A,t}$ and $L_{E,t}$ as the leverage constraints imposed on the AE and EME, respectively (we restrict leverage constraints to be deterministic functions of the state variable). These constraints impose that the market value of an agent's borrowing (debt) cannot exceed $L_{i,t}$ times their wealth (leverage of 0 implies no borrowing). In other words, for an agent in Country i

$$x_{ia,t} + x_{ib,t} \leq L_{i,t} + 1. \quad (11)$$

Given consumption rate $c_{i,t}$ and portfolio weights $(x_{ia,t}, x_{ib,t}, 1 - x_{ia,t} - x_{ib,t})$, the net worth $n_{i,t}$ of an agent evolves according to

$$\frac{dn_{i,t}}{n_{i,t}} = x_{ia,t}dr_t^{ia} + x_{ib,t}dr_t^{ib} + (1 - x_{ia,t} - x_{ib,t})dr_t^F - \frac{c_{i,t}}{n_{i,t}}dt. \quad (12)$$

Thus, agents' problems can be summarized as maximizing utility (6) subject to the budget constraint (12) together with the solvency constraint $n_t \geq 0$ and the borrowing constraint (11). With unit EIS, agents optimally consume a fraction ρ of net wealth, implying $c_t = \rho n_t$ for all agents.

Definition 1 (Equilibrium). *For any initial allocation of wealth, an equilibrium is a map from histories of shocks $\{W_s^A, W_s^E, s \in [0, t]\}$ to the allocation of capital $(\psi_{Aa,t}, \psi_{Ab,t}, \psi_{Ea,t}, \psi_{Eb,t})$ and the aggregate consumption good $(C_{A,t}, C_{E,t})$ as well as price q_t and risk-free rate dr_t^F such that*

1. *All agents solve their optimal consumption and portfolio choice problems, subject to the solvency constraint on their net worth and leverage constraints.*
2. *Capital, consumption, and debt markets clear.*

2.2 Solving for Equilibrium

Since countries cannot issue equity internationally, an agent's portfolio decisions depend on her level of wealth, so equilibrium depends on the aggregate level of wealth in each country. As the AE's wealth increases, its aggregate capital holdings will increase, which will increase the fraction of global capital used to produce good a . Thus, capital allocations and final good production

will depend on country's relative wealth, which will vary in response to global shocks. We use stochastic continuous-time methods to solve for global equilibrium dynamics. We solve for a recursive (or Markov), rational-expectations equilibrium in which the single state variable is the relative wealth of the two countries. Derivations and proofs are in Appendix A.

Denote the aggregate net worth of agents in the AE at time t by $N_{A,t}$. Then the relative share of net wealth held by the AE is defined to be $\eta_t \equiv \frac{N_{A,t}}{q_t K_t}$. Thus, η_t represents the share of global wealth held by the AE. The aggregate portfolio choice of the AE and EME can be written respectively as

$$\left(\frac{\psi_{Aa,t}}{\eta_t}, \frac{\psi_{Ab,t}}{\eta_t}, 1 - \frac{\psi_{A,t}}{\eta_t} \right), \quad \left(\frac{\psi_{Ea,t}}{1 - \eta_t}, \frac{\psi_{Eb,t}}{1 - \eta_t}, 1 - \frac{\psi_{E,t}}{1 - \eta_t} \right),$$

where $\psi_{A,t} = \psi_{Aa,t} + \psi_{Ab,t}$ and $\psi_{E,t} = \psi_{Ea,t} + \psi_{Eb,t}$. Equilibrium consists of an endogenous law of motion for η_t and capital allocations and prices that are functions of the state variable η_t .

The Value Function. The aggregator function (7) implies agents have the value functions

$$V_{A,t} = \frac{(\xi_t n_{A,t})^{1-\gamma_A}}{1-\gamma_A}, \quad V_{E,t} = \frac{(\zeta_t n_{E,t})^{1-\gamma_E}}{1-\gamma_E}, \quad (13)$$

where ξ_t and ζ_t capture the forward-looking value of an additional dollar of net worth for agents in the AE and the EME respectively. We postulate that in equilibrium

$$\frac{d\xi_t}{\xi_t} = \mu_{\xi,t} dt + \Sigma_{\xi,t} \cdot d\mathbf{W}_t, \quad \frac{d\zeta_t}{\zeta_t} = \mu_{\zeta,t} dt + \Sigma_{\zeta,t} \cdot d\mathbf{W}_t. \quad (14)$$

Asset Pricing Equations. When leverage constraints do not bind, agents choose portfolios such that excess returns equal the covariance of the returns with their stochastic discount factor (SDF). We can separate the covariance into two terms. For AE agents, the first term is denoted by $\varsigma_{Aa,t}$, and the second term is denoted by $\varsigma_{\xi A,t}$ ($\varsigma_{Eb,t}$ and $\varsigma_{\zeta E,t}$ for EME agents). The term $\varsigma_{Aa,t}$ captures the “fundamental” variance of returns from holding capital whereas the term $\varsigma_{\xi A,t}$ captures the covariance between the marginal value of AE agents' net worth ξ_t and returns from holding capital. When leverage constraints bind, excess returns generally exceed the risk premium. We prove these claims by examining agents' Hamilton-Jacobi-Bellman (HJB) equations.

The leverage constraint will bind for agents in the AE when, if they were subject to no constraints, $\psi_{A,t}/\eta_t \geq L_{A,t} + 1$ and in the EME when, if they were subject to no constraints, $\psi_{E,t}/(1 - \eta_t) \geq L_{E,t} + 1$. Thus $\psi_{A,t}/\eta_t \leq L_{A,t} + 1$ and $\psi_{E,t}/(1 - \eta_t) \leq L_{E,t} + 1$ over the state space.

Characterizing Equilibrium. Using the returns equations and our conjectures on agents' value functions, together with market clearing for capital and consumption, we can characterize equilibrium as a system of differential equations in the capital price q_t , the AE's value of additional net worth ξ_t , and the EME's value of additional net worth ζ_t .⁹ This system depends on the endogenous state variable η_t . Here, we report the law of motion for η_t and characterize the state space.¹⁰

First, we characterize equilibrium when leverage constraints do not bind.

Proposition 1. *When leverage constraints do not bind, the equilibrium law of motion of η will be endogenously given as*

$$\frac{d\eta_t}{\eta_t} = \mu_{\eta,t} dt + \sigma_{\eta A,t} dW_{A,t} + \sigma_{\eta E,t} dW_{E,t}, \quad (15)$$

⁹The AE's and EME's HJB equations give ODEs for ξ_t and ζ_t . The ODE for q_t is obtained by differencing the AE's and EME's asset pricing equations. For example, if both countries specialize their production, then

$$\begin{aligned} \mathbb{E}[dr_t^{Aa}] - \mathbb{E}[dr_t^{Eb}] &= \gamma_A \varsigma_{Aa,t} + (\gamma_A - 1) \varsigma_{\xi A,t} - \gamma_E \varsigma_{Eb,t} - (\gamma_E - 1) \varsigma_{\zeta E,t} \\ &= \gamma_A \frac{\psi_{A,t}}{\eta_t} ((\sigma + \sigma_{qA,t})^2 + \sigma_{qE,t}^2) + (\gamma_A - 1) \varsigma_{\xi A,t} - \gamma_E \frac{\psi_{E,t}}{1 - \eta_t} (\sigma_{qA,t}^2 + (\sigma + \sigma_{qE,t})^2) - (\gamma_E - 1) \varsigma_{\zeta E,t}. \end{aligned}$$

A lower γ_A causes RHS to shrink. To maintain equality, all else equal, the AE takes more leverage and increases $\psi_{A,t}$. This equation is similar in the case of asymmetric σ . For simplicity, let $\gamma_A = \gamma_E = 1$. Then

$$\mathbb{E}[dr_t^{Aa}] - \mathbb{E}[dr_t^{Eb}] = \frac{\psi_{A,t}}{\eta_t} ((\sigma_A + \sigma_{qA,t})^2 + \sigma_{qE,t}^2) - \frac{\psi_{E,t}}{1 - \eta_t} (\sigma_{qA,t}^2 + (\sigma_E + \sigma_{qE,t})^2).$$

A lower σ_A similarly decreases the RHS, so the AE increases $\psi_{A,t}$, all else equal.

¹⁰[Brunnermeier and Sannikov \(2015\)](#) show that because of the concavity in the price function $q(\eta)$ the economy may feature self-fulfilling sunspot equilibria with “jumps” (i.e., sudden stops). We do not consider the possibility of multiple equilibria because doing welfare analysis, and calculating optimal policy, would require specifying the some sort of equilibrium selection. Accordingly, we focus on the policy prescriptions when equilibrium dynamics do not feature self-fulfilling sunspots.

where

$$\begin{aligned}\mu_{\eta,t} &= \frac{\bar{a}P_{a,t} - \iota_t}{q_t} - \rho + \left(\frac{\psi_{A,t}}{\eta_t} - 1 \right) (\gamma_A \zeta_{Aa,t} + (\gamma_A - 1) \zeta_{\xi A,t}) \\ &\quad - \left(\frac{\psi_{A,t}}{\eta_t} \Sigma_{Aa,t} - (\Sigma_{q,t} + \Sigma_{K,t}) \right) \cdot (\Sigma_{q,t} + \Sigma_{K,t}) - \sigma \sigma_{qE,t}, \\ \sigma_{\eta A,t} &= \frac{1 - \eta_t}{\eta_t} \psi_{A,t} \sigma + \left(\frac{\psi_{A,t}}{\eta_t} - 1 \right) \sigma_{qA,t}, \\ \sigma_{\eta E,t} &= -\psi_{E,t} \sigma + \left(\frac{\psi_{A,t}}{\eta_t} - 1 \right) \sigma_{qE,t}.\end{aligned}$$

The state space is divided into 3 regions. For $\eta < \eta^a$, both countries produce good a and the EME produces good b . For $\eta > \eta^b$ both countries produce good b and the AE produces good a . For $\eta \in [\eta^a, \eta^b]$ countries specialize, using only their most productive technology. Goods prices satisfy

$$\frac{\underline{a}}{\bar{a}} \leq \frac{P_{b,t}}{P_{a,t}} \leq \frac{\bar{a}}{\underline{a}},$$

where the first (second) inequality becomes equality in the left (right) region of the state space.

Equilibrium is slightly modified when leverage constraints bind. In this case, the constraint prevents agents from taking as much risk as they demand. As a result, their excess returns will not equal the covariance of their returns with their SDF. We deal with this issue by observing that in equilibrium either the AE or the EME is a net debtor. Suppose, for concreteness, that leverage constraints bind for the AE. Then the EME must be a net lender, so its agents cannot be constrained, hence their excess returns still equal the covariance of their returns with their SDF. We use this observation to re-express $d\eta_t$. The state variable η_t will follow this new law of motion until the leverage constraint no longer binds, at which point the law of motion reverts to (15).

Proposition 2. *If the EME's leverage constraint binds, then η_t continues to follow the law of motion in Proposition 1. When the AE's leverage constraint binds, $\psi_{A,t} = (1 + L_{A,t})\eta_t$, and the*

drift of η_t becomes

$$\begin{aligned}\mu_{\eta_t} = & \left(\frac{\psi_{A,t}}{\eta_t} - 1 \right) \left(\gamma_E \varsigma_{Eb,t} + (\gamma_E - 1) \varsigma_{\zeta E,t} - \frac{\bar{a}P_{b,t}}{q_t} \right) + \frac{1}{\eta_t q_t} (\psi_{Aa,t} \bar{a}P_{a,t} + \psi_{Ab,t} \underline{a}P_{b,t}) \\ & - \frac{l_t}{q_t} - \rho + \left(\frac{\psi_{A,t}}{\eta_t} - \psi_{A,t} - 1 \right) \sigma(\sigma_{qA,t} - \sigma_{qE,t}) \\ & - \left(\frac{\psi_{A,t}}{\eta_t} \Sigma_{Aa,t} - (\Sigma_{q,t} + \Sigma_{K,t}) \right) \cdot (\Sigma_{q,t} + \Sigma_{K,t}).\end{aligned}\tag{16}$$

The volatility vector $\Sigma_{\eta,t}$ and the division of the state space remain the same as in (15).

When constraints bind for agents in the AE, their excess returns generally exceed the risk premium they would have required in the competitive equilibrium. As a result, the drift in η is generally larger, all else equal. In contrast, the *formula* for the volatility of η depends only on agents' portfolio choices and asset price volatility, so it does not change. However, the exact level of volatility will change because capital allocations change.

Even though η_t follows the same law of motion when leverage constraints do not bind, it does not necessarily imply that, as functions of η , the equilibrium prices, volatilities, and capital allocations are the same in regions of the state space where constraints do not bind. For example, suppose $L_{A,t}$ does not bind when $\eta_t > 0.3$. It does not follow that, for $\eta_t > 0.3$, $\psi_{Aa,t}$ in the equilibrium with an occasionally binding leverage constraint agrees everywhere with $\psi_{Aa,t}$ in the equilibrium with no leverage constraints.

3 Numerical Results

We numerically solve our model using a pseudo-transient relaxation method with upwind finite differences. For details, we refer the reader to Appendix C. For the remainder of this paper, we will suppress time subscripts. Following Brunnermeier and Sannikov (2015), we will also refer to the equilibrium with no leverage constraints ($L_A = L_E = \infty$) as the *competitive equilibrium*.

Calibration Table 1 lists the parameter values we use. While our goal is not a quantitative model, we calibrate our model parameters to be reasonable. We set the risk aversion of the AE to 1,

Table 1: This table lists the model’s parameters, our chosen values, the quantities to match, the target numbers, and the model’s calculations. If the quantities to match are taken from the literature or chosen by another rationale, we do not report the target and the model’s calculation.

Description	Parameter	Value	Quantity to Match	Target	Model
Risk aversion of the AE	γ_A	1.05	—	—	—
Risk aversion of the EME	γ_E	2	—	—	—
Discount rate	ρ	4%	Literature	—	—
First-Best Productivity	$\bar{a}$	1	Normalized	—	—
Second-Best Productivity	$\underline{a}$	0.85	Specialization gains	—	—
Investment Tech Productivity	λ	57	Consumption growth	2%	1.9%
Investment Tech Illiquidity	κ	5200	Investment/output ratio	20%	21%
Depreciation rate	δ	5%	Literature	—	—
Capital Growth Volatility	σ	2%	Consumption volatility	2%	2%
Cobb-Douglas Weight	α	1/2	Symmetry	—	—

which corresponds to log utility and is a common assumption in the continuous-time macrofinance literature. A choice of 2 for the EME falls within the range of reasonable risk aversion coefficients (see [Gourinchas et al. \(2010\)](#)). The discount rate ρ is set at 4% following the continuous-time macrofinance literature. We normalize $\bar{a} = 1$ and let $\underline{a} = 0.85$ to reflect gains from specialization in trade of 18%, but we also check our results are robust to other values of $\underline{a}$ in Appendix E. For computational tractability, we choose the following functional form for $\Phi(\cdot)$:

$$\Phi(\iota) = \frac{\lambda}{\kappa} \log(\kappa \iota + 1). \quad (17)$$

We calibrate the parameters λ and κ to match a 2% growth rate of aggregate U.S. consumption and an investment to output ratio of 20%, following [Di Tella \(2017\)](#). The depreciation rate δ is set at 5% following [Brunnermeier and Sannikov \(2015\)](#) and [Di Tella \(2017\)](#). Finally, we set $\alpha = 1/2$ so that overall demand for intermediate goods a or b does not influence our results, following [Brunnermeier and Sannikov \(2015\)](#). Our results are robust to variations in the trade elasticity (see

Appendix F).

For simplicity, we suppose countries choose a fixed, state-independent leverage constraint L_A and L_E . We first consider how varying constraints affect the stationary distribution (stability) of the global economy and then consider how constraints in each country affect welfare in the AE. Our results do not depend on asymmetry—the effects of leverage constraints on each country are qualitatively similar if $\gamma_A = \gamma_E$, and each country has an incentive to “over-regulate” in Nash equilibrium (Appendix E.4)—but the distributional consequences depend on asymmetric risk tolerance.

Note that the numerical results in Brunnermeier and Sannikov (2015) correspond to a special case of our model with $\gamma_A = \gamma_E = 1$ (the functional form for $\Phi(\cdot)$ is different but quantitatively similar). We obtain their results with closed capital accounts by setting $L_A = L_E = 0$ since if agents in A cannot borrow, then in equilibrium agents in E cannot lend. The equilibrium consequence of completely limiting capital inflows is an economy with completely closed accounts.

3.1 The Competitive Equilibrium

For readers unfamiliar with the continuous-time macrofinance literature, we briefly discuss key characteristics of our model’s allocations and dynamics in the competitive equilibrium. For familiar readers or those more interested in our results on equilibria with binding leverage constraints, we recommend skimming this section or skipping to Section 3.2 because the allocations and dynamics in our model are similar to those in other papers, e.g. Brunnermeier and Sannikov (2014, 2015). Figure 1 demonstrates the model’s severe nonlinearities, while Figure 2 shows how prices fluctuate in response to changing financial conditions. The blue line illustrates the competitive equilibrium.

The volatility $\sigma_\eta \equiv \sqrt{\sigma_{\eta A}^2 + \sigma_{\eta E}^2}$ reflects systemic risk. Intuitively, in response to an instantaneous normally distributed shock, σ_η quantifies the magnitude by which η changes. The larger σ_η is, the more the state of the economy changes. Around the *stochastic* steady state,¹¹ σ_η is relatively low, countries specialize in production, and capital is allocated well. However, if an adverse sequence of shocks drives η away from the steady state toward 0 (low AE wealth share)

¹¹This is the η such that $\mu_\eta = 0$ and is the state the economy drifts toward in the absence of shocks. This steady state is distinct from a deterministic steady state because the latter does not account for the effects of aggregate risk. The location of the stochastic steady state depends endogenously on agents’ consumption and portfolio decisions.

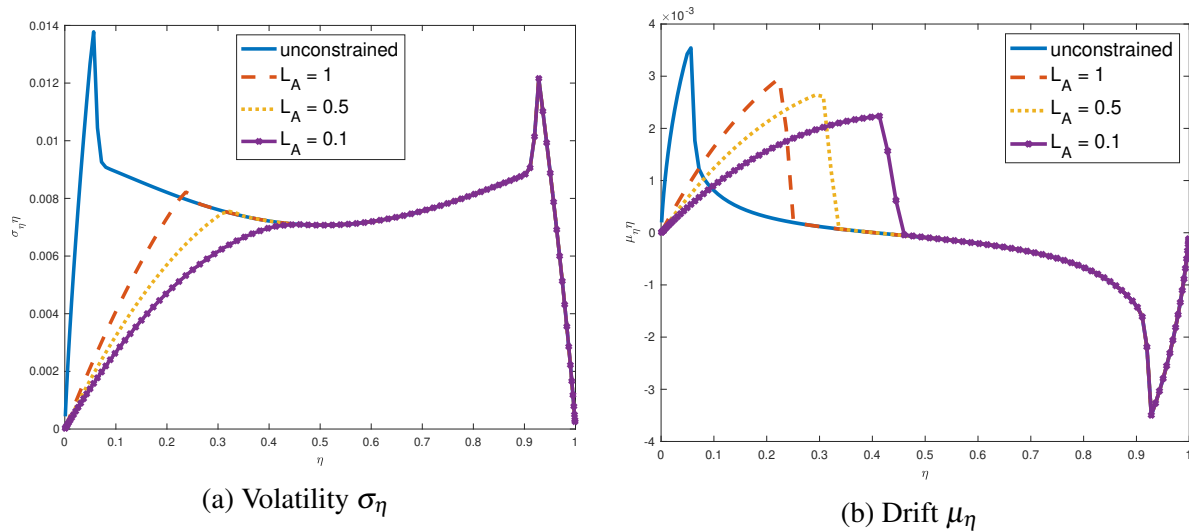


Figure 1: Evolution of η . Tighter constraints in the AE decrease volatility and (generally) increase drift, creating a more stable economy. (EME unconstrained).

in the competitive equilibrium, then the AE accumulates debt. The volatility σ_η slowly increases until it suddenly jumps around $\eta \approx 0.075$, and a financial crisis for the AE ensues. This behavior is consistent with the idea that systemic risk can lay dormant in good times (η near the stochastic steady state) but suddenly erupt when a crisis emerges. The drift μ_η exhibits similarly strong nonlinearities. The drift is the expected growth of η , and if no shocks occur, then the economy's behavior is characterized by μ_η . Near the steady state, μ_η in the competitive equilibrium is close to zero, but as shocks push η close to 0, μ_η spikes upward before decreasing toward zero. As a result, the rate of return toward the steady state is relatively lower when close to the steady state compared to further away.

Why do these nonlinearities occur? The jump in σ_η occurs because the AE has too little wealth and demands a large risk premium, but the returns on capital holdings are too low. As a result, the AE fire sells its capital holdings. To clear markets, the EME stops specializing and starts producing good a . Individual agents in the AE do not internalize the impact of their capital choices on the price, so these fire sales cause excessive asset price volatility which amplifies the initial sequence of shocks and implies higher σ_η . Figure 2(a) illustrates this divergent behavior. For $\eta > 0.075$, q is almost constant in the competitive equilibrium because the AE is willing to buy capital with

leverage, so output and the asset price remain high. Below 0.075, the price of q plunges as the AE fire sells capital, and output falls because the EME produces good a at a lower rate $\underline{a}$.

Excess returns and the terms of trade between goods a and b explain the nonlinear behavior of μ_η . The AE demands a large risk premium when its wealth is low, so excess returns are high during downturns (a typical feature of macrofinance models with state-dependent risk premia). As a result, its wealth recovers toward the steady state at a relatively faster rate during downturns than during good times. However, this faster recovery rate occurs only at the start of a crisis since μ_η decreases toward 0 as η further decreases and the crisis worsens. While the AE demands a larger risk premium, higher equilibrium returns must arise from changes in prices and/or allocations. The driving force is the terms of trade between goods a and b . Figure 2(b) depicts the terms of trade $P_{a,t}/P_{b,t}$. When η decreases, the terms of trade rise, so the production of good a generates higher dividend yields. The AE earns higher returns from producing good a as a result, which explains the sharp increase in μ_η when $\eta \approx 0.075$. This behavior provides insurance to the AE during downturns, hence why Brunnermeier and Sannikov (2015) call it the “terms of trade hedge.”

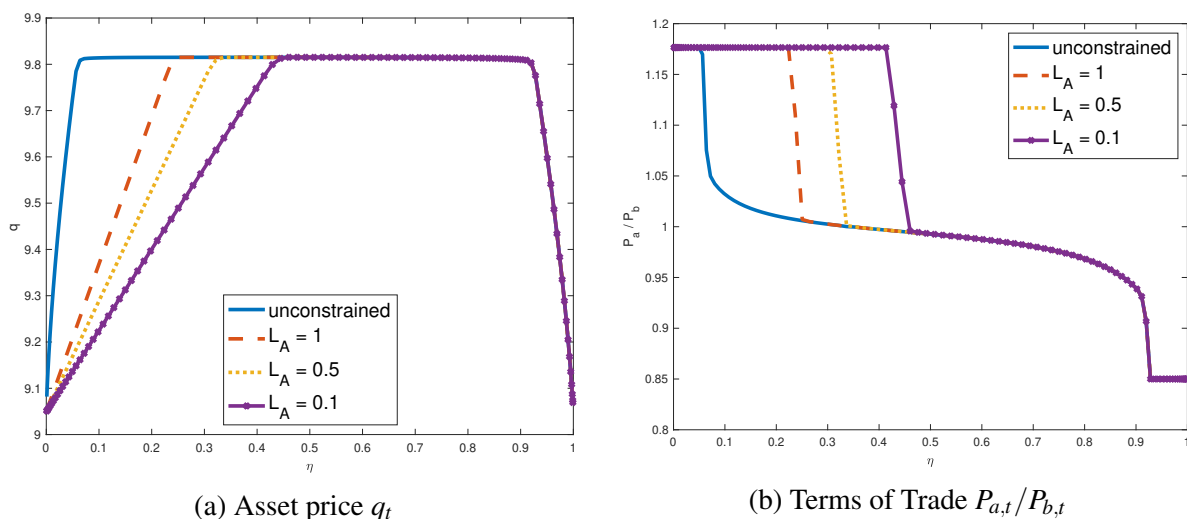


Figure 2: Equilibrium Asset Price and Terms of Trade. (EME unconstrained)

Incomplete markets create three sources of inefficiencies in the competitive equilibrium. First, capital is misallocated, as half should go to producing good a and the other half to good b . Second, investment is lower because the price of capital q does not always obtain its maximal level.

Third, aggregate risk is not perfectly shared, so countries experience additional consumption risk. Leverage constraints can potentially mitigate these inefficiencies by influencing the long-run frequency of capital misallocations and consumption risk, even though they may cause less efficient allocations today. Further, while both the AE and EME reap high excess returns during financial crises, they do not necessarily consider these returns sufficient compensation for the exposure to systemic risk caused by their agents' individual portfolio decisions.

3.2 Stability

In the absence of any policy, the economy's stochastic steady state occurs around $\eta = 0.41$, near where capital is best allocated at $\eta = 0.35$ (since the AE has lower risk aversion), and the economy tends to drift toward the stochastic steady state after shocks move the system away. At the stochastic steady state, the AE's share of world capital is only slightly greater than 1/2, so misallocation is minimal (at $\eta = 0.41$, $\psi_A \approx 0.501$). Thus, the stationary distribution is concentrated at η where flow output is relatively high (i.e., the economy is typically stable). However, the economy can descend into a financial crisis, as the density is visibly positive for $\eta \approx 0.075$.

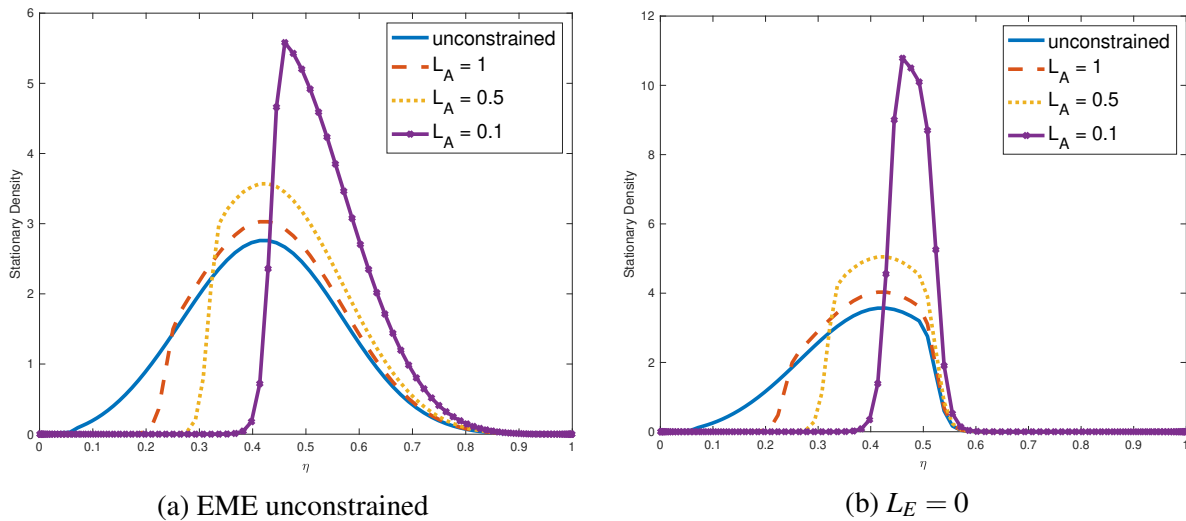


Figure 3: Stationary distribution of η (stability). Tighter constraints in the AE shift mass toward higher η (good for the AE), and tighter constraints in the EME shift mass toward lower η (good for the EME).

Figure 3 plots the stationary distribution of η varying L_A for two cases. Panel (a) considers when the EME does not impose leverage constraints, and Panel (b) considers the other extreme when the EME sets leverage to zero. The blue distribution in Panel (a) thus shows the distribution in the competitive economy without constraints. Notably, it is the most dispersed distribution. This is precisely the notion of long-run financial instability: the distribution of η in the competitive equilibrium is more dispersed than any country would like. Moreover, this dispersion does not occur solely because of the level of endogenous volatility σ_η .

Tighter regulation can shift mass in the direction a country prefers. Of course, the flip-side is that when the AE tightens, the relative wealth distribution must worsen from the perspective of the EME. Contrasting Panels (a) and (b) clearly illustrates how tightening by the EME has shifted the distribution toward low η (bad for the AE). Tighter leverage constraints increase the stability of the economy (in the sense of relative wealth differences) and reduce long-run financial instability because of two reasons. First, leverage decreases the volatility of η . Second, it improves the terms of trade sooner after bad shocks, thus raising the rate at which net worth recovers. The terms of trade hedge increases the drift of η near the stochastic steady state. These two forces together mean that following bad shocks which push the economy away from the steady state, the economy recovers at a faster rate with leverage constraints. In this way, the effect of capital controls in our model is quite complementary to the effect in [Costinot et al. \(2014\)](#). Because in our model taxing/limiting inflows improves the distribution of the economy, taxes on inflows need not be coupled with taxes on outflows.

Tighter regulation is not without cost. When constraints bind, flow allocations are worsened and output suffers. These costs are reflected by lower asset prices, as Figure 2(b) shows, and lower asset prices imply a lower growth rate of capital due to Tobin's q (9). Thus, tighter constraints lead to *flow* decreases in output and growth. As in [Brunnermeier and Sannikov \(2015\)](#), there is a dynamic trade-off between financial stability and the statically efficient allocation of capital as well as a trade-off between financial stability and growth. Relatedly, tighter regulation mitigates exposure to financial stability at the cost of the high excess returns which the AE reaps from acting as a global intermediary. If the AE prefers marginally tighter leverage constraints, then the

marginal benefit of larger excess returns do not exceed the costs of greater instability.

These effects are present in [Brunnermeier and Sannikov \(2015\)](#), but in our model the distributional consequences are different. In both of our models, reducing leverage encourages financial stability by changing the time at which the terms of trade hedge applies. With open capital accounts, the terms of trade hedge for the AE is highest when η is low, spurring faster growth when the AE has low net worth. However, this hedge in bad times comes at the cost of a higher probability of leaving the region near the stochastic steady state. The drift μ_η and the terms of trade are low in that region, so the economy is expected to recover more slowly from shocks. In contrast, leverage constraints shift the terms of trade hedge so that it applies closer to the stochastic steady state. While tighter constraints decrease the drift of η for low η , it increases the drift of η near the stochastic steady state. In the long run, a higher drift closer to good times is better for stability, even though it takes longer to get out of bad times, because only an exceptionally bad sequence of shocks will cause η to deviate far from the steady state. For most shocks, a higher drift of η near the stochastic steady state prevents the economy from getting anywhere close to a crisis. This mechanism is why closed capital accounts improve stability and welfare in [Brunnermeier and Sannikov \(2015\)](#) and in our model.

4 Welfare

The main goal of our analysis is to understand how countries choose regulation in order to maximize the welfare of its agents. As noted, incomplete markets create three sources of inefficiencies in the competitive equilibrium. First, capital is misallocated, as half should go to producing good a and the other half to good b . Second, investment is lower because the price of capital q does not always obtain its maximal level. Third, aggregate risk is not perfectly shared, so countries experience additional consumption risk. These externalities operate through the terms of trade and the capital price: the model features a depressed terms of trade hedge, since agents decide when to produce the other country's good, and agents' borrowing decisions affect the terms of trade; and the model features a financial accelerator, since agents' portfolio choices affect international capital prices, and declines in asset prices decrease the balance sheet wealth of other agents. Ac-

cordingly, there is scope for regulation to improve welfare for both countries by correcting these inefficiencies. We investigate these mechanisms directly in Section 5.2.

Planner's Problem. We first discuss our model's first-best solution in Proposition 3.

Proposition 3. *In the first-best equilibrium, the Planner chooses full specialization, $\psi_{Aa,t} = \psi_{Eb,t} = 1/2$, and the price of capital is a constant $\bar{q}$, which is given by the fixed point*

$$\bar{q} = \frac{\bar{a}/2 - \iota(\bar{q})}{\rho}. \quad (18)$$

The law of motion for aggregate capital can be written as

$$\frac{dK_t}{K_t} = (\Phi(\iota(\bar{q})) - \delta) dt + \sigma_K dW_t, \quad (19)$$

where $\sigma_K = \sigma/\sqrt{2}$ and $dW_t = (dW_{A,t} + dW_{E,t})/\sqrt{2}$, and output is an endowment process satisfying $Y_t = \bar{a}K_t/2$. The Planner assigns a fraction η_t of aggregate consumption to the AE, and the dynamics of η_t are given by

$$\frac{d\eta_t}{\eta_t} = (\zeta_{A,t} - \sigma_K)(\pi_t - \sigma_K) dt + \frac{\Omega_{3,t}}{1 + \Omega_{2,t} - \Omega_{3,t}\Omega_{1,t}} \sigma_K dW_t, \quad (20)$$

where $\zeta_{A,t}$ is the volatility of the AE's aggregate net worth; π_t is the equilibrium price of risk when agents trade in a complete market; and

$$\begin{aligned} \Omega_{1,t} &= \eta_t \left((\gamma_A - 1)\eta_t \gamma_A^{-1} \frac{\sigma_{\xi,t}}{\eta_t \sigma_{\eta,t}} - (\gamma_E - 1)(1 - \eta_t) \gamma_E^{-1} \frac{\sigma_{\zeta,t}}{\eta_t \sigma_{\eta,t}} \right), \\ \Omega_{2,t} &= (1 - \eta_t) \eta_t \left((\gamma_A - 1) \gamma_A^{-1} \frac{\sigma_{\xi,t}}{\eta_t \sigma_{\eta,t}} - (\gamma_E - 1) \gamma_E^{-1} \frac{\sigma_{\zeta,t}}{\eta_t \sigma_{\eta,t}} \right), \\ \Omega_{3,t} &= \frac{(1 - \eta_t)(\gamma_A^{-1} - \gamma_E^{-1})}{\eta_t \gamma_A^{-1} + (1 - \eta_t) \gamma_E^{-1}}. \end{aligned}$$

If $\pi_t > \sigma_K$, which occurs if $\gamma_E > \gamma_A = 1$, then the share of consumption allocated to the AE is expected to grow, i.e., $\eta_t \rightarrow 1$ asymptotically.

The logic of the proof is straightforward. Since markets are complete in the first-best equilib-

rium, capital can be efficiently allocated. When capital is efficiently allocated, output follows an endowment process, so we can characterize equilibrium dynamics as an economy in which agents share their exposure to aggregate risk from a tree. [Brunnermeier and Sannikov \(2015\)](#) characterize the first-best when countries are symmetric. In our setting, the allocation of consumption shares is complicated by the heterogeneity in risk aversion. Regardless, there is no misallocation of capital and countries optimally share aggregate risk. The AE bears more risk than the EME but receives a greater fraction of consumption as capital grows as long as the risk-adjusted excess returns are sufficiently large. Our model's first-best solution is also closely related to that obtained by [Bhamra and Uppal \(2014\)](#), who provides a closed-form solution to the consumption-sharing rule between agents who have CRRA preferences but are heterogeneous in their risk aversion and beliefs.

Constrained Planner. Now consider a constrained planner who chooses allocations while respecting agents' constraints and allowing market clearing to determine prices. The constrained planner can affect prices and the equilibrium dynamics, and equilibrium outcomes depend on the evolution of prices. A Constrained Social Planner with Pareto weights $(\omega, 1 - \omega)$ chooses capital shares, consumption, and investment, $\{c_{A,t}, c_{E,t}, l_t, \psi_{Aa,t}, \psi_{Ab,t}, \psi_{Ea,t}, \psi_{Eb,t}\}$, to maximize

$$\mathbb{E} \left[\int_0^\infty \omega f^A(c_{A,t}, V_{A,t}) + (1 - \omega) f^E(c_{E,t}, V_{E,t}) dt \right], \quad (21)$$

subject to (2), (3), (5), (9), (10), (12). The competitive equilibrium is constrained efficient if a social planner that chooses directly allocations subject to agents' constraints, but lets the goods and capital markets clear competitively, cannot Pareto improve the welfare of agents.

Proposition 4. *The decentralized equilibrium is not constrained efficient.*

The intuition is standard in the literature. In equilibrium, agents' welfare depend on the equilibrium evolution of η_t , but agents do not internalize how their portfolio decisions affect the evolution. The Planner does internalize how changing the allocations affects the equilibrium dynamics and markets are incomplete, which is precisely why the Planner can do better. The optimal constrained solution requires a state-contingent perturbation relative to the competitive allocations. Solving the

full constrained solution, for a given set of Pareto weights, is an extremely complex problem resulting in a completely state-contingent policy. To simplify we therefore consider a much simpler set of instruments for regulators to use, motivated by the result that the competitive equilibrium is constrained inefficient.

Leverage Constraints. In general, leverage constraints will not improve welfare almost everywhere. Consider the AE as an example. When η is close to zero, restricting leverage slows down the rate at which agents rebuild their net worth. The reason is that expected returns will be very high but need to borrow to finance their investment. Limits on their leverage reduces their ability to capitalize on the high returns. As a result, the value function near $\eta = 0$ will decrease when the leverage constraint tightens. However, if η is further away from zero, then restrictions on leverage can promote financial stability enough that the value function increases with tighter constraints.

This non-monotonic response to leverage constraints across the state space complicates the welfare analysis of different regulatory regimes. Since countries are asymmetric, it does not make sense to simply assume equal initial wealth (i.e. $\eta_0 = 1/2$). The stochastic steady state may not be a reasonable initial condition either because the stationary distributions in Figure 3 indicate that the economy exhibits substantial long-run variance in η .¹² Ideally, we want to evaluate the welfare of the AE and EME in such a way that we capture the impact of leverage constraints on the long-run financial stability of the economy—the key motivation for these policy tools in the first place.

To address these issues, we apply an ex-ante measure of welfare. Rather than choose an arbitrary initial condition, we suppose that countries adopt a “prior” about the location of η at time $t = 0$. Since neither country’s information set “before time begins” should include a signal of η_0 , the best “prior” is the stationary distribution of η . We therefore measure welfare by computing the expectation of Country i ’s value function with respect to the stationary distribution of η . We label this measure of welfare by $\mathbb{E}[V_i]$ and refer to it interchangeably as ex-ante welfare.¹³

To make this notation more precise, recall that the value function for Country i $V_{i,0}$ is subject

¹²Another complication is the fact that welfare is non-monotonic with η . Consider the AE. For most of the state space, welfare increases with η . For high enough η , however, aggregate output is so low that the AE would actually prefer if η was lower since the EME can produce good b at a superior rate.

¹³Van der Groot (2020) also uses this measure when conducting welfare analysis.

to an initial condition η_0 . We can reformulate this value function as the conditional expectation

$$V_{i,0} = \mathbb{E} \left[\int_0^\infty f^i(C_{i,t}, V_{i,t}) dt \mid \eta_0 \right].$$

Ex-ante welfare is equivalent to integrating out the initial condition η_0 using a prior distribution.

We prefer this measure of welfare rather than evaluating the value functions at a single point because it captures the impact of regulation on long-run financial stability in two ways. First, conditional on η_0 , leverage constraints influence the future investment opportunities which agents expect to have. For example, the stochastic steady state becomes more stable, so they expect capital to be optimally allocated more often. Second, they alter countries' uncertainty or beliefs about the economy's long-run stability. Evaluating countries' value functions only captures the first effect. The second effect, however, is important because a key benefit of greater long-run financial stability is increased certainty about the economy's health in its current state.

Welfare Effects of Policy Spillovers. In this economy the dynamic benefits of a more stable economy generally outweigh the flow costs and forgone excess returns, and as a result tightening constraints in one country generally improves welfare for that country. However, there are important cross-country spillovers. Figure 4 plots ex-ante welfare for the AE as a function of the leverage constraint chosen by the EME, for three levels of constraints in the AE.

There are two important patterns to notice. First, given the policy in the EME, a tighter regulation in the AE (lower L_A) improves welfare in the AE; the stability trade-off outweighs the flow cost, as discussed earlier. Second, fixing L_A in the AE, welfare in the AE is increasing with L_E ; tightening in the EME decreases welfare in the AE. Macro-level spillovers from capital account policies are reflected by changes in the stationary distribution of η and in welfare.

There are two complementary intuitions for this result, and it is important to consider both. First, when the EME tightens, that shifts mass toward states when the AE is relatively poor. As we have seen, if the EME tightens and shifts mass toward states when the AE is poor, the AE can shift mass away from those states by tightening as well. Hence, uncoordinated regulation to improve stability has a “zero-sum” element: a country cannot shift mass away from $\eta = 1$ without shifting

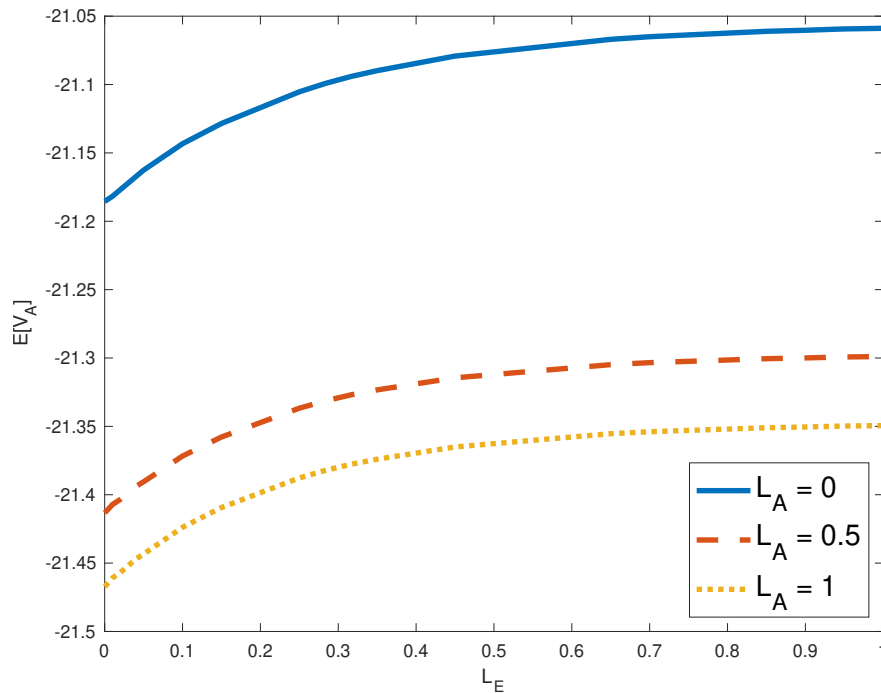


Figure 4: the AE's ex-ante welfare varying leverage constraints in the EME along the x-axis and in the AE across the different lines.

it toward $\eta = 0$. As we will see later, this mechanism is precisely why uncoordinated (Nash) policy choices will be tighter than policies coordinated by a social planner, since each country will have an incentive to tighten in order to improve the distribution of outcomes (from its perspective).

Second, more intermediation requires greater long-run financial instability. When a country takes on leverage (intermediating risk), it must also bear *systemic* risk (endogenous volatility) and a weakened terms of trade hedge, which produce greater financial instability. By restricting leverage, countries can reduce their exposure to sources of instability. These effects are reflected in Figures 1 and 2. In the first figure, the volatility of η decreases when the AE tightens regulation—and importantly, the volatility of η decreases *only* at times when the AE is relatively poor, which is precisely when the AE does not want systemic risk. In the second figure, the terms of trade hedge applies much closer to the stochastic steady state, precisely when the AE needs it to maintain capital levels close to optimal. While excess returns will not be as high and the static allocation of capital can be worse if η is far from the steady state, the stability benefits generally outweigh these costs. Intuitively, because individual agents do not internalize the pecuniary externality from their

portfolio choice on asset prices, in the aggregate their decisions create global dynamics and excess returns that do not compensate the AE enough, so the AE prefers to reduce borrowing. But as we have seen, limiting leverage in order to reduce instability is costly to the other country.

5 Financial Asymmetry and Strategic Incentives

In this section we let countries choose policies to maximize welfare in each country. We briefly clarify the policy game being played by countries. There are two players, the AE and the EME regulators. They play a one-shot game. Before time $t = 0$, each country chooses and commits to a fixed leverage constraint. They maximize their ex-ante welfare subject to constraints stated in Section 2, taking as given the other country's policy choice. We solve the coordinated equilibrium and the uncoordinated Nash equilibrium numerically. This "static game" illuminates some of the key forces governing how countries might engage in coordination without being complicated by the problems of multiple equilibria that emerge in dynamic and repeated games. As an additional benchmark for welfare analysis, we use the competitive equilibrium,¹⁴ defined as the economy in which neither country imposes binding leverage constraints. Comparisons with this equilibrium provide a measure of the gains or losses from macroprudential policy and strategic incentives.

5.1 Coordinated and Uncoordinated Policies

Our numerical results indicate that closing capital accounts is not only a Nash equilibrium but a dominant strategy. Figure 5 plots ex-ante welfare in the AE, varying L_A for a set of L_E .¹⁵ What is clear is that for each L_E , welfare in the AE is maximized by $L_A = 0$, and it monotonically increases as L_A decreases. The same behavior holds for the EME.

Table 2 compares outcomes in the competitive equilibrium (no constraints) to the coordinated

¹⁴The use of "equilibrium" in "competitive equilibrium" refers to the fact that we solve the general equilibrium of our model. This terminology should not be confused with any game-theoretic definitions of equilibrium.

¹⁵This figure only displays a few cases. We determine that closed inflows is a dominant strategy in two ways. First, we compute a much finer grid of pairs of leverage constraints, which again suggests closed inflows are dominant strategies. Second, we conduct a fixed point iteration where we fix one player's constraint, compute the other player's best response, fix that best response, compute the first player's best response, and so on, considering many initial conditions. See Appendix C for a more thorough description.

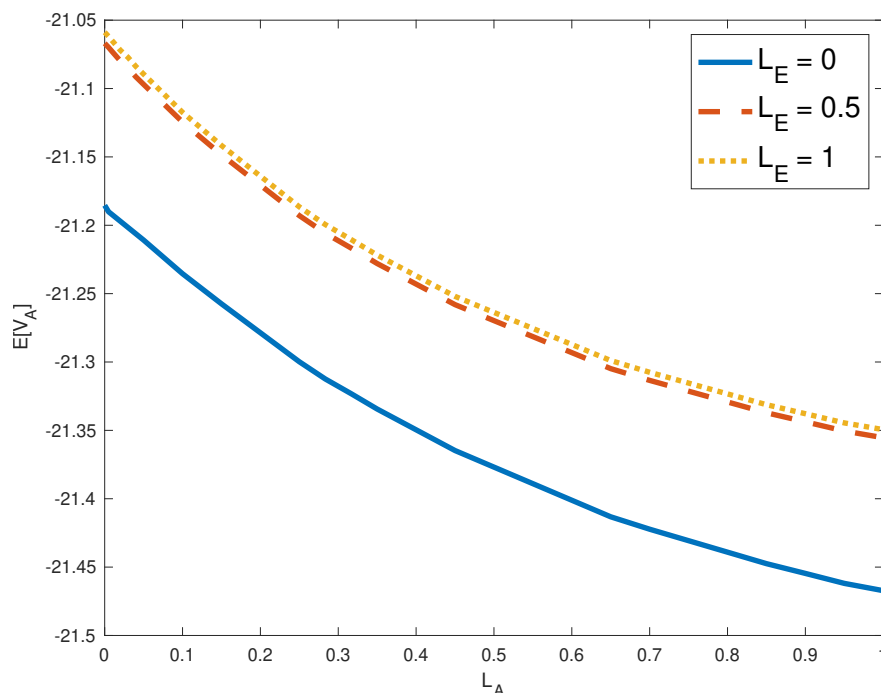


Figure 5: Welfare in the AE varying L_A for given L_E . Setting $L_A = 0$ appears to be a dominant strategy (i.e., best response to any L_E).

and uncoordinated equilibria using the ex-ante measure. Our first main result—that uncoordinated constraints are tighter than coordinated constraints—holds broadly across parameters, including in a symmetric model (see Appendix E). For all parameters we have considered the Nash equilibrium is zero.¹⁶ While prudential regulations in our model are highly stylized, the key insight should apply across a wide range of potential environments. The key mechanism of our model is that, when international credit markets are imperfect, a policy that stabilizes the AE will cause the AE to be relatively richer more frequently.¹⁷ This is a negative spillover to the EME, which increases the incentive for the EME to enact stabilizing policies. While a richer setup is likely to generate positive spillovers through other sets of pecuniary externalities, we expect that the negative exter-

¹⁶The trade literature has found that goods are typically substitutes in international trade. Appendix F considers an extension to CES production functions, which allows us to model goods a and b as substitutes. We find the Nash equilibrium is zero for elasticities of substitution as high as 10, much higher than empirical estimates (2–5).

¹⁷While in our model leverage limits are controls on capital inflows, in reality these instruments can have very different roles. Korinek and Sandri (2016) quantitatively find the optimal capital control and macroprudential regulation for emerging economies to mitigate contractionary exchange rate depreciations and reduce the amount and riskiness of financial liabilities. Nonetheless, the authors find it is optimal for emerging economies to employ both instruments in order to improve stability.

nality present in our model would continue to be present. Thus, while the quantitative importance of our mechanism will depend on the full set of global interactions, *on the margin* the mechanism we highlight will lead to tighter uncoordinated policies relative to global coordination.

Table 2: Consumption equivalent ex-ante welfare in percentage points relative to the competitive equilibrium with coordinated and uncoordinated leverage limits.

	L_A	L_E	Δ Welfare for AE	Δ Welfare for EME
Social optimum	177.4%	0%	-7.88%	13.1%
Nash	0%	0%	26.8%	-7.62%

The second critical result which emerges in this analysis is that the EME is most hurt by a lack of policy coordination. The EME experiences a 13.1% welfare increase in consumption equivalent units in the social optimum relative to the competitive equilibrium but suffers a 7.62% consumption equivalent decrease in Nash equilibrium. In contrast, the low risk aversion AE *benefits* in Nash equilibrium compared to coordination (with equal Pareto weights) and especially compared to the competitive equilibrium. With our calibration, the AE gains 26.8% in consumption equivalents relative to the competitive equilibrium. If countries coordinate, then the AE actually suffers a 7.8% decrease in consumption equivalents. The asymmetry in welfare widens as the financial asymmetry widens. The larger is $\gamma_E - \gamma_A$, the more that the EME benefits from coordination and the more that the EME suffers in Nash equilibrium (see Table 1 in Appendix E). Hence, the AE benefits from lack of coordination (choosing tighter policy than the coordinated optimum) but the EME is hurt from lack of coordination (choosing essentially the same policy in each case).

A note of caution. These welfare changes are very large relative to the literature for two reasons. First, we assume a high degree of market incompleteness (no international equity issuance). Adding more realistic risk sharing would decrease the quantitative significance of our analysis but would not change the qualitative story. Second, our choice of an ex-ante welfare measure increases the significance of improved stability. When welfare is computed for a given initial condition rather

than using the ex-ante measure, the welfare changes and consumption equivalent changes can be on the order of 1%, closer in magnitude to those found in the literature. Table 3 provides consumption equivalent changes comparing the competitive equilibrium to Nash given several initial conditions (not ex-ante welfare). Note that the welfare consequences of the leverage policy depend on the initial condition, which is precisely why the ex-ante measure can generate such large welfare gains. For the AE, Nash is preferred to the competitive equilibrium whenever $\eta_0 \in (0.1, 0.5)$. Appendix E.4 presents additional examples when using log preferences and asymmetric volatility.

Table 3: Consumption equivalent of the competitive equilibrium relative to Nash evaluated at an initial condition. Positive number means competitive equilibrium is better than Nash.

Initial Condition	Δ Welfare for AE	Δ Welfare for EME
$\eta_0 = 0.4$	-7.992%	8.019%
$\eta_0 = 0.5$	-0.529%	0.223%
$\eta_0 = 0.6$	7.097%	-7.18%

Since countries are asymmetric, equal Pareto weights are not necessarily the correct choice for measuring social welfare. It is instructive to consider the change in the AE's and EME's ex-ante welfare as a social planner varies Pareto weights. Toward this end, Figure 6 plots welfare pairs $(\mathbb{E}[V_A], \mathbb{E}[V_E])$ for each country in different regulation regimes. The black asterisk is the welfare pair in competitive equilibrium (no constraints), the black circle is the welfare pair in Nash equilibrium (zero leverage), the red line is the Pareto frontier when the Pareto weight ω is less than 1/2, and the blue line is the Pareto Frontier when ω is greater than or equal to 1/2.¹⁸ The Nash equilibrium is essentially on the frontier. Thus, there exists a Pareto weight (approximately 0.75) where the total welfare loss under Nash is negligible, but the distributional consequences for the AE and EME are large. With weights approximately in the interval $[0.55, 0.67]$, the policy chosen by a planner will *Pareto dominate* the allocation in the competitive equilibrium. When

¹⁸We construct the Pareto Frontier by computing optimal policies across 30 Pareto weights ranging equidistantly from near zero to near one. The markers in the red and blue lines indicate particular Pareto weights.

the weight is 0.55, the EME experiences an increase of 9.5% in consumption equivalents while keeping the AE indifferent relative to the competitive equilibrium. Conversely, when the weight is 0.67, the AE experiences an increase of 15.9% in consumption equivalents while keeping the EME indifferent.¹⁹

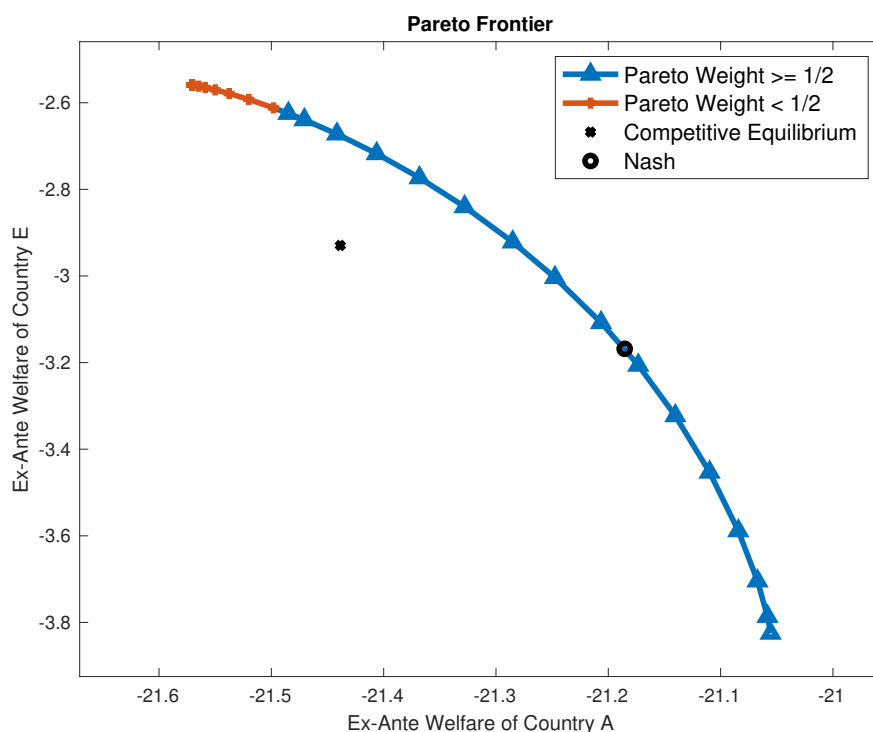


Figure 6: $\mathbb{E}[V_E]$ against $\mathbb{E}[V_A]$ as the Pareto weight ω on the AE's ex-ante welfare varies from 0 to 1. The values from the competitive and Nash equilibria are also plotted.

Figure 7 plots the optimal leverage chosen by a global social planner as we vary the weight put on the AE. When all weight is put on the EME, the social planner calls for very high leverage by the AE and zero leverage for the EME. This is sensible: the social planner wants the AE to bear all risk (fundamental and systemic) and to provide intermediation to the EME. As more weight is put on the AE, the social planner imposes tighter leverage in the AE, thus protecting the AE from systemic risk. If the social planner cares only about the AE, then the EME will be called on to provide intermediation.

¹⁹Table 17 in Appendix F reports the Pareto weight closest to Nash and the maximal Pareto-improving welfare gains for each country when the elasticity of substitution between goods a and b is above 1. The numbers for higher elasticities are similar.

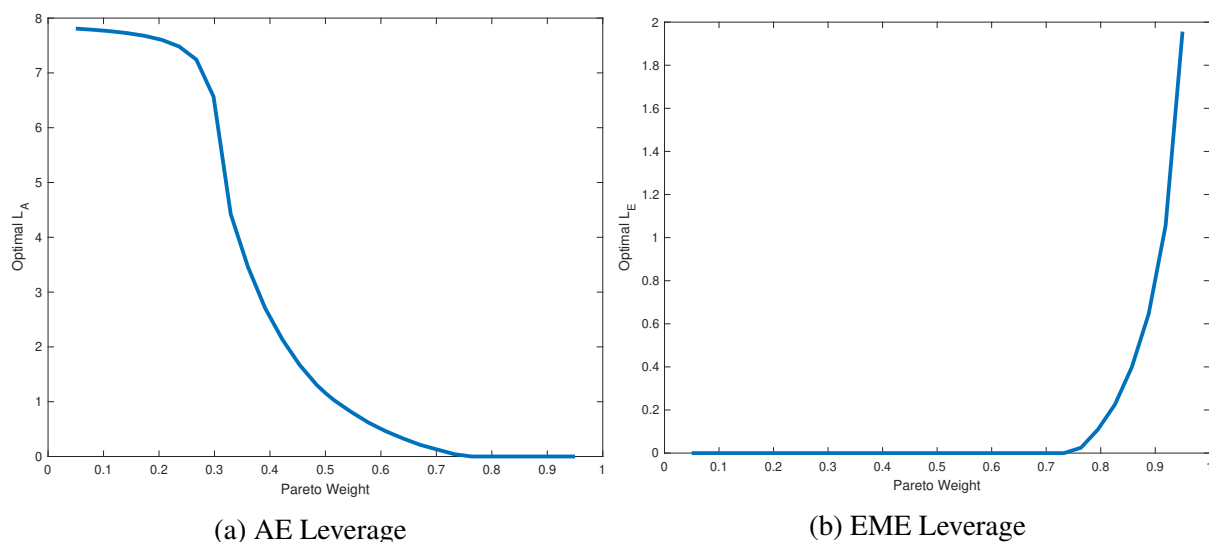


Figure 7: Optimal Leverage Varying the Pareto Weight on the AE.

These results show the stark contrast in welfare relative to the competitive equilibrium when countries choose policies according to Nash: the AE benefits substantially while the EME is hurt. If the planner puts non-trivial weight on the EME, then it is optimal for the AE to intermediate risk for the sake of the EME. However, this requires the AE to suffer worse welfare outcomes. Without coordination the AE is not willing to bear the financial risk that benefits the rest of the world.

Moreover, it is likely that any policy coordination would result in policies similar to those chosen by a social planner who places a large Pareto weight on the AE. The location of Nash equilibrium in Figure 6 indicates that Pareto-improving policy coordination would produce negligible gains, so the outcome would resemble that of a social planner who chooses a fairly large ω . Even if the AE is willing to accept worse welfare outcomes, a priori one would expect the consequent policies to still be close to Nash equilibrium. If coordination requires the AE to give up too much welfare, then the AE can always unilaterally set $L_A = 0$. Coordinating prudential regulations will necessitate policies that are strongly determined by the AE's welfare.

5.2 Mechanisms

Here, we investigate the mechanisms driving our results. First, we consider a benchmark case where we shut off the terms of trade hedge by assuming countries directly produce the final con-

sumption good. This case illustrates the effect of leverage constraints on the pricing of risk in equilibrium. Second, we consider another benchmark case where we shut off amplification through asset prices by assuming countries have access to a linear investment technology, which causes the price of capital to be constant. This case focuses attention on the terms of trade hedge. Finally, we construct counterfactual laws of motion to compare the relative importance of risk pricing and the terms of trade in our baseline model. Due to space constraints, we only briefly describe the benchmark model variants and refer the reader to Appendix B for more details.

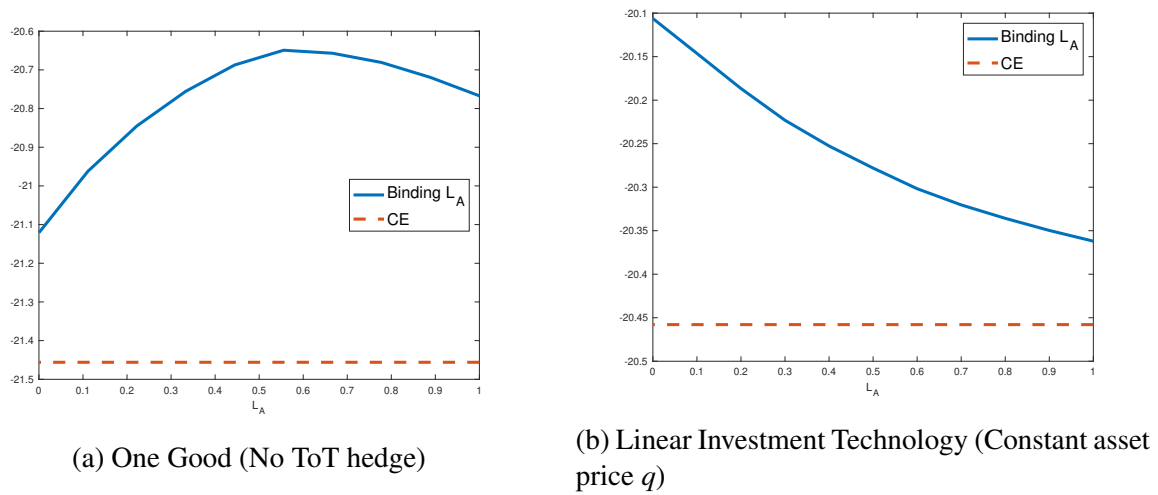


Figure 8: Panels (a) and (b) plot the ex-ante welfare of the AE in the one good model and in the linear investment technology model, respectively. The EME imposes $L_E = 0$. The blue line plots the AE's ex-ante welfare with a binding but varying leverage constraint while the dashed red line plots the AE's ex-ante welfare if it does not impose a binding leverage constraint.

Risk Pricing Only (no terms of trade hedge). Intermediate goods a and b no longer exist in this benchmark. Instead, agents in the AE produce the final consumption good at rate $\bar{a}k_t$ while agents in the EME produce the final consumption good at rate $\underline{a}k_t$, where $\bar{a} > \underline{a}$. This modification removes the terms of trade hedge that promotes the rate at which net worth recovers precisely when a country becomes relatively poor.²⁰ Therefore, if leverage constraints still affect welfare, then the

²⁰In principle, the ideal comparison is setting $\bar{a} = \underline{a}$, but in this equilibrium asset prices are constant, neither country borrows, and the stationary distribution is degenerate (Brunnermeier and Sannikov, 2015). By assuming one country is permanently more productive, we can obtain a stationary equilibrium with fire sales but without the terms of trade

reason is that they alter the pricing of risk in equilibrium and influence the buildup of systemic risk. Figure 8(a) shows how tighter leverage constraints affect the AE's ex-ante welfare, assuming the EME imposes $L_E = 0$. Although restricting leverage improves ex-ante welfare relative to the competitive equilibrium, it is no longer monotonic. Instead, it is optimal to permit some leverage. Thus, while leverage constraints have a meaningful impact on welfare through their effect on equilibrium risk pricing alone, their benefits do not justify completely closed capital inflows.

Intuitively, the static benefit of efficiently allocating capital is more pronounced when no terms of trade hedge applies. Without a terms of trade in intermediate goods, countries only compare the gains from higher output against the gains of lower asset price volatility. In the full model, tighter leverage constraints provide an additional benefit through a better terms of trade hedge. The economy becomes stabler in terms of its volatility and the rate at which countries rebuild their net worth.

Terms of Trade Only (constant asset price). We choose a new functional form for the internal investment technology: $\Phi(\iota) = \lambda \iota$. This linear technology implies a constant price of capital $q = 1/\lambda$, so there is no volatility in the price of capital. We choose λ to match the average price of capital in our original model. The only source of endogenous risk now is from countries' leverage choices. Figure 8(b) shows that it remains optimal for the AE to close its capital accounts, and ex-ante welfare continues to monotonically increase as L_A decreases. Moreover, we verify that, fixing $L_A = 0$, the EME's welfare monotonically increases when L_E decreases, hence $(L_A, L_E) = (0, 0)$ is still a Nash equilibrium. The fact that we obtain these results pinpoints the terms of trade hedge as the key mechanism driving our results.

For intuition, recall that the log of a geometric Brownian motion G_t with drift μ and volatility σ can be solved in closed form as

$$\log(G_t) = \log(G_0) + \left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t.$$

A change in μ has a “first-order” effect on $\mathbb{E}[\log(G_t)]$, but a change in σ only has a “second-order” effect. While this benchmark does not perfectly isolate the terms of trade hedge, it is still informative because it does shut off the hedge.

order” effect since it is the variance that directly affects $\mathbb{E}[\log(G_t)]$. For example, if μ and σ both decreased by one percentage point, the change in μ would have a larger effect (assuming $\sigma < 1$). The behavior of η_t is similar. We can heuristically rewrite (15), the law of motion for η , as

$$\begin{aligned} \frac{d\eta_t}{\eta_t} = & (\text{Dividend Yield} + \text{Covariance Terms}) dt \\ & + \text{Leverage Ratio} \times (\text{Fundamental} + \text{Endogenous Vol.}) d\mathbf{W}_t. \end{aligned}$$

An increase in the terms of trade hedge increases the dividend yield and thus has a “first-order” effect because it directly affects the drift of η . Although a decrease in asset price volatility influences the drift of η , the effect occurs through covariances and is therefore still “second-order.”

In Appendix B.3 we examine the relative contributions of risk pricing and the terms of trade hedge from another perspective by considering “counterfactual” scenarios in which we replace any prices of intermediate goods in the expression for μ_η in (15) with the prices from the constrained equilibrium (thus we suppose the only effect of prudential limits is on terms of trade and not also on endogenous volatility). These results confirm again that the terms of trade hedge is the more important mechanism through which leverage constraints provide financial stability.

Incomplete Markets and the Terms of Trade Although the effect from the terms of trade dominates the effect from endogenous risk, incomplete markets are still the key reason why the terms of trade matter. As noted in Section 2, if markets were complete, then in the symmetric case countries would not strategically manipulate capital flows to influence the terms of trade. Incomplete markets, however, force countries to hold portfolios that cause their production as a share of world output to fluctuate. In equilibrium, their production is more valuable, and excess returns are higher precisely when their net worth is low. This feature creates an incentive to dynamically manipulate the terms of trade between goods a and b . Incomplete markets cause time variation in a country’s income which creates similar incentives for terms-of-trade manipulation to those studied in Costinot et al. (2014).

However, in contrast to previous work on terms-of-trade manipulation, prudential regulations affect the terms of trade through portfolio choice and production decisions, not through consump-

tion behavior. With unit EIS, countries always consume a constant fraction of their share of world wealth (e.g., for the AE, $C_A = \rho q \eta$). Agents consume more or less as a result of policy only due to changes in q . Limiting leverage instead affects the scale of a country's production, which influences the returns a country receives from holding capital. Because individual agents take prices as given, they do not internalize how their leverage decisions change their terms of trade. By limiting leverage, countries earn better returns on capital, which speeds up the rate at which their net worth recovers after bad shocks near the stochastic steady state.

5.3 Discussion

While our model is highly stylized, these results should still hold in some form across a wide range of potential environments. For example, our results are robust to considering other ways of modeling AEs as the financial center. We obtain qualitatively identical results if AEs and EMEs have identical preferences but AEs face lower fundamental volatility for their investments (Appendix E.4). What matters for our results is that AEs have an incentive to bear global risk but financial instability caused by market incompleteness encourages them to, at least in part or on the margin, regulate that risk away. This incentive complicates the conduct of policy coordination which grants EMEs greater access to financial intermediation by AEs. To achieve coordination, EMEs may need to compensate AEs in some form in order for AEs to agree to bear more global risk. If EMEs have strong demand for additional intermediation, then AEs may be able to obtain substantial compensation as the price for coordination.

For tractability and realism we have considered fixed leverage limits. However, the constrained optimal solution would require state-dependent limits. Appendix E.5 makes some progress in that direction and presents an extension with cyclical constraints, allowing some degree of state-contingency in policy decisions. We consider when countries can choose two leverage limits that bind in different states of the world and allow countries to choose the regions of the state space for each policy (thus choosing three parameters altogether). Allowing such “cyclical” policy options, it is optimal for countries to choose countercyclical constraints that are looser in crisis times. Still, countries choose tighter constraints without coordination. Thus, the main thrust of our results goes

through even with some degree of state-contingent policy.

We have abstracted away from channels for positive macro-level spillovers, and richer set-ups would likely incorporate them. However, the key insight of our model is that a stabilizing policy in one country means that country becomes relatively richer more frequently, and we expect this mechanism, on the margin, to remain in models with positive externalities. A more realistic Nash outcome would likely involve tighter leverage constraints relative to the coordinated equilibrium, but constraints would perhaps be positive rather than zero. However, since the EME would still want the AE to provide financial intermediation, any policy coordination will continue to place substantial weight on the AE's welfare. For the interested reader, Appendix D discuss some implications of our model for international financial regulations.

Several dimensions of our model can be further extended to provide greater insight as to how global macroprudential and capital account regulation should be conducted. Our analysis ignores any important heterogeneity within countries. Indeed, [Buch and Goldberg \(2016\)](#) find that heterogeneity among banks lead to different responses to cross-border spillovers. Thus, a homogenous constraint may not be the best choice, and further research should be conducted to determine how agent heterogeneity influences the optimal constraint. Second, including richer heterogeneity across countries (besides asymmetric risk aversions), and particularly across financial sectors, would likely provide additional forces for strategic interactions between countries.

5.4 Robustness

Appendix E verifies the robustness of our results. Appendix E.1 considers Nash and optimal policies when the two countries have symmetric risk aversion. Appendix E.2 reports how our results vary with the degree of asymmetry in risk aversion. Appendix E.3 checks the calibration of the gains from specialization. Appendix E.4 models the AE as a country with lower fundamental volatility $\sigma_A \leq \sigma_E$ rather than lower risk aversion. Appendix E.5 allows symmetric countries to use piecewise leverage constraints and confirms that they optimally choose countercyclical constraints, which are loose in bad times but tight in good times. In Nash equilibrium, these countercyclical constraints are tighter than the social optimum. Appendix F relaxes the assumption

of Cobb-Douglas production and solves the model with a CES production function, which is the more empirically relevant case since goods are typically substitutes in international trade. Finally, Appendix G extends the specification of exogenous capital shocks to include both owner- and location-specific shocks.

6 Conclusion

Emerging market economies depend on “center” countries in the global financial system to provide intermediation and risk-bearing, but to do so requires that AEs bear systemic risk. When international credit markets are imperfect, more stable countries are more likely to be relatively wealthy compared to less stable countries. Prudential regulations, when effective, increases economic stability, creating a macro-level spillover through international capital flows. As a result, tight prudential controls in one country provides strategic incentives for tight policy in the other. Because countries can unilaterally choose their prudential regulations, AEs have an incentive to provide less intermediation than demanded by EMEs. Therefore, coordination will likely result in policies that place relatively more emphasis on the outcomes of AEs than the outcomes of EMEs.

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