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PIERRE-RICHARD AGÉNOR
TIMOTHY JACKSON
ENISSE KHARROUBI
LEONARDO GAMBACORTA
GIOVANNI LOMBARDO
LUIZ A. PEREIRA DA SILVA

Assessing the Gains from International Macroprudential Policy Cooperation

We study the effects of coordinated and noncoordinated macroprudential policies in a core–periphery model that emphasizes the role of international financial centers. After documenting empirically the existence of cross-country macroprudential spillovers and policy interdependence, we derive a number of results. First, even absent financial frictions, self-oriented policymakers attempt to manipulate asset prices to their advantage, resulting in higher long-run capital taxes. Second, financial frictions generate a subsidization bias, as policymakers aim at eliminating the inefficiency wedge between the cost of capital and the deposit rate. Third, self-oriented national

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Enisse Kharroubi, Giovanni Lombardo, and Luiz A. Pereira da silva *are at the Bank for International Settlements* (*E-mail*: enisse.kharroubi@bis.org, giannilmbd@gmail.com, luiz.apereira@bis.org). Leonardo Gambacorta *is at the Bank for International Settlements*, CEPR (*E-mail*: Leonardo.gambacorta@bis.org). Pierre-Richard Agénor *is at the University of Manchester* (*E-mail*: pierre-richard.agenor@manchester.ac.uk). Timothy Jackson *is at the University of Liverpool* (*E-mail*: timjackson100@hotmail.co.uk).

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policies imply insufficient subsidies in the long run and wider efficiency gaps in the short run, resulting in substantial gains from cooperation.

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The Global Financial Crisis of 2007–09, and the unprecedented speed and scale with which it was amplified and propagated internationally, has given renewed impetus to research on cross-border spillovers and policy interdependence.[1]

The broad consensus that emerged from the recent debate is that financial and economic integration exacerbates the trade-offs faced by policymakers, possibly bringing about a "financial trilemma" alongside the traditional monetary trilemma (e.g., Obstfeld 2017).[2] The quest for additional policy instruments, to tackle the new policy challenges, has given prominence to macroprudential policy (MaP) tools.[3] Furthermore, it is increasingly accepted that relying exclusively on national financial policies to attain financial stability in an integrated world might be unfeasible (Schoenmaker 2011, 2013). The financial trilemma thus "... provides the main rationale for a globally collaborative international reform agenda." (Obstfeld 2017). Our paper builds on this idea by providing a quantitative general equilibrium analysis of the key channels underlying the gains from cooperation.[4]

Our theoretical analysis of the gains from cooperation hinges on the existence of cross-country policy spillovers. As the empirical literature on MaP is still in its infancy, we motivate our analysis by deriving some novel empirical evidence on the correlation between macroprudential intervention and output volatility, as well as on the cross-country interdependence of macroprudential interventions, for different degrees of financial interdependence. Using a panel of 64 countries over 29 years, we show that macroprudential interventions could bring about higher macroeconomic stability. Furthermore, macroprudential interventions tend to comove more strongly among financially integrated countries.

Building on this evidence, we develop a stylized model of cross-country financial interdependence in which MaP can impact domestic and foreign resource allocations. Our aim is to shed some light on a very specific dimension of the data: policy interdependence through financial channels. We thus abstract from many features that appear in similar DSGE models—such as sticky prices, differentiated goods, and monetary policy—and focus instead on one single inefficiency wedge consisting of the difference between the return on capital (cost of capital for firms) and the

1. See Bagliano and Morana (2012), Fratzscher et al. (2016), Anaya et al. (2017), Bowman et al. (2015), Aizenman et al. (2016), Barroso et al. (2016), Tillmann (2016), and MacDonald (2017).

2. Some have referred to the new policy constellation in terms of "dilemmas" as opposed to the traditional "trilemma" of monetary policy (Rey 2013).

3. An overview of the experience that central banks have gathered with the use of macroprudential instruments is reported in Committee on the Global Financial System (2016b).

4. We use the term "coordination" to refer to the use of the policy instruments in a "cooperative" game. We thus use "cooperation" to denote the policy regime (game).

return on deposits (cost of finance for financial intermediaries). Likewise, we model macroprudential policies in a simple stylized way. In particular, we interpret macroprudential policies as those policies that aim at tackling the inefficient excess cost of capital emerging from financial frictions. MaP in the real world aims at a more complex objective of reducing the risk of systemic financial crises. In our model, risk—in the sense of undesired uncertainty faced by risk-averse agents—plays an important role. However, for tractability, we are forced to abstract from the endogenous emergence of financial crises. That said, we believe that even our relatively simpler analysis can shed some light on the question of policy interdependence under more complex scenarios.[5]

Our theoretical results can be summarized as follows. First, we show that under complete markets, even in a frictionless environment, noncooperative policymakers try to affect the cross-country allocation of wealth through asset-price movements, in line with Engel (2016)'s analysis. These asset-price changes are engineered using capital taxes. Second, introducing financial frictions generates an inefficiency wedge between the return on capital and the cost of deposits. Benevolent policymakers try to reduce this wedge using subsidies to financial intermediaries (MaP) and vary them to minimize inefficient short-run fluctuations. In the absence of cooperation, policymakers set the MaP instrument to affect allocations to their advantage. The tension between the incentive to manipulate asset prices and the incentive to subsidize banks results in insufficient long-run subsidies and suboptimal short-run adjustments of the policy instrument. Third, the gains from cooperation can be smaller under financial frictions than in the frictionless world. Financial frictions appear to impose some restraints on noncooperative policymakers, inducing them to "'keep their own house in order." At the same time, the cooperative policy cannot bring about first-best allocations. The combination of these two elements generates smaller welfare gaps between the two policy regimes. The reduction of the gains is larger, the larger the dependency of the peripheral banks on global financial intermediaries. We find that gains are sizeable *with or without financial frictions*, amounting to more than 1% of steady-state consumption.

The modeling choice of taxes/subsidies on financial-asset returns as MaP instruments might appear as contrasting the variety and complexity of real-world prudential instruments (e.g., Claessens et al. 2013). Nevertheless, it should be noted that at the level of abstraction adopted here, the salient feature of a MaP instrument is to alter the balance sheet composition of banks and their net worth (or franchise value) by affecting directly or indirectly the cost of borrowing or the interest margin on lending. Indeed, this approach is not novel in the literature on MaPs, where instruments take the form of taxes on deposits, taxes on loans, and taxes on the net worth of banks.[6]

5. We limit our (short run) analysis to second order of accuracy, which cannot capture time-varying correlations. The long-run analysis is based on the nonlinear model.

6. For instance, Kannan et al. (2010), Gertler et al. (2012), and Levine and Lima (2015) specify a tax on loans, as do also De Paoli and Paustian (2013) in a model without banks. Correia et al. (2018) focus on credit subsidies. By contrast Quint and Rabanal (2014) introduce an MaP instrument that operates by affecting the supply of credit, and ultimately the lending deposit spread. These specifications are in almost all cases assumed to be neutral in terms of their fiscal impact. An exception is provided by Reis (2019),

This stylized characterization of MaP instruments (as taxes) can be traced to a large literature highlighting the equivalence of allocations attained under different policy instruments, for example, Farhi et al. (2014). At the same time, it is well known that the allocations produced by noncooperative games can be sensitive to the choice of instruments. Furthermore, while our representation captures the salient mechanism through which MaP tools operate, it does not aim at capturing important details (e.g., implementation constraints, communication, etc.) of real-world measures.[7] Despite these caveats, our analysis reveals important insights on the international dimension of macroprudential policies. The analysis of more detailed macroprudential tools deserves to be addressed in future research.[8]

The remainder of the paper proceeds as follows. Section 1 provides a short review of the literature closely related to our analysis. Section 2 describes the model, which dwells largely on Banerjee et al. (2016). We focus on the key features of relevance to the issue at stake, namely, the financial system and the MaP regime. Section 3 examines some stylized facts that the model is expected to reproduce and discusses the calibration of the model. Section 4 discusses the implications of our theoretical assumptions for the response of the economy to shocks. In that section, both impulse responses (to first order of accuracy) and welfare analysis (up to second order of accuracy) are discussed. Finally, in Section 5, we provide concluding remarks. Some more technical discussion and more detailed empirical evidence are collected in the Appendix.

1. RELATED LITERATURE

Our paper is related to a large and growing literature. In particular, the scope for international MaP cooperation has also been the subject of a number of recent contributions. Bengui (2013), Jeanne (2014), Jeanne and Korinek (2016), and Kara (2016) have provided insights based on small analytic models. Other authors have used two-country dynamic stochastic general equilibrium (DSGE) models with financial market imperfections. Some of these contributions have studied a currency union where national central banks and a common central bank may possibly take on a MaP regulatory role.[9] Closely related to our paper is the work by Aoki et al. (2016),

who explicitly assesses the “fiscal footprint” of macroprudential policies, modeled as taxes/subsidies, like we do here.

7. See Gerali et al. (2010), Agénor et al. (2012), Agénor and Zilberman (2015), Agénor et al. (2018a), and Agénor and Pereira da Silva (2017) for models with explicit macroprudential measures.

8. According to Bank for International Settlements et al. (2011), there are three defining elements that characterize a MaP: (i) objective: to limit systemic risk; (ii) scope: focus on the entire financial system; and (iii) instruments and governance: prudential tools administered by a body with a financial stability mandate. The main challenges in objective setting and communication of macroprudential policies are discussed in Committee on the Global Financial System (2016a). Mishkin et al. (2003) discuss some properties of macroprudential policies, referred to by the authors as “financial policies.” Our analysis tries to see through these aspects to capture a more primitive feature of financial frictions and financial intervention.

9. See, for example, Rubio (2014), Quint and Rabanal (2014), Mendicino and Punzi (2014), Brzoza-Brzezina Michałand Kolasa and Makarski (2015), Palek and Schwanebeck (2015), Agénor et al. (2018b), and Rubio and Carrasco-Gallego (2016).

who study monetary and fiscal policy in emerging markets. In terms of macroprudential policies, these authors derive the welfare implications for a small open economy of introducing taxes on risky investments as well as on borrowing in foreign currency. The former policy, assumed to be of permanent nature, generates little welfare gains. The latter policy, assumed to change cyclically, has instead larger positive welfare implications. Our paper differs from theirs in that we focus on optimal MaP policy and the gains from cooperation in a two-country model. Furthermore, we do not study the interaction with monetary policy. This interaction is instead the focus of Ozkan and Unsal (2014), who assess the optimal mix of monetary and MaPs in small open economies. One of their main findings points out that monetary policy need not be used for financial stabilization purposes in the presence of MaP tools. Jeanne and Korinek (2016) study macroprudential interventions as opposed to *ex-post* fiscal measures. They find that it is generally optimal to use both. Kollmann et al. (2011), Kollmann (2013), and Cuadra and Nuguer (2018) have considered more general core–periphery models where global banks play a key role in the international transmission of shocks.[10] These contributions have considered a number of MaP instruments, often in the form of simple countercyclical rules.[11] Recently Mendoza (2016) discussed different dimensions of MaPs, highlighting in particular the hurdles facing their implementation. Mendoza's contribution is particularly important for our work as it discusses a number of salient aspects of MaP that could be captured in an abstract way, for example, through taxes. Bianchi and Mendoza (2010) discuss some stylized facts associated with the existence of financial constraints similar to those modeled in our paper. In particular, they emphasize the pecuniary externality that this constraint brings about, and thus the room for corrective policy interventions, even in closed economies.

Our paper is also strongly inspired by the literature on the international dimensions of monetary policy.[12] While this literature has shed more light on the sources of possible gains from cooperation, it has also concluded that quantitatively, the gains are generally small.[13] For instance, Banerjee et al. (2016) show, in a model similar to ours, that the incentive to "put one's own house in order" induces self-oriented

10. Some of these contributions have also looked at the combination of monetary policy and MaP regulation (see Mendicino and Punzi 2014, Quint and Rabanal 2014).

11. For example, loan-to-value (LTV) ratios (Rubio 2014, Brzoza-Brzezina Michałand Kolasa and Makarski 2015, Rubio and Carrasco-Gallego 2016), capital requirements (Kollmann et al. 2011, Kollmann 2013), and reserve requirements (Agénor et al. 2018b).

12. Beyond some earlier contributions, for instance, by Hamada (1976), Canzoneri and Gray (1985), and Canzoneri and Henderson (1992) (and the literature cited therein), more recent seminal papers in this area include Obstfeld and Rogoff (2002), Clarida et al. (2002), Devereux and Engel (2003), Corsetti and Pesenti (2005), Benigno and Benigno (2003), ,2006), and Engel (2011).

13. See also Canzoneri et al. (2005) and the general framework proposed by Corsetti et al. (2010). Sutherland (2006) has pointed out that the gains are very sensitive to trade elasticities. That said, for empirically plausible values, the gains remain small and mainly due to the risk-sharing effect of terms-of-trade movements, in the spirit of Cole and Obstfeld (1991), and Obstfeld and Rogoff (2002). Coenen et al. (2009) assess the gains from cooperation in a medium size two-country DSGE model without financial frictions. Their baseline results suggest that the gains are rather small. Nevertheless, they also point out that the degree of openness plays a crucial role, so that growth in international trade could engender larger gains from international cooperation.

plicymakers to follow policies very close to the cooperative ones. The resulting gains from monetary policy cooperation are thus negligible.

2. A MODEL OF INTERNATIONAL MACROPRUDENTIAL POLICY SPILLOVERS

The focus of our analysis is the international dimension of MaP in an asymmetric world, that is, a world in which international capital markets, mainly centered in a few advanced core economies (United States, euro area, and Japan), play a disproportionate role in financing less financially developed periphery economies, such as emerging market economies (EMEs). There are various ways in which these international links can be modeled. Our choice goes to a rather standard two-country DSGE setup with familiar features. The core of the model consists of an international real business cycle model (IRBC). The only departure from an IRBC consists of the introduction of imperfect financial intermediation à la Gertler and Karadi (2011). In particular, we modify the asymmetric open-economy model developed by Banerjee et al. (2016) (BDL) by assuming that countries produce perfectly substitutable goods, and that prices are flexible and by abstracting from monetary policy. While we start our analysis with a symmetric world, we study the implication of various degrees of financial dependency of the EME on the center-country financial market. The EME banks can finance themselves either through domestic deposits (up to an exogenous limit) or through the international capital market. At the same time, we assume that households, in both countries, can trade internationally a complete set of Arrow–Debreu securities.[14] The combination of these two assumptions allows us to focus on one single financial inefficiency wedge: the gap between the return on capital and the cost of finance faced by firms. The assumption of two layers of financial frictions used by BDL offers a parsimonious way to capture two aspects of financing conditions in some EMEs: (i) higher inefficiency and (ii) high sensitivity to conditions in the global financial market. The two-layer assumption emphasizes the strong international policy spillovers, for example, through regulated global banks.[15]

Various types of MaPs have been adopted across countries over time. Some of these policies impose limits that are exogenous to individual banks (e.g., LTV ratios or loan-to-income ratios), while others work through constraints that are endogenous to the choices of individual banks (e.g., reserve requirements, capital charges on risk-weighted assets, large exposure limits, leverage constraints, and so on). A common feature of these policy measures is to affect the incentive to supply credit.[16] As noted

14. A growing literature discusses the role of financial intermediaries in the international propagation of shocks (e.g., Devereux and Yetman 2010; Perri and Quadrini 2011; Dedola and Lombardo 2012; Gabaix and Maggiori 2015). In particular, Maggiori (2017) considers the combination of imperfect financial intermediation and a complete set of Arrow–Debreu securities.

15. See for example Buch and Goldberg (2016).

16. Clearly, from a social welfare point of view, a cost for an individual bank could improve aggregate welfare, for example, if it mitigates frictions or externalities. Furthermore, through the general equilibrium effect, individual banks could eventually benefit from the policy intervention too. Nevertheless, we

in the introduction, we will refer to MaP instruments in a broad sense, as instruments that share the common features of the real-world measures but abstract from the details that characterize each of them.

We build up our understanding of the policy problem starting from the frictionless economy. We show that even absent frictions, noncooperative policymakers try to shift resources to their advantage, thus bringing about suboptimal allocations in equilibrium. We then introduce financial frictions and show how these alter the cross country spillovers and consequently affect the policy problem. The emphasis is on spillovers and trade-offs, in the tradition of the international policy cooperation literature mentioned in the introduction. We follow this literature also by limiting our analysis to first- and second-order effects, in the short run, while preserving the full nonlinearity in deriving long-term optimal taxes and allocations.

An established result in the modern welfare analysis literature is that focusing exclusively on volatility could understate the policy trade-off, for instance, when the economy is affected by long-run frictions. This is particularly true in a model like ours, in which financial frictions increase the long-run cost of capital. In this context, and abstracting from other frictions, the welfare-maximizing social planner would aim at reducing the cost of capital, for instance, through lump-sum financed subsidies. This policy, on the other hand, could distort incentives and increase aggregate volatility inefficiently. The policymaker, in this case, will have to design a policy that deals with both of these intertemporal dimensions. The ability to do so will crucially depend on the type of instruments that are available. In this sense, the dynamic perspective implies that the Tinbergen–Mundell instrument-target principle might not fully reveal the complexity of the policy problem faced by policymakers: a single wedge could give rise to an intertemporal trade-off.[17] Our analysis sheds light on this problem.

We model the world as consisting of two economies, with total population normalized to have unit mass. The core country (denoted by the letter c), which stands for an advanced economy (AE), is populated by $1 - n$ consumers. The periphery (denoted by the letter e), which stands for EME, has economic size of n. We focus on the case of equal size, so that the only asymmetry emerges from financial dependency.[18] Both economies consist of a household sector, a production sector, banks, and a policymaker. Furthermore, an international financial market exists where households can trade in assets. Variables are expressed in real terms.

2.1 The Emerging Market Economy (Periphery Country)

Households. Households consume and work, and act as bankers as in Gertler and Karadi (2011) (more details further below).

exclude the case in which banks benefit directly from a constraint, for example, due to bounded rationality, imperfect information, etc.

17. See Tinbergen (1952) and Mundell (1968, pp. 201–216).

18. The case of asymmetric size is briefly discussed later, with respect to our welfare calculations (see footnote 37) and detailed results are available upon request.

Households maximize their intertemporal utility over consumption (C_t^e) and labor supply (H_t^e) given by:

$$\mathcal{W}_0^e = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{e(1-\sigma)}}{1-\sigma} - \frac{H_t^{e(1+\psi)}}{1+\psi} \right), \tag{1}$$

subject to their budget constraint

$$C_t^e + E_t \Lambda_{t+1}^e B_{t+1}^e + D_t^e = B_t^e + R_{t-1}^e D_{t-1}^e + W_t^e H_t^e + \Pi_t^e, \tag{2}$$

where $\beta \in (0, 1)$ is the discount factor, $\sigma > 0$ is the risk-aversion parameter, and $\psi > 0$ is the inverse Frisch-elasticity of labor supply.

In particular, households trade in the international capital market a complete set of Arrow–Debreu securities B_{t+1}^e at the state contingent price Λ_{t+1}^e (the household stochastic discount factor) and have access to domestic banks' deposits, D_t^e, which pay the gross return R_t^e. Only one type of good is produced in the world, which is in part consumed by households. Households earn a wage W_t^e on their supply of working hours H_t^e and receive Π_t^e in profits earned from banks and capital producing firms, net of new capital injections into banks as well as lump-sum taxes or subsidies.

Risk sharing. While we do not report all the first-order conditions (FOCs) of the households' problem, as they are standard (see, e.g., Banerjee et al. 2016), the risk-sharing conditions implied by complete markets play a central role in our analysis and hence deserve to be explicitly discussed. The optimal choice of Arrow–Debreu securities by the representative households in each country implies the equalization of the stochastic discount factors, state-by-state (e.g., Ljungqvist and Sargent 2012), that is,

$$\Lambda_t^e = \Lambda_t^c; \tag{3}$$

also known as the consumption risk-sharing condition.

Under our assumptions of constant relative risk aversion (CRRA) preferences, the risk-sharing condition can be iterated backwards to yield

$$\log(C_t^c) - \log(C_t^e) = \kappa^{RS}, \tag{4}$$

where $\kappa^{RS} \equiv \log(C_0^c) - \log(C_0^e)$ is the risk-sharing "constant" (i.e., invariant with respect to time) that depends on the (stochastic) initial relative consumption. This constant plays a key role in explaining the gains from cooperation, as we discuss later.

Goods producers. We assume that the production of goods uses labor (H_t^e) and capital (K_t^e) according to a Cobb–Douglas technology:

$$Y_t^e = A_t^e \left(\xi_t K_{t-1}^e\right)^{\alpha} H_t^{e(1-\alpha)}, \tag{5}$$

subject to the total factor productivity shocks (A_t^e) and the capital-quality shock (ξ_t), both modeled as AR(1) processes.

In order to purchase capital, the entrepreneurs obtain funds by selling securities $Z_t^e = K_t^e$ at the price Q_t^e to domestic banks. The payoff of the securities is fully indexed to the marginal return on capital, which is defined as

$$r_t^e \equiv \alpha MC_t^e \frac{Y_t^e}{K_{t-1}^e}, \tag{6}$$

where MC_t^e is the real marginal cost of production, which is equal to 1 under our assumptions.

Capital producing firms. A competitive set of firms produce capital by combining old capital with newly purchased investment goods (I_t^e), subject to the adjustment cost function $\zeta(\frac{I_t^e}{I_{t-1}^e} - 1)^2 I_t^e$ (e.g., Christiano et al. 2005).

Capital producers buy back the old capital from banks at price Q_t^e and produce new capital using final goods subject to the adjustment cost function. Consequently, the aggregate stock of capital evolves according to the following law of motion:

$$K_t^e = I_t^e + (1-\delta)\xi_t K_{t-1}^e.$$

2.2 *EME Banks*

Banks begin with some bequeathed net worth from their households and continue their business with probability θ. With probability $1-\theta$, banks revert back to their households as in Gertler and Karadi (2011). Bank i that begins with net worth N_{it} borrows an amount V_{it}^e, at the real rate R_t^b from the global bank, and an amount D_{it}^e (deposits) from domestic households at rate R_t^e and purchases securities from firms so that the balance sheet is

$$Q_t^e Z_{it}^e = N_{it}^e + V_{it}^e + D_{it}^e. \tag{7}$$

Domestic deposits. In order to assess the importance of financial dependency, while avoiding corner solutions due to arbitrage, we furthermore assume that deposits cannot exceed a fraction κ_D of total bank's liabilities. Defining $\psi_D^e \equiv (1-\kappa_D)^{-1}$, we can rewrite the balance sheet as

$$D_{i,t}^e \leq \left(\psi_D^e - 1\right) V_{i,t}^e. \tag{8}$$

Recall that households price domestic deposits at the international risk-free rate $R_t^e = R_t^c \leq R_t^b$, where the last inequality is due to the presence of credit spreads. Under this assumption, the constraint (8) is always binding. We thus impose equation (8) with equality without loss of generality.

Hence, the balance sheet of the bank reduces to

$$Q_t^e Z_{i,t}^e = N_{i,t}^e + \psi_D^e V_{i,t}^e. \tag{9}$$

Net worth. The net worth of the EME banking system evolves according to:

$$N_t^e = \theta N_{i,t}^e + \delta_T Q_t^e K_t^e, \tag{10}$$

where $\delta_T Q_t^e K_t^e$ is the amount transferred from households to newly established banks, while $N_{i,t}^e$ is the net worth of the surviving banks, that is,

$$N_{i,t}^e = R_{k,t}^e Q_{t-1}^e Z_{i,t-1}^e - \widetilde{R}_{t-1}^b V_{i,t-1}^e, \tag{11}$$

where $\widetilde{R}_t^b \equiv (R_t^b - R_t^e) + \psi_D^e R_t^e$ is the effective cost of funds and $R_{k,t}^e$ is the gross return on capital defined as

$$R_{k,t}^e \equiv \frac{\left(1 - \tau_{k,t}^e\right) r_t^e + (1 - \delta)\xi_t Q_t^e}{Q_{t-1}^e}, \tag{12}$$

where $\tau_{k,t}^e$ is a tax (subsidy) used for MaP purposes as discussed further below.

Optimization problem. Contracts between savers and banks are subject to limited enforceability. Banks could abscond with part of their assets and leave only a fraction $1 - \kappa^e$ of them to cover for their debt. The incentive compatibility constraint (ICC) therefore requires that the franchising value of the bank be at least as large as the value of the assets. If this is not the case, bankers would prefer to "default." Bankers maximize the franchising value of the bank that they are expected to pay to the household when the time to leave their activity comes (i.e., with probability $1 - \theta$). The problem of the (i-) banker can thus be expressed as

$$J^e\left(N_{i,t}^e\right) = E_t \max_{N_{i,t}, Z_{i,t}^e, V_{i,t}^e} (1 - \theta) \sum_{j=0}^{\infty} \Lambda_{t+1+j}^e \left[\theta^j N_{i,t+1+j}^e\right], \tag{13}$$

subject to the net-worth accumulation law (11) and the ICC

$$J_{i,t}^e\left(N_{i,t}^e\right) \geq \kappa^e Q_t^e Z_{i,t}^e, \tag{14}$$

where $J_{i,t}^e$ is the value of bank i (as a function of the state variable $N_{i,t}^e$), and Λ_t^e is the household discount factor.

First-order conditions. The FOC of the banker's problem is

$$Z_t : E_t \Omega_{t+1|t}^e \left(R_{k,t+1}^e - \widetilde{R}_t^b\right) = \gamma_t^e \kappa^e, \tag{15a}$$

the envelope condition is,

$$N_{s,t}^e : J^{e\prime}\left(N_t^{e,s}\right)\left(1 - \gamma_t^e\right) = E_t \Omega_{t+1|t}^e \widetilde{R}_t^b, \tag{15b}$$

and the complementary slackness condition is

$$\gamma_t^e \left(J_t^e \left(N_{i,t}^e \right) - \kappa_Z^e Q_t^e Z_t^e \right) = 0, \tag{15c}$$

where γ_t^e is the Lagrange multiplier on the ICC and $\Omega_{t+1|t}^e \equiv \Lambda_{t+1}^e [1 - \theta + \theta J_{t+1}^{e\prime}]$ is the effective pricing kernel of the bank.

In the FOCs, we have omitted the bank-specific index as the banker problem is invariant to scale, and we can thus refer to a representative bank. The only useful distinction remains between $N_{i,t}^e$ and N_t^e for obvious reasons.

2.3 The Advanced Economy (Core Country)

The core country household and production sectors are identical to those of the EMEs, except for (i) the possibility of the limitless access of households to domestic bank deposits and (ii) the country size. For the sake of conciseness, we therefore omit the description of these sectors and move straight to the banking sector.

Core country banks. The global bank j has a balance sheet constraint given by

$$V_{j,t}^e + Q_t^c Z_{j,t}^c = N_{j,t}^c + D_{j,t}^c, \tag{16}$$

where $V_{j,t}^e$ is claims on the EME bank, and $Q_t^c Z_{j,t}^c$ is claims on the core country capital stock. $N_{j,t}^c$ is the bank's net worth, and $D_{j,t}^c$ are deposits received from domestic households.

The return on investment in the domestic (core country) capital stock is:

$$R_{k,t}^c = \frac{\left(1 - \tau_{k,t}^c\right) r_t^c + (1 - \delta) \xi_t^c Q_t^c}{Q_{t-1}^c}. \tag{17}$$

The global bank's value function can then be written as:

$$\begin{aligned} J_{j,t}^c \left(N_{j,t}^c \right) &= E_t \max_{N_{j,t}^c, Z_{j,t}^c, V_{j,t}^e, D_{j,t}^c} \Lambda_{t+1}^c \\ &\times \left[(1 - \theta)(R_{k,t+1}^c Q_t^c Z_{j,t}^c + R_t^b V_{j,t}^e - R_t^c D_{j,t}^c) + \theta J_{j,t+1}^c \left(N_{j,t+1}^c \right) \right]. \end{aligned} \tag{18}$$

The bank faces the incentive compatibility constraint:

$$J_{j,t}^c \left(N_{j,t}^c \right) \geq \kappa_V^c V_{j,t}^e + \kappa^c Q_t^c Z_{j,t}^c; \;\; \kappa_V^c, \kappa^c > 0, \tag{19}$$

where we allow for the possibility that the ICC is affected asymmetrically by the different types of assets (e.g., Gertler et al. 2012).

First-order conditions. The FOCs of the core country bank problem are:

$$Z_{j,t} : \; E_t \Omega_{t+1|t}^c \left(R_{k,t+1}^c - R_t^c \right) = \kappa^c \gamma_t^c, \tag{20}$$

$$V^e_{j,t} : E_t\Omega^c_{t+1|t}\left(R^b_t - R^c_t\right) = \kappa^c_V \gamma^c_t, \tag{21}$$

and the envelope condition

$$J^{c\prime}_j\left(N^c_{j,t}\right)\left(1-\gamma^c_t\right) - E_t\Omega^c_{t+1|t}R^c_t = 0. \tag{22}$$

2.4 *Macroprudential Policy and Scope for Policy Intervention*

In our model, when financial frictions are present, benevolent policymakers could have an incentive to eliminate the related inefficiency and thus reduce excess volatility. Financial frictions generate a wedge between the deposit rate (household stochastic discount factor) and the cost of capital, akin to a markup accruing to monopolists. In the latter case, a subsidy financed with nondistortionary taxes can bring back the efficient allocation (where prices equal marginal costs). Likewise, a "macroprudential" intervention can bring the economy closer to the first best.

For the sake of concreteness, equation (15a) summarizes the inefficiency gap in terms of the wedge between the credit spread and the households' risk premium. This wedge is present only if the ICC (14) (and/or the equivalent constraint for the AE) binds at present (i.e., $\gamma^e_t > 0$) or is expected to bind in the future in certain states of the world (i.e., $E_t(\Omega^e_{t+1|t} - \Lambda^e_{t+1}) > 0$). We can therefore denote the inefficiency gap as

$$\chi^j_t\left(\tau^e_{k,t}, \tau^c_{k,t}\right) \equiv E_t\left(\Omega^j_{t+1|t} - \Lambda^j_{t+1}\right)\left(R^j_{k,t+1} - R^j_t\right);\ j = \{e, c\}. \tag{23}$$

For example, in the IRBC version of our model, we have that $\chi^e_t = \chi^c_t = 0\ \forall t$. We are interested in knowing whether MaP can increase welfare by steering these wedges.

It should be noted though that the strategic interaction of policymakers emerging from trade and financial openness can be a further source of inefficiency (relative to the global optimum). When they act independently, policymakers deviate from the first best in an attempt to reap domestic benefits at the expense of the other country. This temptation would indeed be present even in a frictionless world, under assumptions similar to those entertained here (as shown below). On top of this "natural" temptation, financial frictions create a further incentive to shift the inefficiency to the other country. These strategic incentives are clearly absent under cooperation.

Achieving the first best might be hampered by the lack of appropriate instruments (e.g., lump-sum taxes) or by the presence of costs (e.g., motivated by political economy considerations, or by the complexity of policy interventions). There are various possible ways to model costly policy interventions. One relatively popular way consists of imposing some *ad hoc* costs of intervention (see, e.g., Gertler and Karadi 2011 or Dedola et al. 2013), while assuming that the government can finance MaP interventions only through lump-sum taxes (or transfers). Another possibility consists of taking a richer public finance perspective and thus consider alternative fiscal policy schemes to finance MaP interventions. Our choice goes to the first setup. In particular, we assume that policymakers are averse to the use of MaP instruments (reminiscent of the interest rate smoothing preference in optimal monetary policy problems discussed, e.g., by Woodford 2003).[19] Furthermore, in each period, policymakers must balance their budget by offsetting any revenue (or expense) due to MaP interventions using lump-sum taxes (or transfer) only.

We study policies under commitment. The global benevolent policymaker chooses the constrained efficient allocation in order to maximize the expected present value of the population-weighted sum of households' utilities (see equation (1) and the core–country counterpart), in the cooperative case, or only the domestic households' utility in the noncooperative (Nash) equilibrium. The policymaker discounts the future at the same rate as households. The public welfare function is augmented by a term penalizing policy interventions as discussed below.

We study the Ramsey cooperative policy and the open-loop Nash optimal policies. This approach is also followed by Coenen et al. (2009), Gross (2014), and Banerjee et al. (2016).[20] Contrary to monetary policy games, in which the choice of policy rates as "instruments" would lead to nonsaddle-path equilibria (for reasons akin to the lack of saddle-path equilibrium under pegged nominal rates, see, e.g., Sargent and Wallace 1975), in the case of taxes/subsidies, this problem does not emerge. This allows us to make the rather appealing assumption that each policymaker takes the whole future path of the other country MaP instrument as given. Importantly, each policymaker takes into account the global effects of their choice on all the other endogenous variables.

We assume that the policymaker dislikes using distortionary policy instruments. We thus add to the welfare function a quadratic term in the MaP instrument. In particular, we define the welfare objective of the two policymakers as $\psi_{\tau,k} > 0$ is a preference parameter and $\tau^j_{k,ss}$ denotes the long-run taxes chosen by country j.[21]

19. In experiments documented in a precursor of this paper (Agénor et al. 2017), we considered the public finance perspective, with the drawback that the results were partially driven by how other taxes and/or sovereign debt had to be adjusted to finance MaP interventions. Due to the ensuing opacity of the results, we opted for the current specification. Reis (2019) offers an explicit analysis of the "fiscal footprint" of macroprudential policies.

20. See Coenen et al. (2009) for a discussion of this equilibrium in a DSGE modeling context. The Ramsey optimal policy as well as the Nash open loop is implemented using Dynare (Adjemian et al. 1996) together with the Dynare-compatible toolbox (OPDSGE) used, for example, by Coenen et al. (2009) and Banerjee et al. (2016). The code is available at http://www.giovannilombardo.ch/. See also Bodenstein et al. (2019) who recently developed a toolbox with similar features. Fudenberg and Levine (1988) discuss the game-theoretic foundations of open- and closed-loop equilibria. In the game-theory literature, these equilibria differ in terms of the information set available to players. Open-loop equilibria are typically defined as equilibria of games in which players know only the initial value of state variables, and on the basis of this define the whole sequence of actions, which are then played "by the clock" (see, e.g., Başar and Olsder 1998, Cellini and Lambertini 2004). This equilibrium concept is typically preferred on computational grounds, which motivate our choice too. Closed-loop equilibria refer to a larger set of games in which actions are state dependent, although the information set can contain different portions of the sequence of states, or of observables. In our policy game, the sequence of actions is state contingent. Yet the sequence of actions taken by the other policymaker is not observed. This is clearly a limitation of the open-loop equilibrium, as policymakers in our model never learn about (or take advantage of) the link between state variables and policy actions of the other policymakers. Gross (2014) models a game between fiscal authorities in open economies, which is very close to ours. An important difference relates to international financial markets; while Gross assumes an explicit portfolio diversification, we assume complete markets.

21. We find that changes to the functional form of the tax aversion penalty have minimal effects on the optimal long-run taxes.

2.5 *Cooperative and Noncooperative Equilibria*

Formally, we can define the two alternative policy equilibria as follows.

Definition 1 (Cooperative policy problem). *Under the cooperative policy (CP) problem, both policymakers choose the vector of all endogenous variables Θ_t, and the policy instruments $\tau^e_{k,t}$ and $\tau^c_{k,t}$ in order to solve the following problem:*

$$\widehat{\mathcal{W}}_{CP,0} \equiv \max_{\Theta_t, \tau^e_{k,t}, \tau^c_{k,t}} \left[n\widehat{\mathcal{W}}^e_0 + (1-n)\widehat{\mathcal{W}}^c_0 \right], \tag{25}$$

subject to

$$E_t F\left(\Theta_{t+1}, \Theta_t, \Theta_{t-1}, \tau^e_{k,t+1}, \tau^c_{k,t+1}, \tau^e_{k,t}, \tau^c_{k,t}, \tau^e_{k,t-1}, \tau^c_{k,t-1}, \Phi_{t+1}, \Phi_t, \Phi_{t-1}; \varphi\right) = 0, \tag{26}$$

where Φ_t is the vector of all exogenous shocks, φ is the parameter measuring the importance (loading) of the exogenous shocks in the model ($\varphi = 0$ implies that the model is deterministic), and $F(\cdot)$ is the set of equations representing all the private sector resource constraints, the public-sector constraints and budget rules, and all FOCs solving the private sector optimization problems.

Furthermore, the policymaker is subject to the "timeless-perspective" constraint, which defines the $t = 0$ range of possible policy interventions (see Benigno and Woodford 2012).

The FOCs of this problem can be defined as

$$E_t \mathcal{P}\left(\Theta_{t+1}, \Theta_t, \Theta_{t-1}, \tau^e_{k,t+1}, \tau^c_{k,t+1}, \tau^e_{k,t}, \tau^c_{k,t}, \tau^e_{k,t-1}, \tau^c_{k,t-1}, \right)$$
$$(\Phi_{t+1}, \Phi_t, \Phi_{t-1}, \Gamma_{t+1}, \Gamma_t, \Gamma_{t-1}; \varphi) = 0, \tag{27}$$

where Γ_t is a vector of Lagrange multipliers related to the constrained maximization problem of the policymaker.

Definition 2 (Cooperative equilibrium). *The cooperative equilibrium is the set of endogenous variables (quantities and relative prices) and policy instruments, such that given any exogenous process Φ_t, equations (26) and (27) are jointly satisfied $\forall t$.*

Definition 3 (Noncooperative policy problem). *Under the noncooperative policy (NP) problem, each policymaker chooses independently all endogenous variables and her own instrument in order to solve the following problem:*

$$\widehat{\mathcal{W}}^j_{NP,0} \equiv \max_{\Theta_t, \tau^j_{k,t}} \widehat{\mathcal{W}}^j_0 : \; j = \{e, c\}, \tag{28}$$

subject to

$$E_t F\left(\Theta_{t+1}, \Theta_t, \Theta_{t-1}, \tau^e_{k,t+1}, \tau^c_{k,t+1}, \tau^e_{k,t}, \tau^c_{k,t}, \tau^e_{k,t-1}, \tau^c_{k,t-1}, \Phi_{t+1}, \Phi_t, \Phi_{t-1}; \varphi\right) = 0. \tag{29}$$

Furthermore, the policymaker is subject to the "timeless-perspective" constraint, which defines the $t = 0$ range of possible policy interventions.

The FOCs of this problem can be defined as

$$E_t\mathcal{P}^j\left(\Theta_{t+1},\Theta_t,\Theta_{t-1},\tau^e_{k,t+1},\tau^c_{k,t+1},\tau^e_{k,t},\tau^c_{k,t},\tau^e_{k,t-1},\tau^c_{k,t-1},\right)$$
$$\left(\Phi_{t+1},\Phi_t,\Phi_{t-1},\Gamma^j_{t+1},\Gamma^j_t,\Gamma^j_{t-1};\varphi\right)=0, \tag{30}$$

where Γ^j_t is a vector of Lagrange multipliers related to the constrained maximization problem of the j policymaker, where $j=\{e,c\}$.

Definition 4 (Nash equilibrium). *The noncooperative (Nash) equilibrium is the set of endogenous variables (quantities and relative prices) and policy instruments, such that, for any exogenous process Φ_t, equations (29) and (30), both for $j=e$ and $j=c$, are jointly satisfied $\forall t$.*

2.6 Second-Order Approximation of the Welfare Gains

We solve the model using perturbation methods, to first order of accuracy for the evaluation of the impulse response functions and of second moments, and to second order of accuracy for the evaluation of welfare.[22]

Definition 5 (Exact welfare gain). *We define the welfare gain from cooperation as*

$$Gain\equiv\widehat{\mathcal{W}}_{CP,0}-\left(n\widehat{\mathcal{W}}^e_{NP,0}+(1-n)\widehat{\mathcal{W}}^c_{NP,0}\right). \tag{31}$$

From this definition, it follows that taking the second-order Taylor expansion of equation (31) around the point $\varphi=0$, that is, around the deterministic steady state, leads to the following definition.

Definition 6 (Second-order accurate welfare gain). *The second-order accurate gain deviates from the exact gain by a term of order 3 or larger:*

$$\widetilde{Gain}\equiv Gain-\mathcal{O}\left(\varphi^3\right). \tag{32}$$

From this definition, and from the asymptotic property of the Taylor expansion (Holmes 1995), it is clear that our measure of the gains from cooperation can be arbitrarily accurate as $\varphi\to 0$.

Note, in particular, that if $\varphi=0$, the two economies (under Nash and cooperative equilibria) are at their long-run equilibrium (and our solution is exact). These equilibria do not coincide with the maximum steady-state welfare, but rather with the steady state of the maximum welfare that the policymakers can achieve. This distinction is important and is analogous to the distinction between the "Golden Rule" and the "Modified Golden Rule" in the neoclassical growth model (e.g., Romer 1996) or in the optimal monetary policy literature (e.g., King and Wolman

22. For the definition and application of perturbation methods, see Judd (1998), Holmes (1995), Schmitt-Grohé and Uribe (2004), Lombardo and Sutherland (2007), and Lombardo and Uhlig (2018).

1999, Woodford 2003). In this respect, our approximation point differs from that of Clarida et al. (2002).

3. EMPIRICAL EVIDENCE AND MODEL FIT

Before providing a quantitative assessment of the gains from MaP cooperation, we need to calibrate our model according to some specific empirical stylized facts. In particular, the welfare gains that we report are proportional to the variance of the underlying shocks. Thus, whether they are "economically" significant in part depends on whether the model generates moments that are reasonably close to the empirical counterparts. Furthermore, we want to generate some confidence that the assumed channels of policy transmission are not in contrast to those that can be gauged from the data.

We proceed as follows. First, we provide some novel stylized facts on the effectiveness of MaP interventions in reducing macroeconomic volatility in open economies, as well as on the interdependence of macroprudential interventions. This evidence ensures that the necessary (albeit not sufficient) condition for the existence of gains from cooperation, that is, policy spillovers, is present in the data. Second, we compare some empirical first and second moments with those produced by our model.

3.1 Evidence on the Effectiveness of Macroprudential Policy

The first stylized fact consists of the impact of macroprudential interventions on output volatility. This channel is often referred to as one important macroeconomic effect of macroprudential policies (e.g., Committee on the Global Financial System 2016a). Financial frictions generate inefficient volatility (i.e., different from that generated in a frictionless economy) thus creating a "stabilization motive" for the policymaker.

Our benchmark econometric model follows Beck and Levine (2004, table 4) and is an extension of the study by Boar et al. (2017), to which we refer for further details on the econometric technique and data. In particular, we regress the (5-year nonoverlapping) standard deviation of real GDP growth of country i ($\sigma_{\Delta y,i,t}$) on the number of macroprudential interventions (during the same period) in country i as well as in all the other countries, weighted by financial interdependence $MaP^F_{j,t}$ (sum of bilateral balance sheet claims and liabilities), and a number of controls (X_t, including the lagged dependent variable) as in Boar et al. (2017) (see Appendix A for details). In short, our empirical model is

$$\sigma_{\Delta y,i,t} = \beta_1 MaP_{i,t} + \beta_2 MaP^F_{j,t} + \beta_3' X_{i,t} + \eta_i + \varepsilon_{i,t}, \tag{33}$$

where i and t represent country and time period, respectively, and η_i is a country fixed effect.[23]

23. As in Beck and Levine (2004), we used the dynamic generalized method of moments (GMM) panel methodology to obtain consistent and unbiased estimates of the relationship between financial structure and economic growth in the presence of the lagged dependent variable.

TABLE 1

Macroprudential Intervention and Volatility: Cross-Country Spillovers

Dependent variable: Country i 5-year standard deviation of yearly real GDP growth.			
VARIABLES	Total	Resilience	Cyclical
$MaP_{i,t}$	-0.0076^{**}	-0.0154^{***}	-0.0062^{*}
	(0.0033)	(0.0044)	(0.0034)
$MaP^{F}_{j,t}$	-0.0379^{***}	-0.0666^{***}	-0.0519^{***}
	(0.0110)	(0.0220)	(0.0124)
Other controls	Y	Y	Y
Observations:	343	343	343

Note:Robust standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Details in Appendix A.

Table 1 reports the estimation results, where we have further distinguished between MaP measures according to a widely used classification (e.g., Borio 2011, Claessens et al. 2013, Boar et al. 2017): MaPs aimed at strengthening financial markets resilience, MaPs aimed at containing cyclical fluctuations, and total MaPs. We can derive two results. First, domestic macroprudential interventions have a dampening effect on domestic volatility. Second, foreign macroprudential interventions have positive spillovers on domestic volatility: that is, macroprudential policies are effective both domestically and abroad. This effect is stronger for countries that are more financially interconnected.[24] If the only MaP objective were the reduction in macroeconomic volatility, our results could suggest that there are "free riding" incentives for policymakers: reduce costly domestic interventions if the foreign country intervenes. Nevertheless, it is important to note that volatility does not *per se* generate a motive for policy intervention (as we will see below in relation to the frictionless economy). A benevolent policymaker would rather aim at closing inefficiency gaps. As these are not directly observable, further assumptions or a structural model are needed in order to interpret these results. We postpone this discussion to the second part of this paper.

A second important dimension that can be investigated with our data set consists of the degree of policy interdependence across countries. The null hypothesis in this case is that macroprudential interventions across countries are independent from each other, and/or that their interdependence is not affected by financial integration. To this end, we estimated the following model on yearly data:[25]

$$\Delta MaP_{i,t} = \beta_1 \Delta MaP_{j,t} + \beta_2 \Delta MaP^{F}_{i,j,t} + \beta_3' X_{i,j,t}, +\eta_{i,j}, +\varepsilon_{i,j,t}, \tag{34}$$

24. Among the controls, we have MaP in other countries weighted by trade links as discussed in Appendix A. This controls helps to ensure that $MaP^{F}_{j,t}$ is not capturing trade linkages too.

25. Note that ΔMaP is positive if the number of tightening episodes in the period exceeds the number of loosening episodes. See Appendix A for further details.

TABLE 2

Policy Interdependence

Dependent variable: Change in country *i* yearly MaP index.			
VARIABLES	Total	Resilience	Cyclical
$\Delta MaP_{j,t}$	0.0058	0.0117*	−0.0023
	(0.0064)	(0.0066)	(0.0061)
$\Delta MaP^{F}_{j,t}$	1.6706***	2.7037***	1.5105***
	(0.0706)	(0.0641)	(0.0724)
Other controls	Y	Y	Y
Observations:	42,676	42,676	42,676

Note:Standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
The dependent variable varies to match the MaP class on the right-hand side: that is, we pair cyclical with cyclical, etc. Further details in Appendix A.

where the change in the macroprudential index in country i at time t ($\Delta MaP_{i,t}$) is regressed on the corresponding change in the macroprudential index in country j at time t and on a measure of foreign MaP weighted by financial integration ($\Delta MaP^{F}_{i,j,t}$).

Results presented in Table 2 indicate that we can reject our null hypothesis when countries are financially integrated. The sign of the coefficients suggests that countries (especially those with strong financial integration) tend to move their macroprudential instruments in the same direction and at the same time. Contrasting this result with that displayed in Table 1 suggests that MaP interdependence might not reflect "free-riding" incentives, but rather some degree of coordination or the desire to counter possible "beggar-thy-neighbor" effects of policy.

To cast some light on the possible drivers of MaP interventions and, in particular, on their cross-country interdependence, we turn now to our structural model.

3.2 Parameterization and Empirical Fit

The main objective of our parameterization is rather minimalist, consisting of generating second moments that are not "too far" from the empirical counterparts, in the spirit of calibration exercises. In this light, the quantitative results should be interpreted only as suggestive of the order of magnitude of MaP effects. Our parameterization strategy is twofold: First, we aim at choosing parameter values that are within the ballpark offered by the current related literature; second, we aim at generating moments that are not too far from those empirically observed.[26]

The outcome of our parameter selection is presented in Table B1. Under this parameterization, Tables B2 and B3 show that the model performs relatively well

26. In practice, we start from parameter values used in the related literature, for example, Gertler and Karadi (2011) and Banerjee et al. (2016), and adjust them to reduce the distance between a small set of moments (steady-state ratios and standard deviations). This calibration is not meant to validate our model, which misses important features like nominal rigidities and monetary policy. It is instead intended to scale the numerical results to magnitudes observed in the data.

in matching historical data, both in terms of volatility and in terms of long-run measures. In light of the relatively good fit of our model (albeit along a minimalist set of criteria), we can take the numerical results of our experiments as suggestive of the possible quantitative implications of alternative MaP strategies.

A further criterion to assess the empirical fit of the model consist of addressing the same question tackled empirically. In particular, our model can generate positive correlations of macroprudential interventions (under both cooperative and noncooperative regimes), provided that EME banks borrow a sufficiently large share of their liabilities from the global bank, that is, provided that the financial system be sufficiently interconnected.[27] In the rest of the paper, we use our structural model to understand the incentives faced by policymakers and to describe how strategic policy interdependence can bring about gains from cooperation.

4. STRUCTURAL ANALYSIS OF MACROPRUDENTIAL POLICY INTERDEPENDENCE

To gain intuition, we start our analysis with the symmetric frictionless version of our model. Absent policy interventions, this version generates first-best allocations in the long run and in response to shocks. Comparing its implications with those produced by the model with financial frictions allows us to gauge the role of these frictions and of policy in shaping the economic equilibrium. The interpretation of our results is addressed further below.

4.1 The Frictionless Economy

The frictionless version of our model amounts to a standard IRBC model. We start by reviewing the response of this economy to the two types of shocks entertained in our analysis. Figures 1 and 2 show the response of the IRBC to total factor productivity (TFP) and capital quality shocks, respectively.[28]

The figures show three policy scenarios: (i) no intervention, (ii) cooperative policies, and (iii) noncooperative (Nash) policies.[29] A clear result is that the cooperative policy requires no intervention under TFP shocks, as expected, given the efficiency of the economy. Noncooperative policymakers instead adjust their instrument *procyclically*. The net effect of the tax adjustments is expansionary on investment. That said, the effects of intervention are relatively small.

Moving to the capital quality shock (Figure 2), cooperative policy again implies no response, while under Nash, the tax falls in the epicenter country (AE) and increases in the periphery. Compared to the case of no policy response, the noncooperative

27. Specifically, for a positive correlation, domestic deposits must be less than 80% of total bank liabilities, $\kappa_D < 0.8$.

28. Impulse responses are expressed in percentages (hundred basis points) for a 1% change in the respective innovation. Horizontal axes show quarters after the shock.

29. We show only the case of shocks originating in AE as this version of the model is symmetric.

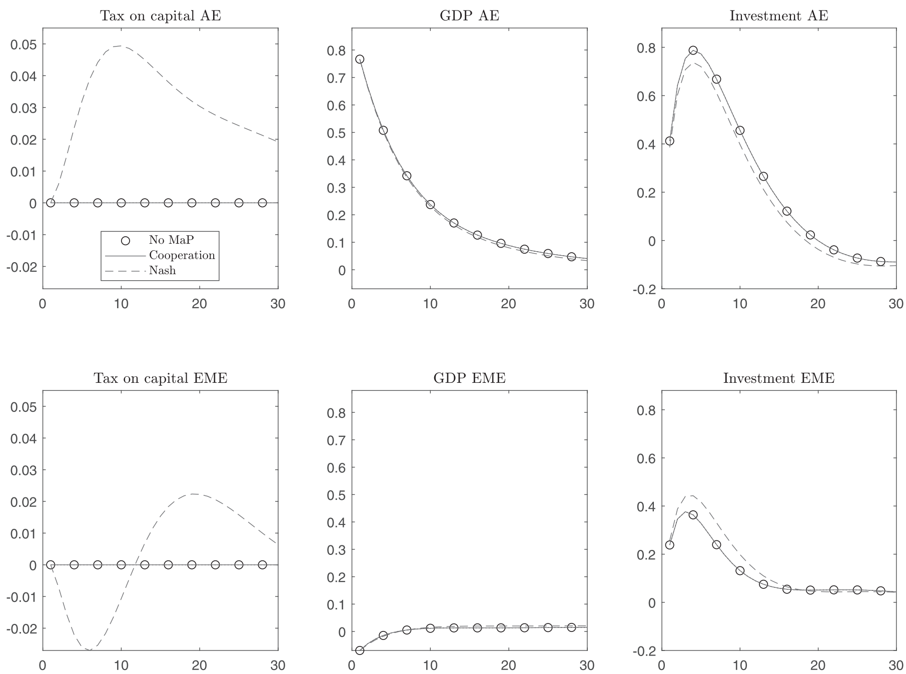


FIG 1. Frictionless Economy.
TFP shock in AE (IRBC): No intervention = black dotted line; Cooperation = solid blue line; Nash = dashed red line.

policy amplifies the response of GDP in the two economies. Investment is also boosted in AE by the intervention. In EME, the response of investment is dampened for several quarters.

Bearing in mind these results, we can now bring back financial frictions and assess how these alter the response of the economies and thus affect the policy prescriptions.

4.2 *Introducing Financial Frictions*

In this section, we introduce financial frictions but restrict our attention to regimes in which the policymaker does not engage in macroprudential policies. Further, we assume that the ICC constraint is always binding. It should be noted that even under this assumption, as opposed to occasionally-binding constraints, credit spreads could vary considerably, as the intensity at which the constraint is binding changes over the cycle. Aiming at matching empirical credit spreads (see Appendix B), we assume that $\kappa^c = .25$; $\kappa_V^c = \kappa^c$; and $\kappa^e = 0.25$.

In Figures 3 and 4, we compare the frictionless response to two cases of financial frictions: (i) EME's banks borrow only domestically ($\kappa_D = 1$) and (ii) EME banks borrow only from the AE ($\kappa_D = 0$). These cases are labeled "symmetric" and

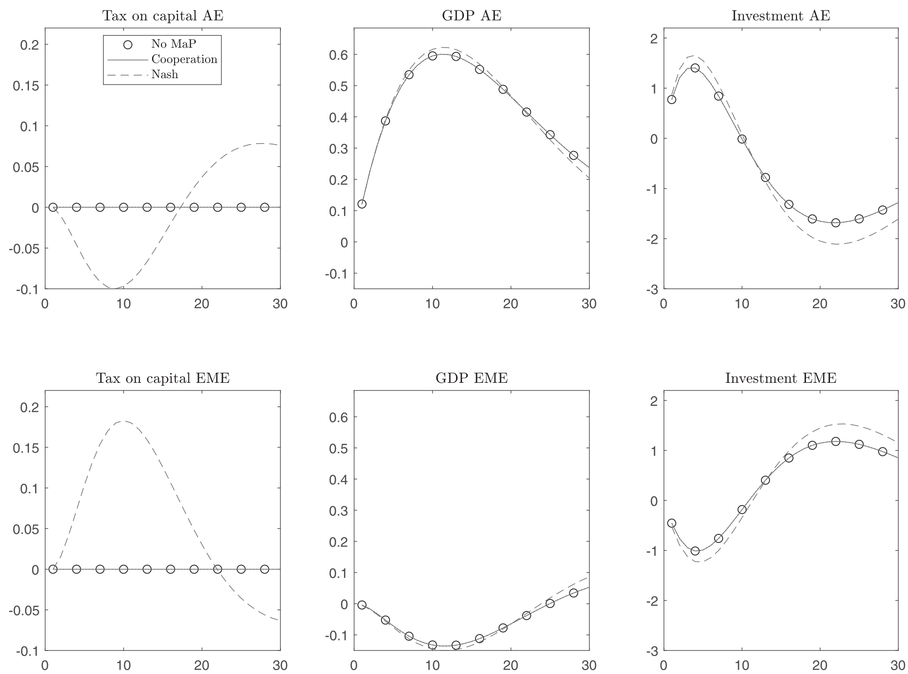


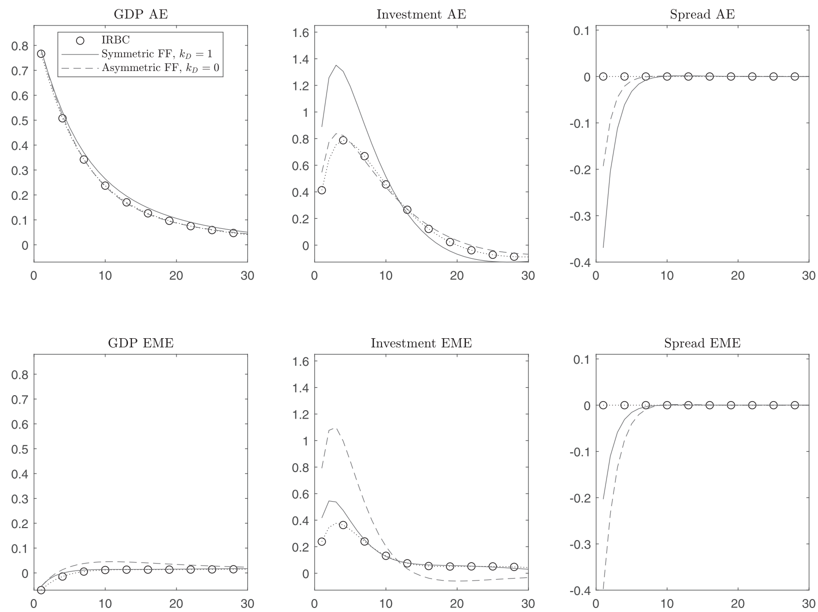
FIG 2. Frictionless Economy.
Capital quality shock in AE (IRBC): No intervention = black dotted line; Cooperation = solid blue line; Nash = dashed red line.

"asymmetric" financial frictions, respectively. Results are shown for TFP and capital quality shocks, respectively.[30]

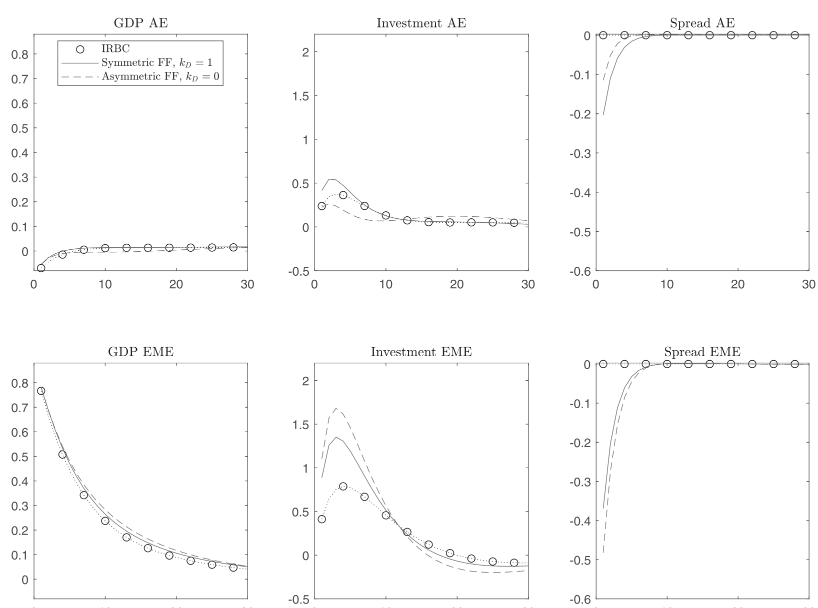
Introducing financial frictions has strong implications for the response of the economy to shocks. A notable effect of introducing financial frictions is the stronger cross-country spillover of AE shocks (as discussed, e.g., by Dedola and Lombardo 2012). The rationale for the heightened spillovers rests on the cross-country arbitrage of returns by financially constrained intermediaries. In the frictionless environment discussed above, arbitrage ensured the equalization of expected returns on capital.[31] By contrast, the extended model allows for different degrees of arbitrage opportunities across countries. When both banks borrow exclusively domestically ($\kappa_D = 1$), direct arbitrage opportunities are excluded. In this case, the expected excess return on EME capital, relative to the AE return, depends on the difference between the credit spreads in the two countries (see equations (15a) and (20)). When the EME bank can borrow exclusively from the global bank ($\kappa_D = 0$) and $\kappa^c = \kappa_V^c$, the difference in

30. The response of other variables is omitted for conciseness, as it does not provide further significant intuition. Results are available from the authors on request.

31. This would also be the case under incomplete markets. Complete markets equalize the *ex-post* real return on deposits.



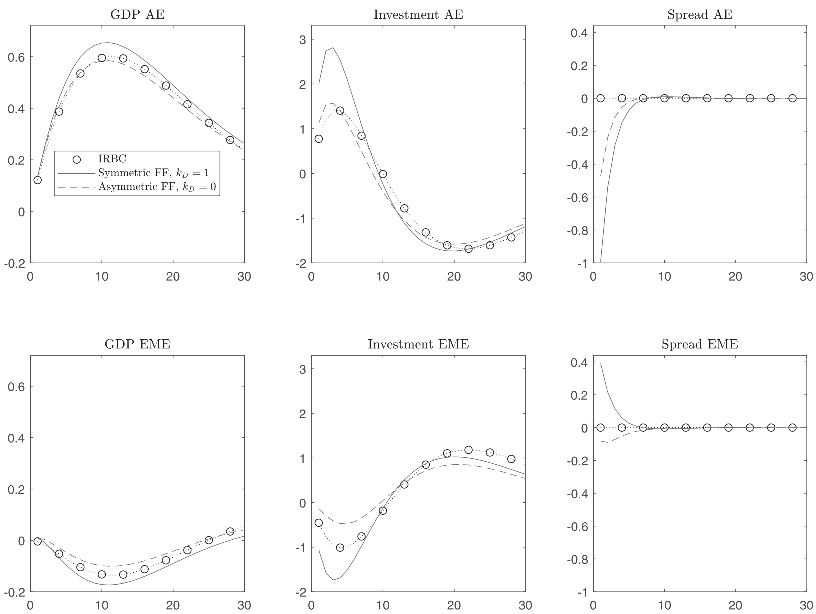
(a) TFP shock in AE



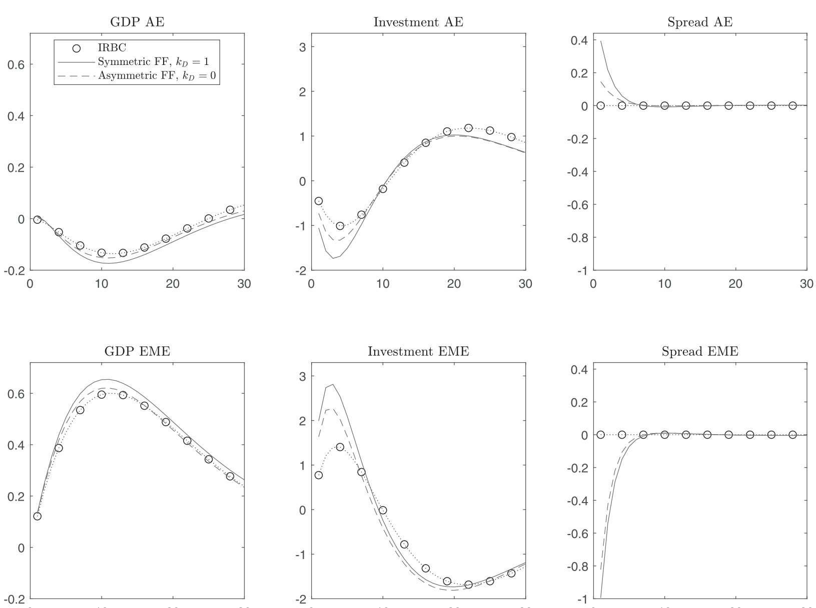
(b) TFP shock in EME

FIG 3. TFP Shock in AE (Upper Panel) and EME (Lower Panel).

No Macroprudential Policy. IRBC = dotted black line; Symmetric financial frictions = solid blue line; Asymmetric financial frictions = dashed red line.



(a) Capital quality shock in AE



(b) Capital quality shock in EME

FIG 4. Capital Quality Shock in AE (Upper Panel) and EME (Lower Panel).

No Macroprudential Policy. IRBC = dotted black line; Symmetric financial frictions = solid blue line; Asymmetric financial frictions = dashed red line.

expected capital returns across countries amounts to EME credit spreads (per equations (15a), (20), and (21)). In our extended model, perfect cross-country arbitrage of capital returns à la Dedola and Lombardo (2012) is excluded, and thus, the international spillovers are bound to be more muted.

The financial accelerator effect is clear in the response to both types of shocks, as the fall in credit spreads provides further incentive to invest. That said, under TFP shocks (Figure 3), the effect on GDP is mainly compositional, overall leaving the GDP response under financial frictions similar to that in the frictionless economy. Under capital quality shocks (Figure 4), instead, the amplification effect is markedly visible also for GDP.

Concerning spillovers, when countries have symmetric size as in Figures 3 and 4, the degree of financial dependency of EME banks has sizeable consequences for both economies, most notably when hit by capital quality shocks. Importantly, higher financial integration (dependency) has a "portfolio-diversification" effect for AE-centered shocks: the effects are mitigated for the epicenter country and magnified for the periphery. Due to the "one-way" nature of financial dependency, the effects of financial integration are less marked for the AE when the shock takes place in the EME.

These results suggest that we should expect a different response of policymakers to these shocks in the presence of financial frictions, as compared to the IRBC.

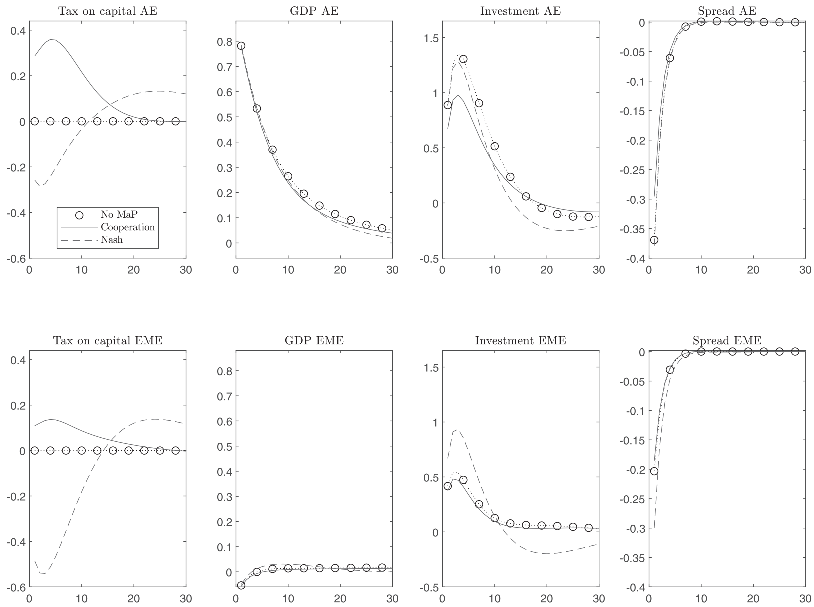
4.3 The Response of Optimal Policy to Shocks: The Effect of Cooperation

To summarize, we have confirmed that financial frictions play a nonnegligible role in the response of the economies to shocks in our model, consistent with the existing literature. Furthermore, we have seen that in the absence of financial frictions, the cooperative policymakers do not respond to efficient shocks, whereas noncooperative policies display interventions even in a frictionless economy, albeit to a limited extent.

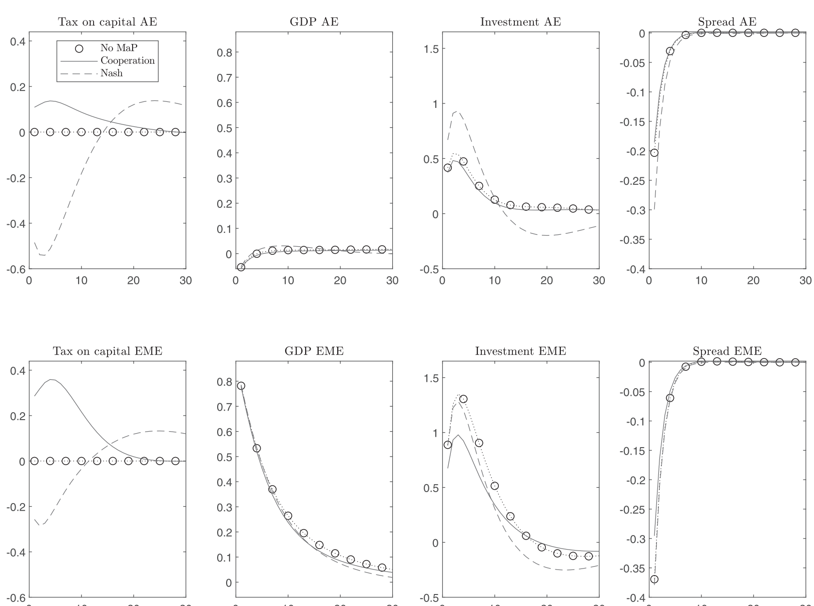
In this section, we repeat our comparison of policy regimes under the assumption that financial intermediation is imperfect. As the degree of financial dependency is an important determinant of the response to shocks, we show the two extreme scenarios: full dependency ($\kappa_D = 0$) and full independence ($\kappa_D = 1$). Figures 5 and 6 display the responses to TFP and capital quality shocks in the case of $\kappa_D = 1$, while Figures 7 and 8 show the case of $\kappa_D = 0$.

In interpreting the IRFs, it is important to note that the variables are in (log) deviations from the deterministic steady state. The latter changes across regimes, as discussed further below. In light of this, the figures show the extent to which each regime succeeds in stabilizing the variables around their specific steady state.

Starting with the response of taxes, it is apparent that cooperative and noncooperative equilibria imply markedly different policy interventions across all cases. In particular, under TFP shocks, the sign of the policy responses is opposite across the two policy regimes (no change in the No MaP case) if financial frictions are symmetric (Figures 5 and 6). Cooperative policymakers respond to an increase in productivity by increasing taxes, while noncooperative policymakers reduce them. The consequence



(a) TFP shock in AE



(b) TFP shock in EME

FIG 5. Imperfect Financial Markets, Symmetric Deposits, $\kappa_D = 1$.

TFP shock in AE (upper panel) and EME (lower panel): No intervention = black dotted line; Cooperation = solid blue line; Nash = dashed red line.

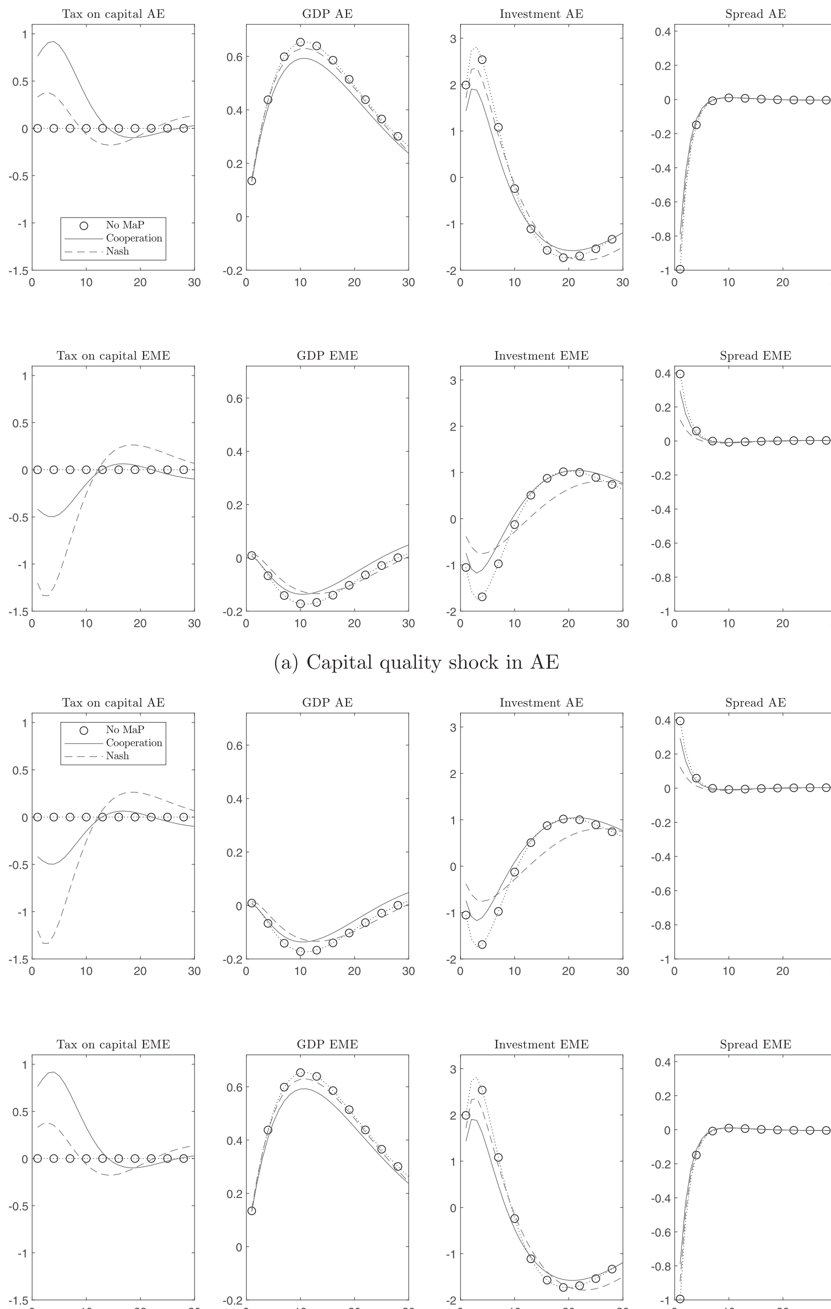


FIG 6. Imperfect Financial Markets, Symmetric Deposits, $\kappa_D = 1$.

Capital quality shock in AE (upper panel) and EME (lower panel): No intervention = black dotted line; Cooperation = solid blue line; Nash = dashed red line.

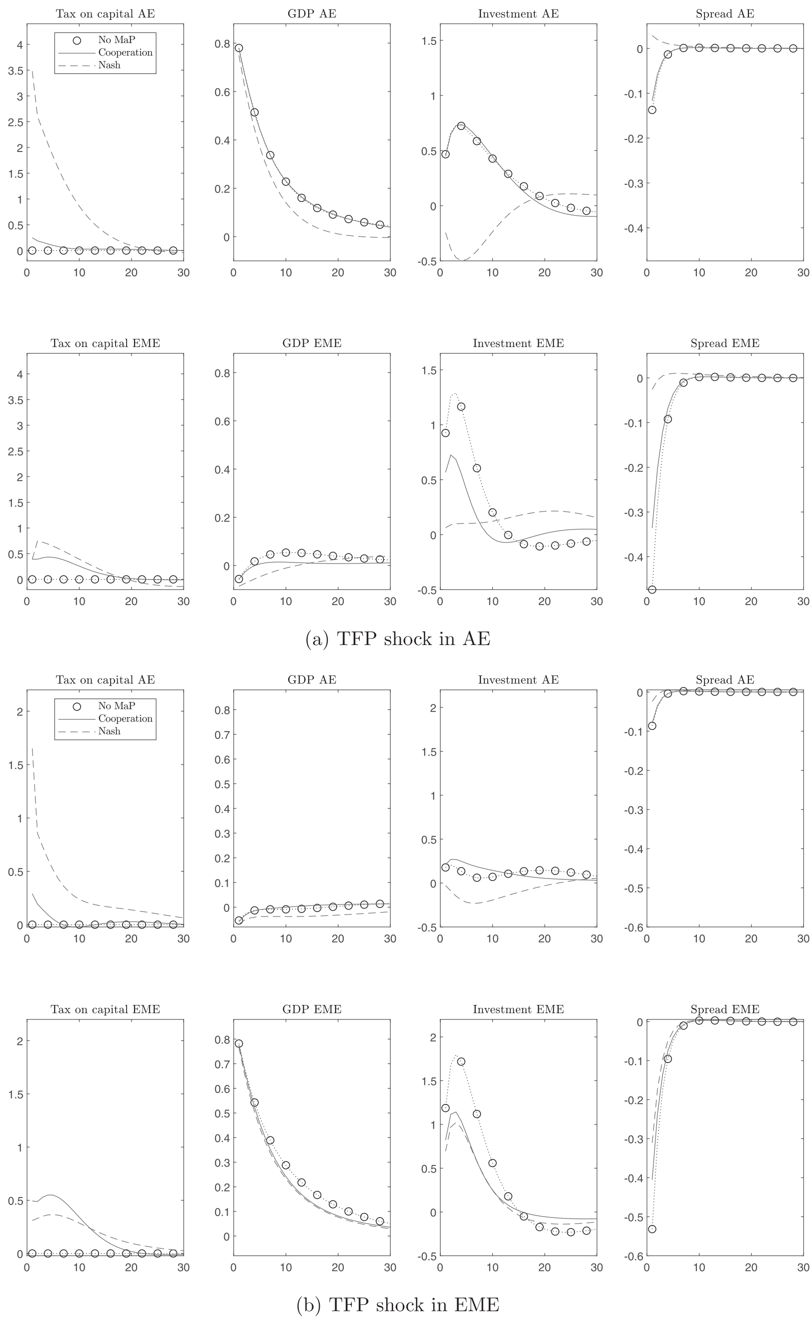
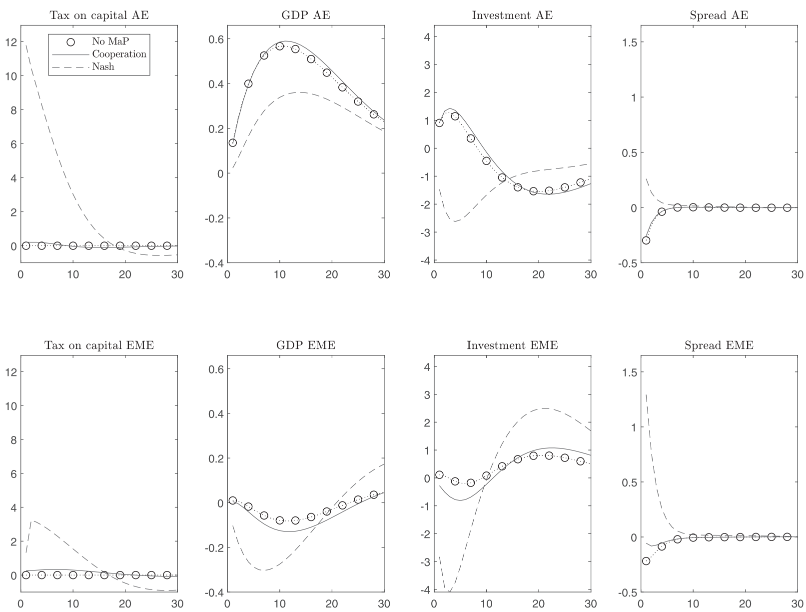
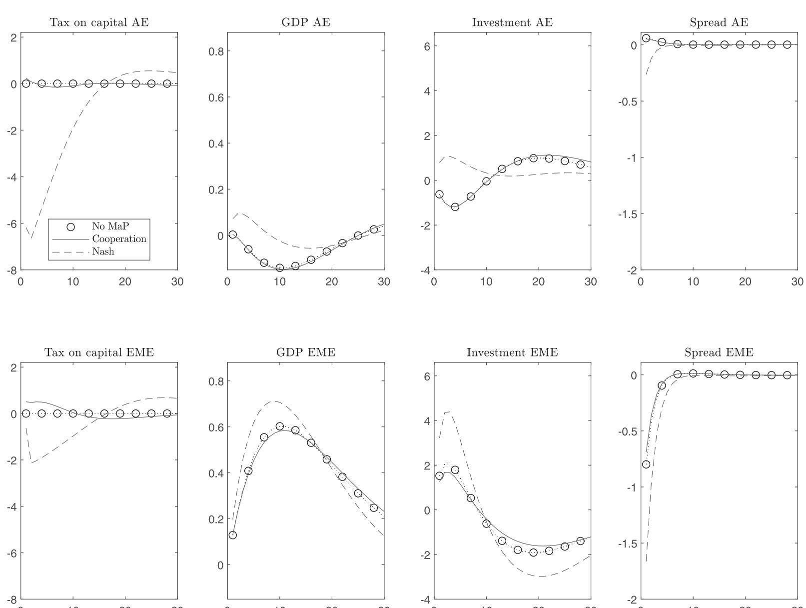


FIG 7. Imperfect Financial Markets, Asymmetric Deposits, $\kappa_D = 0$.

TFP shocks in AE (upper panel) and EME (lower panel): No intervention = black dotted line; Cooperation = solid blue line; Nash = dashed red line.



(a) Capital quality shock in AE



(b) Capital quality shock in EME

FIG 8. Imperfect Financial Markets, Asymmetric Deposits, $\kappa_D = 0$.

Capital quality shocks in AE (upper panel) and EME (lower panel): No intervention = black dotted line; Cooperation = solid blue line; Nash = dashed red line.

is a more pronounced boom in investment in the latter case, stimulated by a larger contraction in spreads. Under symmetry and capital quality shocks, taxes move in the same direction across regimes (at least for several quarters). That being said, cooperative policymakers implement relatively higher taxes than under the Nash equilibrium, implying that spreads are also higher under the former regime. Across the two shocks, the effects on GDP are mainly compositional, especially for productivity shocks.

Under financial asymmetry and TFP shocks (Figures 7 and 8), taxes move in the same direction under the two regimes. Now, though, under Nash, the AE increases taxes considerably more than under cooperation, while differences are visibly smaller for the financially dependent EME. The contractionary hike in noncooperative taxes turns the positive productivity shock into a contraction of investment in the AE, whether the shock originates there or in the EME. The response is associated with larger spreads. The differences in the response of GDP are also more sizeable under financial asymmetry. A very similar picture is produced by capital quality shocks under financial asymmetry, although the differences in the responses are more marked due to the larger changes in noncooperative taxes.

This analysis illustrates that cooperative and noncooperative policies imply markedly different responses to shocks. However, policymakers are not only interested in the short-run response of the economy to shocks. Welfare gains can also be obtained also affecting long-run allocations, as we discuss in the following sections.

4.4 Optimal Policy in the Deterministic Steady State

As mentioned above, the long-run equilibrium of the model depends on the policy regime, that is, on the long-run value of taxes, including their deterministic steady-state component. This underlying value is an integral part of the policy strategy, and could even surpass the dynamic adjustment of the instruments in terms of shaping the response of the economy to shocks and in terms of welfare.[32]

Table 3 reports the unique long-run taxes for each country under both cooperation and in the Nash equilibrium for the frictionless model and for different degrees of asymmetry in the financial-friction model. In the frictionless model (first line), cooperation implies no intervention, consistent with the fact that there are no frictions in the global economy that a benevolent central planner would like to eliminate. On the contrary, under Nash, each policymaker provides a lump-sum transfer to households financed by a tax on capital (of about 21.5%). Unilaterally, this generates a reduction in labor supply, capital, and production (and to some extent in consumption). When both countries do so, the overall welfare falls below the case of no intervention. The second to fourth lines introduce financial frictions with different degrees of financial dependency. The overall effect of financial frictions is, as expected, to call for

32. To obtain the long-run deterministic capital taxes, we solve the nonlinear model—inclusive of the FOCs of the policymakers—in the nonstochastic steady state.

TABLE 3
Long-Run Subsidies, with and without Financial Frictions

	$\tau_{k,ss}$ (MaP)[a]			
	Cooperative		Nash	
	EME	AE	EME	AE
International RBC model	−0.00%	0.00%	21.46%	21.46%
Symmetric model ($k_D = 1$)	−18.16%	−18.16%	6.92%	6.92%
Asymmetric model ($k_D = \frac{1}{2}$)	−25.76%	−20.82%	1.77%	4.30%
Asymmetric model ($k_D = 0$)	−33.48%	−21.90%	−4.81%	3.44%

[a]These values are obtained solving the dynamic Ramsey model in the nonstochastic steady state, as opposed to choosing optimal subsidies in the static version of the economy. See the discussion in Woodford (2003) for the monetary-equilibrium counterpart. Starting from an equilibrium without MaP in which the ICC is binding, the latter is still binding under the large subsidies.

subsidies to banks. These subsidies have the same theoretical justification as the subsidies to a monopolistic producer. The agency problem generates a spread between the lending rate (return on capital) and the deposit rate (cost of funds). By subsidizing banks, the cooperative policymakers can bring the economy closer to its first best. When policymakers fail to cooperate, the net effect is a lower taxation relative to the frictionless economy. The gap between the taxation under cooperation and under Nash, though, tends to be larger under financial frictions.

Importantly, the fully optimal (cooperative) subsidies are larger, the stronger the financial asymmetry; the more so for the financially dependent EME. The shift toward lower taxes is reflected in the downward movement of taxes under Nash, as the asymmetry increases.

Understanding the strategic interaction in the frictionless model is thus important for the correct interpretation of the policy choices in the presence of financial frictions. The latter shift "leftward" the entire distribution of optimal taxes relative to the frictionless world.

4.5 Quantifying the Welfare Gains from Cooperation

So far, we have seen that cooperative and noncooperative policies can bring about markedly different allocations in the long run as well as in response to shocks. To which extent these differences should be a concern for households and policymakers, though, depends on how these differences translate into welfare gains. Table 4 addresses this question by displaying the welfare gains of cooperation relative to the noncooperative policy, both globally and for each country. Furthermore, it reports gains without tax aversion, with varying proportions of deposits in foreign banks, as well as in the absence of financial frictions (IRBC). Gains are expressed in percentages of permanent consumption under the noncooperative regime. These values,

TABLE 4

Gains from Cooperation in Percentage of Permanent Consumption [a]

Global welfare		EME welfare		AE welfare	
International RBC model					
1.95%	(1.95%)[b]	1.95%	(1.95%)[b]	1.95%	(1.95%)[b]
Symmetric model ($k_D = 1$)					
1.50%	(1.50%)[b]	1.50%	(1.50%)[b]	1.50%	(1.50%)[b]
Asymmetric model ($k_D = \frac{1}{2}$)					
1.55%	(1.48%)[b]	0.71%	(0.69%)[b]	2.40%	(2.26%)[b]
Asymmetric model ($k_D = 0$)					
1.42%	(1.30%)[b]	−0.92%	(−0.95%)[b]	3.77%	(3.56%)[b]

[a]Values represent the percentage increase in average consumption that solves equation (35). Figures are rounded to two digits.
[b]Excluding the aversion factor.

denoted by ς^j where $j = \{e, c\}$, are obtained by solving the following equations:[33]

$$\mathcal{W}\Big((1 + \varsigma^j_{Nash})\bar{C}^j_{Nash}, \bar{H}^j_{Nash}\Big) = \mathcal{W}^j_{Nash}, \tag{35}$$

$$\mathcal{W}\Big((1 + \varsigma^j_{Coop})\bar{C}^j_{Nash}, \bar{H}^j_{Nash}\Big) = \mathcal{W}^j_{Coop}, \tag{36}$$

where the bar denotes the deterministic steady state of the model and $\mathcal{W}^j_i$ denotes the mean welfare conditional on the initial conditions of the model for country j and regime $i = \{Nash, Coop\}$.[34] Having assumed that preferences are separable in labor and consumption, and that they are in logs with respect to the latter, welfare units are equivalent to consumption units, so we can express the gain from cooperation as $\varsigma^j \equiv \varsigma^j_{Coop} - \varsigma^j_{Nash}$ where $j \in \{e, c\}$. Global welfare is expressed as the population-weighted sum of consumption-units, that is, $n\varsigma^e + (1 - n)\varsigma^c$.

We first consider global welfare. The first column of Table 4 shows that *global* permanent consumption can be increased by about 1.95%, moving from the Nash regime to the cooperative one even in the frictionless IRBC model. By symmetry, these gains are equal for both core and periphery countries. With financial frictions, gains for cooperation are considerable, a 1.5% increase in steady-state consumption, but less than the frictionless case. Two factors appear to affect this result. First, the cooperative policy under financial frictions cannot bring about the first best, contrary to the case in the frictionless model. When the ensuing equilibrium is sufficiently inefficient, the gap with other inefficient allocations could shrink. Second, each policymaker faces

33. Welfare gains depend both on first- and second-order moments. Computing the former under complete markets and asymmetric economies requires the computation of the "risk-sharing" constant, that is, the ratio of domestic to foreign consumption levels (see Ljungqvist and Sargent 2012, Ch. 8). We solve this "fixed-point" problem following the simple approach recently developed by Corsetti et al. (2019).

34. As the tax policy is nonneutral in the steady state, we must take a decision for this initial condition. We assume that the economy begins at the unconditional mean of the economy without macroprudential intervention for each experiment and then simulate for 6,000 periods to obtain the conditional mean. As the model is recursively linear, this is equivalent to integrating over all the possible initial conditions of the No MaP regime.

two separate and possibly conflicting incentives under financial frictions: to reduce the inefficiency and to shift allocations in favor of domestic households. Disentangling these two factors does not appear to be possible without changing the nature of the game. Some intuition though can be gained by observing the behavior of long-run taxation under the two regimes, as discussed in the previous section. Financial frictions call for strong interventions even in the cooperative case. As argued above, the shift toward subsidies is evident under both policy regimes, suggesting that, indeed, the noncooperative incentives are pulling in opposite directions. The magnitude of the distortion exerted by financial frictions creates the incentive for each country to primarily keep its own house in order, thereby trumping the desire to extract value from the other country. Appendix C provides additional details on the incentives to tax in the long run.

When the periphery is financially dependent on the core, the shift toward subsidization is more pronounced, especially in the periphery, and gains are asymmetrically distributed in favor of the core country. Global gains fall relative to the symmetric model. This effect becomes more pronounced as financial dependency is increased and the periphery actually loses from cooperation—though the world gains due to large core gains.[35]

Within the ranges considered here, the tax aversion to intervention reduces welfare within each policy regime only marginally, although to an increasing extent with large degree of asymmetry. However, the difference between gains including penalty and gains excluding penalty could be of either sign, depending on whether the penalty in one regime is higher or lower than the penalty in the other regime.[36] We find that neither changing the parameterization of the tax aversion penalty nor including a zero-order term that penalizes the scale of long-run taxes has a significant effect on the optimal choice of long-run taxation.[37] Lacking a precise microfoundation of the costs of macroprudential intervention, our analysis sheds some light on the likely range of possible gains. The real-world complexity of implementing appropriate interventions, as well as the possible political economy costs of fine-tuning banks' incentives to extend credit, might point to even larger welfare costs, which could thus significantly alter the gains from cooperation.[38]

35. The design of the cooperative policy assumed in this paper implies that, in some cases, the gains from cooperation could be enjoyed by both countries only under appropriate transfers. In general, one could think of designing a cooperative objective with appropriate Pareto weights that make each country better off. We thank Mike Woodford for having suggested this perspective. We leave this extension to future research.

36. To see this note that Gain With Penalty = Gain Without Penalty + $(n\, penalty^{e}_{Coop} + (1-n) penalty^{c}_{Coop}) - (n\, penalty^{e}_{Nash} + (1-n) penalty^{c}_{Nash})$, where $penalty^{j}_{i}$ is the second term in equation (24), where $j = \{e, c\}$ and $i = \{Coop, Nash\}$. In each case considered, the global tax-aversion penalty amounts to less than 0.2% of global welfare.

37. This was true whether the penalty is applied as reducing consumption or as requiring more labor effort.

38. Another possible source of asymmetry consists of the relative size of the countries. We experimented along this dimension, assuming that periphery was smaller than the core ($n < 0.5$). The combination of financial and size asymmetry generated extremely large gains. Nevertheless, we believe that country size is not a distinctive feature of EMEs or AEs, and would confound the independent role played

TABLE 5

Risk-Sharing Constant κ^{RS}, Financial Interdependence, and Policy Regimes

	Financial frictions					IRBC
κ_D	0	0.25	0.5	0.75	1	–
Level						
No MaP	0.114303	0.0846001	0.0535031	0.0225744	0	0
Nash	0.0901826	0.0693594	0.0468951	0.0221639	0	0
Coop	0.123282	0.0901996	0.0570305	0.0253518	0	0
Deviation from steady state						
No MaP	−0.00727204	−0.00766467	−0.00793719	−0.00727552	0	0
Nash	−0.0100665	−0.00732784	−0.00536915	−0.00466854	0	0
Coop	−0.00631128	−0.00660675	−0.00661133	−0.00546104	0	0

4.6 The Source of Welfare Gains

Why does the noncooperative policy generate markedly lower levels of welfare across countries? And how does financial dependency affect the welfare gains? To answer these questions, we refer to the risk-sharing condition (4). As pointed out by Engel (2016), noncooperating policymakers have an incentive to alter the relative distribution of initial wealth—and thus to shift consumption in favor of domestic households. As amply discussed in the literature on the gains from risk sharing,[39] the latter implies changes in asset prices, which tilt the distribution of consumption in a way that reflects initial cross-country asymmetries. Clearly, in an otherwise symmetric environment, noncooperative policymakers' effort to do so would be vain, resulting in a symmetric suboptimal allocation. Table 5 reports values of κ^{RS} (the difference between AE and EME consumption) under three policy regimes (no MaP, Nash, and cooperation) for different degrees of financial interdependence (κ_D) as well as for the frictionless economy. The upper part of the table reports the log level of the risk-sharing constant (κ^{RS}, up to second order of accuracy), while the lower part reports deviations from the deterministic steady state (i.e., steady-state gap between AE and EME consumption). Negative (positive) values imply that the level of AE consumption is lower (higher) than the level of EME consumption, where $\kappa^{RS} = 0$ if $\kappa_D = 1$, that is, in the symmetric case. The table shows that as countries become asymmetric (lower κ_D), the periphery country's households consume less than the center country's households. Nevertheless, in deviation from the deterministic steady state, the opposite is true. This opposite direction is due to two factors. First, in the deterministic steady state (driving the results in the upper part of the table), asymmetry implies that the EME economy is less efficient (stronger financial frictions) than the AE, implying lower consumption in the former. Second, the asymmetry makes

by financial asymmetries. In this respect, our welfare gains can be seen as conservative measures. Results are available from the authors on request.

39. See, for example, van Wincoop (1994), Lewis and Liu (2015), Engel (2016), Coeurdacier et al. (2019), and Corsetti et al. 2019, among others.

the AE's income more volatile, that is, riskier.[40] Under the risk-sharing agreement EME households must be compensated for this higher risk, and the compensation takes the form of higher average consumption (driving the results in the lower part of the table).[41] While we cannot gauge the intensity of the strategic incentives from the equilibrium values of the risk-sharing constant, it is instructive to note that under Nash, they differ considerably from the cooperative equilibrium, both in level and in deviation. In particular, the overall consumption differential is too low under Nash compared to cooperation. As for the stochastic component, while the consumption differential is always negative, under cooperation, it is nonmonotonic in κ_D preventing a unique ranking between policy regimes.

While this perspective adds to our understanding of the sources of strategic motives, it does not fully capture the source of the welfare gains in equilibrium. To shed further light on the latter, Table 6 shows the discounted sum of conditional means and standard deviations of different policy regimes in symmetric model with and without financial frictions. We show consumption and hours as these are the direct arguments of preferences, and spreads as these are the source of inefficiency. A number of observations are in order.

The frictionless economy, under cooperation (which implies no macroprudential intervention), displays first-best allocations. Even in this environment though, noncooperating policymakers fail to achieve the first best, unnecessarily increasing taxes. Consequently, this policy regime pushes consumption and hours worked below the efficient equilibrium. With financial frictions, the significant subsidization under cooperation reduces bank spreads relative to both No MaP and Nash regimes. This can be seen to improve welfare by significantly bringing consumption and hours worked closer to the first-best allocation. Labor supply is reduced too much under the other two policy regimes, independently of the degree of financial asymmetry. As financial asymmetry increases, EME's households work considerably more under all policies than those in the center country.

Finally, under financial frictions, cooperative intervention brings second moments closer to the efficient counterpart.[42] Under cooperation, volatility of consumption is virtually identical to that achieved in the first best, although it is higher than the case of no intervention, independently of the degree of financial asymmetry. Hours are more volatile under cooperation than in the case of no intervention, except for the symmetric case. Compared to cooperation, under Nash, volatility of consumption and hours tends to be higher under financial asymmetry.

40. Periphery income volatility is 53% (32%) lower relative to the core under the cooperative (Nash) regimes with asymmetric financial frictions, $\kappa_D = 0.5$. The fall is more pronounced with greater asymmetry, $\kappa_D = 0$: a reduction of 93% under cooperation and 84% under Nash.

41. Corsetti et al. (2019) show how the gains from risk-sharing emerge from consumption smoothing, asset-valuation effect, and changes in the terms of trade, as a function of size and risk asymmetry. Our results concerning κ^{RS} are an implication of those findings.

42. Note that the standard deviation of consumption is identical across countries due to perfect consumption risk sharing both without financial frictions and with symmetric frictions, and irrespective of whether policymakers intervene or not.

TABLE 6

First and Second Moments of Key Variables under Nash, Co-operative, and No MaP Policies

Conditional mean	C^e	C^c	H^e	H^c	$spread^{e\dagger}$	$spread^{cA}$
IRBC						
No MaP	2.559		0.971		0	
Nash	2.461		0.949		0	
FF with symmetry, $k_D = 1$						
No MaP	2.433		0.957		244	
Nash	2.403		0.952		267	
Cooperation	2.488		0.974		213	
FF with asymmetry, $k_D = 0.5$						
No MaP	2.338	2.467	0.960	0.95	335	272
Nash	2.332	2.444	0.958	0.947	379	269
Cooperation	2.402	2.543	0.983	0.967	290	256
FF greater asymmetry, $k_D = 0$						
No MaP	2.239	2.51	0.962	0.944	446	275
Nash	2.27	2.484	0.965	0.942	554	296
Cooperation	2.309	2.612	0.993	0.959	394	262
Standard deviation[B]	C^e	C^c	H^e	H^c	$spread^{eA}$	$spread^{cA}$
IRBC						
No MaP	2.976		0.680		0	
Nash	2.747		0.657		0	
FF with symmetry, $k_D = 1$						
No MaP	2.877		0.742		547	
Nash	2.936		0.736		486	
Cooperation	3.000		0.688		433	
FF with asymmetry, $k_D = 0.5$						
No MaP	2.84	2.84	0.677	0.687	495	252
Nash	3.331	3.331	0.848	0.821	829	173
Cooperation	2.997	2.997	0.682	0.696	400	232
FF greater asymmetry, $k_D = 0$						
No MaP	2.815	2.815	0.664	0.656	528	162
Nash	3.664	3.664	0.96	0.911	1,042	173
Cooperation	2.996	2.996	0.676	0.698	417	141

Note: Baseline parameterization.
[A] Annualized basis points.
[B] Percentages.

These results illustrate that assessing MaP policies exclusively on the basis of volatility could be misleading. When the first best is not achievable, policymakers might have to trade off volatility with average levels. In this perspective, cross-country policy spillovers of economic stabilization that can be gauged with existing data (see Section 3) might not fully account for the nature of the strategic interaction.

Indeed, these theoretical results can be further used to interpret the empirical evidence provided in Section 3.[43] In particular, Table 2 provides some evidence of a positive (and significant) correlation between domestic and foreign MaP changes

43. Obvious caveats apply in using our simple model to interpret the available data on MaPs. On the one hand, the model lacks a number of important elements that could have generated the observed data on MaPs, including institutional factors and political economy considerations. On the other hand, the data are very coarse, consisting of a binary index and thus lacking important quantitative dimensions.

TABLE 7
CORRELATION BETWEEN MACROPRUDENTIAL TAXES

	Cooperative	Nash
International RBC model	–[a]	−0.86
Symmetric FF model ($k_D = 1$)	−0.69	−0.32
Asymmetric FF model ($k_D = 0.75$)	0.1	0.89
Asymmetric FF model ($k_D = 0.5$)	0.59	0.79
Asymmetric FF model ($k_D = 0.25$)	0.73	0.65
Asymmetric FF model ($k_D = 0$)	0.79	0.5

[a]No intervention in the frictionless cooperative.

for financially integrated countries. What does our model predict in this regard, and how does the prediction depend on the policy regime? To answer this question, we simulated our model under cooperation and Nash and computed the correlation between changes in policy instruments ($\Delta\widehat{\tau}^{c}_{k,t}$ and $\Delta\widehat{\tau}^{e}_{k,t}$) reported in Table 7.

Our simulation shows that a positive correlation of policy instruments would emerge under both policy regimes, cooperation and Nash, as long as financial interdependence is sufficiently strong (lower κ_D). The two regimes differ in that the relationship between correlation of interventions and openness is monotonic under cooperation, while it is not when countries are self-oriented. This implies that, other things equal, we should observe stronger comovements of interventions among countries with strong financial interdependence if policymakers tend to cooperate. While our data set is admittedly too coarse to test rigorously this hypothesis, the estimated higher correlation of policy intervention among euro area countries ($\Delta MaP^{EA}_{i,j,t}$ in Table A2) appears to point in this direction.[44]

5. CONCLUSION

The Global Financial Crisis, and the spillovers produced by policy responses, have generated renewed interest in macroprudential policies and their international coordination. Based on a core–periphery model that emphasizes the role of international financial centers, we study the effects of coordinated and noncoordinated stylized macroprudential policies.

We show that even in a frictionless world, self-oriented policymakers would try to affect asset prices to tilt global wealth in favor of their jurisdictions. In the frictionless version of our model, this would imply introducing long-run capital taxes. Even in this case, the gains from cooperation can be substantial.

44. A broad range of economic policies—fiscal, prudential, and obviously monetary policies—in euro area countries tend to be informed, if not directly dictated, by supranational agreements and can thus result in coordinated interventions.

Introducing financial frictions induces opposite incentives for policymakers: cooperation would call for subsidies aimed at closing the inefficiency gap. While noncooperative policymakers are still tempted to increase taxes, an element of "keeping-one's-house-in-order" pulls policies toward subsidies. The tension between these two incentives can result in welfare gains from cooperation that are smaller under financial frictions relative to the frictionless environment. Furthermore, as policymakers fail to achieve the first best under financial frictions, the loss generated by departing from the globally optimal policy is smaller. This result is increasingly evident as the degree of financial dependency of the EME economy on global banks increases.

We show that the policy regimes differ both in the long and in the short run. In the short run, noncooperative policies result in larger responses to shocks; in some cases even of the opposite sign. In the long run, the result is significantly different degrees of taxation.

While our characterization of MaP falls short of capturing both the full motivation of macroprudential policies and the subtleties of the various macroprudential measures, it has the benefit of bringing to the fore, in a simple and transparent way, one of the salient features of macroprudential tools: its effect in generating (dis-)incentives to extend credit. Our simple setup provides us with a number of important lessons. First, it enables us to separate the pure stabilization and strategic incentives, which would also exist in a frictionless world, from the incentives to mitigate the consequences of financial frictions. Our analysis shows that, under cooperation, the frictionless world would not warrant a policy intervention, while financial frictions call for a coordinated global policy reaction. Second, it allows us to provide a conservative measure of the gains from cooperation. If the gains from cooperatively dealing with financial frictions are substantial, it is likely that in the real world, where financial volatility can be much more severe than in our model, the gains will be orders of magnitude larger. Indeed, even our model, calibrated around "normal" scenarios, would predict an increase in the gains from cooperation that is proportional to the variance of the underlying shocks. Thus, periods of persistently higher volatility would generate proportionally larger gains from cooperation.

We believe that our analysis sheds new light on some of the deepest conceptual aspects of the international dimensions of macroprudential policies. To emphasize these aspects, we abstracted from the details that characterize the various macroprudential tools available to policymakers (as noted earlier) but also from the complexity of real-world financial intermediation. Future research should introduce additional layers of complexity to our analysis, with the aim to uncover the specific benefits and drawbacks of the macroprudential tools discussed in the policy circles.

APPENDIX A: DATA AND ESTIMATION DETAILS

To estimate the international spillovers of macroprudential interventions, we use the following data. For macroprudential interventions (defined as number of tightening and loosening of interventions per year), we use the same data set as in Boar et al. (2017), which, in turn, combines Lim et al. (2011), Kuttner and Shim (2016), and Cerutti et al. (2017) to cover a panel of 64 countries with yearly data from 1984 to 2014.

For the other variables, we use various sources. In particular, among control variables for the regression in Table 1, we include the average number of years of schooling (in logs), government consumption (in logs), the inflation rate, the real interest rate, the Chinn-Ito measure of financial openness (Chinn and Ito 2006), and financial crises dummy. The regression summarized in Table 2 controls only for country-pair fixed effects, GDP growth in country i and country j, a dummy for

TABLE A1

Macroprudential Interventions and GDP Volatility

VARIABLES	Total	Resilience	Cyclical
Lagged dependent variable	-0.0926	-0.1423^{***}	-0.0752
	(0.0591)	(0.0529)	(0.0621)
Log initial income per capita	-0.0001	0.0009	-0.0004
	(0.0014)	(0.0009)	(0.0014)
log(MaP)	-0.0076^{**}	-0.0154^{***}	-0.0062^{*}
	(0.0033)	(0.0044)	(0.0034)
FD	-0.0501^{***}	-0.0445^{***}	-0.0461^{***}
	(0.0080)	(0.0066)	(0.0075)
Chin-Ito	-0.0001	-0.0004	-0.0002
	(0.0008)	(0.0008)	(0.0008)
log(MaP)*FD	0.0175^{***}	0.0250^{***}	0.0172^{***}
	(0.0057)	(0.0089)	(0.0057)
MaP Finance	-0.0379^{***}	-0.0666^{***}	-0.0519^{***}
	(0.0110)	(0.0220)	(0.0124)
MaP Trade	0.0128^{**}	0.0935^{***}	0.0109^{*}
	(0.0060)	(0.0206)	(0.0065)
log(schooling)	0.0080	0.0068^{*}	0.0095
	(0.0090)	(0.0035)	(0.0093)
log(Gov. Consumption)	-0.0144^{***}	-0.0157^{***}	-0.0147^{***}
	(0.0045)	(0.0028)	(0.0045)
GDP deflator inflation	0.0015	0.0012^{*}	0.0017^{*}
	(0.0009)	(0.0006)	(0.0010)
Real interest rate	-0.0001	-0.0001	-0.0001
	(0.0001)	(0.0001)	(0.0001)
Financial crises dummy	0.0239^{***}	0.0229^{***}	0.0232^{***}
	(0.0066)	(0.0042)	(0.0068)
Country fixed effect:	Yes	Yes	Yes
Observations:	343	343	343
Number of countries:	64	64	64

Note: Robust standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Dependent variable: Nonoverlapping 5-year standard deviation of yearly real GDP growth.

TABLE A2

Macroprudential Interdependence

VARIABLES	Total	Resilience	Cyclical
$\Delta MaP_{j,t}$	0.0058	0.0117*	−0.0023
	(0.0064)	(0.0066)	(0.0061)
$\Delta MaP^{T}_{j,t}$	8.0154***	4.8879***	8.3789***
	(0.1087)	(0.0996)	(0.1094)
$\Delta MaP^{F}_{j,t}$	1.6706***	2.7037***	1.5105***
	(0.0706)	(0.0641)	(0.0724)
$\Delta MaP^{EA}_{i,j,t}$	0.0033	0.0606***	0.0183**
	(0.0080)	(0.0085)	(0.0076)
$\Delta MaP_{j,t} * \Delta FD_j$	0.0423***	0.0816***	0.0343***
	(0.0082)	(0.0083)	(0.0081)
$\Delta \log GDP_{i,t}$	0.0092	−0.6927***	0.7323***
	(0.1236)	(0.0588)	(0.1034)
$\Delta \log GDP_{j,t}$	−0.3282***	−0.1871***	−0.1288**
	(0.0729)	(0.0344)	(0.0610)
Country-pair fixed effect:	Yes	Yes	Yes
Observations:	42,676	42,676	42,676
R^2	0.2863	0.2988	0.2719

Note: Standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Dependent variable: Change in country *i* yearly MaP. Positive values indicate tightness.

euro area membership, and the relative degree of financial development based on the Financial Development Diversity index, that is, ratio between the financial development index in country j and that of country i. The financial development index (FD) is described in Sahay et al. (2015), and is normalized to be between 0 and 1.

For the results shown in Table 1, we measure MaP as the sum of (absolute) yearly interventions over five nonoverlapping years. For the results in Table 2, we take the yearly value of MaP interventions. The finance-weighted foreign macroprudential interventions are obtained using total claims from the BIS International Banking and Financial Statistics. The trade-weighted measure is obtained using IMF—Direction of Trade Statistics.

Tables A1 and A2 provide some more details on the panel regressions. Further analysis of this data set can be found in Boar et al. (2017).

APPENDIX B: PARAMETERIZATION AND MOMENT MATCHING

The aim of the parameterization of our model is to ensure that the welfare gains—proportional to the variance of the shocks—are commensurate to the scale of the observable magnitudes. To assign values to the parameters of our baseline model, we adopt the following strategy. First, we pick parameter values from the recent related literature (e.g., Gertler and Karadi 2011, Banerjee et al. 2016). Second, we search in a neighborhood of these values for combinations that deliver first and

TABLE B1

Parameter Values Used in the Baseline Simulations

Definition	Label	Value
EME size	n	$\frac{1}{2}$
Household risk aversion	σ	1
Time preference factor	β	0.9926
Inverse of Frisch elasticity of labor supply	ψ	3
Exit rate of bankers	$\theta_e = \theta_c$	0.9
Transfer rate to new bankers	$\delta_{T,e} = \delta_{T,c}$	0.01
Capital share	α	0.35
Capital depreciation	δ	0.025
Definition	Label	Value
Adjustment cost of investment	ζ	2
Share of domestic deposits to foreign loans	$\psi_D^e - 1$	0
ICC parameter	κ^c	0.25
ICC parameter	κ^e	0.25
ICC parameter	κ_V^c	κ^c
Tax smoothing preference	$\psi_{\tau,k}$	0.05
Shock persistence	$\rho_{A,e} = \rho_{A,c} = \rho_{\xi,e} = \rho_{\xi,c}$	0.85
Standard dev. TFP shocks	$\sigma_{Ae} = \sigma_{Ac}$	0.007
Standard dev. capital quality shocks	$\sigma_{\xi_c} = \sigma_{\xi_e}$	0.003

TABLE B2

Steady-State Ratios without Macroprudential Policies

	Model[A]	Data
Spread AE (annual bp)	257	221–606[B]
Spread EME (annual bp)	340	407–748[C]
Leverage AE	7.16	6.14–12.02[D]
Leverage EME	6.1	4.46 –7.94[D]
$\frac{Investment}{GDP}$ AE	22.5%	24%[E]
$\frac{Investment}{GDP}$ EME	21.3%	24%[E]

[A]Values are computed using the ergodic stationary solution up to second order of accuracy for the asymmetric baseline model with financial frictions, $\kappa_D = 0.5$.

Sources: [B]BofA Merrill Lynch US Corporate BBB Option-Adjusted Spread versus High Yield (from FRED, Federal Reserve Bank of St. Louis), period: 1999.01–2016.10.

[C]Bank of America, Merrill Lynch Emerging Markets Corporate Plus Index Option-Adjusted Spread versus High Yield (from FRED, Federal Reserve Bank of St. Louis), period: 1999.01–2016.10.

[D]World Bank, one-stdev confidence interval of total bank-assets over bank-equity minus 1.

[E]World Bank, cross-country averages; Period:1980–2014. Emerging economies: Argentina, Brazil, Bulgaria, Chile, China, Colombia, Croatia, Czech Republic, Estonia, Greece, Hong Kong SAR, China, Hungary, India, Indonesia, Kuwait, Latvia, Lebanon, Lithuania, Malaysia, Mexico, Nigeria, Peru, Philippines, Romania, Russian Federation, Saudi Arabia, Serbia, South Africa, Thailand, Turkey, Ukraine, United Arab Emirates, Uruguay, Vietnam. Advanced economies: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Taiwan, United Kingdom, United States.

second moments close to those observed in the data. This exercise delivers the set of parameters shown in Table B1. With this constellation of parameter values, we obtain the first and second moments reported in Tables B2 and B3 alongside the empirical counterparts.

TABLE B3

Standard Deviations for Regime without Macroprudential Policies

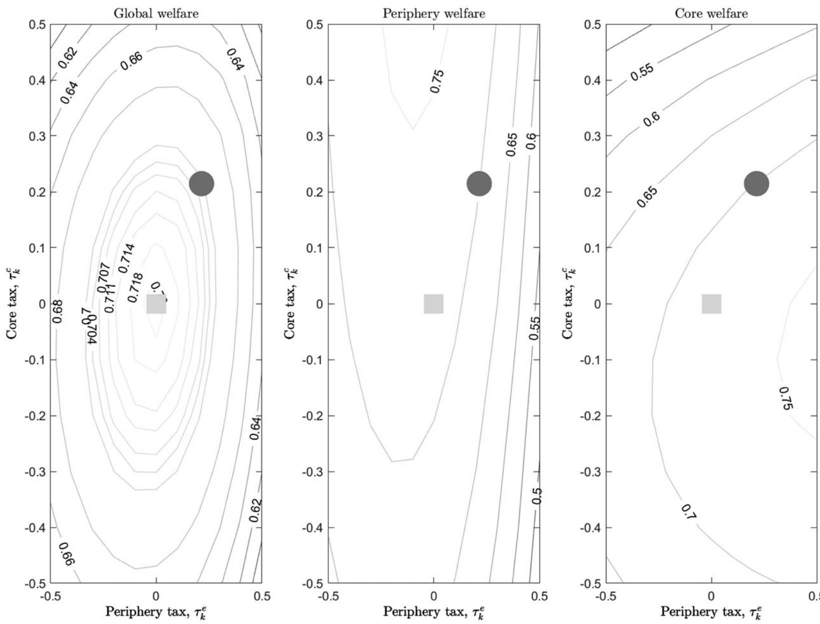
Variable	Model[a]	Data:[b] average (stdev)
Growth GDP AE	0.85	0.74 (0.35)
Growth GDP EME	0.85	1.17 (0.57)
Growth Investment AE	1.99	2.61 (1.20)
Growth Investment EME	2.69	7.48 (21.48) [median = 3.39]
Spread AE	252	110 − 275
Spread EME	495	202 − 391

[a]Values are computed using the ergodic stationary solution up to first order of accuracy for the asymmetric baseline model with financial frictions, $\kappa_D = 0.5$.
[b]Sources: World Bank, FRED (Federal Reserve Bank of St. Louis) and BIS. Sample as in Table B2.

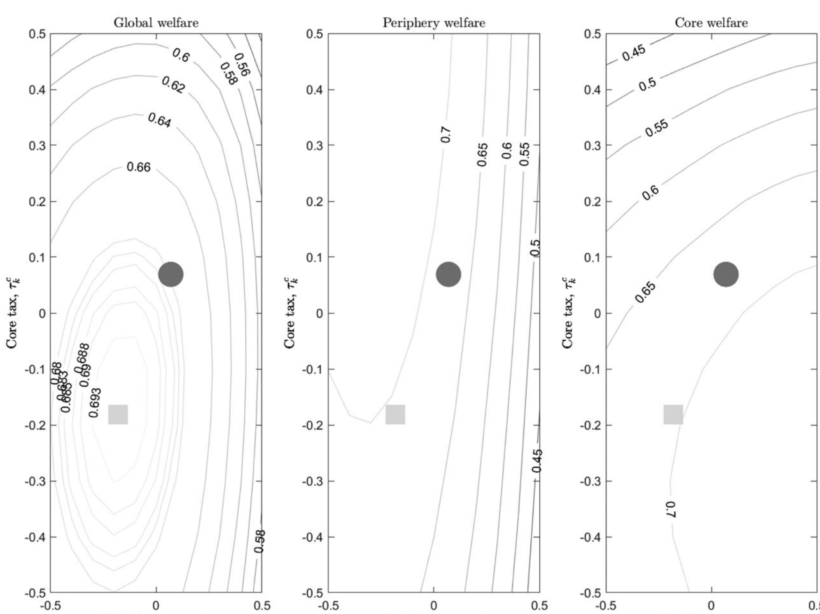
APPENDIX C: WELFARE AND LONG-RUN TAXES

To further shed light on the policy incentives, Figure C1 displays a contour plot of welfare for both core and periphery, inclusive of the tax aversion penalty, equation (24), and global welfare, defined as the maximand in equation (25): $[n\widehat{\mathcal{W}}_0^e + (1-n)\widehat{\mathcal{W}}_0^c]$, for different values of the long-run taxes chosen by each country. While this perspective hides the dynamic responses discussed in the previous section, it sheds light on the equilibrium values of long-run taxation. The upper panels display the frictionless economy in which global welfare is maximized without intervention in the cooperative equilibrium, represented by the green square. In the upper-right panels, we see that each country's welfare can be significantly improved if it subsidizes its own capital and encourages the other country to tax: a shift North-West from the zero-intervention point for the periphery, and South-East shift for the core. The incentive to engineer large taxes in the other country lead to a Nash equilibrium, shown by a red circle, in which both countries levy significant taxes,[45] leaving both countries worse off. This produces significant gains to cooperation even in the frictionless IRBC model. The lower panels present the same information for the model with financial frictions. The first salient result is the south-west shift relative to the frictionless case to compensate for the wedge introduced by financial frictions. The cooperative equilibrium implies significant subsidies for both countries. This south-west shift also reduces the noncooperative level of taxation for both countries. A second feature of financial frictions is a significant flattening of the welfare contour relative to the frictionless economy in the neighborhood of the cooperative equilibrium, implying reduced gains to cooperation.

45. In the symmetric case, $\tau^k_{e,ss} = \tau^k_{c,ss} = 21\%$. These taxes are inversely proportional to the relative size of the country.



(a) Welfare resulting from long-run tax choices in frictionless economy.



(b) Welfare resulting from long-run tax choices with financial frictions.

FIG C1. Contour Plot of Welfare in Frictionless Economy (Upper Panel) and with Financial Frictions (Lower Panel): Green Square = Cooperative Equilibrium, Red Circle = Nash Equilibrium.

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