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Essays on Financial Instability and Crises

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A thesis submitted for the degree of Doctor of Philosophy, at the University of Oxford, in Michaelmas 2015.

Abstract: The thesis presents three papers in macroeconomics and monetary economics with an emphasis on financial instability and crises.

The first paper, entitled "**Interbank Market Crises and Financial Openness**," studies the effect of financial openness on financial stability by extending a closed-economy DSGE model (Boissay, Collard and Smets, 2015) to an open economy in which banks are allowed to invest abroad. Financial internationalisation in the form of outward banking flows alters the behaviour of the economy in the run up to a typical interbank crisis, reducing the role played by domestic credit build ups. Prior to an interbank crisis, the level of assets typically builds up in an economy without access to international investment opportunities. In contrast, financial openness attenuates the build up of assets during productivity booms, which reduces the likelihood of financial overheating resulting in a banking crisis once productivity reverts to trend. Simulations of the model show that the open economy would generally experience fewer banking crises in the long run compared to an economy blocked from investing abroad. This finding may not obtain in the short run, however, should the economy be subject to large negative productivity shocks consequent upon a financial opening up to the external domain.

The second paper, entitled "**Unconventional Monetary Policy and Asset Allocation of International Mutual Funds**," a joint work with Gino Cenedese and Menno Middeldorp (both at the Bank of England), analyses the spillovers of unconventional monetary policy from the US to the Rest of the World. Using panel regressions on a fund-level data-set of globally domiciled mutual funds, the study examines the degree to which the operations and surprises of US unconventional monetary policy prompt mutual fund managers to change their portfolio country weightings. Unconventional monetary policy by the US Federal Reserve is found to induce fund managers to reduce their portfolio exposure to the US whilst increasing it to other countries in the Rest of the World. Specifically, the Fed's purchases of Treasury securities trigger

portfolio rebalancing in equity funds, while its acquisition of mortgage backed securities and agency debt has a minimal effect on equity and bond fund portfolio allocations. Fed policy surprises do affect the portfolio allocations of equity funds. The main results continue to hold in a number of robustness checks. An extension of the study examines portfolio rebalancing effects of policy surprises by three other major monetary authorities, the ECB, BoJ and BoE. The main focus of the paper, however, is on the broader effects of US unconventional monetary policy on the asset allocation of international mutual funds.

The third paper, entitled **"Sovereign Debt Negotiations as a Macroeconomic Game with Strategic Interactions among Players**," aims to show that existing methods analysing games with more than two players can be usefully applied to macroeconomic games involving strategic interactions among three or more players. This is shown in the context of sovereign refinancing negotiations which are modelled as a bargaining game between three players: a debtor country in need of finance (player 1); its creditors from the international official-sector (player 2); and its foreign private-sector creditors in the form of international banks (player 3). The presence of a third player has important effects on the distribution of the gains from trade and the stability of the game if one allows for the possibility that any two players may form a coalition against another player. After deriving these general results, the model is applied to the Greek sovereign debt crisis to provide an economic application and to show that the framework can be applied to a wide range of other macroeconomic games.

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Contents

Chapter 1

Interbank Market Crises and Financial Openness

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Abstract

The effect of financial openness on financial stability is analysed by extending a closed-economy DSGE model (Boissay, Collard and Smets, 2015) to an open economy in which banks are allowed to invest abroad. Financial internationalisation in the form of outward banking flows alters the behaviour of the economy in the run up to a typical interbank crisis, reducing the role played by domestic credit build ups. Prior to an interbank crisis, the level of assets typically builds up in an economy without access to international investment opportunities. In contrast, financial openness attenuates the build up of assets during productivity booms, which reduces the likelihood of financial overheating resulting in a banking crisis once productivity reverts to trend. Simulations of the model show that the open economy would generally experience fewer banking crises in the long run compared to an economy blocked from investing abroad. This finding may not obtain in the short run, however, should the economy be subject to large negative productivity shocks consequent upon a financial opening up to the external domain.

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1 Introduction

The motivating question is whether outward financial openness will increase the incidence of domestic interbank-market crises. This paper extends a closed-economy model with an interbank market (Boissay, Collard and Smets, 2015) to the open economy by lifting the restriction on outward banking flows emanating from domestic banks.

The open economy extension model, developed in this paper, adds an additional mechanism in triggering a financial crisis. The financial system in open economies is structurally vulnerable to unsustainable investment rushes in the aftermath of a sequence of benign productivity shocks following upon one another. A significant bulk of domestic banks hasten to repatriate capital from their international investment portfolios back to their home base in order to take advantage of the new, unexpected, investment opportunities, having opened up domestically by dint of these productivity improvements. The resultant investment increase and the asset boom thus associated is much more sizeable, relative to the closed economy, simply because capital repatriation acts as a propagation mechanism for TFP shocks in the open economy. The gradual 'repatriation of capital' slows down as the asset booms is under way, which reduces the domestic interest rate and prompts larger gross capital outflows in the form of outward banking flows.

Gross capital outflows are pro-cyclical in the second phase of the asset boom which can end in a sudden and abrupt 'retrenchment of capital' as soon as the amount of assets exceeds the asset absorption capacity of the financial system. Once productivity reverts back to its lower long-run trend, the level of assets which were built up during the short asset boom, will tend to exceed the financial intermediation capacity of the interbank market, which thereby ushers in a financial crisis.

The other, seemingly surprising finding is that opening up the financial system reduces the role of domestic credit build-ups in driving interbank crises. While the level of assets typically builds up prior to the occurrence of a crisis in the interbank market within the closed economy, in the financially open economy access to international investment opportunities by contrast acts as a safety valve for domestic capital when the home economy suffers a productivity slowdown. Whether financial openness improves financial stability, under these conditions, depends on the stochastic environment facing the economy. The open economy is less subject to banking crises in the long run, a result that may however not apply in the short run whenever the economy is deemed to be subject to large negative productivity shocks.

The probability of interbank crises is lower in the open economy model given the fact that it spends on average less time in the crisis regime and that a crisis tends to last half as long relative to its incidence in a closed economy. Banking crises in a closed economy are associated with an adverse productivity shock of a median size of 1.45 standard deviations. Typically a larger shock of some 1.95 s.d. is required to trigger a crisis in a financially-open economy. Moreover, crises in the open economy tend to be less predictable, ex-ante, given that early warning signals, including the one-step ahead probability of a crisis, do not rise significantly in the run-up to a typical interbank crisis in the open economy, a matter that contrasts sharply with the closed economy case.

Adding outward financial openness to the closed economy framework of Boissay et. al. (2015) is motivated by empirical patterns showing that financial crises and, in particular, banking crises are associated with episodes of ’capital retrenchment', a phenomenon defined as a sudden fall in gross capital outflows normally effected by local investors. Forbes and Warnock (2012) stress the result that the 2007/8 global financial crisis has been marked by a widespread retrenchment of capital. This holds generally true for many financial crises, as shown by Broner, Didier, Erce and Schmukler (2013). Their study covers more than one hundred countries over a sample period of 1970-2009 where they find gross capital outflows collapsing precipitously from about 4% above trend ex-ante, to some 5% below trend of their GDP as recorded at the onset of the financial crises.[1] Surveying the extant theoretical literature, Broner et. al. (2013) suggest that "models without financial or other frictions are unlikely to be able to match the main empirical regularities of gross capital flows."

The suggestion as to the role of financial frictions is taken up in the present paper. The basic framework is derived from Boissay, Collard and Smets (2015), a standard real business cycle model except for the presence of financial frictions in the form of 'moral hazard' and 'asymmetric information' between banks. Frictions between banks are relevant for the question at hand given that we investigate interbank market crisis. [2]

The extension to the open economy developed here endogenously determines the international investment activity of the domestic banking system. In the baseline model, as developed by Boissay et. al. (2015), banks are primarily heterogeneous in their skill of investing in corporate firm projects. The point is extended here by adding a second layer of heterogeneity between banks by

[1]This refers to the average for high-income countries. Low- and middle-income countries also experience a fall in gross capital outflow but it is smaller as a percentage of trend GDP.

[2]Other forms of financial frictions include bank-firm, or bank-household frictions. Examples of the latter include Bernanke, Gertler, Gilchrist (1999) as well Kiyotaki and Moore (1997), which has recently been implemented by Gertler and Kiyotaki (2010), Brozoza-Brezezina, Kolasa, Makarski (2013), and Christiano, Motto, and Rostagno (2013). A more recent paper is Gertler and Kiyotaki (2015).

assuming differences in their cross-cultural communication efficiency which is important for operating in a culturally foreign environment. It is assumed that a bank's cross-cultural communication efficiency is at least as good as its corporate lending skill. The consequence is a self-effected selection of banks into the supply and demand sides of an interbank funding market, with a part of the latter endogenously sorting into banks investing in the domestic firm, while another mass of banks invests their levered funds abroad.

A basic result emerges. An interbank crisis in the model developed in this paper is associated with a retrenchment of capital by local investors away from their international investment positions as interbank market funding dries up in the course of a crisis, reducing the leverage of domestic banks, including of those banks investing abroad, to a critical point inappropriate to a normal functioning of the interbank market. This result is in line with Broner et. al. (2013), suggesting that "a tightening of domestic financial constraints during crises can lead to a retrenchment as a result of de-leveraging."

From a policy perspective, examining the nexus between financial stability and outward financial openness is an important topic, chiefly for three reasons. Firstly, recent studies, including that of Rothenberg and Warnock (2011), itself building on work by Faucette, Rothenberg and Warnock (2005), find that as many as one in five episodes of 'sudden stops' were induced by the international investment behaviour of local investors instead of being driven by the decisions of foreign investors. Moreover, Cowan et. al. (2007) point out that the frequency of outflow-induced capital account reversals has been increasing in the last two decades prior to this study. Secondly, many emerging market economies, see Aizenman and Pasricha (2013) for an illustrious study, have loosened controls on capital outflows. Finally, as pointed out by Desormeaux et. al. (2008), imposing or rather re-imposing restrictions on capital outflows has historically occurred ex-post after financial crises erupted such that, and particularly in the aftermath of the present global financial crisis, investigating the link between outward financial openness and financial instability has become an active, indeed pressing research question both for policy makers and academic economists alike.

1.1 Related literature

The present paper relates to two strands in the literature. The first relates to papers studying the effects of financial frictions, which differ according to the kind of friction (asymmetric information, moral hazard, etc.); the location of the friction in the model (bank-to-household, bank-to-firm, or bank-to-bank frictions); and the domain of analysis (micro- or macro-focused).

Micro-financial frictions deal with problems in the banking system without investigating the full general equilibrium effects of crises. An example is Diamond and Dybvig (1983) which was further developed in Diamond and Rajan (2001), and then subsequently applied to the interbank market by Allen, Carletti, Gale (2009). Few papers, including, among others, Angeloni and Faia (2012), have attempted to embed the Diamong-Dybvig idea into a DSGE model.

Macro-financial frictions consider the effect of financial constraints on the wider economy and often assess the effects in a DSGE framework. Bank-to-household frictions are present in Gertler and Kiyotaki (2010) in which a bank may abscond with the funds it borrowed from the household. An incentive compatibility constraint prevents the ’moral hazard’ action from occurring, at the cost of imposing a financial constraint on the bank’s borrowing ability that is predicated upon its net worth. It leads to the ’financial accelerator’ effect whereby a fall in a bank's net worth, say due to a fall of asset prices during a recession, limits borrowing and decreases investment in firms, which further decreases asset prices and, thereby, depresses net worth further. A different kind, namely bank-to-firm frictions, are present in Kiyotaki and Moore (1997) which is embedded in Brozoza-Brezezina, Kolasa, Makarski (2013) in a general equilibrium model with nominal rigidities, as is done in Curdia and Woodford (2010), Gertler and Karadi (2011), as well as Christiano, Motto, and Rostagno (2013).

The second strand of the literature studies financial openness, capital flows and financial stability. Models of capital flow determination can be distinguished by their emphasis on pull factors specific to a country or push factors outside the country. Push factor include global credit and liquidity (Calvo, 2012; Giannetti, 2007; and others), risk (Bacchetta and van Wincoop, 2013; Gourio et al., 2013), or world productivity shocks (see Albuquerque et al., 2005). Models of pull factors, in contrast, study the role of institutional factors, such as a country's level of financial development, as Ju and Wei (2011) and Mendoza et. al. (2009), or domestic productivity shocks. Aguiar and Gopinath (2007) argue that emerging markets are subject to swings in capital flows because their economies are frequently hit by permanent productivity shocks altering the country's level of trend productivity. Aghion et al. (2004) is related to the spirit of the present as they study the role of financial openness as a source of financial fragility although their focus is on the effect of liberalising capital inflows, whereas the model extended in the present paper focuses on the effect of liberalising outward financial openness.

The rest of this paper is structured as follows. Section 2 explicates the basic structure of the model. Section 3 describes the solution to the model.

Section 4 presents simulations of the model and derives the typical path to an interbank crisis in the open economy. Section 5 discusses the results of the model. A final section concludes.

2 Model

The economy is populated by three types of agents: firms, households and banks. Firms are capital constrained and have to borrow from banks to finance production activity. Households earn wage income from supplying labour to the firm and receive profit from owning firm shares. The household saves part of its income in the form of assets on which it receives interest from banks. The banking system uses these deposits of the household to fund its operations in lending to the firms.

Households and firms are homogeneous and modelled by a representative household and a representative firm. There is a firm at home and one firm abroad. Banks are heterogeneous in (i) their skill bearing on investing their available funds in firms' projects as well as in (ii) their efficiency of operating in a culturally foreign environment. An inter-bank lending market arises in which banks, with relatively poor corporate investment skills, lend their funds to other banks having relatively better skills in investing in various firms. This difference has the effect of creating a spectrum of banks as intermediaries in the production-distribution activities. Banks borrowing from the domestic interbank market will lend to the firm located abroad if they have a sufficiently good ability of cross-cultural understanding and acting upon it, whilst the rest of the banks, with humbler levels of cross-cultural understanding, borrow through the interbank market to invest in the firm located at home only.

The interbank market is subject to financial frictions in two forms. First, there is ’asymmetric information’ in that a bank’s skills are non-publicly observable private information. Second, there is ’moral hazard’ in the sense that banks borrowing through the interbank market can walk away, as it were, and divert interbank funding to different channels, instead of investing in any particular firm’s project.

The presence of moral hazard and asymmetric information in the interbank market jointly places a limit on the level of interbank funding that banks are typically able to obtain. An increase in the amount of assets, that is to be intermediated by the interbank market, will raise the incentives for diversion, thus tightening financial constraints. As the amount of assets grows, domestic interest rates tend to fall with a two-fold effect. First, the fall in the interbank interest rate leads to adverse selection of assets in that the banks with poorer lending skills switch from the supply to the demand side of the interbank market as borrowing interbank funds has become more attractive. Second, banks already borrowing through the interbank market have an increasing incentive to divert funds given that investing in the domestic firm tends to yield a lower rate of return when the corporate loan rate falls. Once the level of assets exceeds the ’asset absorption capacity’ of the economy, interest rates are so low and interbank market counter-party lending risks so high that the only level of interbank funding, compatible with incentives not to divert interbank funding, is zero or nearly so. This interbank market freeze is the key event defining a financial crisis in the baseline model of Boissay et. al. (2015).

In the open economy extension developed in the present paper, an interbank crisis is also associated with an episode of capital retrenchment as domestic banks partly pull back from their international investment positions, which they financed with leverage before the market for interbank funding dried up.

2.1 Firm

Our extension of Boissay et. al. (2015) to the open economy allows for domestic banks to invest in a firm abroad, not only in the firms at home. However, simplification of the model means that the extension refrains from allowing domestic banks to borrow from foreign banks, or foreign banks to invest in the domestic firm.

2.1.1 Domestic firm

It is assumed that the representative firm exists for one period, in which it produces a homogeneous good by dint of a Cobb-Douglas technology:

$$y_t = z_t k_t^{\alpha} h_t^{1-\alpha} \tag{1}$$

where $\alpha > 0$. The firm hires labour h_t at the wage rate w_t and borrows capital k_t at the corporate loan rate R_t. Loans are intra-periodic, such that the firm pays back the interest at the end of the same period. Capital depreciates at the rate of $\delta \in (0, 1)$. The firm's optimisation problem is to maximise profit net of input cost and depreciation:

$$\max_{\{k_t, h_t\}} \pi_t \equiv z_t k_t^{\alpha} h_t^{1-\alpha} - R_t k_t - w_t h_t + (1-\delta) k_t. \tag{2}$$

The exogenous growth rate of all input is: $g = 0$.

The level of z_t represents total factor productivity (TFP), which is stochastic

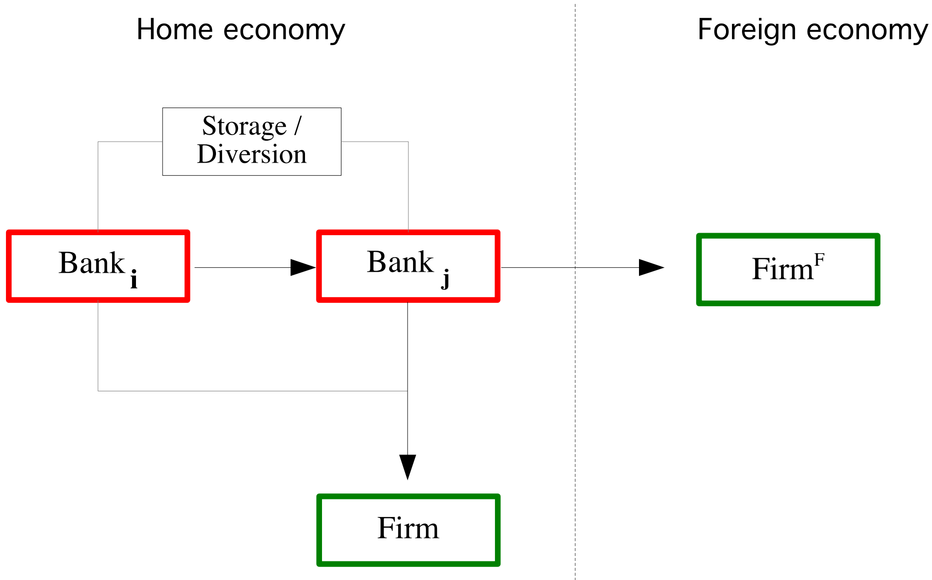


Figure 1: Extension to the open economy

and follows an auto-regressive process of the first order with persistence, $|\rho_z| < 1$, and Hicks-neutral technology shocks that are normally distributed, thus: $\varepsilon_t \sim N(0, \sigma_z)$. The firm's decision, as to its optimal production plan, takes account of the shock, ε_t, which is realised at the start of the period. The firm does not make any supernormal profits as all profits are distributed to households, which are the firm's shareholders.

2.1.2 Foreign firm

Figure 1 depicts the extension of the model from a closed to an open economy. The foreign economy is represented by the rate of return on the foreign firm. While the domestic firm offers a rate of return R_t, the firm located abroad offers a rate of return R^F. It is assumed that $R^F > R_t$. Whilst the home economy can be considered a large open economy, the quantity of its outwardbanking flows is assumed small in relation to the total size of the rest of the world, such that the return on the foreign firm is fixed.

2.2 Households

The preferences of the domestic households are specified in line with the type suggested by Greenwood, Hercowitz and Huffman (1988), which have the useful property of making the household's labour supply decision independent of its level of wealth. This allows the equilibrium solution to the model to be represented by a decision rule specifying the optimal level of savings, i.e. the level of next period's assets, a_{t+1}, as a function of the current period's level of assets a_t.

The household derives utility from consumption, c_t, and incurs disutility from working h_t hours. It maximises the infinite sum of the expected discounted utility subject to an inter-temporal budget constraint:

$$\max_{\{c_{t+i},h_{t+i},a_{t+1+i}\}} \quad \mathbb{E}_t \sum_{i=0} \beta^i \frac{1}{1-\sigma} \left(c_{t+i} - \frac{\vartheta}{1+v} h_{t+i}^{1+v} \right)^{1-\sigma} \tag{3}$$

$$s.t. \quad c_{t+i} + a_{t+1+i} = r_{t+i} a_{t+i} + w_{t+i} + \pi_{t+i}. \tag{4}$$

The discount factor applied to future utility is β, while σ indicates the rate of relative risk aversion, ϑ the disutility from labour and v the Frish elasticity of labour supply. Households fund consumption expenditure by drawing on their wage income w_t, their profits from the domestic firm π_t and their assets a_t that were deposited in the banking system in period $t-1$ yielding the household a rate of return r_t in period t. The response of r_t to TFP shocks will differ between the open and closed economy, with important implications for asset accumulation dynamics and financial fragility.

2.3 Banks

The banking system at home is populated by a continuum of risk-neutral banks collecting household deposits, a_t, at the end of period $t-1$ for use in period t. A bank may choose to: (i) lend its funds to another bank or (ii) **place its funds in a storage technology**. Banks borrowing funds from another domestic bank can (iii) divert these interbank funds for private gain, or invest its funds by lending to a firm (iv) at home or (v) abroad. Each of these options are briefly explored below.

The result is an endogenous sorting out of banks into the demand and supply sides of the interbank market as well as a separation of the banks borrowing through the interbank market with the purpose of investing either in the domestic or the foreign firm. This is depicted in Figure 2.

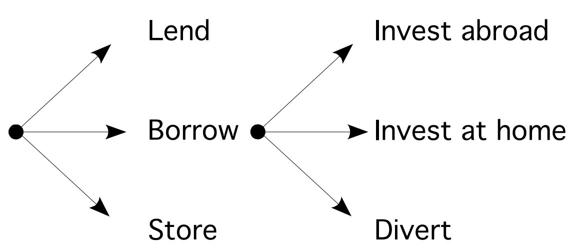


Figure 2: Endogenous bank sorting

Firstly, when a bank lends its funds to others in the interbank market, it earns a rate of return of ρ_t. Secondly, storage earns the bank a rate of return γ. When an unleveraged bank stores its funds, the storage technology may be thought of as reserve-holdings, i.e. a short-term liquid and safe asset as in Diamond and Dybvig (1983).[3] Thirdly, diversion to storage by a bank that has borrowed ϕ_t on the interbank market yields the bank $\gamma(1+\phi_t\theta)$ where $1 \geq \theta > 0$

[3]It is noteworthy to mention that Boissay et. al. (2015) show how the assumption that the return on storage is constant can be relaxed to require only that its "return is less sensitive to the business cycle than the corporate loan rate."

indicates a positive private gain from diverting funds.

The notion of placing borrowed funds in storage as constituting 'diversion' is standard in the literature on incomplete contracts as exhibited in Hart (1995). The motivation in the context of the present model is provided in Boissay et. al. (2015) by the assumption that "the proceeds of the storage technology are not traceable and cannot be seized by creditors." This relates to the idea by Burkart and Ellingsen (2004) that the agent, here the borrowing bank, "may use (part of) the available resources to generate non-verifiable private benefits" from diverting funds to storage. Gertler and Kiyotaki (2015) provide a complementary interpretation of diversion as "selling the fraction θ of assets secretly on a secondary market in order to obtain funds for personal use. "

During an interbank market crisis, banks previously on the supply side of the interbank market will switch to storing their funds instead of lending them to other banks, given high interbank market counter-party risks. These counter-party risks are due to the option that a bank borrowing from the interbank market can divert such borrowed interbank funds.

Fourthly, a bank borrowing through the interbank market may chose to invest in the domestic firm, earning a gross return of $p_j R_t(1 + \phi_t)$. The return to bank of type-j is dependent on p_j, its skill of investing in corporate firm projects , as well as the corporate loan rate R_t which is a function of domestic productivity as specified in the marginal product of capital.

Fifthly, and finally, a bank may invest in the firm abroad instead, yielding a return of $p_j f_j R^F(1 + \phi_t)$. The return to bank j is dependent on its skill of investing in corporate firm projects p_j and its ability of mastering cross-cultural understanding f_j, both of which affect its efficiency of investing abroad $p_j f_j$ and, inter alia, its effective rate of return from investing in the foreign firm's project $p_j f_j R^F$.

It is assumed that banks make zero super-normal profit with the assumptions of marginality, size, etc., as these banks would pass on the net investment return to relevant households. Banks are jointly liable to the household sector such that a diversion of one bank's funds is a mere redistribution among the banks. However, financial frictions place a limit on the amount of leverage a bank may obtain, resulting in a reduced efficiency of the financial system in view of the asymmetric information assumption concerning banks' heterogeneous qualities, as explained next.

2.3.1 Heterogeneities among banks

Banks are assumed to be twice heterogeneous: first, in their skill of investing in corporate firm projects and, second, in their efficiency of cross-cultural understanding when navigating in a foreign environment.

Heterogeneity 1: Corporate investment skill p_j

At the beginning of each period, each bank draws a random bank-specific corporate lending skill $p \in [0, 1]$. The higher the p-value, the more skilled the bank at investing in firm projects.

Bank j with p_j obtains a rate of return $p_j R_t$ when investing in the domestic firm. The bank faces a bank-to-firm intermediation cost of $(1 - p_j)R_t$ per unit of domestic corporate loan. The distribution of the skills follows $\mu(p) = p^{\lambda}$.

An interbank funding market will arise, reallocating assets from comparatively less efficient to the relatively more skilled banks. Better skilled banks, i.e. those with relatively higher p values, will borrow from the lesser skilled banks. We extend this interbank market model, as developed in Boissay, Collard and

Smets (2015), by allowing banks to invest in firms located abroad. We introduce a second heterogeneity among banks which endogenously determines the economy's financial openness.

Heterogeneity 2: Cross-cultural communication efficiency f_j

A large literature in international economics emphasises cultural differences as a determinant of trade and investment. As early as the work by Ozawa (1979) and Yoshino (1976), studies emphasised that differences in culture might inhibit outward foreign direct investment just as much as enhance it.

At the beginning of each period, each bank draws a bank-specific skill representing its ability to operate in a culturally foreign environment. The higher the value of $f \in [0,1]$, the higher a bank's efficacy of cross-cultural communication and, therefore, the lower its costs of navigating in a foreign environment. The term 'culture' refers to various variables such as (i) language, (ii) general business environment, as well as (iii) regulatory and legal settings in the foreign economy.[4]

Firstly, the costs arising from cultural distance may be due to linguistic frictions, either because of the need for competence in the foreign language used in the investment destination, or due to substantial differences in the lingua franca, where both parties employ the same diction as a means of communication but at significantly different levels of proficiency. Both conditions are associated with a cost to the parties involved when conducting smooth business communications, such as significant misunderstandings which would be to the detriment of one or both sides. The skill of such cross-cultural communication is likely to be heterogenous among banks (see Cuypers et. al., 2015,

[4]The model abstracts from the cost and benefit of the acquisition and maintenance of these skills and ancillary aspects.

and Sui et. al., 2015).

Secondly, cross-border transaction frictions may be due to differences in the business environment, including unfamiliar suppliers, customers, competitors, organised labour as well as other constituencies and stakeholders, as noted in Lee et. al. (2008). These differences impose costs that might discourage committing resources abroad (Erramilli, 1990, and Erramilli and Rao, 1993).

Thirdly, the cross-cultural efficiency of a bank can be thought of as measuring its competence in dealing with cross-border regulatory or institutional barriers of entry. These might take the form of tariffs or non-tariff barriers such as cross-border remittance rules and documentation requirements, all of which have a potential impact upon approval time periods for different kinds of international investment. Reportedly, this is a crucial issue for international investors (Standard Chartered Global Research, 2013)

In the closed economy of Boissay et. al. (2015) model, all banks investing in corporate projects are entities that borrow through the domestic interbank market. To maintain this property of the model, which allows for an unconfounded and clear comparison of the closed and the open economies, we assume that a bank's ability of cross-cultural understanding is at least as good as its corporate investment skill such that $f_j \geq p_j$. The distribution of f follows a uniform distribution with p as its lower bound: $\mathsf{U}\left[p,1\right]$.

The interaction of the two sets of skills constitute the bank-specific efficiency of investing abroad. Bank j, with p_j and f_j, obtains a rate of return $f_j p_j R^F$ from investing abroad. The bank faces a bank-to-foreign-firm intermediation cost of $(1-p_j)(1-f_j)R^F$ per unit of international corporate loan. The multiplicative here measures the iceberg cost of investing abroad, with one part of the loss being associated with the cost of monitoring the corporate loan and the other being due to the costly frictions that are associated with operating in a culturally foreign environment. Instead of a simple additive interaction, such as $f + p$, the multiplicative interaction rules out the following scenario. When a bank has a zero corporate lending skill, increasing the bank's cross-cultural understanding would not increase its incentive to invest abroad. This case is ruled out by the multiplicative interaction because a bank with no skill to invest ($p_j = 0$) though having some cross-cultural understanding ($f_j > 0$) would not invest in any firm, whether at home or abroad. Instead, the firm would delegate the investing activity to banks enjoying better corporate lending skills.

The purpose for maintainting the key property of the Boissay et. al. (2015) model, namely that that all banks investing in corporate projects are entities borrowing through the domestic interbank market, is to allow for a clear comparison of the closed and the open economies models. The above specification of bank heterogeneities rules out the situation that those banks investing overseas in the open economy would, if the economy were of the closed type, fail to borrow from the interbank market. It implies that internationally active banks would continue to borrow from, instead of lending to, others in the interbank market, if the economy were closed.

Significantly, the specification also implies that the limit on interbank lending continues to be predicated solely upon the quality of the financial institution at the margin of the demand side of the interbank market, which is discussed further in Section 2.3.4.

2.3.2 Participation constraints

There is an endogenous sorting of banks into the supply side ($p < \overline{p}_t$) and demand side ($p \geq \overline{p}_t$) of the interbank market as well as an endogenous determination of which type of the bank borrowing through the interbank market will invest in the domestic firm ($f < \overline{f}_t$) or the firm abroad ($f \geq \overline{f}_t$).

Domestic interbank market borrowing

Bank j will borrow, in order to invest in a domestic firm project, if the return to such investment is at least as large as the return that would obtain from lending the funds earmarked for such operation to another domestic bank, i.e. if $p_j R_t \geq \rho_t$. This condition can be rewritten as to say that a bank will borrow on the interbank market if

$$p_j \geq \overline{p}_t, \text{ with } \overline{p}_t \equiv \frac{\rho_t}{R_t}, \tag{5}$$

where $\overline{p}_t$ signifies the corporate investment skill of the bank on the margin of the demand side for interbank funding. All banks with investment skills of at least $\overline{p}_t$ will enter the demand side, leaving all banks with skills lower than the threshold, $p_i < \overline{p}_t$ for $\forall i$, to enter into the supply side of the interbank market.

International corporate firm investing

All banks with $p_j \geq \overline{p}_t$ face an additional decision: to invest in the domestic firm or the firm abroad. A bank of type-j invests in the foreign firm if the return there dominates the return obtainable from investing domestically, that is if

$$p_j f_j R^F (1 + \phi_t) \geq p_j R_t (1 + \phi_t), \tag{6}$$

where ϕ_t signifies the amount of interbank funding. R^F and R_t are the gross rates of returns from investing in the domestic and the foreign firm, respectively. If $R^F > R_t$ is a viable assumption, at least some banks will be internationally active.

If $f_j = 0$ for $\forall j$, then the banks are parochial in their cross-cultural understanding ability, in that the transaction costs from navigating around in a culturally foreign environment are prohibitive. No bank would have an incentive to engage in international corporate lending, even if the foreign rate of return is quite high when compared with what is obtainable domestically.

If $f_j > 0$ for $\exists j$, as is assumed here, banks with a sufficiently high efficiency of cross-cultural understanding would entertain the prospects of borrowing on the interbank market in order to invest internationally. The participation constraint (6) can be rearranged and simplified so as to see a bank borrowing through the interbank market in the hope of investing abroad should

$$f_j \geq \overline{f}_t, \text{ with } \overline{f}_t \equiv \frac{R_t}{R^F}. \tag{7}$$

This is where $\overline{f}_t$ signifies the cross-cultural understanding of the bank at the margin of investing funds internationally. The higher the foreign return, the lower the threshold $\overline{f}_t$, i.e. the lower the required cross-cultural skill of the marginal, internationally active bank and, therefore, the larger the number of banks investing abroad. Analogously, the lower the domestic rate of return, the fewer the number of banks that will attempt investing at home. The domestic corporate lending rate R_t is a function of domestic total factor productivity where $\overline{f}_t$, indicating the degree of the financial openness of the economy, is determined endogenously and varies over time according to the realisation of the domestic productivity shock. If $\overline{f}_t$ is low, banks with relatively poor efficiency in cross-cultural understanding will invest abroad as these entities are attracted by the differential return available overseas.

A zero outward investment is likely if the threshold reaches, or indeed exceeds, unity which occurs when $R^F \leq R_t$. The cross-cultural understanding skill variable f_j is drawn from a uniform distribution with an upper bound of 1. If it were assumed that $R^F \leq R_t$, then the home economy would be effectively shut off from cross-border capital flows. This would relegate the model back to that of Boissay et. al. (2015) which is a special case of the more general framework depicted here.

The optimisation question for the internationally active bank is how to choose leverage ϕ_t so as to maximise the returns from its leveraged investment, viz.:

$$\max_{\phi_t \geq 0} r_t(p_j) \equiv p_j(1+\phi_t)f_j R^F - \rho_t \phi_t \quad (8)$$

$$s.t. \quad p_j \geq \overline{p}_t \quad (9)$$

$$f_j \geq \overline{f}_t. \quad (10)$$

In the absence of asymmetric information and moral hazard, all banks have a propensity to lend their excess funds to the most skilled bank among them which would then opt to choose infinite leverage. However, the presence of frictions in the interbank market limits leverage to an amount compatible with the marginal borrowing bank having no incentive to divert funds.

2.3.3 Financial frictions between banks

The interbank market has two types of financial frictions. One arises from asymmetric information as banks do not know each others' type in actual practice, although they can calculate the quality $\overline{p}_t$ of the marginal borrowing bank, given knowledge of the aggregate distribution $\mu(p)$. Another friction comes from the potential for a 'moral hazard' problem between and among banks as the funds they borrow through the interbank market may be diverted for a private gain by the borrowing bank.

In equilibrium, diversion of funds is ruled out, for banks on the supply side of the interbank market would otherwise have an incentive to unilaterally deviate from their decision to lend to banks on the demand side.

To rule out such diversion, the return to the borrowing bank from diverting inter-bank funds must be less than, or equal to, lending the interbank market in the sense of: $\gamma(1 + \phi_t\theta) \leq \rho_t$. This incentive compatibility constraint is strictly binding. The presence of financial frictions, by way of moral hazard and asymmetric information, results in a 'pooling contract' that limits leverage to one level of leverage $\overline{\phi}_t$ for all banks, irrespective of their type, such that:

$$\phi_t = \overline{\phi}_t \equiv \frac{\rho_t - \gamma}{\theta\gamma}. \tag{11}$$

Under perfect information and in the absence of moral hazard, $\theta \to 0$, all banks lend to the best bank ($\overline{p}_j = 1$) which would have infinite leverage $\phi_t \to \infty$. The presence of asymmetric information does not permit lending banks to write a 'separating contract' specifying leverage according to the p-type of the counter-party bank. Banks draw a random p value anew each period, such that households or banks cannot learn about the quality of any individual bank.

2.3.4 Interbank market crisis and asset absorption capacity

A fall in the interbank interest rate, from ρ_t to ρ_t^*, tightens the incentive compatibility constraint on interbank borrowing and, thereby, reduces interbank leverage.

A fall in the interbank interest rate reduces the costs of borrowing, thus incentivising the lowest skilled banks to switch from the supply to the demand side of the interbank market. The quality of the marginal borrowing bank drops, whereby $\overline{p}_t \equiv \frac{\rho_t}{R_t} < \overline{p}_t^*$, raising counter-party interbank lending fears; thus the bank that switches to borrowing funds must have an incentive to divert these funds, yielding $\gamma(1+\overline{\phi}_t^*\theta)$, instead of investing in the domestic firm and thus earning $\overline{p}_t(1+\overline{\phi}_t^*)R_t$. Leverage, in this case, will be reduced to a lower, incentive-compatible level, $\overline{\phi}_t < \overline{\phi}_t^*$, and in the limit drops to zero. When interbank leverage is zero, the interbank market seizes up. This event is defined as a 'financial crisis' in this model.

An increase in the supply of assets, intermediated by the interbank market, pushes the interbank rate to lower levels and acts as the main mechanism of causation in creating banking crises. As suggested in the model of the interbank market by Boissay et. al. (2015), a crisis occurs when the amount of assets reaches a threshold level $\overline{a}$, the 'asset absorption capacity' of the financial system. The asset absorption capacity is a function of household preference and technology, as can be seen from its definition:

$$\overline{a}_t = \Phi z_t^{\frac{1+v}{v(1-\alpha)}} \tag{12}$$

where $\Phi \equiv \left(\frac{1-\alpha}{\vartheta}\right)^{\frac{1}{v}} \left(\alpha/\overline{R}+\delta-1\right)^{\frac{v+\alpha}{v(1-\alpha)}}$ with v being the labour supply elasticity, α the capital share in production, δ the capital deprecation rate, ϑ the labour disutility and the lower limit on the interest rate $\overline{R}$ being pinned down by $R_t = \frac{\rho_t}{\mu^{-1}\left(\frac{\rho_t - \gamma}{\rho_t - \gamma(1-\theta)}\right)}$ where μ is a function of λ, the density parameter for banks' corporate lending skill, γ the return on storage, and, finally, θ the private return on diversion.

A supply of assets that is equal to or goes above that threshold, such that $a_t \geq \overline{a}_t$, implies that the level of assets is 'too large', pushing the interbank rate so low as to equal the return on storing funds, γ, where no bank is willing any longer to supply funds to the interbank market and resorting, instead, to storing the funds. As explained later in Section 3.1, the condition $a_t \geq \overline{a}_t$ describes the occasionally binding constraint that triggers the economy to switch from being in the tranquil regime to that of the crisis situation.

Recall from Section 2.3.1 above that the specification of bank heterogeneities in the open economy extension implies that the limit on interbank lending continues to be predicated solely upon the quality of the financial institution at the margin of the demand side of the interbank market. The incentive compatibility constraint equalises the expected return from the two options available to the bank at the margin of switching from the supply to the demand side of the interbank: that is, on the one hand, lending to the interbank markets, or, on the other hand, borrowing from the interbank market in order to invest in the domestic firm. Given its relatively low ability of navigating in a foreign environment, this marginally borrowing bank has no incentive to invest in the firm abroad. Opening up the economy, therefore, leaves the asset absorption capacity and the incentive compatible leverage limit of the economy unchanged.

The motivation for this assumption is to allow for an unconfounded analysis between the open and closed economies such that any results regarding the properties of the each model are not driven merely by a mechanical change in the occasionally binding constraint. This is a common procedure in the literature on business cycle models with capital market frictions: capital account openness does not directly affect credit frictions but only indirectly via the effect of capital flows on, e.g. asset prices, interest rates, and net worth.

The Zeira (1991) model on credit rationing in an open economy has an incentive compatibility constraint on borrowing and lending that is not affected by the openness of the capital account. This is because the moral hazard is modelled in an OLG model where the young have the option to use borrowed funds from the older generation to either invest in their human capital or to consume the funds instead.

Xu (1998) analyses the effect of capital outflow restrictions on the severity of credit rationing using a two-country two-sector model in which entrepreneurs are capital constrained and need to obtain funding from banks. Each entrepreneur can invest in either of the two production sectors. There is Townsend (1979) like costly state verification as banks need to pay a monitoring cost to observe the outcome of an entrepreneur's project. The borrowers differ in the quality of their projects, which is private information. There is moral hazard in that a borrower with a high quality project has an incentive to pretend that his ex post return is low, implying that he cannot pay back all the debt owed to the lender. However, liberalising the capital account does not affect the incentive compatibility constraint because potential entrepreneurs at home do not have the ability to invest abroad. Only non-entrepreneurs are able to lend internationally to banks overseas which are not affected by moral hazard.

In Aghion, Bacchetta and Banerjee (2004), the credit frictions of the Bernanke-

Gertler (1989) kind, are only indirectly affected by financial liberalisation in that capital flows affect the price of domestic assets and, thereby, the net worth of domestic investors. For further papers, Arellano and Mendoza (2002) provide a survey about credit frictions in small open economy business cycle models.

2.4 Capital availability and return on bank equity

Financial openness affects both the quantity of working capital k_t that is available to domestic producers, and the rate of return r_t that the banking system is able to offer on the aggregate amount of assets a_t deposited with banks. The effect of openness must be characterised, for normal times and for periods of crisis, as illustrated below.

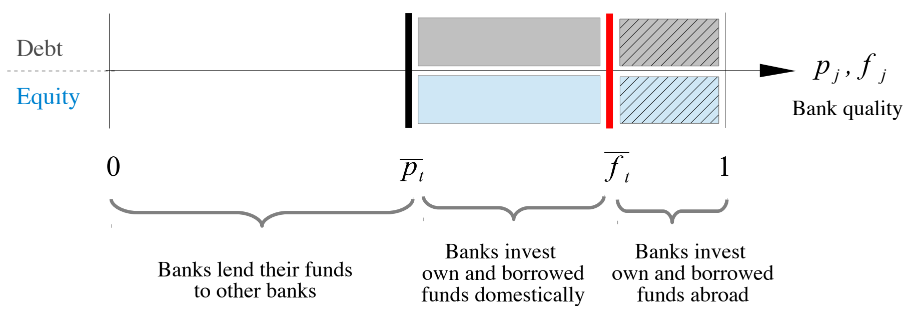


Figure 3: The open economy in tranquil times

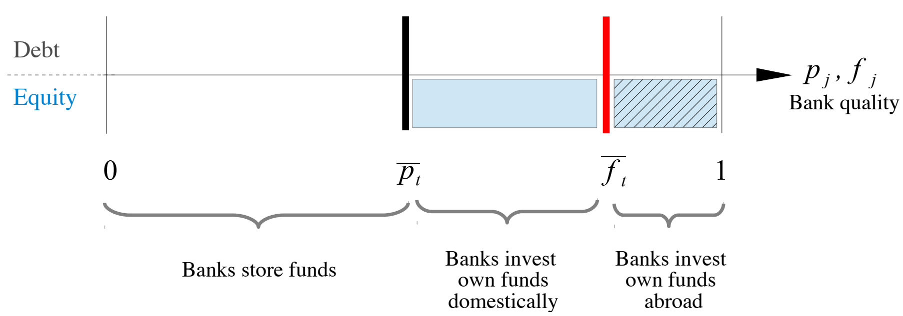


Figure 4: The open economy in times of crisis

In tranquil times, the interbank market reallocates funds from relatively less skilled banks (with $p_i < \overline{p}_t$, $\forall i$) to their more skilled counterparts (with $\overline{p}_t \leq p_j \leq 1$, $\forall j$). A segment of the latter group invests its funds domestically (with $\overline{p}_t \leq p_j < \overline{f}_t$), whilst the remainder (with $\overline{f}_t \leq p_j \leq 1$) enjoy sufficiently good cross-cultural communication efficiency to bolster their propensity to invest abroad.

In times of crisis, the interbank market does not operate in that way and interbank lending is, thereby, zero. In the throes of a crisis, banks will only use their 'own' funds (those obtained from households) as during crises they are unable to borrow from others through the interbank market. Banks with a low aptitude for corporate investing ($p_i < \overline{p}_t$) tend to hold back and store their funds for a less critical time. By contrast, the relatively better laced banks, in the category of $\overline{p}_t \leq p_j \leq 1$, $\forall j$, will deploy their funds and invest either in the domestic or the foreign firm.

2.4.1 Tranquil times

For a closed economy, the capital k_t that is available to the firm at home is equal to the aggregate level of assets within this domain, namely a_t, all of which are funds channelled to the domestic firms to render $k_t = a_t$.

In the open economy extension, banks lending to foreign firms will act as a drain on the capital available to the domestic firm. Specifically, if domestic investment opportunities yield a lower return relative to the reward obtainable from a foreign project ($R_t < R^F$), the financial system will have a propensity to take a share of aggregate assets and invest it abroad. Given the heterogeneity among the domestic banks, banks that are sufficiently proficient in dealing in a culturally foreign environment, that is to say banks with $f_j \geq \overline{f}_t$, will invest overseas. In tranquil times, when the interbank market functions as normal, a mass of $1 - \mu\left(\overline{f}_t\right)$ banks will take their leveraged funds $(1 + \phi_t)$ out of the economy and place them in profitable pursuits across the border. The capital k_t available to the domestic firm is, thus, no longer equal to a_t. Instead it is equal to

$$k_t = a_t \left(1 - (1 + \phi_t)\left[1 - \mu(\overline{f}_t)\right]\right). \tag{13}$$

The reduction in the amount of capital available to the domestic firm tends to reduce the volume of output and the demand for labour. In the open economy, the amount of domestic investment is socially suboptimal whenever openness lowers the steady state level of consumption. Banks do not take into account that their investment activity abroad imposes a negative externality on the domestic household, reducing output and employment below the level achievable in the closed economy. Such a macro consideration is beyond their raison d'être. Short of government intervention, this behaviour can be observed in reality with relative ease. The welfare loss is not outweighed by any significant increase in the banking system's return on investments, even though these are fully passed on to the households.

The return which the households earn on their equity in the banking system is the sum of the latter's total net return from investing in the domestic as well as the foreign firm. More precisely, the return on bank equity is twice composed: (i) of the return R_t on domestic investment earned by the banks that borrow through the interbank market so as to invest at home, and (ii) of the return on foreign investment R^F by the banks that borrow in the interbank market to invest internationally:

$$r_t = R_t \int_{\overline{p}_t}^{\overline{f}_t} p(1+\phi_t)d\mu(p) + R^F \int_{\overline{f}_t}^{1} \left(\int_{\overline{f}_t}^{1} fp(1+\phi_t)d\mu(p) \right) d\eta\left(f\right). \tag{14}$$

The gross returns from investing overall are modulated by the quality of the investing bank p, with $p_j \in \left[\overline{p}_t, \overline{f}_t\right)$ in the case of domestically active banks, as well as by the foreign communication skill f, available to the internationally active banks, with $p_j, f_j \in \left[\overline{f}_t, 1\right]$.

2.4.2 Crisis times

When the price of interbank loans falls too low so to reach the return obtainable from storing funds ($\rho_t = \gamma$), banks that were previously willing to lend to others of their number tend to switch their funds and place them in storage. This is a non-productive use of funds, given the fact that a share of aggregate assets is not available for use by the domestic firm.

One implication relating to the quantity of capital available for domestic production is as follows. Banks of mass of $\mu(\overline{p})$ place funds in storage, while the higher quality mass $1-\mu(\overline{p})$ of banks will invest in production projects, a segment of which, $1-\mu(\overline{f}_t)$, will invest abroad, albeit at zero leverage. Now the capital available to the domestic firm is:

$$k_t = a_t\left(1-\mu(\overline{p}_t)-\left[1-\mu(\overline{f}_t)\right]\right). \tag{15}$$

Therefore, an open economy characterised by an interbank crisis has two kinds of capital leakage: capital confined to storage and capital invested in the foreign investment domain.

The return which households earn on their deposit in the banking system is:

$$r_t = \gamma\mu(\overline{p}_t) + R_t \int_{\frac{\gamma}{R_t}}^{\overline{f}_t} p d\mu(p) + R^F \int_{\overline{f}_t}^{1} \left(\int_{\overline{f}_t}^{1} f p d\mu(p) \right) d\eta\,(f)\,. \tag{16}$$

The return on bank equity comprises three types of the use of funds by the banking system. Firstly, banks earn γ when storing their funds in storage. Secondly, banks with lending skills, at least equal to $\overline{p}_t$, would like to borrow, if they could, but find themselves unable to do so given that interbank-market counter-party fears are prohibitively high to the extent that interbank lending comes to a halt. Banks, thus, invest no more than their own funds in the domestic firm. Thirdly, banks with a sufficiently good ability of cross-cultural communication will invest overseas but at no leverage.

This concludes the description of how introducing financial openness alters some of the key equations of the closed economy model.

The equilibrium behaviour of the economy can be obtained by solving the optimisation problems of each set of the economy's agents: (i) Euler equations for consumption and labour supply choice, derived from the household's optimisation problem; (ii) the level of technology as well as of production, the demand for labour, investment and the corporate loan rate, all are determined by the firm's optimisation problem; (iii) the return on bank equity, the quality of the marginal bank, as determined by an incentive compatibility constraint, as well as the interbank interest rate, plus an economy-wide resource constraint. The complete set of equations for both the closed and open economies can be found in Appendix 7.3 below.

Table 1: Parameter calibration

Relative risk aversion	σ	4.500	Absconding cost	θ	0.1
Discount factor	β	$1/1.03$	Investment skill $\mu(p) = p^{\lambda}$	λ	24
Labour supply elasticity	υ	$1/3$	Cross-cultural skill $\eta(f) = f^{\Lambda}$	Λ	1.000
Labour disutility	ϑ	0.944	Return on foreign investment	R^F	1.050
Capital share in production	α	0.300	Threshold for domestic return	$\overline{R}$	1.0243
Capital deprecation rate	δ	0.100	TFP shock standard deviation	σ_z	0.018
Return to storage	γ	0.936	TFP shock persistence	ρ_z	0.900

3 Model solution

The model is solved by Guerrieri and Iacoviello's (2015) piecewise-linear solution method. After briefly describing the calibration, the solution of the model is described thereafter by the asset accumulation decision rule of the representative household.

3.1 Calibration

In order to derive the asset accumulation rule and assess the economy's dynamic behaviour, one needs to set the values for the model's parameters. We extend the calibration used in Boissay et al. (2013) to the open economy case introduced here. The rate of return on foreign investment projects is 5%, that is at a higher level than the steady state rate of return on domestic corporate loans. The distribution of bank cross-cultural understanding, measuring its f efficiency when navigating in a foreign environment, follows a uniform distribution with p as its lower bound such that $f \sim \mathsf{U}[p, 1]$.[5]

[5] An improvement in cross-border capital flow efficiency could be modelled by assuming $\eta(f) = f^{\Lambda}$ with $\Lambda > 1$.

3.2 Occasionally-binding constraint

The economy can be either in tranquil or critical times, whereby the switch between the two states is governed by an occasionally binding constraint. The economy switches from the reference regime ('tranquility') to the alternative regime ('crisis') when assets exceed the maximum threshold $\overline{a}_t$ that the financial system is able to intermediate efficiently. When $a_t > \overline{a}_t$, the asset supply has grown too large for the norm and has pushed the interbank rate downward to the level of the fixed return on storage. Banks that were previously lending, no longer have an incentive to continue offering their funds and, instead, veer towards hoarding their funds. This asset absorption threshold $\overline{a}_t$ is pinned down by contemporaneous productivity and takes the form $\overline{a}_t = \Phi z_t^{\frac{1+v}{v(1-\alpha)}}$, where Φ is a function of the model's structural parameters as derived by Boissay et al. (ibid). Opening up the economy, as introduced in the present paper, leaves the asset absorption capacity unchanged. Table 2 presents the value of the the asset absorption capacity for selected levels of productivity.

Table 2: Productivity and crisis threshold

Productivity	Crisis threshold $\overline{a}_t$
1.095	7.48554
1.010	4.71729
1.000	4.45656
0.910	2.59986

The assumed distribution of the second heterogeneity among banks implies that the leverage limit is predicated solely upon the quality of the financial institution at the margin of the demand side of the interbank market. Due to its relatively low ability of exploring and committing resources in a foreign environment, the marginally borrowing bank has no incentive to invest abroad.

Opening up the economy, therefore, leaves unchanged the financial constraint, i.e. the incentive that is compatible with the leverage limit. This follows from our assumption that $\lambda > \Lambda$ which implies that j-type banks, with an investment skill greater than that of k-type banks, will also be relatively more efficient in cross-cultural communication, such that: $p_j > p_k \geq \overline{p}_t$ and $f_j > f_k \geq \overline{p}_t$.

However, one should not conclude that openness has no adverse effect on financial fragility. On the contrary, it will be seen below that the rate of asset accumulation is much higher in the open economy case, rendering it more or less exposed to interbank crises and its ravages, depending on the sequence of productivity shocks to which it is exposed to, as explained in Section 4.

3.3 Piecewise-linear solution method

The model is solved by the Guerrieri and Iacoviello (2015) algorithm, which applies the first-order perturbation method in a piecewise manner. The piecewise-linear perturbation solution produces results that are close to the non-linear projection methods, with Euler errors being vanishingly small.

The economy is characterised by an occasionally binding constraint ($a_t \geq \overline{a}_t$) determining when the economy switches from tranquility to crisis. The point $\overline{a}_t$ in the state space determines the regime switch.

The piecewise-linear solution method produces a decision rule of the form

$$a_{t+1} = V_t a_t + W_t \qquad \forall \text{t} \in \{2, \infty\} \tag{17}$$

with the initial solution at $t = 1$ being $a_1 = V_1 a_0 + W_1 + X_1 \varepsilon_1$ where the shock in the initial period is ε_1. Here the coefficients V_t, W_t and X_t depend on the state of the economy a_t and the initial shock ε_1.

A few important notes are in order: The model is solved around the non-stochastic steady state of one of the regimes denoted as the reference regime. Here this is the economy in tranquil times. The Guerrieri and Iacoviello (2015) solution method requires that the Blanchard-Kahn conditions hold in the reference regime and that the economy, if shocks compel it to switch to the crisis regime, will eventually return to the tranquil regime over the simulation horizon, assuming that agents expect no future shocks. We check the stability conditions and find that they hold in our model.

A guess-and-verify approach is applied by Guerrieri and Iacoviello (2015) with the express desire to solve for the decision rule.[6] Whilst in the crisis regime, the approach produces a guess that, from period T onwards, the reference regime applies forever. One solves the model, then proceeds to the next iteration of the guess. One stops when the latest guess is verified. For any period $t+1 \geq T$, the solution is: $a_{t+1} = Va_t + \varepsilon_t$ given $V_t = V$ and $W_t = 0$.

One feature of the piecewise-linear solution method implies that it does not encompass in the model the effect of the households' precautionary savings behaviour, in contrast to the fully non-linear solution methods including projection methods and dynamic programming. Precautionary saving occurs on the part of the households, given their awareness and anticipation of future regime switches that are due to as yet unrealised shocks. It is an open question whether precautionary saving in anticipation of interbank market crises, as a determinant of such crises, is a realistic assumption or a desirable element in any model of banking crises. Therefore, in contrast to Boissay et. al. (2015), we explain interbank crises without reference to precautionary savings behaviour on the part of households.

[6] The algorithm builds on work by Jung, Teranishi, and Watanabe (2005) and Eggertsson and Woodford (2003).

The piecewise-linear solution implies a lower rate of asset accumulation around the point at which the economy switches into the crisis regime, relative to the non-linear solution. This is because the non-linear solution would take account of the fact that the closer the state a_t is to the threshold $\overline{a}_t$ defining the occasionally binding constraint, the higher is the likelihood of future productivity shocks pushing the economy to switch into the crisis regime. Given the absence of the precautionary saving motive in our piecewise-linear solution, there is a lower rate of asset accumulation, and thus a higher path of interest rates, compared with their state in a non-linear solution. This finding yields a lower predicted frequency at which the economy experiences interbank market crises. When simulated on a quarterly series for US TFP, the model solved with piecewise-linear techniques is still able to capture the relevant episodes of financial instability in the US. See Section 4.3.

Under the piecewise-linear solution method, implemented here, the realisation of productivity shocks affects the expected length or duration of the crisis regime. This, in turn, affects the contemporaneous values of the endogenous variables. The solution method thus allows for the dynamic behaviour of the economy to be influenced by the agents' expectations of the duration of the two regimes under consideration. The dependence of the solution on the expected length of each regime, which depends on the current state of the economy, produces a non-linear behaviour despite the solution being piecewise-linear.

Figure 5 depicts the piecewise-linear asset accumulation decision rule for selected levels of steady state productivity in the closed and open economies. The underlying levels of productivity are $\widetilde{z} \in [0.85;\ 1.00;\ 1.15]$ respectively. First, one notes that the level of assets is more responsive to productivity shocks in the open economy, which can be gleaned from the larger vertical

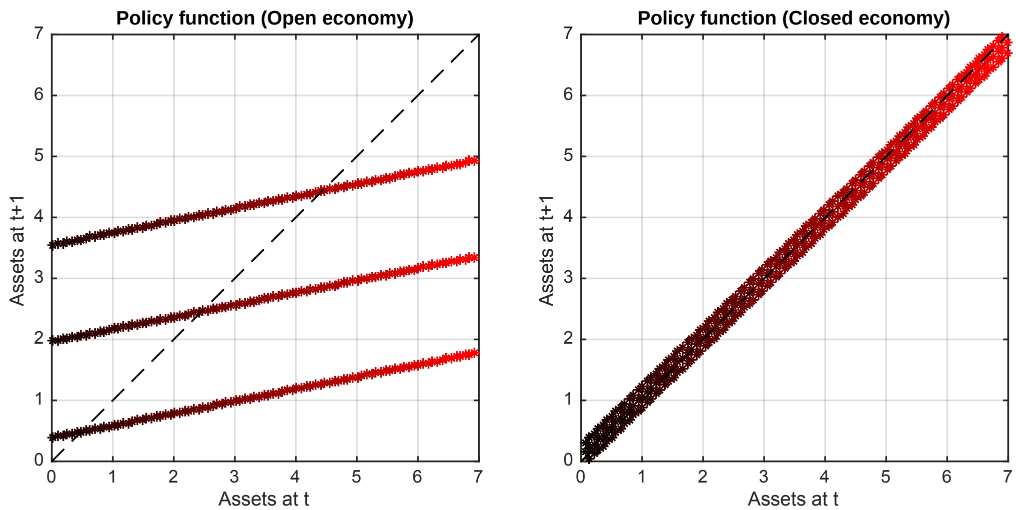


Figure 5: Asset accumulation rules (for selected levels of productivity)

distance between the three policy functions in the open compared with the closed economy. Second, the asset accumulation rule is flatter in the open economy. Put differently, the open economy has a higher rate of asset accumulation than its closed counterpart. The closed economy's decision rule has a slope close to unity as the function runs close to the 45 degree line, implying that the optimal change in assets between one period and the next is small in the closed economy, whereas in the open economy the change in assets occurs more rapidly.

The reason for the speed of asset accumulation to be larger in the open than the closed economy lies in the fact that the the return to saving in the former is more responsive to productivity shocks than in the latter. When there is, say, a positive domestic productivity shock in the financially open economy, some of the banks previously investing abroad return to the home economy hoping to invest in the domestic firm. The switch from foreign to domestic investment avoids the losses associated with cross-border investment when $\overline{f} < 1$, the resultant gain being passed on to the households in the form of a higher return on their bank deposits. Additionally, the repatriation of capital has a positive externality when increasing the working capital available to the domestic firm, thereby increasing economic activity and employment in the home domain.[7]

Financial openness affects the financial stability of the domestic economy as follows. A higher rate of asset accumulation in the open economy renders it susceptible to an interbank crisis as, for example, when a short series of large, positive TFP shocks results in a large asset boom. Given the higher rate of asset accumulation, the level of assets builds up more quickly during the boom. It is more likely to exceed the asset absorption capacity $\overline{a}_t$ of the banking system once productivity returns to trend. In the closed economy and for the same short series of large positive TFP deviations, the closed economy experiences a relatively smaller rate of increase in assets, given that its decision rule implies more gradual asset accumulation. In the open economy, by contrast, asset levels build up rather quickly, leading to an investment rush which may end in an interbank crisis as soon as productivity reverts to its average steady steady.

Moreover, the investment rush and the resulting asset boom are more likely to end in an interbank crisis if the domestic economy has suffered from a structural break in trend productivity. For two economies with different TFP trend levels, a large deviation above trend will be more likely to cause an interbank crisis the lower the economy's secular level of productivity. The reason, as shown in Appendix 7.2, is that the asset absorption capacity, i.e. the crisis threshold, $\overline{a}_t$, is an increasing convex function of productivity.

[7] The higher rate of asset accumulation in the open relative to the closed economy is not due to a higher elasticity of substitution on the part of the consumer. Preferences are assumed identical in both economies. For $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, a higher elasticity of inter-temporal substitution $\psi \equiv 1/\sigma$ would mean that the household's consumption smoothing motive is less pronounced; it would accept relatively larger consumption swings.

4 Simulation

This section summarises the results of simulating the model. To examine how financial openness affects the economy's dynamic response to shocks, we first subject the economy to a small productivity shock. Then we subject the two economies to a sequence of random productivity shocks and draw out stylised results for the incidence and duration of interbank crises in each type. Finally, we apply the model to US data. The model does capture important episodes of financial instability, including the 2007/8 crisis, which is as should be expected by the reasoning above.

4.1 A small productivity shock

Let the economy be subject to a small positive productivity shock of 1% in the initial period, followed by no shocks in subsequent periods.

First, we describe the dynamic response of the economy to the positive productivity shock as recorded by an impulse response function (IRF) for each endogenous variable. We describe in detail the mechanisms driving the response of the endogenous variables.

Second, we explicate the difference between the open versus the closed economy's dynamic response to shocks, which sheds light on the difference in asset accumulation rules as derived in the previous section.

Figure 6 depicts the impulse response functions of the endogenous variables following a positive productivity shock. Following the increase in productivity z, the corporate loan rate R increases given that investing in the domestic firm becomes more profitable. Aggregate demand by banks for interbank loans increases, pushing up the interbank interest rate ρ. This eases banks' borrowing constraints determining the quantum of interbank funding $\phi_t \equiv \frac{\rho_t - \gamma}{\theta\gamma}$. A higher cost of interbank borrowing mitigates the moral hazard problem as inefficient banks with a lower lending skill switch from the demand to the supply side of the interbank market, reducing counter-party lending fears. The quality of the marginally borrowing bank $\overline{p}$ rises above steady state. This allows banks on the demand side of the interbank market to borrow more than otherwise to the effect that bank leverage ϕ increases.

Whilst the return on bank deposits r is high, saving becomes more attractive and households accumulate assets. Investment rises, as does consumption, the hours worked and output. However, as the amount of assets and thus capital in the economy grows, the marginal product of capital starts to fall, which pushes interest rates down. The economy starts to reverse, back to its steady state. In the transition, the interest rate R does not fall much below its it steady state value in any period, given that, during the productivity boom, the increase in the amount of assets remains relatively short lived and of an insignificant magnitude. In response to a small productivity shock, the level of assets a does not exceed the asset absorption capacity of the economy $\overline{a}$, which implies that the economy remains in tranquility, i.e. in calm waters for the duration contemplated.

Next, we describe and explain differences in the dynamic responses of the open and closed economies.

In Figure 6, the red solid line depicts the response of the open economy, whereas the black dashed line portrays the response of the closed economy. The impulse response function illustrates how financial openness propagates the effects of TFP shocks.

One recalls that (7) exhibits the participation constraint for bank $\overline{f}$ to in-

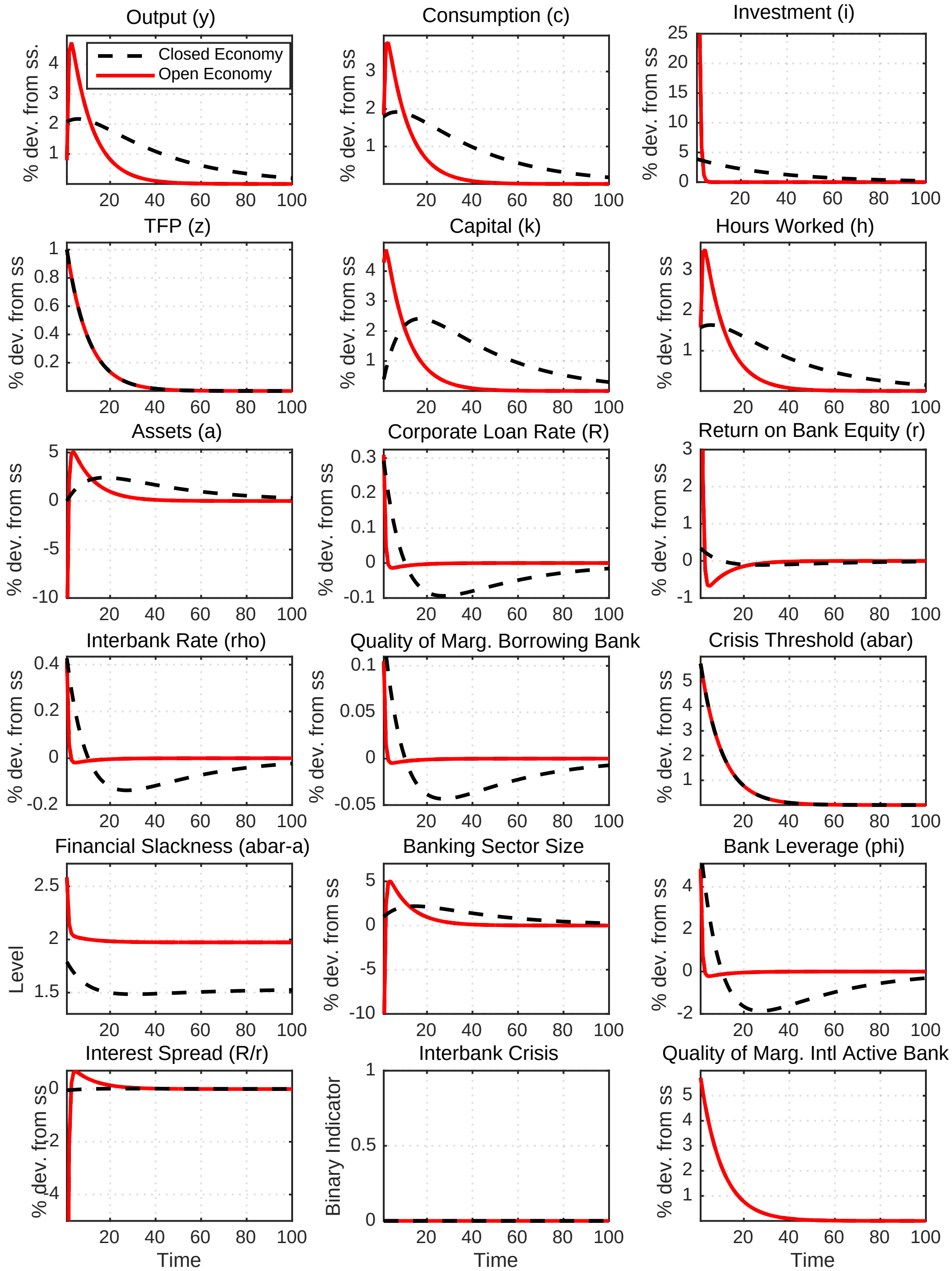


Figure 6: Response to a 1% productivity shock

vest in the foreign firm in preference to the domestic firm. This constraint determines the type of the marginal bank that is indifferent between the two investment opportunities. Banks on the demand side of the interbank market with $f < \overline{f}_t$ delegate investing abroad to banks with better cross-cultural communication efficiency wherever $f \geq \overline{f}_t$ with $\overline{f}_t \equiv \frac{R_t}{R^F}$.

Following a positive TFP shock, the increase in the corporate loan rate R_t available at home, augments the quality of the marginal internationally active bank $\overline{f}_t$. It signifies the minimum cross-cultural communication efficiency that a bank needs to have in order to find investing abroad attractive. The positive shock to domestic productivity tightens, i.e, increases this threshold, a process which encourages more banks to become inward-looking and repatriate capital from overseas in order to invest at home. The decrease in the mass of banks $1 - \mu(\overline{f}_t)$ investing abroad means that more capital is at the disposal of the domestic firm.

On impact the positive domestic productivity shock, a proportion of assets that was previously invested abroad is repatriated back to the home economy and becomes available once more for investment at home. Hence the larger response of investment i_t, which results in a large increase in the quantum of working capital k_t available to the domestic firm. This is the mechanism by which hours worked, consumption and output all increase in the open economy more than in the closed counterpart.

The increased amount of assets, however, exerts a negative pressure on the level of domestic interest rates. The flatter slope of the asset accumulation decision rule in the open economy implies that households de-cumulate assets at a rate higher than in the closed economy. Consequently, as households dissave, the level of assets and interest rates revert to their steady state more quickly in the open economy than in the alternative set-up. Generally speaking this pattern has a positive effect on financial stability, as expounded next.

When subjecting the economy to a negative productivity shock of -1% magnitude, the economy's response mirrors the response consequent upon a positive shock of the same magnitude. The results are depicted in Appendix 7.1.

4.2 Typical pre-crisis path

This section analyses the typical path to an interbank market crisis in the open economy and compares it with the typical pre-crisis behaviour of the closed economy. This exercise sheds light on the typical conditions under which interbank crises occur in the model, and illustrates if and, to what extent, the conditions leading to crises differ between the closed and open economy.

In the closed economy model of Boissay et. al. (2015), some freezes of the interbank market are events driven by credit-booms, instead of shocks being the primary initiator. The characteristics of such 'shock driven' crises are an unusually low level of TFP at the inception of the crisis, while the level of assets in the run up to the outbreak of the crisis is a not unusually high. The level of TFP at the time of the 'credit-boom driven' crises is, conversely, not unusually low, while the level of assets is unusually large.

In the following, the genesis of interbank crises is of crucial difference. The open economy's median path to a crisis is perceived as unmarked by an unusually high level of assets. The role of credit in precipitating crises in the open economy is thus reduced, whilst the role of shocks magnified. As simulations below amply show, the open economy is generally less susceptible to interbank crises except as a result of large negative domestic productivity shocks

Table 3: Selected summary statistics

	Closed Economy	Open Economy
Probability of banking crisis	5.66%	4.58%
Average length of crisis	2.67 years	1.15 years
Median length of crisis	2 years	1 year
Length of longest crisis	16 years	6 years

increasing the relative rate of return of investment opportunities abroad in comparison with these triggers at home.

Table 3 presents summary results of the simulations described thereafter. The overall probability of an interbank crisis is lower in the open economy, given that it occupies on average less time in the crisis regime than otherwise. The average duration of a crisis episode is shorter than in the closed economy, as is the span of the longest crisis episode. Using the data-set from Jorda et. al. (2011), dating banking crises from 1870 to 2008 for 14 OECD developed countries, Boissay et. al. (2015) report that the frequency of crises in the sample is 4.49%. The open economy model seems to approximate this stylised fact fairly closely.

The mechanisms driving these results are analysed and discussed in two parts. First, the typical behaviour of the economy leading to an interbank crisis is analysed. Then, we examine the typical pre-crisis path of assets and TFP preceding a crises. This allows for a detailed analysis of the differential role that assets, or credit, and productivity shocks play in precipitating interbank crisis in the closed versus the open economy.

4.2.1 Pre-crisis behaviour of the economy

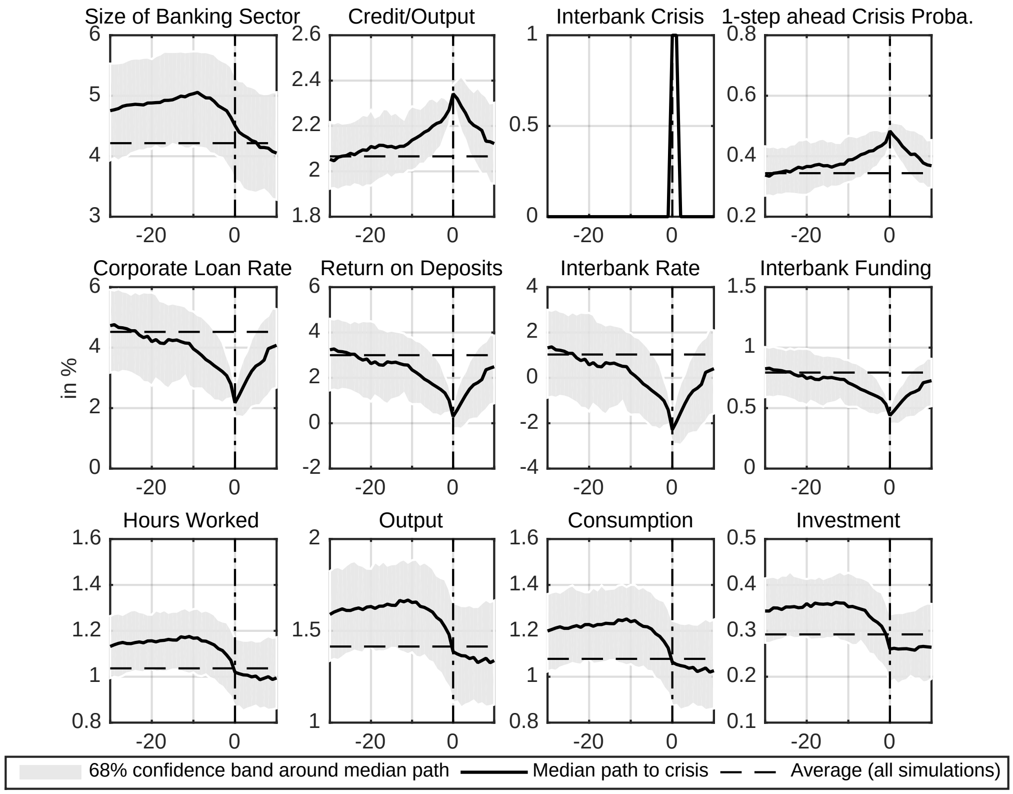
The following presents and discusses the results obtained from simulating the model over $100,000$ periods, with the initial state of the economy being its average steady state.

The periods in which an interbank crises breaks out are identified by the condition where the level of assets exceeds the banking sector's absorption capacity: $a_t > \overline{a}_t$. This is used to extract the paths of all endogenous variables 30 periods preceding, and 10 periods following, the inception of an interbank crisis. The figures discussed below plot the median of the distribution of the path of each variable, as well as a 68% confidence band, alongside with the average of each variable across all simulations. The median path is denoted as the 'typical pre-crisis path' of a variable.

Figure 7 depicts the pre-crisis behaviour of the closed economy, tracking the pattern put forward by Boissay et. al. (2015) in their baseline model. This separates the pre-crisis path into two phases. TFP stays above trend in the first phase, and in the second, it reverts to trend, eventually falling below it. Interestingly, in the first phase productivity remains above trend for a long time. See the periods between $T - 30$ to $T - 10$ for the first phase.

The economy booms during the first phase of the pre-crisis path. Consumption, hours worked, investment and output achieved are well above average and rising. The ratio of credit to output is above average. Come the second phase, productivity is still above trend, and households continue to accumulate assets for purposes of smoothing consumption. The increase in the level of assets swells the banking sector. The rising amount of capital in the economy eventually starts to depress the marginal product of capital, bearing down on interests rates, including the return to corporate lending, which depresses the

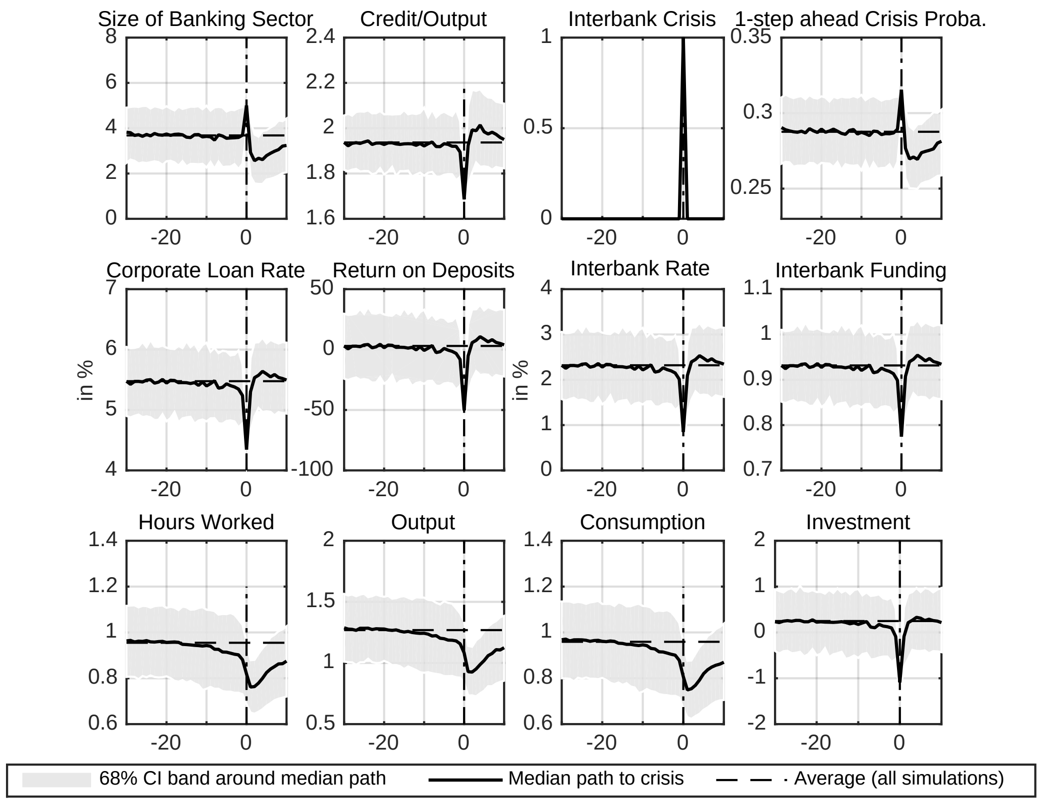
Figure 7: Typical path to interbank crisis in the closed economy



demand for interbank loans. This result exerts a negative pressure on the interbank rate.

As the interbank rate starts to fall, less efficient banks are enticed to switch from the supply to the demand side of the interbank market. Bearing in mind that the quality of the counter-party on the interbank funding market is publicly non-observable and that only the average quality of the borrower is known, counter-party interbank lending fears begin to intensify. The amount of interbank market funding starts to nose-dive. Once the level of assets exceeds the asset absorption capacity, the return on interbank lending falls so low that storing funds becomes more attractive and the banks completely shun lending to the interbank market. The pattern is closely associated with an interbank

Figure 8: Typical path to interbank crisis in the open economy



market freeze, indicated by period $T = 0$. The crisis indicator implies that the median interbank crisis is short-lived, lasting about 2 periods, which is close to the average length of crisis reported in Table 3. However, some crises last longer. Once a crisis hits the closed economy, it continues to deteriorate and subsequently recovers only sluggishly.

Figure 8 depicts the pre-crisis behaviour of the open economy, the present paper's extension of the Boissay et. al. (2015) closed economy model.

During the first phase of the path pre-cursing a crisis in the open economy, a boom materialises but lasts for no more than a few periods. Quantitatively it remains less significant than is the case in the closed economy, in line with the median level of TFP which is marginally above average and remains so before TFP starts to fall below trend. As the second phase of the pre-crisis path begins around $T-20$, i.e. long before the crisis erupts, the open economy begins to enter a slowdown journey, though remaining close to its steady state. Only immediately antecedent to the outbreak of a crisis, does output, and with it consumption, investment and hours worked, fall rapidly.

It is noteworthy that the ratio of credit to output falls in the open economy, primarily because the level of capital available to domestic firms falls in tandem, as the reduction in the return on corporate lending at home prompts a larger mass of banks to invest abroad. Finally, the slump and eventual recovery following an interbank crisis occur more rapidly in the open economy compared to the closed economy.

4.2.2 Underlying path of TFP preceding a crisis

Figure 9 depicts the median path of total factor productivity (TFP), in advance of an interbank crisis in the open as well as the closed economy. The size of the median TFP shock in period T, associated with the outbreak of the crisis, is smaller in the closed economy, where interbank crises are typically triggered by a $1.45\,\sigma_z$ sized negative productivity shock. In the open economy, the shock is larger at $1.95\,\sigma_z$ where σ_z is the standard deviation of the process for TFP innovations. In both economies, the confidence interval bands around the typical pre-crisis TFP path are below their long-run average.

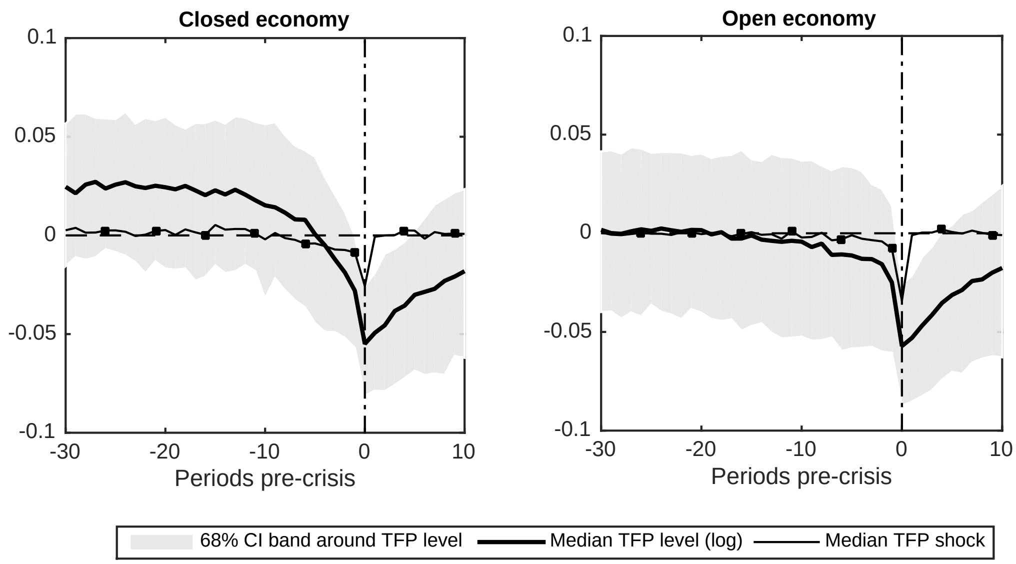
As can be seen from the plot on the left-hand side of Figure 9, the outbreak of crises in the closed economy is typically preceded by a long sequence of small positive productivity shocks, which raises the level of TFP more than 2% above average. The confidence band around the typical path for TFP level is unevenly distributed between $+6\%$ and -1.5% until about 10 periods before crisis, which occurs when the sequence of productivity shocks turns negative, and the level of productivity starts to revert to its trend.

In the open economy, (see Figure 9, right-hand side) the level of TFP is above its trend for a brief while only and does not grow more than 0.25% above its long-run mean. TFP is below its long-run average for most of the periods, leading up to a crisis. The confidence band around the typical path for the level of TFP is distributed between $+4\%$ and -4% from the beginning but starts to be slightly skewed towards the negative quadrant as early as 20 periods before a crisis.

It is important to recall that, in the first phase of the pre-crisis path, TFP is above trend, but in the second pre-crisis phase, it starts to revert, returning back to trend and eventually falling below it. In the open economy, the first phase of the pre-crisis path is hardly significant, as TFP is barely above trend for periods that are rather remote from the outbreak of the crisis. This can be seen from the confidence interval band for TFP being quite evenly distributed around its long-run mean. Furthermore, the first phase of the median pre-crisis path in the open economy is short lived and the second phase commences earlier, around 20 periods before a crisis.

Interbank crises occur more ’suddenly’ in the open economy than in the closed, and not just because they are driven by productivity shocks of larger median size. The contemporaneous 1-step ahead model prediction of a interbank crisis in the closed economy rises during the second phase of the path to a crisis, whilst the crisis probability is close to its long-run average in the run up to a crisis erupting in the open economy, as can be learned from Figure 8.

Figure 9: Underlying path of TFP preceding a crisis



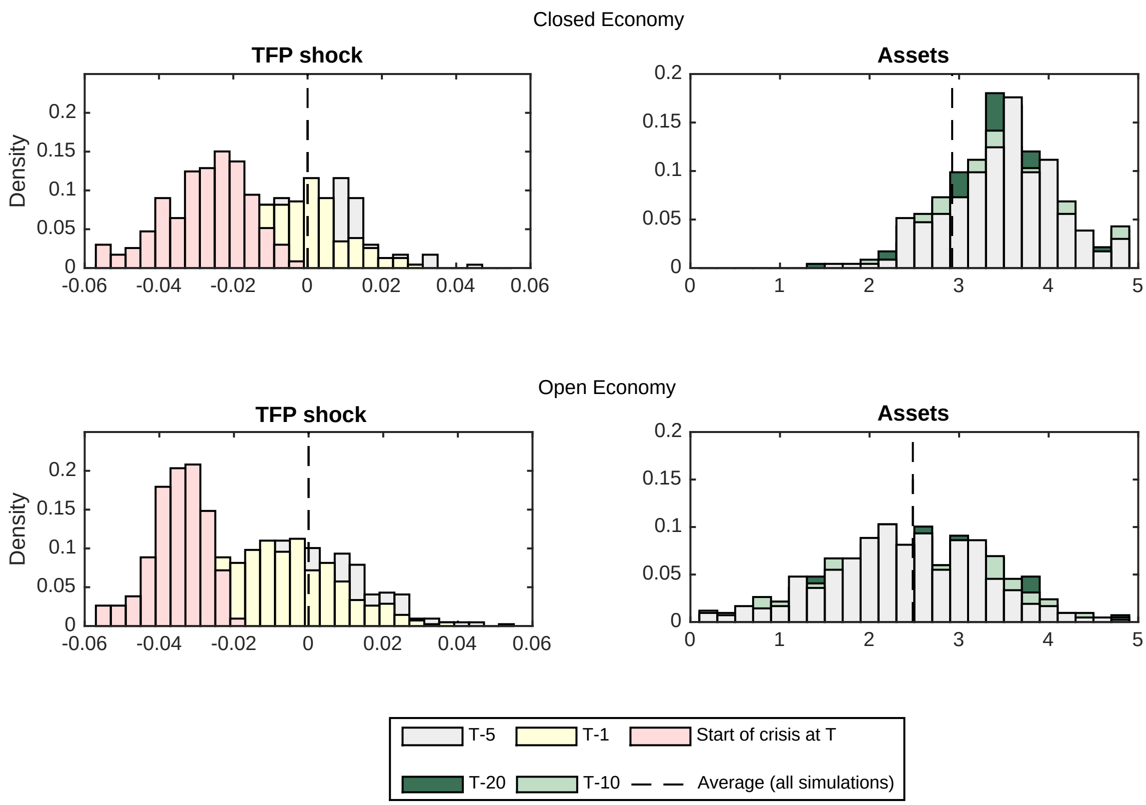
4.2.3 Role of productivity shocks and the level of assets

The following section analyses whether and to what extent productivity shocks, rather than an excessive built up of assets preceding a crisis, play a key role in creating banking crises. It yields hopefully important insights about the different triggers of interbank crises in the open economy.

Figure 10 depicts the distribution of TFP shocks and the level of assets at different stages of progress before the incidence of an interbank crisis. By convention, period T marks the outbreak of a crisis. First, we discuss the role of assets and then turn to the role of productivity shocks in triggering crises.

Figure 10 (lower plot, right-hand side) shows that the level of assets remains around its long-run average prior to an interbank crisis in the open economy. Gradual and long-lasting asset build-up plays an insignificant role in

Figure 10: Distribution of TFP shocks and assets preceding an interbank crisis



triggering crises in the open economy, which is a crucial difference between the two economies rendering banking crises in the open economy more related to shock-driven events rather than being predominantly driven by credit-booms. In contrast, assets are significantly above average at various stages before a crisis in the closed economy. Figure 10 (upper plot, right-hand side) demonstrates that assets rise well above their long-run mean, staying most of the time well above 10% of their average steady state.

A careful comparison with the Boissay et. al. (2015) results reveals that the findings here, for the closed economy as presented above, indicate a smaller density of interbank crises that are driven by credit booms. In Boissay et. al. (2015) a greater number of crises are preceded by assets that are above their average level. There is no significant difference arising thus, and the difference involved can be explained by having adopted an alternative solution method in the present paper. Recall from Section 3.3, that the piecewise-linear solution method does not rely on household's precautionary saving to create interbank crises. This absence of the precautionary saving motive implies a lower rate of asset accumulation in our piecewise-linear solution than compared to a solution by projection methods.

The absence of the precautionary savings motive reduces the model's reliance on credit as a driving force in creating banking crises. Meanwhile they have the effect of increasing the role of productivity shocks in triggering such crises. Boissay et. al. (2015) note that "in some, but only a few instances, [does] the model generate a crisis without a negative technology shock." In the present paper, however, both the open and closed economies are associated with a negative productivity shock at the time crises materialise.

The increased incidence of credit-boom driven crises in Boissay et. al.

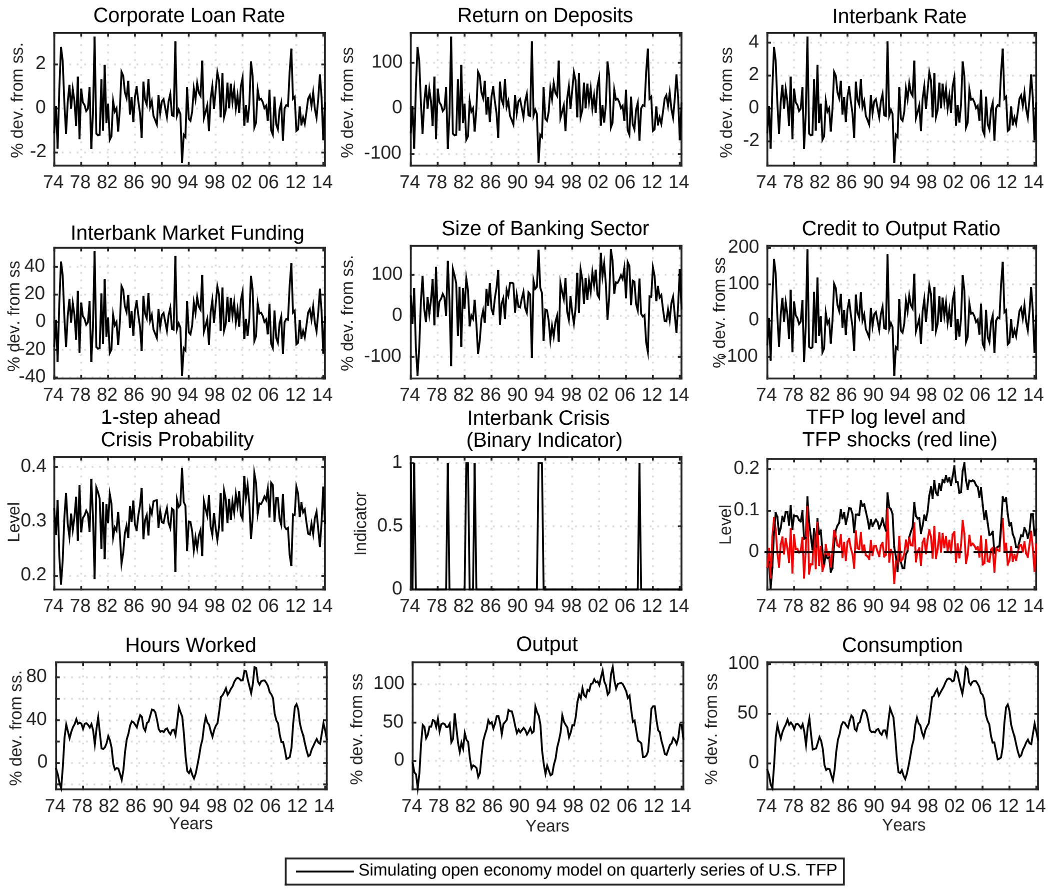
(2015) is due to the household taking account of the increase in the probability of interbank crises leading up to a crisis, which unintentionally causes an increase in the likelihood of the crisis occurring. This inconsistency in household behaviour, resulting from precautionary saving that does not internalise the externality of excessive saving in anticipation of a crisis, is not an assumption made here. The demerits and merits of the idea are further discussed in Section 1.1.

4.3 The 2007/8 interbank crisis in the US

To see whether and to what extent the model relates to the 2007/8 financial crisis, the open economy model is simulated on a series of U.S. TFP. The calibration of the model derives from Boissay et. al. (2013), see Table 1. This is predicated on data pertaining to the US and fourteen OECD countries (1870-2008). The sequence of technology shocks follows the quarterly utilisation-adjusted total factor productivity series from the work done by Fernald (2015) studying the U.S. economy over the period 1974-Q1 to 2014-Q2.

Figure 11 illustrates the case for the open economy model which captures the 2007/8 interbank crisis, an episode in which the economy underwent a switch from tranquil times to the crisis regime, as characterised by interbank funding having dropped precipitously. The model also features other episodes of stress and strains in the banking sector as the interbank crisis indicator suggests.

Figure 11: Simulation on U.S. data



Consider Figure 11 (sub-plot for TFP) to see the US economy exhibiting a bout of positive technology shocks pushing up total factor productivity well above the average obtained in the late 1990s. Whilst several negative productivity shocks hit the US economy immediately preceding the 2007/8 crash, the reversion of TFP to trend had already started around 2003, well before the outbreak of the crisis.

The main mechanisms driving the crisis in the model is as follows.

Firstly, in line with a basic insight in the work of Boissay et. al. (2015), an increase in productivity entails that investment in corporate firm projects and, consequently, a prior borrowing from banks through the interbank market becomes more appealing, especially to the lower skilled banks. The latter switch from the supply to the demand side of the interbank market. The quality of the marginal bank falls in consequence and the amount of interbank funding diminishes with effect on the incentive compatibility that normally constrains this activity, ruling out diversion of borrowed funds.

Secondly, the open economy extension model, developed in this paper, adds an additional mechanism in triggering a financial crisis. The financial system in open economies is structurally vulnerable to unsustainable investment rushes in the aftermath of a sequence of benign productivity shocks following upon one another. A significant bulk of domestic banks hasten to repatriate capital from their international investment portfolios back to their home base in order to take advantage of the new, unexpected, investment opportunities, having opened up domestically by dint of these productivity improvements. The resultant investment increase and the asset boom thus associated is much more sizeable, relative to the closed economy, simply because capital repatriation acts as a propagation mechanism for TFP shocks in the open economy. The gradual 'repatriation of capital' slows down as the asset booms is under way, which reduces the domestic interest rate and prompts a larger mass of domestic banks to invest abroad. Capital outflows are pro-cyclical in the second phase of the asset boom which can end in a sudden and abrupt 'retrenchment of capital' as soon as the amount of assets a_t exceeds the asset absorption capacity $\overline{a}_t$ of the US financial system. Once productivity reverts back to its lower long-run trend, the level of assets which were built up during the short asset boom, will tend to exceed the financial intermediation capacity of the interbank market, which thereby ushers in a financial crisis.

The data on capital flows for the US prior to the global financial crisis lends credence to this narrative that emerges from the open economy model developed in this paper. Broner et. al. (2013) show the capital outflows from the US by domestic agents was at a low in 2002 which is when the level of US TFP started peaking. From 2002/3 onwards, as TFP started its reversion to trend, gross capital outflows from the US increased from approximately 3% of trend GDP in 2002/3 to about 11% of trend GDP in 2007, and then precipitously reverted back to trend in 2008.

Using data from the US Bureau of Economic Analysis, Shin (2012) and Brunnermeier et. al. (2012) show that there were large capital outflows from the U.S. principally via the banking sector. The data include (i) U.S. holdings of foreign securities, (ii) claims of US non-banks on foreigners and (iii) claims of US banks and securities brokers on the rest of the world. The latter categories is the most significant in driving the capital outflows, followed by the first category. Similar to the picture provide by Broner et. al. (2013), capital outflows were at a low of less than 0.2 trillion USD in 2002 and then grew to more than 1 trillion per year in 2006 and 2007, before collapsing and, in fact, reversing in 2008, in line with a financial crisis being associated with a sudden ’retrenchment of capital’ in the model.

5 Discussion

In the model at hand, the 2007/8 interbank crisis was associated with the retrenchment of capital by local investors within the US from their international investments activities, because, in part, domestic interbank funding dried up during the crisis, reducing the leverage of US-based banks including those investing abroad. In this sense, the insight of Broner et. al. (2013) that “a tightening of domestic financial constraints during crises can lead to a retrenchment [of capital] as a result of de-leveraging" is captured by the open economy model developed here in the present paper.

The open economy model in this paper, having extended the Boissay, Collard and Smets (2015) framework, remains radically different in two related respects: the solution method and a behavioural assumption concerning household expectations.

The model in the present paper is solved by the piecewise-linear perturbation method of Guerrieri and Iacoviello (2015), whereas BCS use projections methods. The former is a local optimisation method for solving a model, while the latter optimises the behaviour of the approximated solution globally, not just in the proximity of the steady state. Global optimisation methods are important when the decision rule is discontinuous, as is the case here with the economy either being in tranquil times or in times of crisis. But, as pointed out in Section 3.3, the piecewise-linear solution produces results that are close to the fully non-linear projection methods including small Euler errors, without relying on the assumption that households anticipate interbank crises.

The perturbation method is arguably more suitable for the household behavioural assumption chosen in the present setting. Applying projection methods, BCS assume the presence of precautionary saving motives on part of the household: In response to a positive TFP shock, households not only increase their assets to take advantage of the higher return to saving, but have an additional incentive to save more on the margin so as to safeguard themselves against the possibility of a reversion to trend TFP and the eruption of an interbank crisis. Households, in BCS, build up some buffer stocks in anticipation and as a precaution. This affects the shape of the asset accumulation rule and creates the possibility of 'endogeneous crises', a switch from the norm to a crisis regime even in the absence of a negative productivity shock at the time of the crisis.

This behavioural assumption on the part of the household has been avoided in the present paper as the possibility of endogenous crises in the BCS model is driven by what appears to be inconsistent household behaviour. When forming their optimal asset accumulation behaviour, households are inclined, on the one hand, to consider the probability of a regime switch, and on the other hand, to ignore the contribution precautionary savings make in ensuring that a crisis becomes more likely. The behavioural assumption underlying the BCS approach consequently characterises the 2007/8 crash, and other financial crises, as events partly caused by the households increasing their precautionary savings in anticipation of said crises.

In contrast, this paper assumes that the households do not take into account the probability of an interbank market crisis erupting. This is, in part, on the ground that such a forethought is unlikely to occur to most households, and partly because crises were hitherto rare events at any rate. The seizure of the interbank market in 2007/8 is here assumed not to have been anticipated for three further empirical reasons.

In the run up to the crisis, the household savings rate in the United States, according to data by the U.S. Federal Reserve Board, remained at a low and constant level. Bucks, Kennickell, Mach and Moore (2009) report that the proportion of families who saved stood unchanged at 56.5 percent when the savings rate in the U.S. is estimated to have been 1 percent over the 2004-07 period.

Households and markets did not anticipate an increase in the probability of

TFP, reverting to trend in the run up to the crisis in 2007/8. On the contrary, the private sector was under an illusion that the deviation in productivity above trend was of a permanent nature, rather than being a transitory one. Preceding the crisis, the U.S. was considered to be in a high TFP growth regime. This reading, though mistaken ex-post, is in line with professional estimates prevalent at the time among many observers in the public and private sectors. The upward movement in productivity, which began in late 1997 and started to exceed the trend in 2001, was by 2005 already over. It took some time, indeed until mid-2007 for this phenomenon to come into view, as indicated by Kahn and Rich’s (2011) retrospective real-time estimates of U.S. productivity. These unexpectedly fell in July 2007. Thus solving the model without relying on precautionary saving, to model anticipation of TFP mean-reversion and precaution against interbank crises, is more suitable for the questions investigated in the model here.

In addition to the alternative solution method, another albeit minor difference is that the present paper assumes a zero growth steady state, instead of modelling the steady state as exhibiting a balanced exogenous non-zero growth path. However, this extension, implemented in the baseline model of BCS (2015), does not materially change the results as can be seen by comparing its results with those of the earlier version in BCS (2013).

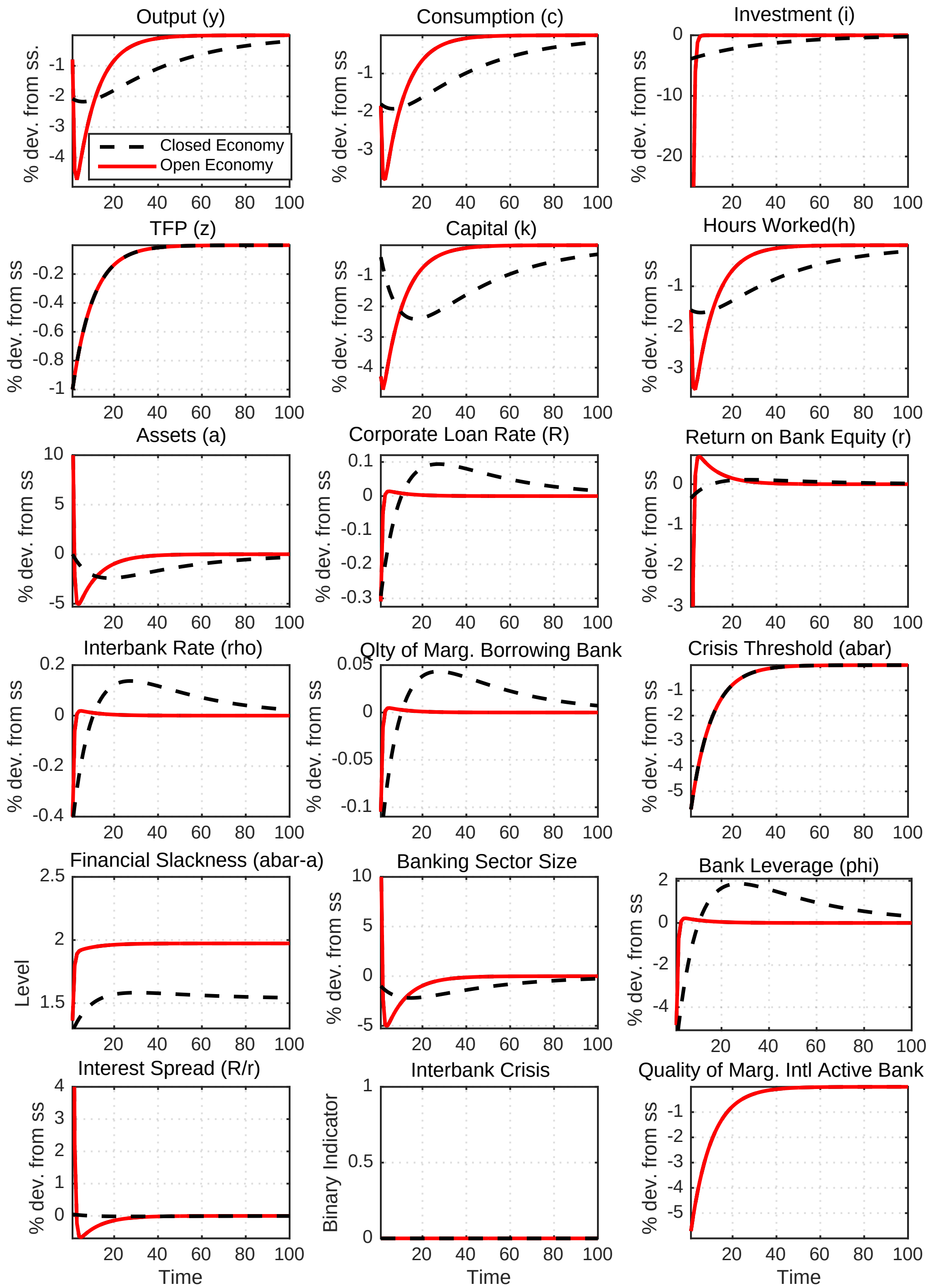
6 Conclusion

The main result of this paper is that allowing banks to invest abroad reduces the role of domestic credit build-ups in driving interbank crises; while the level of assets typically builds up preceding a crisis in the interbank market in the closed economy, in the financially open economy, contrastingly, access to international investment opportunities acts as a safety valve for domestic capital when the home economy exhibits a productivity slowdown. In addition, the open economy is less subject to banking crises in the long-run, a finding which may not be exhibited in the short-run if the economy is subject to large negative TFP shocks after financially opening up. This paper also finds that financial internationalisation in the form of outward investment alters the behaviour of the economy one can expect in the run up to a typical interbank crisis in the open economy, even in the absence of shocks from abroad.

The extension to the open economy as developed here is highly stylised and could be extended. For one, it would be important to study whether the open economy continues to exhibit fewer crisis on average and what the shape of the typical path to an interbank crisis is when allowing for shocks from the rest of the world. One way to extend the current framework is by modelling the foreign economy in greater depth by allowing for trade in goods as well as two-way flow of funds between foreign and domestic banks. This would also allow an analysis of the determinants of international interbank market crises.

7 Appendix

7.1 A small negative productivity shock



7.2 Financial intermediation capacity

The absorption capacity is $\overline{a}_t = \Phi z_t^{\frac{1+v}{v(1-\alpha)}}$ where $\Phi \equiv \left(\frac{1-\alpha}{\vartheta}\right)^{\frac{1}{v}} \left(\alpha/\overline{R} + \delta - 1\right)^{\frac{v+\alpha}{v(1-\alpha)}}$. The first and second derivatives are $d\overline{a}_t/dz_t = \frac{1+v}{v(1-\alpha)} \Phi z_t^{\frac{1+v\alpha}{v(1-\alpha)}}$ and $d^2\overline{a}_t/dz_t^2 = \frac{1+v}{v(1-\alpha)} \frac{1+v\alpha}{v(1-\alpha)} \Phi z_t^{\frac{1+2v\alpha-v}{v(1-\alpha)}}$. Given the calibration, it is the case that $d\overline{a}_t/dz_t > 0$ and $d^2\overline{a}_t/dz_t^2 > 0$.□

7.3 Model equations

Extending the basic model to the open economy adds two regimes, Ib and IIb.

		Reference regime (Tranquil times) $a_t \leq \overline{a}$	**Alternative regime** (Crisis times) $a_t > \overline{a}$
Closed economy	$\overline{A} \geq 1$	Ia	IIa
Open economy	$\overline{A} < 1$	Ib	IIb

The condition $a_t \leq \overline{a}$ describes the occasionally binding constraint.

The size of the banking sector is measured as the sum of all banks' assets including interbank lending, such that $bs_t = a_t + (1 - \mu(\overline{p}_t))\, \phi_t a_t$.

7.3.1 Open economy

$$
\begin{aligned}
&\text{Technology:} && (1) && \ln z_t &&= \rho_z \ln z_{t-1} + \varepsilon_t \\
&\text{Production:} && (2) && y_t &&= z_t k_t^{\alpha} h_t^{1-\alpha} + (\gamma + \delta - 1)(a_t - k_t) \\
&\text{Corporate loan rate:} && (3) && R_t &&= \alpha k_t^{\frac{-v(1-\alpha)}{v+\alpha}} z_t^{\frac{1+v}{v+\alpha}} \left(\frac{1-\alpha}{\vartheta}\right)^{\frac{1-\alpha}{v+\alpha}} + 1 - \delta \\
&\text{Euler consumption:} && (4) && 0 &&= \left[c_t - \frac{\vartheta}{1+v} h_t^{1+v}\right]^{-\sigma} - \beta \mathbb{E}_t \left[c_{t+1} - \frac{\vartheta}{1+v} h_{t+1}^{1+v}\right]^{-\sigma} r_{t+1} \\
&\text{Euler labour condition:} && (5) && h_t &&= \left[\frac{(1-\alpha) z_t}{\vartheta}\right]^{\frac{1}{v+\alpha}} k_t^{\frac{\alpha}{v+\alpha}} \\
&\text{Investment:} && (6) && i_t &&= a_{t+1} - (1-\delta) a_t \\
&\text{Working capital:} && (7) && k_t &&= a_t \left(1 - (1+\phi_t)\left[1 - \mu(\overline{f}_t)\right]\right) \\
& && && &&= a_t \left(\frac{\overline{f}_t^{\lambda} - \overline{p}_t^{\lambda}}{1 - \overline{p}_t^{\lambda}}\right) \\
&\text{Return on bank equity:} && (8) && r_t &&= R_t \int_{\overline{p}_t}^{\overline{f}_t} p(1+\phi_t) d\mu(p) + R^F \int_{\overline{f}_t}^{1} \left(\int_{\overline{f}_t}^{1} f p (1+\phi_t) d\mu(p)\right) d\eta(f) \\
& && && &&= \left\{R_t \left(\overline{f}_t^{1+\lambda} - \overline{p}_t^{1+\lambda}\right) + R^F 0.5 \left(1 - \overline{f}_t^{2}\right)\left(1 - \overline{f}_t^{1+\lambda}\right)\right\} \\
& && && &&\quad \times \left(\frac{1}{1-\overline{p}_t^{\lambda}} \frac{\lambda}{1+\lambda}\right) \\
&\text{Incentive compatibility:} && (9) && \overline{p}_t &&= \frac{\rho_t}{R_t} \\
&\text{Interbank loan rate:} && (10) && \rho_t &&= \frac{R_t}{\mu^{-1}\left(\frac{\rho_t - \gamma}{\rho_t - (1-\theta)\gamma}\right)} \\
&\text{Resource constraint:} && (11) && y_t &&= c_t + i_t + (R_t - r_t) a_t
\end{aligned}
$$

——In crisis times—— ——Eqs. (7-11) change to (7*-11*)——

$$
\begin{aligned}
&(7^*) && k_t &&= a_t \left(1 - (1+\phi_t)\left[1 - \mu(\overline{f}_t)\right]\right) \\
& && &&= a_t \left(\overline{f}_t^{\lambda} - \overline{p}_t^{\lambda}\right) \\
&(8^*) && r_t &&= \gamma \mu(\overline{p}_t) + R_t \int_{\frac{\gamma}{R_t}}^{\overline{f}_t} p d\mu(p) + R^F \int_{\overline{f}_t}^{1} \left(\int_{\overline{f}_t}^{1} f p d\mu(p)\right) d\eta(f) \\
& && &&= \frac{\lambda}{1+\lambda} \left(R_t^H \left(\overline{f}_t^{1+\lambda} - \left(\frac{\gamma}{R_t}\right)^{1+\lambda}\right) + R^F \frac{1}{2} \left(1 - \overline{f}_t^{1+\lambda}\right)\left(1 - \overline{f}_t^{2}\right)\right) \\
& && &&\quad + \left(\frac{\gamma}{R_t}\right)^{1+\lambda} \\
&(9^*) && \overline{p}_t &&= \frac{\gamma}{R_t} \\
&(10^*) && \rho_t &&= \gamma \\
&(11^*) && y_t &&= c_t + i_t + (R_t - r_t) a_t - (R_t - \gamma)(a_t - k_t)
\end{aligned}
$$

7.3.2 Closed economy

$$
\begin{array}{rrcl}
\text{Technology:} & (1) & \ln z_t & = \rho_z \ln z_{t-1} + \varepsilon_t \\
\text{Production:} & (2) & y_t & = z_t k_t^{\alpha} h_t^{1-\alpha} + (\gamma + \delta - 1)(a_t - k_t) \\
\text{Corporate loan rate:} & (3) & R_t & = \alpha k_t^{\frac{-v(1-\alpha)}{v+\alpha}} z_t^{\frac{1+v}{v+\alpha}} \left(\frac{1-\alpha}{\vartheta}\right)^{\frac{1-\alpha}{v+\alpha}} + 1 - \delta \\
\text{Euler consumption:} & (4) & 0 & = \left[c_t - \frac{\vartheta}{1+v} h_t^{1+v}\right]^{-\sigma} - \beta \mathbb{E}_t \left[c_{t+1} - \frac{\vartheta}{1+v} h_{t+1}^{1+v}\right]^{-\sigma} r_{t+1} \\
\text{Euler labour condition:} & (5) & h_t & = \left[\frac{(1-\alpha) z_t}{\vartheta}\right]^{\frac{1}{v+\alpha}} k_t^{\frac{\alpha}{v+\alpha}} \\
\text{Investment:} & (6) & i_t & = a_{t+1} - (1-\delta) a_t \\
\text{Working capital:} & (7^{\ddagger}) & k_t & = a_t \\
\text{Return on bank equity:} & (8^{\ddagger}) & r_t & = R_t \int_{\overline{p}_t}^{1} p_t \left(1 + \phi_t\right) d\mu(p_t) \\
 & & & = R_t \frac{1}{1 - \overline{p}_t^{\lambda}} \frac{\lambda}{\lambda + 1} \left(1 - \overline{p}_t^{\lambda+1}\right) \\
\text{Incentive compatibility:} & (9) & \overline{p}_t & = \frac{\rho_t}{R_t} \\
\text{Interbank loan rate:} & (10) & \rho_t & = \frac{R_t}{\mu^{-1}\left(\frac{\rho_t - \gamma}{\rho_t - (1-\theta)\gamma}\right)} \\
\text{Resource constraint:} & (11) & y_t & = c_t + i_t + (R_t - r_t)\, a_t
\end{array}
$$

——In crisis times—— ———Eqs. ($7^{\ddagger}$-11) change to ($7^{\ddagger *}$-11*)——

$$
\begin{array}{rcl}
(7^{\ddagger *}) & k_t & = a_t \left[1 - \mu(\overline{p}_t)\right] \\
 & & = a_t \left[1 - \overline{p}_t^{\lambda}\right] \\
(8^{\ddagger *}) & r_t & = \gamma\, \mu\left(\frac{\gamma}{R_t}\right) + R_t \int_{\frac{\gamma}{R_t}}^{1} p_t \, d\mu(p_t) \\
 & & = \gamma \left(\frac{\gamma}{R_t}\right)^{\lambda} + \frac{\lambda}{\lambda+1}\left[1 - \left(\frac{\gamma}{R_t}\right)^{\lambda+1}\right] R_t \\
(9^{*}) & \overline{p}_t & = \frac{\gamma}{R_t} \\
(10^{*}) & \rho_t & = \gamma \\
(11^{*}) & y_t & = c_t + i_t + (R_t - r_t)\, a_t - (R_t - \gamma)(a_t - k_t)
\end{array}
$$

where ‡ indicates differences between the closed and open economies.

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Chapter 2

Unconventional Monetary Policy and Asset Allocation of International Mutual Funds

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Abstract

This paper analyses the spillovers of unconventional monetary policy from the US to the Rest of the World. Using panel regressions on a fund-level data-set of globally domiciled mutual funds, the study examines the degree to which the operations and surprises of US unconventional monetary policy prompt mutual fund managers to change their portfolio country weightings. Unconventional monetary policy by the US Federal Reserve is found to induce fund managers to reduce their portfolio exposure to the US whilst increasing it to other countries in the Rest of the World. Specifically, the Fed's purchases of Treasury securities trigger portfolio rebalancing in equity funds, while its acquisition of mortgage backed securities and agency debt has a minimal effect on equity and bond fund portfolio allocations. Fed policy surprises do affect the portfolio allocations of equity funds. The main results continue to hold in a number of robustness checks. An extension of the study examines portfolio rebalancing effects of policy surprises by three other major monetary authorities, the ECB, BoJ and BoE. The main focus of the paper, however, is on the broader effects of US unconventional monetary policy on the asset allocation of international mutual funds.

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1 Introduction

In the wake of the 2008/9 financial crisis, many monetary authorities in the world reduced their interest rates to zero or close to zero. In the face of an actual, or possible, slowdown in general economic activities, the major central banks adopted unconventional monetary policies in their quest for restoring financial market stability during the acute phases of the crisis and to boost economic activity in the subsequent recession.

Unconventional monetary policy can be defined in contrast to conventional monetary policy which targets the short-term interest rate, such as the Federal Funds rate in the US or the bank rate in the UK. Central banks employ unconventional monetary policies if the short rate is already at or near zero per cent. Unconventional monetary policy can take different forms, including: (1) credit easing, a policy of asset purchases aimed at improving liquidity in a specific market such as the mortgage-backed securities; (2) quantitative easing, which targets the quantity of central bank reserves held by commercial banks; (3) policies changing the composition of the central bank balance sheet, such as Operation Twist under which the US Fed sells short-term debt in order to buy long-term debt; and finally, (4) forward guidance, a policy communication strategy regarding the likely future path of short-term interest rates.

Unconventional monetary policy in one country, as a policy of macroeconomic management, is considered to affect other countries whose economies and financial markets are increasingly interconnected. Such policy spillovers have reportedly been perceived in emerging market economies; for one, the President of Brazil, Dilma Rousseff, is on record to have likened the effects of developed countries' quantitative easing to a 'global monetary tsunami' in reference to a major natural disaster a few years earlier.

This paper examines the international effects of unconventional monetary policy by examining the role of mutual fund managers in their contribution to the global transmission of large-scale asset purchases as well as policy surprises sprung by the US Federal Reserve in this framework.

This study chiefly analyses the effect of the US Fed's policies, that is to say, its actions that took the form of asset purchases as well as its policy surprises. As unconventional monetary policy was adopted in several other advanced economies, including the UK, Japan and the Eurozone, an extension of this analysis also considers the portfolio rebalancing effects of monetary policy surprises by the the ECB, BoJ and BoE.

The main results can be summed up as follows: (i) The effects of monetary policy generally differ in size and significance between equity and bond funds. There is more evidence for unconventional monetary policy triggering portfolio rebalancing in equity funds than in bond funds. (ii) Purchases by the US Fed of Treasury securities leads equity fund managers to shift their portfolio away from the US and into the Rest of the World, with the composition of the latter tilting in favour of developed markets, other than the US, relative to emerging market economies. (iii) Monetary policy easing announcement surprises lead to a portfolio shift in the same direction, that is, into the Rest of the World excluding the US. This result holds for equity funds, but is not significant for bond funds.

Our findings provide some evidence regarding the role of portfolio rebalancing by the managers of international mutual funds, as a subset of the global asset management industry, in the international transmission of unconventional monetary policy. The motivation for analysing mutual funds is that policy makers have been increasingly interested in the asset management industry, particularly mutual funds. This interest is due partly due to the size of the industry which has about $US 146 trillion in assets under management globally, as of 2014-Q1, with mutual funds comprising more than one-fourth of the industry total, approximately some $US 31 trillion.

As to the related literature, there are many studies that analyse the domestic effects of unconventional monetary policy, with much fewer studies looking at the transmission of unconventional monetary policy in one country to the rest of the world. Moreover, most papers focus on assessing how unconventional monetary policies impact on the prices of various assets, but ignore analysing the impact on the asset allocation behaviour of investors. As rightly argued by Fratzscher et. al. (2013), analysing the effect of these policies on asset allocation decisions is important for shedding light on the portfolio rebalancing channel that has been mentioned by many a policy marker as a transmission mechanism for unconventional monetary policy.[1] Finally, many papers in the related literature study the effects of policy announcements, but frequently do not consider the effects of monetary policy operations, that is analysing the impact emanating from the implementation of asset purchase programs.

As stated above, we find evidence for portfolio rebalancing effects resulting from announcements and operations, similar to Fratzscher et. al. (2013). Our paper goes further in that (i) we provide direct evidence on the portfolio rebalancing by mutual fund *managers* as opposed to analysing flows into and out of funds by their underlying *clients*; (ii) we analyse the effects of different announcements types on portfolio rebalancing by distinguishing between

[1] See Bernanke (2010), Bean (2011), and Yellen (2011).

LSAP-related announcements and other type of announcements; and while we focus our analysis on the unconventional monetary policy operations and announcements by the US Fed, in an extension (iii) we also analyse how mutual funds portfolio allocations are affected by policy announcement surprises by the other major central banks, that is the ECB, BoJ and BoE .

The following briefly relates our paper to the existing literature.

1.1 Related literature

The literature on the international effects of unconventional monetary policy is sizeable and continues to grow. It can be separate into two strands.

One strand of the literature analyses the impact of unconventional policies on international asset prices. Glick and Leduc (2013) and Chinn (2013) study the effects of US unconventional monetary policy announcements on the value of the dollar. Neely (2010) and Bauer and Neely (2014) consider how large-scale asset purchases affect international bond yields. Moore, Nam, Suh and Tepper (2013) analyse the effect on the foreign ownership share of emerging market debt. Lo Duca, Nicoletti, Vidal Martinez (2015) examine the effect of US quantitative easing on global corporate bond issuance. Miyajima, Mohanty and Yetman (2014) consider the effect of a change in the US term premium induced by unconventional monetary policy in the US on domestic long-term bond yields in Asia. Chen, Filardo, He and Zhu (2012) investigate balance sheet measures of the US Federal Reserve, Bank of Japan, Bank of England and European Central Bank and study the empirical effects of these measures on a broad range of international asset markets and global macroeconomic variables. Hosono and Isobe (2014) consider how the exogenous component of unconventional monetary policies by the four major central banks affects bond yields, exchange rates, corporate bond spreads, interbank loan spreads, and stock prices, while controlling the results for market expectations.

The second, and more closely related, strand of the literature focuses on international portfolio rebalancing, a transmission mechanisms by which monetary policy in one country affects other countries. Many papers in this field provide evidence bearing on the salient patterns of aggregate capital flows or a subset of capital flows, such as portfolio flows that are intermediated by a particular type of private sector agent including banks, asset management companies and mutual funds. Important studies studies were conducted by the IMF (2013), Fratzscher et. al. (2013) and Feroli et. al. (2014).

As pointed out below, this literature is, however, less informative about the portfolio rebalancing of any particular type of private sector agent. Feroli et. al. (2014), for instance, analyse financial flows into and out of mutual funds domiciled in the US, some of which are dedicated to a particular asset class, including emerging market debt, corporate debt or US Treasuries. Their study concludes that unconventional monetary policy actions are typically followed by the underlying client investors in such funds shifting out of US Treasury funds into domestic US corporate debt funds. Yet, by our reckoning, this does not provide evidence for the domestic portfolio rebalancing channel of quantitative easing as the mutual fund intermediated capital flow data necessary for this presumption does not track the total portfolio of US households investing in funds. Another problem is that the wealth of these households changes over time which impacts seriously on the behaviour studied.

The IMF (2013) study finds the first round of large-scale asset purchases to be associated with a rebalancing of mutual fund intermediated capital away from many emerging markets (EMs) into the United States. This movement is interpreted as a flight to safety at the height of the crisis, while the second round of LSAPs and subsequent rounds of quantitative easing were, by contrast, associated with a rebalancing from the US into EMs. Fratzscher et. al. (2013) analyse mutual fund flows to the countries involved and confirm the first part of the IMF study but not the other, adding the interesting observation that the second round of QE was associated rather with cross-asset rebalancing from bonds into EMs equities. Fratzscher et. al. (2013) point out that their focus was "not on analysing the portfolio allocation strategy of individual fund managers, but [of] individual firms or other institutional investors who invested in those funds following monetary policy actions."

The above studies of country flows are not sufficient evidence for portfolio rebalancing for the following reasons. First, the portfolio wealth in the data-set under consideration changes over time, as pointed out by Curcuru, Thomas, Warnock, and Wongswan (2011) and Kroencke et. al. (2015). Second, the investment in mutual funds is only a fraction of the complete portfolio of the underlying client investors. Third, and most importantly, capital flows intermediated by mutual funds are the outcome of the joint behaviour of fund clients, i.e. the so-called underlying investors, combined with the decisions of the managers of those funds, a point emphasised by Raddatz and Schmukler (2012).

In this paper we concentrate on the portfolio rebalancing behaviour of mutual fund managers using a data-set of mutual funds from EPFR, tracking the monthly geographical portfolio allocation of globally domiciled mutual funds comprehensively as to portfolio country weightings. Our study permits an analysis of the portfolio choice of mutual fund managers, as differentiated from the portfolio rebalancing behaviour of their underlying investors. The behaviour of fund managers has been studied by Kaminsky, Lyons, Schmukler, (2004), Hau and Rey (2008), and others. For instance, Jotikasthira, Lundblad, and Ramadorai (2012) and Raddatz and Schmukler (2012) analyse how fund managers respond to shocks. Hau and Lai (2014) study how monetary policies affect asset allocations, restricting the analysis to portfolio rebalancing within the Euro-zone only.

The work closely related is that of Kroencke, Schmeling and Schrimpf (2015) which differs in two main respects from our study. Firstly, their paper uses different variables to represent US monetary policy by primarily following Lucca and Moench (2015) and Cieslak, Morse, and Vissing-Jorgensen (2014) in analysing scheduled FOMC meetings. We use the flow measure of asset purchases, as with D'Amico and King (2010) and Lo Duca, Nicoletti, Vidal Martinez (2015) and consider the effects pertaining to the exogenous component of unconventional monetary announcements from the unconventional monetary policy shock series as derived by Wright (2012) and extended in Rogers, Scotti and Wright (2014). Secondly, Kroencke et. al. (2015) look at the portfolio rebalancing of underlying investors across asset classes and across countries; instead we focus on the rebalancing of mutual fund managers across countries following unconventional monetary policy.

Using the same EPFR data-set as in the present study, Fratzscher et. al. (2013) investigate mutual fund intermediated capital flows but their study does not differentiate the flows as being composed of the portfolio rebalancing decisions by (i) fund managers and (ii) the underlying investors investing in those funds. Without such differentiation, the observed country flow patterns might be partly driven by, for instance, wealth affects rather than portfolio rebalancing on the part of the underlying client investors.

Our study permits an analysis of the portfolio choice of mutual fund managers, as differentiated from the portfolio rebalancing behaviour of their underlying investors. It allows for a subsequent quantitative examination as to whether and to what extent fund managers undo or exacerbate the allocation decisions by their respective underlying investors.

The remainder of the paper is structured as follows. Section 2 raises theoretical considerations pertaining to the portfolio rebalancing channel of unconventional monetary policy and its international ramifications. Section 3 describes the data. Section 4 derives the empirical specification. The main results are presented and discussed in Section 5. Robustness checks are discussed in Section 6. An extension to the portfolio rebalancing effects of policy surprises by the other main central banks are in Section 7. Section 8 concludes. The Appendix in Section 9 provides a full description of the mutual fund data-set and details of the estimation results.

2 Theoretical framework

This section elaborates on the theoretical considerations behind the transmission of unconventional monetary policy.

There are many transmission channels by which unconventional monetary policy can affect economic activity and asset prices. Some of the prominent transmission channels in the literature include the signalling channel, portfolio rebalancing channel, confidence channel and liquidity channel. An overview of the different transmission channels through which unconventional monetary policy operates is provided in Joyce et. al. (2011), Woodford (2012), as well as Hosono and Isobe (2014). The following discussion is based on Fratzscher et.

al. (2013) and Krishnamurthy and Vissing-Jorgensen (2011).

2.1 Signalling channel

One of the channels by which unconventional monetary policy can affect bond markets is the signalling channel. Bond yields may be decomposed into two components: first, a risk-neutral component, equal to the sum of the current and future expected short-term interest rates, in line with the expectation hypothesis of the term structure. The second component is the term premium composed, according to Bauer and Rudebusch (2013), of a term for general interest rate risk and an idiosyncratic 'instrument-specific term premium.'

The signalling channel of unconventional monetary policy captures the potential of a central bank to exert downward pressure on bond yields by lowering the risk-neutral rate component. This is effected when financial market participants consider the policy announcement or its implementation as news as to the future path of interest rates. See Krugman (1998), Eggertsson and Woodford (2003), Jung et. al. (2005), Jeane and Svensson (2007) and Woodford (2012). More specifically, Clouse et. al. (2003) argues that asset purchases of assets with a long duration can function as a commitment device to keep policy interest rates lower than otherwise anticipated. These kind of large-scale asset purchases are a commitment device because the monetary authority would incur losses on these assets if it were to increase interest rates prematurely.

2.2 Portfolio balance channel

The portfolio rebalancing channel relates to unconventional monetary policy reducing long-term bond yields by exerting downward pressure on the interest term premium. The presence of the term premium may indicate deviations from the expectation hypothesis of the term structure of interest rates, with such deviations possibly being due to financial market frictions such as arising from the imperfect substitutability of assets.

Motivating the portfolio rebalancing channel by a specific form of imperfect asset substitutability is the preferred-habitat hypothesis. Leading papers in this regard include those of Andrés et. al. (2004), Bernanke and Reinhart (2004), Vayanos and Vila (2009), with applications thereof in Chen et. al. (2012) and Ellison and Tischbirek (2014). Also see Gagnon et. al. (2011), D'Amico and King (2011), and Doh (2010), as well as Krishnamurthy and Vissing-Jorgensen (2010, 2012).

The segmentation of asset markets along the demarcations of maturity, default risk or other asset class characteristics, might "reflect the specific needs of pension funds, other institutional investors [including mutual funds], and arbitrageurs that are institutionally constrained," according to Bauer and Rudebusch (2013). This relates to our paper which focuses on mutual funds which may be constrained by their investment mandate. The investment mandate, usually laid out in the prospectus of a fund, can restrict fund managers to a particular asset class (equities for equities funds, bonds for bond funds), or certain asset types (such as when bond funds might be required to invest at least some 75% of their portfolio in government bonds if pursuing an investment style set out in their investment prospectus as of 'government bond focus') or indeed a geographical focus (as when invested with no less than three quarters of the assets under their management in particular regions such as 'global emerging markets').[2]

[2]One may consider a sample-splitting exercise by which one can test if there is any effect from these constraints. However, while in our dataset there are Global-exUS funds which

We draw on Krishnamurthy and Vissing-Jorgensen (2010, 2012) for distinguishing the portfolio balance channel into: the mechanism due to capital constraints, and, the mechanism due to asset scarcity.

2.2.1 Capital constraints mechanism

Central bank asset purchases can have an effect on financial markets when the market for the asset is segmented and limited. As Krishnamurthy and Vissing-Jorgensen (2012) point out, this applies to purchases of morgage-backed securities and agency debt which experience liquidity problems after the financial crisis, but does not apply to asset purchases of Treasuries.

2.2.2 Asset scarcity mechanism

Large-scale asset purchases exercise an impact on the relative supply and, inter alia, the relative prices and return of the assets involved, a case highlighted empirically by, for instance, D'Amico et. al. (2012) and theoretically by Greenwood and Vayanos (2014). The private sector is thought to respond to these asset purchases by adjusting its portfolios by means of seeking alternatives, either at home or abroad, as substitutes for the assets that are purchased by the central bank. Rebalancing to or from foreign assets is thus a part of the international dimension of the portfolio rebalancing channel by which unconventional monetary policy in one country can overflow to the economies and financial markets of other countries.

cannot invest more than 25% of their assets in the US, the observations from these funds are insignificant in number to form a meaningful control group. We would expect that global-ex-US funds should rebalance less than Global-including-US funds. One further idea would be that one draw a line between funds which already have e.g. >50% invested in US vs. funds with <50% invested in the US. But this cutoff would be arbitrary and there are many reasons why US portfolio exposure differs between funds other than their investment mandate constraints constraints.

When considering the US Fed's asset purchases of US Treasuries, as opposed to other type of assets, the asset scarcity mechanism is sometimes referred to as the 'safety premium' mechanism of the portfolio rebalancing channel.[3] This is (i) because there is a significant set of investors that are constrained to invest in safe assets such as Treasuries and (ii) these US government bonds are often used as a safe haven in times of financial distress.

2.2.2.a Local asset scarcity effects

Following large-scale asset purchases, the yields of the securities thereby purchased are likely to fall so as to incentivise the private sector to sell to the central bank a part of its holdings, a tendency shown in the findings of Gagnon et. al. (2011). When the US implements LSAPs, it might push mutual fund managers to decrease the US weighting in their portfolio, and tilt their portfolios towards the Rest of the World, thus bearing on other countries with potentially differential effects.

2.2.2.b General asset scarcity effects

In addition to lowering the instrument-specific term premium on long-term government bonds, the actions of major developed countries central banks may also lower the term premium of interest rates with respect to many other fixed-income securities, and not merely those that have been purchased under an LSAP programme. When a central bank conducts large-scale asset purchases, it alters the supply of bonds, thereby affecting the aggregate amount of maturity risk and, amongst other things, the interest rate risk term premia

[3] See Krishnamurthy and Vissing-Jorgensen (2010).

on a wide range of bonds.[4]

This effect is of an international dimension particularly in markets that are closely interconnected. Miyajima, Mohanty and Yetman (2014) find that a 1.0 pct point increase in the US 10-year term premium will lead to a 0.6 pct point increase in Asian domestic long-term bond yields. Following monetary easing in the US, the implication is that the differential return between US and emerging markets long-term bonds widens, leading global bond fund managers to potentially increase the portfolio weighting of emerging markets in which they deal.

2.3 Confidence channel

Announcements by the central bank can act as a release of information about the current macroeconomic conditions, which will impinge on confidence and risk-taking in financial markets. This works in both directions as Neely (2010) shows that a pronouncement by the US Fed regarding large-scale asset purchases can lead to a retreat from risky portfolio positions in order to rush to safer asset classes.

2.4 Liquidity channel

When unconventional monetary policy operations or announcements improve the the functioning of financial markets, it reduces the liquidity premium paid on many liquid assets.

Purchases of MBS can have an effect in this manner as they improved the

[4] Bauer and Rudebusch (2013) refer to the two components of the portfolio rebalancing channel as (i) the ’local supply’ sub-channel that reduces term premia only of those securities purchased by the central bank and (ii) the ’duration’ sub-channel of portfolio rebalancing reducing the term premia on all fixed-income securities.

conditions in this part of the capital markets, as shown empirically by Joyce et. al. (2011) and Gagnon et al. (2011). As to purchases of Treasuries, Krishnamurthy and Vissing-Jorgensen (2011) point out that Treasury bonds' liquidity premium was large during the height of the US financial crisis given that many other asset classes were affected by illiquidity problem. However, the expansion in the liquidity in by the central bank by its liquidity operations, such as the Asset-Backed Commercial Paper, Money Market Mutual Fund Liquidity Facility, the Commercial Paper Funding Facility, and the Money Market Investor Funding Facility, as well as the swap lines with other major central banks, improved liquidity and thus reduces the liquidity premium paid on many liquid bonds, including Treasuries, relative to less liquid asset classes.

2.5 Testing for the transmission channels

Given that many monetary policy instruments, that is both operations and policy announcements, are considered by the literature to operate via multiple transmission channels, as opposed to a single channel exclusively, this study is unable to provide either a direct test for any one transmission mechanism nor a conclusive analysis regarding which one of the channels is responsible for the observed portfolio rebalancing of mutual funds.

However, the data allow us to compare and contrast the effects of different monetary policy instruments, some of which relate to different transmission channels than other instruments of monetary policy. The empirical approach in this study can be summarized in four parts.

First, the study compares the effects of US Fed's unconventional monetary policy *operations* to unconventional monetary policy *announcements* generally. See Section 5.

Second, we compare the effects of the US Fed's large-scale asset purchases to the effects of LSAP-related announcements, a subset of all monetary policy announcements. This is implemented in two parts: (2.a) LSAP-related announcements are modeled as an *event* by use of a 0/1 dummy variable, which ignores the role of expectations. See Section 5.4.3. This compares to (2.b) unconventional monetary policy *surprises* about LSAP-related announcements, which takes account of financial market expectations.

Third, we directly compare the effects of LSAP-related announcement surprises by the US Fed to the impact of its 'other' types of unconventional monetary policy surprises, which principally but not exclusively related to forward guidance about the likely path of future interest rates. See Section 9.8.

Fourth, we compare the impact of unconventional monetary policies of all the major central banks. This has two parts: (4.a) we analyse the effect of unconventional monetary policy announcement surprises, and then (4.b) differentiate between LSAP-related announcement surprises to the impact of 'other' types of unconventional monetary policy surprises for the US Fed, ECB, BoJ and BoE. See Section 7.

In short, the transmission channels are not mutually exclusive and multiple channels can be responsible for the international transmission of unconventional monetary policy.

2.6 Policy operations vs. announcements

Fewer studies in the literature analyse the effects of operations, such as D'Amico and King (2010) and Lo Duca, Nicoletti, Vidal Martinez (2015), given that most papers narrowly focus on the effects of announcements. Fratzscher et. al. (2013) point out that an LSAP-related announcement by the US Fed does not contemporaneously impact on the supply of Treasuries, indicating that any portfolio rebalancing observed by mutual funds following announcements is not related to the asset scarcity effect of portfolio rebalancing. Instead, the announcement can have an effect by the signalling channel which affect private sector expectations about the future prices of assets, leading to a direct impact of announcements on asset allocation and prices at the time of the announcement.

This is part of the rationale offered by studies narrowly focusing on announcements: there are no news emanating from the implementation of large-scale asset purchases because they have been announced and their path as well as pace are well known in advance.

However, the central bank's policy function for LSAPs has not been revealed and many announcements relayed a upper bound on asset purchases in the future, instead of laying out the precise state contingency of the policy. Fratzscher et. al. (2013) offer two further considerations why the literature also needs to analyse operations. Firstly, asset purchases might had an effect at the time of the implementation of the program because the asset markets in which it intervened were dysfunctional implying that the price signals in those markets were not operative as normal. This reasoning should apply more to purchases of mortgaged-backed securities and agency debt instead of Treasuries purchase operations. Secondly, despite knowing the path and pace of asset purchases in advance, the private sector might not have been perfectly accurate in their forecasts about the effectiveness of the operations in restoring dysfunctional markets as well as boosting the macroeconomic conditions in the US and countries in the rest of the world.

3 Data summary

3.1 Global asset management industry

This section provides a brief overview of the size and composition of the asset management industry. The industry consists of private wealth managers, alternative funds (comprising hedge funds, private equity funds, foreign exchange traded funds, and sovereign wealth funds) and conventional funds (including pension funds, insurance companies and mutual funds). In this paper, we focus on mutual funds.

The asset management industry is large and its role on the global economy is growing, as pointed out by Shin (2013), Feroli et. al. (2014) and the IMF (2014, 2015). By the year 2014-Q1, this sector claims $US 146 trillion of assets under its management. The subset of mutual funds manage some $US 30.9 trillion, which exceeds 20% of the industry total. See Figure 6.

The industry is growing in absolute terms as well as relative to the size of the economies in which the funds are domiciled. Figure 7 shows the size of the asset under management as a percentage of the GDP of the country in which a fund is domiciled. Since 1980, the assets under management in the United Kingdom, for instance, have grown from half the size of UK GDP to over three times its quantum. The United States is the most important centre, with US-domiciled mutual funds managing half of the industry's assets under management.

3.2 Fund-level portfolio data

The data on global mutual funds are compiled by Emerging Portfolio Fund Research (EPFR), whose output is widely used in the literature.[5]

Our data-set covers salient fund characteristics that include: fund domicility, asset class focus (bonds or equity), investment focus (e.g. government bonds, corporate bonds, or, a certain maturity of debt instruments), benchmark, and style (active or passive investor), the fund's total net assets in $US terms, the change in net asset value (measuring the rate of return on the fund, inclusive of dividends), portfolio country weightings, and cash holdings. The data frequency is monthly.

We focus on the period that starts with November 2008, a crucial date representing the commencement of the first quantitative easing programme in the US, and ends in April 2014, a total of 65 months. The cross-sectional coverage of the data-set improves over time. The average number of equity (bond) funds reporting portfolio weightings starts with 394 equity funds (56 bond funds) in the year 2008 and reaches 628 equity funds (90 bond funds) in 2014. The data-set contains 5275 equity fund-month (691 bond fund-month) observations for 2009, which increases to 7350 equity fund-month (1189 bond fund-month) observations in 2013. Throughout the period 2007 to 2014, there is an average of 488 distinct equity funds (73 distinct bond funds) reporting portfolio country weightings each month.

The funds survive a long time in the sample chosen. In the full sample,

[5] Studies that use EPFR data include Jinjarak, Wongswan, and Zheng (2011), Jotikasthira, Lundblad, and Ramadorai (2012), Fratzscher, Lo Duca, and Straub (2012), Fratzscher (2012), Lo Duca (2012), Raddatz and Schmukler (2012), Puy (2013), Gauvin, McLoughlin and Reinhardt (2014), Kroencke et. al. (2015) as well as by Koepcke (2013) and IMF (2013). The link between EPFR and balance of payment capital flow data is studied by Jotikasthira et. al. (2012) and Pant and Miao (2012).

about 90% of equity and bond funds report monthly country allocations consecutively for two or more years. Approximately 70% (63%) of equity (bond) fund-month observations are from funds that report portfolio weightings, consecutively and continuously, for 4 years or more.

As to fund-domicility, 88% (90%) of the observations are from equity (bond) funds domiciled in Ireland, Luxembourg, UK or the US. About 19% (21%) of the observations in the equity (bond) sample come from US-domiciled funds.

As to the economic size of the funds, 89% (78%) of the total assets under management tracked in the sample emanates from equity (bond) funds domiciled in Ireland, Luxembourg, UK and the US, with 42% (54%) of total AUM being tracked by the US-domiciled equity (bond) funds alone. The EPFR data-set is quite representative of the global asset management industry in this respect as well, given that data on the industry show convincingly that the US-domiciled funds manage 50% of the total global wealth invested in mutual funds. Again, see Figure 7.

The investment prospectus of a mutual fund specifies its geographical focus which requires the fund to be invested with at least three quarters of their portfolio wealth in the countries that fall under their geographical designation, such as developed markets (DM) or emerging markets (EM). In our data-set, 32% (81%) of the observations and 44% (92%) of the portfolio wealth tracked for equity (bond) funds are from either such DM- or EM-dedicated funds. Other significant fund types, in terms of their geographical focus, are Asia ex-Japan and Emerging Europe funds, jointly accounting for 31% (11%) of the fund-month observations and 14% (5%) of AUM as tracked in our equity (bond) fund sample.

Appendix 9.3 provides additional summary statistics of the fund data-set.

3.2.1 Data cleaning

Prior to empirical analysis, we clean the data in four ways: We (i) remove 'passive', also called index funds whose geographical allocation is mechanically linked to the country weightings used in the composition of a benchmark, such as the Morgan Stanley MSCI index for equity funds, or the JP Morgan index for bond funds. We (ii) winsorise the fund returns at the -50% and +200% points[6], in order to reduce the influence of potential outliers on the relative return variable and (iii) remove the fund-month observations from funds that report at a frequency other than monthly. Finally and crucially, we (iv) exclude the funds that report monthly portfolio weightings for less than 12 consecutive months in the entire sample, even if they are available at the end of the sample period.

This data cleaning follows the standard methods in the literature using EPFR data such as Raddatz and Schmukler (2012) and Jotikasthira et. al. (2012).

3.3 Monetary policy instruments

The variables used to measure unconventional monetary policy, both policy surprises and policy actions, together with their data sources, are as follows.

Unconventional monetary policy surprises of the US Fed are measured as the intra-day change in government bond yields around the Fed's policy announcements. We apply from Rogers et. al. (2014) the series identifying policy surprises as the first principal component of the change in 2-, 5-, 10-, and 30-year Treasury futures, using a 30-minute window bracketing Fed an-

[6]This is a standard winsorisation in the mutual fund literature. In any case, there are only very few observations falling outside this window.

nouncements.[7]

We use the policy surprise series from Rogers et. al. (2014) measuring movements in yields during these narrow intra-day 30-minute windows, which are likely to be mostly due to unanticipated changes in the stance of US monetary policy, a factor inducing us to use them in preference to other techniques.

This identification strategy assumes, of course, that no other economic news was released within this short interval to have a significant bearing on the outcome. The unconventional monetary policy series may, however, not be entirely due to (i) news about the Fed's monetary policy stance as it may be confounded by (ii) news about the Fed's expectations as to the current state and the future path of the economy. To cleanly distinguish between the two, one could extract the central bank's private information about the economy by using the residual of the regression that regresses the Fed's staff Greenbook forecasts on the private sector's consensus forecasts, such as those from the Survey of Professional Forecasters. The difference between, on the one hand, the aforementioned residual, and, on the other hand, the UMP surprise series of Rogers et. al. (2014) would yield a 'pure' monetary policy stance surprise series cleaned for the release of the central bank's private information about the future path the economy. See for example Barakchian and Crowe (2013). It is not possible to implement this procedure here as the Greenbook forecasts for our sample period are currently unavailable. This is due to the Federal Reserve releasing its staff's Greenbook projections to the public domain only with a 5-year lag.

It also needs to be considered that high frequency identification may not

[7] Announcements could have been modelled as binary 1/0 time-dummies for the month during which the announcement was made. This, however, would ignore the policy's magnitude and the role of expectations.

fully capture unconventional monetary policy surprises, given that it "may take considerable time for a policy shock to be properly reflected in yields" pertaining to bond futures as pointed out by Hosono and Isobe (2014). One solution would be to use inter-day data as in Hosono and Isobe (2014) who identify policy surprises in an event study by measuring the changes of asset returns from the day preceding a policy announcement to the day of the announcement and the three days post the announcement. However, such an identification method would increase the likelihood that the recorded change in asset returns is partly due to factors other than the monetary policy announcement.

An alternative solution might be to widen the window from 30 to 120 minutes as suggested in Rogers et. al. (2014). The correlation between the narrow- and wide-window surprise series are, respectively: 0.87 for the Fed, 0.82 for the BoE, 0.86 for the ECB and 0.49 for the BoJ. The difference is thus not that significant at least for three of the four central banks involved.

Policy surprises are normalised to a 25 basis points (bps) surprise change in the yield and signed in a way that a positive number represents a surprise monetary policy easing. The signing of the shocks implies that a negative surprise represents a surprise tightening, instead of a 'less than expected' policy easing.

We also consider the effects that arise from policy operations in the form of asset purchases by the central bank. We measure the amount of assets purchased in percentage points of total amount outstanding in Treasury securities and MBSAD, respectively. This relates to the measure of 'asset scarcity' that the Fed may be contributing to by way of reducing the share of outstanding quantity of Treasuries, or MBS and agency debt, available to the private sector. This has been pointed out empirically by D'Amico, English, López-Salido and Nelson (2012), as well as theoretically by Greenwood and Vayanos (2014).

The unconventional monetary policy variables are illustrated in Fig. 1 - 2b.

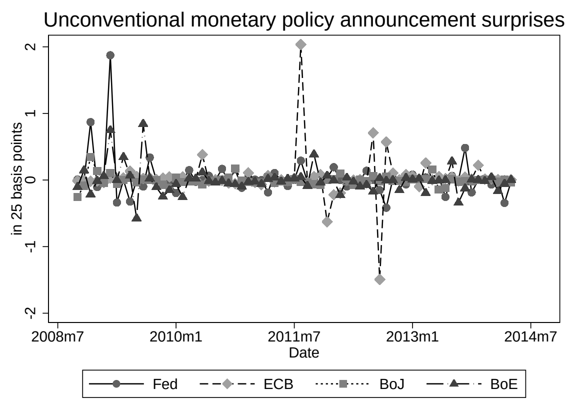
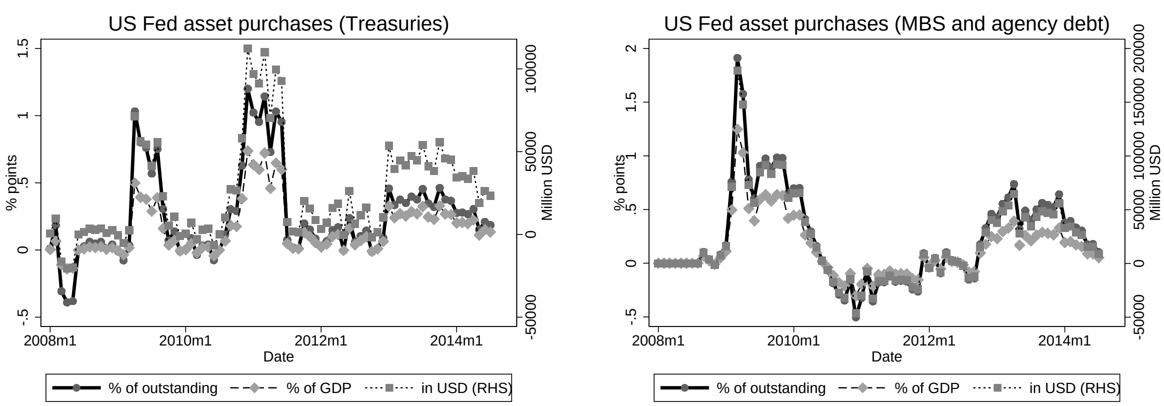


Figure 1: Unconventional monetary policy surprises



(a) Fed Treasury purchases (b) Fed MBSAD purchases

Figure 2: Unconventional monetary policy operations

4 Empirical specification

The empirical approach, testing the link between unconventional monetary policy and portfolio rebalancing by international mutual funds, is described below.

The decision problem facing the manager of a mutual fund seems, in the first instance, similar to the basic portfolio selection problem of any investor. The starting point in the literature on portfolio selection is the mean-variance portfolio optimization approach of Markowitz (1952) which allows one to derive structural asset demand functions. These structural equations determine the optimal portfolio weights as a function of the mean, variance, and covariance of the return for each asset.[8]

Mutual fund managers as a particular type of investor might have particular risk preferences, while also facing regulatory and institutional constraints that affect their portfolio selection. Sharpe (1967), and others since, derived an explicit solution for the portfolio selection problem of mutual funds taking into account some of the constraints faced by mutual fund.

However any such structural models are likely to be seriously misspecified, as pointed out by Pesaran and Smith (2014). They suggest that one should instead estimate a reduced form model. We follow this suggestion because the focus of this study is not the estimation of a structural mutual fund portfolio selection model, but rather an analysis of the impact of unconventional monetary policy on the portfolio allocation of mutual funds.

[8]More advanced models also consider higher moments of the return distribution. For an application to the effects of Japanese quantitative easing on portfolio rebalancing, see Kimura and Small (2006).

4.1 Partial adjustment portfolio model

Motivating the lagged dependent variable in the reduced form specification derived from the following partial adjustment portfolio model.

The desired portfolio weighting, X_t^*, of a fund i at time t is a function of a fund-specific component a_i and a dynamic component V_{it}, which consist of variables common to all funds as well as fund-specific controls, such that:

$$X_{it}^* = a_i + bV_{it} + \lambda_{it}. \tag{1}$$

The desired portfolio weighting may not be achievable instantaneously. The actual weighting is unlikely to be exactly equal to the desired weighting in each period which might be due to the presence of institutional constraints and adjustment costs, amongst other frictions. The actual allocation X_{it} is, thus, a function of the desired allocation as well as last period's allocation:

$$X_{it} = \theta X_{it}^* + (1-\theta)X_{it-1}$$

with $0 < \theta < 1$. The higher the value of the adjustment parameter θ, the more instantaneous is the achievement of the desired portfolio allocation. In the limit, when $\theta = 1$, we have $X_{it} = X_{it}^*$ in all periods. Here it is assumed that $\theta < 1$.

The partial adjustment of the portfolio weightings is:

$$X_{it} - X_{it-1} = \theta\left(X_{it}^* - X_{it-1}\right). \tag{2}$$

Substituting equation (1) into equation (2) yields:

$$X_{it} = \rho X_{it-1} + \gamma V_{it} + \alpha_i + \epsilon_{it} \tag{3}$$

with $\alpha_i = a_i\theta$, $\rho = 1-\theta$, $\gamma = b\theta$ and $\epsilon_{it} = \theta\lambda_{it}$.

4.2 The benchmark specification

The effect of unconventional monetary policy, both in its operations and surprise announcements in the US, is estimated by its effect on the log weighting of a country or region X_{it} in the portfolio of fund i and month t:

$$X_{it} = \rho X_{it-1} + \beta \mathbf{MP}_t + \mu + \phi_i + \epsilon_{it} \tag{4}$$

$$\text{with } \mathbf{MP}_t = [asset\,purchases_t, policy\,surprises_t]$$

The variable X_{it} represents the log of portfolio weightings of fund i in month t of a country or a set of countries $X \in${US, Rest of the World excluding the US (ROW), Developed Markets excluding US (DMexUS)}.

We allow for fund-specific intercepts by including fund fixed-effects ϕ_i so as to account for unobserved time-invariant differences between funds.

The effects of unconventional monetary policy are measured by the coefficients on the policy variable $\mathbf{MP}_t$ which includes unconventional monetary policy surprises and operations. The coefficient β should pick up the indirect and direct effects of unconventional monetary policy on the portfolio weightings.

Following Pesaran and Smith (2014), we drop all elements of the vector of control variable $\mathbf{V}_{it}$ that are not invariant to the policy. In the case of US quantitative easing, we drop all controls that could act as push and pull factors, such as GDP, the current account, inflation, and so on, given that they are very likely to respond to monetary policy by the US Fed. The same applies to fund-specific controls such as fund flows, which measure the net redemptions from or net injections into a fund by its underlying client investors, which have been shown to be affected by quantitative easing.[9]. These controls may well be invariant to US unconventional monetary policy if we had data at a higher than monthly frequency.

The portfolio weightings of all countries have been re-weighted to exclude a fund's cash holdings, which we report separately, and are expressed in percentage points. The functional form of the weighting in the benchmark specification is the portfolio weighting in log levels. A robustness check considers other forms such as the log weights in first-differences.

The set of explanatory variables consist of six elements. (1) A lagged dependent variable, whereby the weighting from the previous month (X_{it-1}) is included owing to the theoretical considerations described by the partial adjustment model.

The monetary policy vector $\mathbf{MP}_t$ comprises (2) unconventional monetary policy operations in the form of asset purchases of mortgage-backed securities and agency debt (MBSAD) as well as Treasury securities purchases.[10] The asset purchases are measured in percentage terms, respectively, of the amount of MBSAD and Treasuries outstanding. We further consider (3) unconventional monetary policy surprises measured as the exogenous component

[9] For example, see Fratzscher et. al. (2013)

[10] Asset holdings by the US Fed are not included in the specification due to its non-stationarity.

of policy pronouncements. In a further refinement, we also study the subset of policy pronouncements related to announcements about asset purchases, as opposed announcements about forward guidance and other types of policy announcements. See Section 5.4.3.

4.3 Econometric methodology

This section briefly explains the estimation technique with which we estimate the panel model.

The main benchmark model

$$X_{it} = \rho X_{it-1} + \beta \mathbf{MP}_t + \mu + \phi_i + \epsilon_{it} \tag{5}$$

can be averaged over all time periods for each fund i:

$$\overline{X}_i = \rho \overline{X}_i + \beta \overline{\mathbf{MP}} + \mu + \phi_i + \bar{\epsilon}_i \tag{6}$$

where $\overline{X}_i = \frac{1}{T_i}\sum_t X_{it}$, $\overline{MP}_i = \frac{1}{T}\sum_t MP_t$, and $\bar{\epsilon}_i = \frac{1}{T_i}\sum_t \epsilon_{it}$. The fixed effects by definition are time invariant such that $\overline{\phi}_i = \phi_i$.

Take the difference between (5), that is the observation on each mutual fund i, and (6), that is the within-unit average. The result is the fixed-effects or within-group transformed equation:

$$\left(X_{it} - \overline{X}_i\right) = \rho\left(X_{it-1} - \overline{X}_i\right) + \beta\left(\mathbf{MP}_t - \overline{\mathbf{MP}}\right) + \left(\epsilon_{it} - \bar{\epsilon}_i\right) \tag{7}$$

The fixed effects estimation technique performs Ordinary Least Squares on the transformed equation (7). It provides an estimate of ρ, the coefficient on the lagged dependent variable, and β, the effect of monetary policy on the portfolio weighting, which is the main object of interest in this study.

The model we estimated is a dynamic panel model as it includes a lagged dependent variable as a regressor. As our panel dataset is long ($T > 60$) the Nickell (1981) bias, typically associated with short dynamic panels, should not be a substantive issue as illustrated, for instance, in Beck et. al. (2014).[11]

5 Empirical results

The following section discusses our main findings bearing on the role that mutual funds play in the global portfolio channel of unconventional monetary policy. We highlight whether, and what measures of US unconventional policy induce mutual fund managers to re-balance their portfolios between the US and the Rest of the World (ROW) and whether the composition of the latter, in terms of the share of Developed Markets excluding the US (DMexUS), changes as a result of US unconventional policy operations and policy surprises.

First, the results pertaining to equity-designated funds are presented, followed by the results relating to bond-designated funds. In each case, we analyse the relationship between the portfolio country weightings and the US Fed's operations in the form of: (a.i) purchases of Treasury securities and (a.ii) purchases of mortgage-backed securities and agency debt, as well as (b) unconventional monetary policy announcement surprises.

[11]The Nickell bias is negative and of the magnitude $\underset{N\to\infty}{\text{plim}}\,(\hat{\rho}-\rho) = -\frac{1+\rho}{T}$. If the panel were short, as for example in the portfolio rebalancing study by Joyce et. al. (2014) where $T = 6$, one would need to use a general method of moments estimator. This may be either the difference GMM estimator of Arellano and Bond (1991) or the more efficient system GMM estimator of Arellano and Bover (1995) and Blundell and Bond (1998). These and other methods are discussed in standard textbooks such as Hsiao (2003).

5.1 Main findings

The results are three-fold. (1) The effects of monetary policy generally differ in size and significance between equity and bond funds. There is more evidence for unconventional monetary policy triggering portfolio rebalancing in equity funds than in bond funds. (2) Purchases by the US Fed of Treasury securities leads equity fund managers to shift their portfolio away from the US and into the Rest of the World, with the composition of the latter tilting in favour of other developed markets instead of emerging markets. (3) Monetary policy easing announcement surprises lead to a portfolio shift in the same direction, that is, into the Rest of the World (excluding the US). This result holds for equity funds only.

In the following, we will first present the results for the whole sample. An interpretation of these results is offered in Section 5.3. Then, we analyse sub-samples associated with the different rounds of US unconventional monetary easing.

5.2 Full sample

In the empirical specification, discussed in Section 4, US unconventional monetary policy operations and surprises are thought to affect a set of portfolio weightings of fund i in month t. A portfolio weighting measures a fund's portfolio allocation to the United States (US), the Rest of the World (ROW) excluding the US, and Developed Markets (DMexUS) relative to emerging markets. The effect of monetary policy is also estimated on cash holdings (hereafter: cash).

The results below discuss the estimation results when the portfolio log weight is regressed on the following set of variables: the lagged log weight;

the return of the country or region relative to the fund's overall portfolio return; and US unconventional monetary policy comprising of the size of the US Fed's purchases of Treasury securities ('Fed Treasury purchases') as well as purchases of mortgage-backed securities and agency debt ('Fed MBSAD purchases'). Purchases are measured in percentages of the outstanding amount of the relevant assets. Monetary policy announcement surprises are measured by the exogenous change in the yield of 2-, 5-, 10-, and 30-year Treasury futures ('Fed announcement').

All the regressions carried out include fund-fixed effects and a constant. The constant has been omitted in the Tables below for presentation purposes. The full estimation details are relegated to Appendix 9.4.

5.2.1 Equity funds

Table 1 exhibits the results for equity funds only (and bond fund results follow thereafter). The interpretation of the coefficients is as follows. Recall that policy announcement surprises are normalised to a 25 basis points (bps) surprise change. Then, a 0.25 bps surprise announcement easing leads to a 0.0033% increase in the ROW-exUS weighting, while US Fed purchases of Treasuries equivalent to 1% of outstanding Treasuries will lead to a 0.0358% decrease in US weighting by equity funds.

Equivalently, to scale the results, US Fed purchases of Treasuries equivalent to 3% of outstanding Treasuries will lead to a 1.074% decrease in the US weighting. And a 100 bps surprise announcement easing leads to an approximately 0.0132% increase in ROW-exUS weighting in the portfolios of mutual equity funds.

The findings are that (a.i) purchases of Treasuries are statistically signific-

Table 1: *Main results (equity funds)*

VARIABLES	(1) US	(2) ROW	(3) DMexUS	(4) cash
Log lagged weight	0.663***	0.921***	0.868***	0.328***
Fed Treasury purchases	-0.0358***	0.00342***	0.0136***	-0.0371
Fed MBSAD purchases	0.0119	0.000560	-0.00185	0.00993
Fed announcement	-0.00795	0.00330***	0.00387	0.00312
Observations	6,722	11,662	10,209	10,451
Number of fundid	262	288	282	285
Adjusted R-squared	0.556	0.854	0.764	0.108
Fund fixed effects	Yes	Yes	Yes	Yes

ant in inducing equity fund managers to change country portfolio weightings, in contrast with (a.ii) purchases of MBS and agency debt which do not appear to have a significant effect on the portfolio allocations of equity funds. The direction of portfolio rebalancing due to Treasury purchases is the same as that of (b) unconventional monetary policy easing surprises. The portfolio rebalancing direction is three-fold: a reduction in the portfolio exposure to the US, an increase in a fund's exposure to countries in the Rest of the World (ROW), and a change in the composition of the ROW portfolio weighting in favour of other developed markets (DMexUS).

(a) Fed's asset purchases

Purchases of Treasury securities by the Fed lead equity fund managers to tilt their portfolio away from the US (column 1 in Table 1) towards the Rest of the World (column 2). The composition of the ROW share moves in favour of developed markets other than the US (column 3). Purchases of MBS and agency debt are not consistently associated with portfolio rebalancing in the statistics gathered. Equity funds increase cash holdings in the wake of every measure of unconventional policy (column 4).

(b) Fed's announcement surprises

Unconventional monetary policy in the garb of monetary easing surprises seem to have the same effect as Treasury purchases. In this vein, equity funds shift into the ROW (column 2 in Table 1). We cannot find significant effects as to the composition of the ROW share tilting away from the emerging market economies towards developed markets other than the US (column 3).

Announcement surprises and Treasury purchases have a positive effect on the ROW share, but their coefficient is marginally larger in the case of Treasury purchases. One may not conclude that these operations are more economically significant than, for example, the impact of central bank announcements in triggering portfolio rebalancing. The reason lies in differences that exist in the units of measurement. Fed purchases of Treasuries, for example, are measured in percentage points of outstanding US Treasury securities, while policy surprises are normalised to measure a 25 basis points surprise change in Treasury futures.

5.2.2 Bond funds

Table 2 depicts the effects that arise from unconventional monetary policy on portfolio rebalancing by managers of bond funds. Neither announcements nors policy actions in the form of asset purchases do not seem to exert any effect on portfolio rebalancing by bond funds, save for the effect of Treasury purchases on the composition of the ROW share which tilts in favor of developed markets relative to emerging markets (column 3).

Table 2: *Main results (bond funds)*

VARIABLES	(1) US	(2) ROW	(3) DMexUS	(4) cash
Log lagged weight	0.882***	0.861***	0.710***	0.430***
Fed Treasury purchases	0.00577	-0.00241	0.0271**	-0.0251
Fed MBSAD purchases	0.00313	-0.00215	0.0117	-0.208***
Fed announcement	-0.0162	0.00962	-0.0158	0.0814
Observations	1,091	1,982	1,215	1,671
Number of fundid	39	51	40	47
Adjusted R-squared	0.736	0.732	0.510	0.219
Fund fixed effects	Yes	Yes	Yes	Yes

5.3 Interpretation of the main results

Table 3: *Summary of main results*

Fund Type	Equity Funds			Bond Funds		
Portfolio weight	US	ROW	DMexUS	US	ROW	DMexUS
Fed Treas purchases	–	+	+	0	0	+
Fed MBS purchases	0	0	0	0	0	0
Fed announce surprise	0	+	0	0	0	0

The main results are summarised in Table 3. Considering equity funds, the Fed's purchases of Treasury securities have a portfolio rebalancing effect in the same direction as the monetary easing announcement surprises it makes: in consequence the managers of these equity funds increase the portfolio weighting of the countries they deal with in the Rest of the World. Equity funds thus change the composition of the ROW weighting with respect to other developed markets besides the US.

As for bond funds, policy easing surprises occasioned by the Fed do not seem to prompt bond funds to change their US-country weighting, and nor do they seem to change their portfolio exposure to other countries in the Rest of the World. Asset purchase operations by the Fed have no statistically significant effect on the portfolio allocation of bond funds.

An interpretation of these portfolio rebalancing effects arising from unconventional monetary policy is set out below in relation to three transmission channels.

The *signalling channel* might partly explain why equity funds increase the weighting of countries situated in the Rest of the World (ROW) and, moreover, change the composition of the ROW share in favour of other developed markets. A policy announcement that constitutes a monetary easing surprise could generate ’news’ concerning financial markets assessing how long the Fed expects the US economy to remain sluggish. Adverse news intimating the macroeconomic outlook can, in this fashion, compress expected US equity returns, and prompt equity funds to move over to countries in the Rest of the World, but in particular to other developed markets as the closest substitute for US equities.

This signalling channel may also lie behind the finding that, following a surprise policy easing in the US, bond funds reduce their US portfolio exposure. An announcement surprise provides new information as to how much longer the US Fed will keep interest rates near the zero lower bound, exerting downward pressure on bond yields in general, by lowering the risk-neutral rate component of bond yields.[12]

The *portfolio rebalancing channel* relates to our findings of bond fund managers’ reaction to monetary easing surprises by explaining how such policy sur-

[12]Separating these two aspects of the signalling channel has been discussed in Section 3.3. See Barakchian and Crowe (2013).

prises can reduce long-term bond yields by bearing down on the term premium component of bond yields. As explained in Section 2, the presence of the term premium has been motivated in part of the literature by the assumption that, for investors who are somehow or another constrained, assets are imperfectly substitutable. This has been modelled as some investors having a ’preferred-habitat’ restricting them to invest in a specific asset class as constrained by one or several asset characteristics such as its maturity profile.

Specifically, the portfolio rebalancing channel can be divided into two components: the (i) ’local asset scarcity’ sub-channel of portfolio rebalancing, explaining why asset purchases reduce term premia of those securities that are purchased by the central bank; in this regard Greenwood and Vayanos (2014) have explained how asset purchases reduce the quanta of such type of bonds available to the private sector, thereby affecting excess returns from the type of bonds purchased. Portfolio rebalancing also operates through (ii) a ’maturity risk’ sub-channel. This explains the reason for asset purchases reducing the non-instrument-specific term premia on a wide range of fixed-income securities, and not just on those assets that have been purchased under an LSAP programme alone.[13] Central bank purchases of Treasury securities removes interest-rate risks from the balance sheet of the private sector, a fact that might lead the participants in bond markets, including mutual bond funds, to attempt to reattain their desired level of maturity risks in their portfolios by rebalancing away from the US towards the Rest of the World, and, in particular, towards other developed market bonds given that these are arguably the closest substitutes for US Treasuries.

A complementary, third interpretation of the main results concerns the fin-

[13]This terminology regarding the two sub-channel is based on Bauer and Rudebusch (2013) but has been adapted here.

ancial market *confidence and liquidity channel*. These aspects were seen to have been improved by UMP announcements, when emboldening mutual funds to invest in markets other than the US.

In principle, when monetary policy has a negative effect on the US portfolio weighting, it should mechanically exert a positive effect on the portfolio weighting that is composed of the countries in the Rest of the World excluding the US (ROW), given that, by construction, the two factors must add up to one hundred percent for any one fund. The fact that we do not always find significant effects in both the US regressions and ROW regressions is partly due to the fact that there are a number of funds that, in some or all months, do not have any portfolio exposure to the US. Examples of funds that do not invest in the US are those with an investment mandate specifying 'global ex-US' or 'global emerging markets' as their prime geographical investment focus. Appendices 9.3 and 9.3 provide an overview of the average US weighting in the portfolios of equity and bond funds differentiated by their geographical investment mandate. Given that the country portfolio weighting is expressed in logs, with the log of zero being undefined, we have fewer observations for the US regressions for those months in which a fund has a US weighting of zero, either in the current month t, or the preceding month $t-1$, or both. However, when either the current or lagged US weighting is zero, one observes a rebalancing effect away from or to the US by running the regression on the ROW weighting instead.

The regression on the share of the developed markets other than the US (DMexUS weight) indicates a change in the composition of the ROW portfolio share between, on the one hand, emerging and frontier markets and, on the other hand, developed markets other than the US. Our finding is that the

DMexUS weighting increased rather than decreased in the wake of many unconventional policy measures pursued by the US monetary authorities.

This finding seems to go against the assertion that fund managers have contributed to the 'tsunami' phenomenon of capital flows migrating to certain emerging markets following the unconventional monetary policy response to the 2007/8 financial crisis. We do not find significant evidence of fund managers tilting their ROW share in favour of emerging markets. This might be because the QE-induced mutual fund capital flows arriving in emerging markets are due more to the underlying client investors taking their money out of DM-dedicated funds in order to switch from one fund to another, specifically to EM-dedicated funds. Policy implications are discussed in Section 8.

5.4 Unconventional monetary policy in different subsamples

We implement the benchmark model on smaller sub-samples defined by the different phases that quantitative easing (QE) took. Hancock and Passmore (2014) provide the dates of the QE phases. A description of each large-scale asset purchase program is provided in Appendix 9.1.1.

As for the different QE phases, most of the effects for the full sample in Table 3 continue to hold at least for some of the individual QE programs for equity funds. The insights from this analysis are:

(1) The direction of the portfolio rebalancing effect is not always the same across all QE phases. A changing sign in the portfolio rebalancing effect would indicate either that the different vintages of QE had different effects, given that they were created to serve different purposes. It may also be the case that the

monetary policy measures might be picking up effects not captured by our macro controls. Finally, the effects of QE on portfolio rebalancing may be too weak, or our data-set insufficiently large to establish the effects for each QE phase separately. When the sign of the effect is the same throughout the different QE phases, it would seem to indicate that each round of unconventional monetary policy had a consistent effect on mutual fund portfolio rebalancing, and that the portfolio rebalancing effects are sufficiently strong to continue to hold in the smaller sub-samples.

(2) For equity funds, the sub-sample regressions show significant effects on portfolio rebalancing between the US, the Rest of the World as well as the share of the developed markets, relative to emerging market economies. This might permit a more differentiated insight as to which QE program had global spillover effects by means of mutual equity funds' portfolio rebalancing.

(3) For bond funds, the policy announcement effects are not significant in the smaller sub-samples. The following discussion of the results of the sub-sample analysis is, hence, restricted to equity funds.

5.4.1 QE1 and Operation Twist

(a) Fed's asset purchases: When considering all QE programmes jointly, as well as during QE1 and Operation Twist, the Fed's large-scale purchases of Treasuries prompts equity funds to increase their ROW portfolio weight. The share of developed markets in the latter also increases at the expense of the relative weighting of emerging markets during Operation Twist (See columns 2 and 4 in Tables 24 and 25.)

(b) Fed announcements: The effect of announcements has the same effect on the US versus the ROW weighting as Treasury purchases: equity fund man-

agers rebalance their portfolio away from the US into the Rest of the World, with the composition of ROW share tilting in favour of developed markets.

5.4.2 QE2 and QE3

Consider columns 2 and 4 in Tables 23-25. See that QE2 and QE3 lead to portfolio rebalancing in the opposite direction to QE1 and Operation Twist.

(a) Fed's asset purchases: Treasury securities purchases lead equity fund managers to decrease their portfolio exposure to countries in the Rest of the World, in addition to the composition of the ROW share tilting towards developed markets. Purchases of MBS and agency debt instruments do not seem to exert any significant effect on the relative share of developed markets in the ROW portfolio weight.

(b) Fed announcements: Surprises do not seem to exert any effect except on the DMexUS share of the ROW weight during QE2. But overall, the results for the QE2 and QE3 sub-samples are either statistically insignificant, or have signs opposite to the other QE phases. Yet, the main results regarding the portfolio rebalancing effects of Treasury purchases and announcements continue to hold in the sub-samples, driven mainly by QE1 and Operation Twist.

5.4.3 Pure signalling effect of LSAP announcements

The previous section analysed the effect of unconventional monetary policy announcement surprises and the impact of large-scale asset purchase operations. However, one may also ask if the mere announcement of an LSAP program has an affect on the portfolio allocation of mutual funds.

We estimate the pure signalling effect of LSAP announcements by defining a dummy which takes the value 1 in the months where there was an LSAP-related announcement by the US Fed, and takes the value 0 otherwise.

This implies that we differentiate US unconventional monetary policy announcement into two types: an announcement is either LSAP-related or non-LSAP-related. The differentiation we adopt in this paper follows the judgmental classification of Fed announcements in Rogers et. al. (2014).

The results are reported in Tables 35 and 36. In short, there are no significant effects of LSAP announcements on the portfolio allocation of mutual funds. This contrasts with the results once expectations are taken into account, as the monetary policy surprise variable Fed Announcement does in the benchmark specification. Recall that announcement surprises did exert significant effects on equity funds which tend to switch away from the US towards the ROW and tilt the composition of the ROW share towards developed markets other than the US, at the expense of the EM share in the ROW weight.

In Section 7.2, we carry out a complementary analysis of the pure signalling effect of LSAP announcements that takes into account financial market expectations for all the major central banks' unconventional monetary policies.

6 Robustness checks

This section carries out robustness checks to see whether the results from the benchmark model continue to hold when: controlling for unconventional monetary by other major central banks; measuring Fed asset purchases in proportion to the size of the US economy; and expressing the portfolio weightings in first differences. This section also discusses the results of panel unit-root tests on the log portfolio weightings.

6.1 Controlling for global ex-US QE

For unconventional monetary policy by the other main central banks, we build a control variable to account for 'global ex-US' quantitative easing. This is constructed as the first principal component of (i) changes in the size of the balance sheet of the Bank of England, the Bank of Japan and the European Central Bank, measured in percentage of GDP of the economies of the UK, Japan and the Euro-Zone respectively; and (ii) the surprise component of unconventional monetary policy announcements of their respective central banks. Principal component analysis is used to capture any joint unconventional monetary easing action, or announcement surprises, by the BoE, BoJ and ECB.

Table 4: *Controlling for global ex-US QE (equity funds)*

	(1)	(2)	(3)
VARIABLES	US	ROW	DMexUS
Log lagged weight	0.663***	0.922***	0.866***
Fed Treasury purchases	-0.0334***	0.00278***	0.0103***
Fed MBSAD purchases	0.0138	8.25e-05	-0.00435
Fed announcement	-0.00524	0.00251***	8.29e-05
Global ex-US QE	0.00325*	-0.000900***	-0.00440***
Observations	6,722	11,662	10,209
Number of fundid	262	288	282
Adjusted R-squared	0.556	0.854	0.765
Fund fixed effects	Yes	Yes	Yes

The results from adding this control to the main empirical specification is that the benchmark results for equity funds continue to hold. The results for bond funds regarding the effects from Fed announcements continue to be statistically non-significant. The results for both fund types are reported in

Appendix 9.5. Here we focus on equity funds.

Table 4 shows that Fed Treasury purchases (columns $1-3$) prompt equity fund managers to reduce their US portfolio weightings and increase their exposure to the ROW, whilst also triggering a change in the composition of the ROW share in favour of developed markets, excluding the US, at the expense of emerging markets.

Surprise policy easing by the Fed (column 2) is associated with equity funds increasing their portfolio exposure to the ROW. The effects for the regressions on the US and DMexUS weights are non -significant as in the benchmark model that did not include the global ex-US QE control.

Fed policy surprises as well as Treasury purchases are less economically significant compared with that in the main benchmark specification.

The global ex-US QE variable has the opposite effect to that of QE by the US Fed. (See column 2). When the ECB, BoE and BoJ jointly ease monetary conditions, equity funds move out of the ROW, while the share of emerging markets in the ROW share increases. US QE has the opposite effect of triggering equity fund managers to increase both the portfolio weightings in the ROW as well as the relative share of developed markets.

6.2 Alternative measure of Fed asset purchases

Asset purchases by the Fed can be measured in terms of the change in the monetary value of Treasuries held, and, respectively, MBS plus agency debt. However, measuring asset purchases in this manner can be misleading as it does not account for the amount of debt instruments that expire each month. In the benchmark model, we overcame this issue by expressing asset purchases in percentage terms of the outstanding amount of the asset purchased. This relates to the measure of ’asset scarcity’ that the Fed may be contributing to by way of reducing the share of outstanding quantity of Treasuries, or MBS and agency debt available to the private sector. This has been pointed out empirically by D’Amico, English, López-Salido and Nelson (2012), as well as theoretically by Greenwood and Vayanos (2014).

Alternatively, one can express the US Fed’s asset purchases as a percentage of US GDP, and thereby relate unconventional monetary operations to the size of the US economy. We find that the results for bond and equity funds continue to carry over from the benchmark specification. Full results are presented in Appendix 9.5.

6.3 Panel-unit root tests

There may be a concern that the portfolio weightings in log levels are non-stationary. This would lead to spurious regressions and seriously undermine any results. An examination of the average portfolio weightings of mutual funds (see Appendix 9.3) may lead one to think that the log weightings used for the empirical specification are non-stationary, given their rather high persistence. To examine this formally, we implement Fisher panel unit root tests. The benefit of the Fisher-type test is that it can be applied to unbalanced panels and, instead of a common persistence coefficient, it allows for auto-regressive coefficients that are heterogeneous between panels, that is fund-specific.

The panel unit-root tests strongly reject the hypothesis that the log portfolio weightings expressed in levels are non-stationary. The null hypothesis is that “all panels contain unit roots” against the alternative “at least one panel is stationary.” Tables 5 and 6 present the results of the Fisher unit-root test on the log portfolio weights. We report the Z-statistic and p-values of the null hy-

Table 5: *Panel unit-root tests (equity funds)*

	Z-statistic (p-value) of Fisher unit-root test for			
Log Weight	US	ROW	DMexUS	cash
Demean/trend (no/no)	-14.3939	-5.9101	-14.4916	-87.5019
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Demean/trend (yes/yes)	-14.2533	-5.6342	-14.1902	-88.0604
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Number of panels	285	862	674	855
Avg. number of periods	27.99	43.30	35.01	38.25

pothesis using the Phillips-Perron specification. The Z-statistic is reported as the most appropriate in practice, according to Choi (2001). Using the Phillips-Perron instead of the augmented Dickey-Fuller specification, we make the test robust to serial correlation in the error by using a heteroscedasticity and auto-correlation consistent estimator. The number of the lags are set in proportion to the time dimension of the panel. Our sample spans $10/2008$ to $04/2014$ so we include 4 Newey-West lags. The asymptotic assumptions of the test are that the time-dimension of the panel T approaches infinity, while the number of cross-sections N can be finite.

A p-value close to zero allows us to reject the null hypothesis in favour of the alternative hypothesis that at least one fund's portfolio weighting in log levels is stationary. As the number of panels N increases, the number of funds that do not have a unit root in their log portfolio weighting is proportional to the number of panels. Examining the results allows us to assume that all log level weightings are indeed stationary.

The dependent variable can be expressed in first differences if there was any remaining concern regarding the issue of non-stationarity. The results of this transformation into first-differences are reported in Appendix 9.5 and show that they are similar to those for the regression in levels. Namely, Treasury purchases push equity funds to increase the Rest of the World weight in their portfolio, and tilts the ROW share in favour of developed markets. The same directional effect can be observed for announcement surprises in equity and bond funds. Yet, one notes that asset purchases have a significant effect on bond funds in the regression in first-differences, in contrast to the regression in levels.

Given that there is no cause to be concerned about non-stationarity, and because the results are similar in both specifications, one reason to prefer the regression in levels over the regression in first-differences is one of economic interpretation. Underpinning our main empirical specification in levels is the partial adjustment portfolio model. As explained in Section 4.1, the partial adjustment model supposes that (i) the current level of portfolio exposure to a region $X_{it} \equiv \log W_{it}$ is a function of the desired portfolio weighting in that period X_{it}^* and the previous period's realised weighting. The observed portfolio allocation this period is assumed to be affected by the previous period's allocation: $X_{it} = \theta X_{it}^* + (1-\theta)X_{it-1}$. If one were to express the dependent variable in first-differences, $X_{it} \equiv \Delta \log W_{it}$, then (ii) the observed portfolio change is affected by the previous period's change. In this second case, it is supposed that a fund, moving into a region in one period, would have to continue to rebalance its portfolio towards that region in the next period, even if the desired re-allocation in that period is zero.

It is arguable whether or not mutual fund managers face adjustment costs and constraints in terms of the level or, instead, the change of the portfolio weighting, i.e. whether the (i) the *allocation* in one period is constrained by the portfolio allocation in the previous period, or if, instead, (ii) the *re-allocation* in

Table 6: *Panel unit-root tests (bond funds)*

	Z-statistic (p-value) of Fisher unit-root test for			
Log Weight	US	ROW	DMexUS	cash
Demean/trend (no/no)	-3.3692	-9.0485	-3.8310	-28.1191
	(0.0004)	(0.0000)	(0.0001)	(0.0000)
Demean/trend (yes/yes)	-12.1506	-11.3106	-8.2991	-27.4579
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Number of panels	46	141	63	132
Avg. number of periods	27.04	39.33	25.92	34.47

one period is constrained by the portfolio re-allocation in the previous period. The model, using the portfolio weightings in differences rests on the second case, whilst the first case motivates the model expressing the portfolio weights in levels.

7 Extensions

This section estimates the effects of unconventional monetary policy announcements across the major central banks. It also investigates if there is a differential effect between asset purchase related announcements and other announcements.

7.1 Announcements surprises by the major central banks

It would be interesting to compare and contrast how unconventional monetary policy surprises from all the main major central banks, i.e. the Fed, European Central Bank, Bank of Japan and Bank of England, affect international mutual funds' portfolio allocations. This is what we have done in the following section.

The focus is on how managers of equity and bond funds respond to unconventional monetary announcement surprises. We drop the variables relating to purchases, given that it is difficult to compare the myriad set of asset purchase programmes across central banks.

First, we consider the unconventional monetary policy surprises jointly across the Fed, ECB, BoJ and BoE by taking the first principal component of the four policy surprises series. Second, we consider each central bank separately and compare how mutual fund managers adjust their portfolio exposure to the US and the Rest of the World, and whether the composition of the ROW share, as made up for developed markets excluding the US and emerging markets, is affected by unconventional monetary policy surprises.

The main result for equity funds is summarised in Table 7.[14] Column II shows that a surprise unconventional monetary easing by the main central banks jointly drives equity fund managers to increase the portfolio weighting of countries in the Rest of the World excluding the US.

We find the same effect emanating from a surprise easing by the US Fed (column $II.2$) and the Bank of Japan (column $II.4$) separately. Notably, portfolio rebalancing effects from the BoJ policy surprises are economically more significant than the US Fed's policy surprises. Column III indicates that the composition of the ROW weight also changes, tilting in favour of developed markets other than the US, at the expense of the relative share of emerging and frontier markets in the ROW weight. The effects from the Bank of Japan are the largest in terms of economic significance: compare a magnitude of 0.0565 for the BoJ surprises with 0.0117 for the US Fed surprises.

The main result for bond funds is summarised in Table 8. Similar to the benchmark model, the effects of monetary policy surprises are less significant

[14] The full results from this exercise are reported in Appendix 9.7.

Table 7: *Policy surprises by major central banks (equity funds)*

		Log portfolio weight		
		(I)	(II)	(III)
Announcement surprises		US	ROW	DMexUS
1	Global UMP announcement	-0.00418	0.000955***	0.00161*
or: 2	Fed announcement	0.0132	0.00174*	-0.00365
or: 3	ECB announcement	0.00125	-0.000109	-0.00178
or: 4	BoJ announcement	-0.109***	0.0228***	0.0339**
or: 5	BoE announcement	-0.0235	-0.00119	0.0103**
	Fixed effects and LDV	Yes	Yes	Yes
	Observations	6,722	11,662	10,209
	No. of fund id	262	288	282

for bond funds than for equity funds overall. The effect from policy surprises of all main central banks jointly, does not seem to exert any statistically significant effect in terms of pushing bond funds out of the US and into the Rest of the World. This might be partly due to the fact that while the Fed, ECB and BoJ policy surprises separately push bond funds into the ROW, policy surprises by the Bank of England seem to exert the opposite effect, triggering bond fund managers to increase their portfolio exposure to the US (column $I.5$), while decreasing their exposure to the Rest of the World (column $II.5$). Also, BoE policy surprises tilt the distribution within the ROW weight in bond funds in favour of emerging markets at the expense of the relative share of developed markets (column $III.5$).

The implication is that, for equity funds, unconventional monetary policy surprises by the main central banks, whether jointly or separately, seem to exert an effect in one direction: equity funds increase the weighting of the Rest of World in their portfolio, and change the composition thereof in favour

Table 8: *Policy surprises by major central banks (bond funds)*

		Log portfolio weight		
		(I)	(II)	(III)
	Announcement surprises	US	ROW	DMexUS
1	Global UMP announcement	-0.00292	0.00164	-0.00320
or: 2	Fed announcement	-0.0245	0.0107	- 0.0138
or: 3	ECB announcement	-0.0269	0.00150	0.0173
or: 4	BoJ announcement	-0.151**	0.0675**	-0.0250
or: 5	BoE announcement	0.0714**	-0.0265**	-0.00541
	Fixed effects and LDV	Yes	Yes	Yes
	Observations	1,091	1,982	1,215
	No. of fund id	39	51	40

of developed markets excluding the US. Bond funds also rebalance towards the ROW, but this finding is of weaker statistical significance.

In order to analyse further these preliminary results for the effects of policy surprises by the major central banks, one needs to study how asset purchase programmes and policy surprises of, say, the Bank of England affect the UK in terms of mutual fund intermediated capital flows. One would see how the BoE policy operations and surprises effect mutual funds portfolio weightings in the UK, the Rest of the World and developed markets excluding the UK; and similarly for the effects of the BoJ and ECB on international mutual funds.

7.2 Effects of different types of announcements

In this section, we investigate if there is a differential effect between asset purchase related announcement surprises relative to other type of announcement surprises for the major central banks. This contrasts with the previous section, where announcements were not differentiated by type. The classification follows that of Rogers et. al. (2014) which is described in Appendix 9.1.2.

Table 9: *Policy surprises by major central banks (equity funds)* – Differentiated by type of announcements

Surprise announcements differentiated by type		Log portfolio weight (I) US	(II) ROW	(III) DMexUS
Global	LSAP-type announcement	-0.000757	0.000251*	0.000540
	Other	-0.00624**	0.000273	0.000925
Fed	LSAP announcement	-0.00614	0.00233**	-0.00108
	Other	0.0559	0.00549*	0.00660
ECB	LTRO announcement	-0.00394	0.000193	-0.00218
	Other	0.126***	-0.00412	0.0208*
BoJ	APP announcement	-0.0937**	0.0229***	-0.0275
	Other	-0.124**	0.0239***	0.0604***
BoE	APF announcement	-0.0161	0.00369***	0.00905
	Other	-0.0405	-0.00797***	0.0169**
	Fixed effects and LDV	Yes	Yes	Yes
	Observations	6,722	11,662	10,209
	No. of fund id	262	288	282

Analysing the effects of different types of announcements is implemented by running the regression for unconventional monetary policy (UMP) announcement surprises separately on (1) the series where the monetary policy surprise is an asset purchase/LTRO announcement, and then on (2) the series of monetary policy surprises related to “other” types of UMP announcements-. The ’other’ type of announcements might relate to forward guidance by the central bank about the likely future path of policy rates, according to Rogers et. al. (2014). The results are summarised in Tables 9 and 10. The 'global' announcement variable is constructed as the first principal component of the underlying series for the four central banks.

Table 10: *Policy surprises by major central banks (bond funds)* – Differentiated by type of announcements

Surprise announcements differentiated by type		Log portfolio weight (I) US	(II) ROW	(III) DMexUS
Global	LSAP-type announcement	0.00254	-0.000857	-0.00183
	Other	0.00603	-0.000516	0.00202
Fed	LSAP announcement	-0.00558	0.00909	-0.0185
	Other	-0.0944*	0.0126	-0.0121
ECB	LTRO announcement	-0.0214	0.000991	0.0224
	Other	-0.187	0.0256*	-0.124
BoJ	APP announcement	-0.0444	0.0273	0.0547
	Other	-0.171**	0.0779**	-0.0539
BoE	APF announcement	0.0539*	-0.0262**	8.10e-05
	Other	0.0943	-0.0213	-0.0240
	Fixed effects and LDV	Yes	Yes	Yes
	Observations	1,091	1,982	1,215
	No. of fund id	39	51	40

The important overall result from this analysis is that the magnitude of the effect of LSAP-related announcement surprises is smaller than that of forward guidance and other type of announcements. Furthermore, there is a lot of heterogeneity in the significance, sign and size of the effects. Announcement surprises by the BoJ seem to exert a statistically significant effect on both equity and bond funds in the same direction: the portfolio of the US decreases, and the ROWexUS weighting increases. Interesting, the BoJ effects are economically larger than any significant effects emanating from announcement surprises by the other main central banks.

8 Conclusion

We are interested in how mutual fund managers, through their asset allocation decisions, transmit US unconventional monetary policy to other countries. This speaks to the policy issue of whether fund managers or their underlying client investors, or both jointly, are responsible for the capital flows, rushing to and from emerging markets, in response to QE by central banks in developed markets. In addressing this issue – one of the main findings of this paper – is that the weighting of developed markets relative to emerging markets in equity fund portfolios is, if at all, positively but not negatively affected by unconventional monetary policy in the US.

This finding seems to obvert the assertion often made by some commentators to the effect that fund managers have contributed to the 'tsunami' phenomenon of capital flows migrating to certain emerging markets following the unconventional monetary policy response in developed countries in the wake of the 2007/8 financial crisis. We cannot find significant evidence for the hypothesis that mutual fund managers were significantly tilting their portfolio towards emerging market economies. A possible interpretation of this finding is that the QE-induced mutual fund capital flows seeping to emerging markets are due more to the underlying client investors opting to take their money out of DM-dedicated funds in order to switch from one fund to another, specifically to EM-dedicated funds.

The finding that international mutual funds portfolio exposure to developed markets, relative to emerging markets, seems to be positively, or at least not negatively, affected by unconventional monetary policy, implies that fund managers are leaning against the wind of what Fratzscher et al. (2013) and the IMF (2013) found for *country flows*. That is, mutual fund intermediated flows shifted from the US and developed markets towards emerging markets in some phases of US QE, though partly reversed following June 2013 when the Fed suggested a tapering or scaling back of quantitative easing.

The contribution to the literature of our analysis of *portfolio weightings* is that these capital flows to EMs are most likely due to underlying client investors switching to investing in funds dedicated to emerging markets, rather than fund managers changing their relative portfolio weightings.

When considering policy surprises by all the major central banks in developed markets, we find evidence that neither a surprise monetary easing by the Fed, ECB, BoE and BoJ jointly, nor by them separately, exerts a positive effect on mutual funds portfolio weighting of emerging markets. In fact we find a significant positive effect from policy easing surprises on the developed markets ex-US weight in equity funds.

This paper has analysed the immediate impact of policy actions and surprises. It is of equal importance to ascertain whether these effects persist over time, or quickly reverse, both of which may have destabilising effects for the countries receiving these capital flows. Suitable techniques for analysis in this regard include vector auto-regressions and local-projection methods. See Jorda (2005). Complementary extensions are to analyse the model at longer than monthly frequencies, such as quarterly or half-yearly, and to examine evidence for any lag structure in the response of mutual funds to unconventional monetary policy.

A possible implication of the main findings for regulatory policy is that capital flow management measures should perhaps be aimed less at constricting the asset allocation by fund managers, but instead place greater focus on circumscribing underlying client investors decisions to withdraw their capital on demand from mutual funds. This notion of imposing ’exit fees’ on client investors has already gathered support at a policy level, such as from the formed Fed governor Jeremy Stein (2014). Theoretical work by Feroli et. al. (2014) suggests how unlevered financial actors, such as mutual funds, can be a source of financial stability when they are subject to client investors that can withdraw money on demand, despite the mutual funds possibly having difficulty in immediately liquidating their investments to meet those redemption requests. The maturity transformation thus performed by mutual funds, especially bond funds, may be a source of market dislocation and financial instability once monetary policy starts tightening.

9 Empirical Appendix

9.1 Unconventional monetary policy

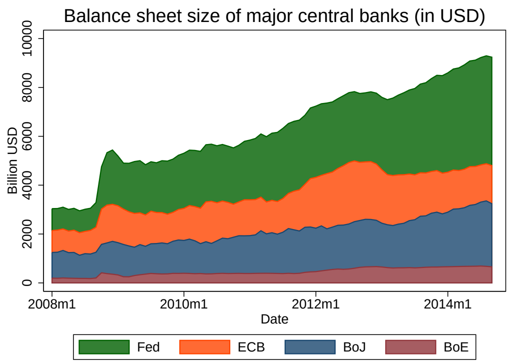


Figure 3: Size of asset holdings of major central banks in USD

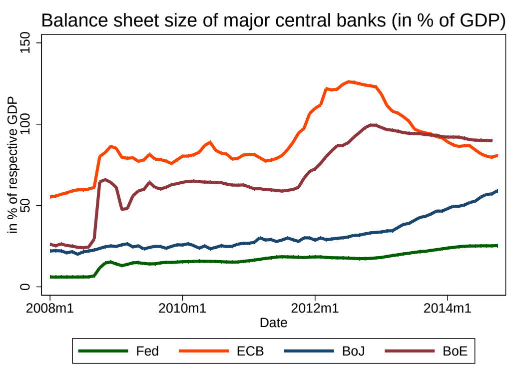


Figure 4: Size of asset holdings of major central banks in % of GDP

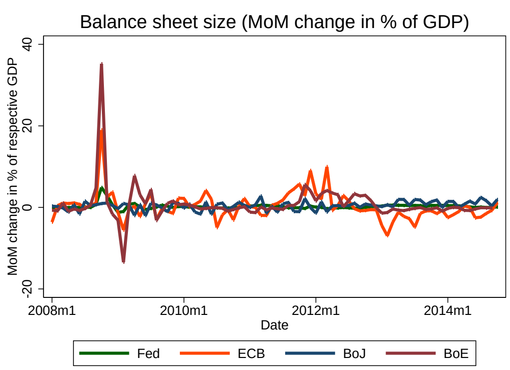


Figure 5: Change in size of asset holdings of major central banks in % of GDP

9.1.1 US Fed's large-scale asset purchase programs

Hancock and Passmore (2014) provide the following overview:

US Fed's LSAP phases

- QE1: November 2008 – March 31, 2010 [coded as 2008/10 – 2010/04]
  - Purchase MBS backed by Ginnie Mae, Fannie Mae and Freddie Mac
  - Purchase agency debt
- QE2: August 2010 – June 20, 2011 [coded as 2010/05 – 2011/06]
  - Purchase longer-term US Treasury securities
- Operation Twist: September 2011 [coded as 2011/07 – 2012/08]
  - Extend average maturity of US Treasury holdings
  - Reinvest income from agency debt and MBS into MBS, rather than US Treasuries
- QE3: commenced September 13, 2012 [coded as 2012/09 onwards]
  - Purchase Agency MBS. Extend average maturity of agency debt holdings and agency MBS holdings
  - Continue to reinvest income from agency debt and agency MBS into agency MBS

LSAPs consist of the US Fed purchasing "longer-term securities issued by the U.S. government and longer-term securities issued or guaranteed by government-sponsored agencies such as Fannie Mae or Freddie Mac." See http://1.usa.gov/1LKAoBq.

9.1.2 Unconventional monetary policy announcements by type

Table 11: Unconventional monetary policy announcements

	Announcements by major central banks (type of announcement)			
	US Fed (LSAP)	ECB (LTRO)	BoJ (APP)	BoE (APF)
Date	2008-11-25	2008-03-28	2010-10-05	2009-01-19
	2008-12-01	2009-05-07	2010-10-28	2009-01-29
	2008-12-16	2009-06-04	2011-03-14	2009-02-11
	2009-01-28	2009-12-03	2011-08-04	2009-03-05
	2009-03-18	2010-03-04	2011-10-27	2009-05-07
	2010-08-27	2010-05-09	2012-02-14	2009-08-06
	2010-09-21	2011-03-03	2012-04-27	2009-11-05
	2010-10-15	2011-08-04	2012-07-12	2010-02-04
	2011-08-26	2011-08-07	2012-09-19	2011-10-06
	2012-06-20	2011-10-06	2012-10-30	2012-02-09
	2012-09-13	2011-12-08	2012-12-20	2012-07-05
	2013-05-22	2012-02-09	2013-01-22	
		2012-02-28	2013-04-04	
		2012-07-26		
		2012-08-02		
		2012-09-06		

Source: Classification of announcements as in Rogers, Scotti, and Wright (2014).

9.2 Global asset management industry

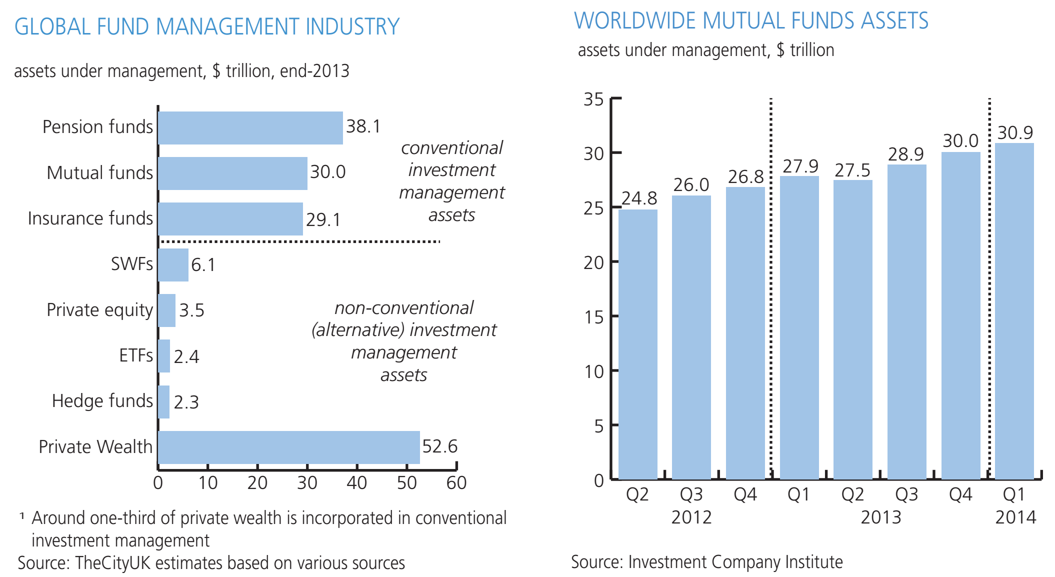
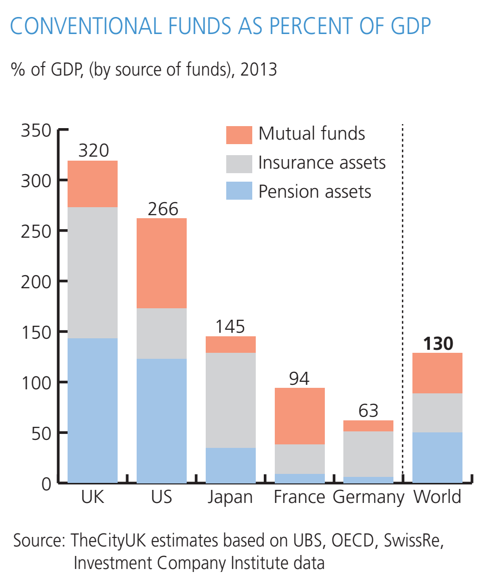


Figure 6: Size of Mutual Fund Industry



LARGEST GLOBAL INVESTMENT MANAGEMENT CENTRES

$bn, end-2013	Pension funds	Insurance assets	Mutual funds	Total conventional	% share
US	21,233	8,458	15,018	44,709	*46.0*
UK	3,618	3,282	1,167	8,067	*8.3*
Japan	1,732	4,620	774	7,126	*7.3*
France	265	781	1,532	2,578	*2.7*
Germany	242	1,649	383	2,274	*2.3*
Netherlands	1,346	354	85	1,785	*1.8*
Switzerland	804	428	397	1,628	*1.7*
Other	8,866	9,538	10,674	29,078	*29.9*
Total	38,106	29,109	30,030	97,245	*100.0*

¹ figures are for domestically sourced funds regardless where they are managed. No reliable comparisons are available for total funds under management by country
Source: TheCityUK estimates based on UBS, OECD, SwissRe, Investment Company Institute data

Figure 7: Geography of Mutual Fund Industry

Source: TheCityUK (2014)

9.3 Mutual fund data-set

Table 12: *Equity funds*

Mth/Yr	2007	2008	2009	2010	2011	2012	2013	2014	Avg (mth)
1	359	395	413	454	456	514	583	635	476
2	379	366	425	452	486	507	596	642	482
3	356	388	427	448	484	511	595	636	481
4	383	371	426	435	482	514	608	639	482
5	389	389	449	458	489	505	605	634	490
6	380	383	451	452	492	496	602	626	485
7	379	386	451	470	498	491	616	627	490
8	389	389	457	479	506	501	606	625	494
9	400	410	450	481	498	534	623	618	502
10	399	408	436	470	509	562	639	602	503
11	379	425	449	479	514	576	641	n/a	495
12	377	413	441	464	510	590	637	n/a	490
Avg (yr)	381	394	440	462	494	525	613	628	488
Total	4569	4723	5275	5542	5924	6301	7351	6284	

Table 13: *Bond funds*

Mth/Yr	2007	2008	2009	2010	2011	2012	2013	2014	Avg (mth)
1	65	57	56	60	70	78	96	101	73
2	63	56	56	58	73	78	101	90	72
3	61	56	55	58	72	81	102	90	72
4	64	56	52	56	73	81	104	89	72
5	65	56	60	62	77	81	97	90	74
6	62	56	59	63	77	81	98	90	73
7	59	57	59	59	74	83	99	87	72
8	57	56	61	66	78	84	96	88	73
9	59	59	57	70	76	88	98	89	75
10	60	56	59	69	77	91	100	85	75
11	58	54	58	74	78	94	97	n/a	73
12	57	56	59	73	77	96	101	n/a	74
Avg (yr)	61	56	58	64	75	85	99	90	73
Total	730	675	691	768	902	1016	1189	899	

Maximum consecutive runs of portfolio data

Table 14: *Equity funds*

Maxrun	Observations	in %
1-2 years	6,437	9.25
2-4 years	14,313	20.56
4-6 years	15,627	22.45
6+ years	33,229	47.74
Total	69,606	100

Table 15: *Bond funds*

Maxrun	Observations	in %
1-2 years	952	10.59
2-4 years	2,305	25.65
4-6 years	2,285	25.43
6+ years	3,445	38.33
Total	8,987	100

Geographical investment focus

Table 16: Geographical investment focus of equity funds

Investment Focus	Obs.	(in %)	Funds	(in %)	AUM	(in %)
Africa	394	0.53	9	0.85	35,309	0.06
Asia ex-Japan	15,288	20.59	176	16.70	6,886,943	11.26
BRIC	894	1.2	13	1.23	952,324	1.56
Emerging Europe	7,910	10.65	81	7.69	2,285,283	3.74
Europe Regional	5,724	7.71	125	11.86	3,856,185	6.31
Europe ex-UK	4,199	5.66	83	7.87	3,210,566	5.25
EMEA Regional	576	0.78	9	0.85	157,304	0.26
Global	7,824	10.54	154	14.61	11,168,409	18.32
Global Emerging Markets	16,176	21.79	191	18.12	15,545,326	25.35
Global ex-US	4,370	5.89	74	7.02	13,534,217	22.08
Latin America	6,685	9	80	7.59	2,165,012	3.54
Middle East & Africa	651	0.88	13	1.23	97,105	0.16
Middle East	581	0.78	9	0.85	66,946	0.11
Pacific Regional	2,980	4.01	37	3.51	1,238,710	2.03
Total	74,252		1054		61,199,640	

Table 17: Geographical investment focus of bond funds

Investment Focus	Obs.	(in %)	Funds	(in %)	AUM	(in %)
Asia ex-Japan	620	6.9	14	8.64	493,809	4.57
Emerging Europe	390	4.34	7	4.32	78,045	0.72
Europe ex-UK	45	0.5	1	0.62	138,329	1.28
Global	1,876	20.87	35	21.60	4,942,998	45.71
Global Emerging Markets	5,417	60.28	96	59.26	5,067,297	46.86
Global ex-US	62	0.69	1	0.62	4,805	0.04
Latin America	577	6.42	8	4.94	89,075	0.82
Total	8,987		162		10,814,358	

Fund domicile

Table 18: Domicile of equity funds

Fund Domicile	Obs.	(in %)	Funds	(in %)	AUM	(in %)
Australia	291	0.42	5	0.47	238,584	0.39
Austria	697	1.00	9	0.85	154,035	0.25
BVI	550	0.79	6	0.57	168,277	0.27
Bahrain	210	0.30	4	0.38	13,008	0.02
Belgium	583	0.84	9	0.85	70,056	0.11
Bermuda	237	0.34	2	0.19	22,817	0.04
Canada	2,244	3.22	31	2.94	822,722	1.34
Cayman	442	0.64	7	0.66	123,097	0.20
Denmark	1,045	1.50	15	1.42	121,608	0.20
Estonia	123	0.18	1	0.09	7,592	0.01
Finland	313	0.45	7	0.66	32,661	0.05
France	2,129	3.06	39	3.70	1,080,556	1.77
Germany	1,247	1.79	27	2.56	2,129,377	3.48
Guernsey	929	1.33	12	1.14	314,932	0.51
Hong Kong	57	0.08	4	0.38	24,709	0.04
Ireland	5,687	8.17	79	7.50	2,052,050	3.35
Japan	55	0.08	3	0.28	2,382	0.00
Jersey	216	0.31	6	0.57	16,301	0.03
Luxembourg	25,840	37.12	378	35.90	18,861,948	30.82
Mauritius	105	0.15	2	0.19	55,608	0.09
Netherlands	292	0.42	5	0.47	53,154	0.09
Norway	294	0.42	8	0.76	589,590	0.96
Singapore	171	0.25	3	0.28	26,051	0.04
Sweden	154	0.22	7	0.66	85,152	0.14
Switzerland	1,344	1.93	18	1.71	299,698	0.49
USA	12,930	18.58	220	20.89	25,907,588	42.33
United Kingdom	11,421	16.41	146	13.87	7,926,086	12.95
Total	69,606		1053		61,199,639	

Table 19: Domicile of bond funds

Fund Domicile	Obs.	(in %)	Funds	(in %)	AUM	(in %)
Austria	39	0.43	1	0.62	9,404	0.09
Bahamas	42	0.47	2	1.23	1,198	0.01
Canada	105	1.17	1	0.62	99,851	0.92
Cayman	70	0.78	1	0.62	160,569	1.48
Denmark	479	5.33	8	4.94	193,658	1.79
Germany	44	0.49	1	0.62	3,445	0.03
Guernsey	349	3.88	3	1.85	657,263	6.08
Ireland	1,048	11.66	19	11.73	572,486	5.29
Japan	18	0.20	1	0.62	8,205	0.08
Luxembourg	4,281	47.64	85	52.47	2,989,416	27.64
Singapore	17	0.19	1	0.62	107	0.01
USA	1,898	21.12	28	17.28	5,839,302	54.00
United Kingdom	597	6.64	11	6.79	279,458	2.58
Total	8,987		162		10,814,362	

Investment style

Table 20: Equity funds’ investment style

	Currency			Maturity						High	Total		
				Short	Intermediate			Long					
Investment Focus	Blend	Hard	Local	Govt	Any	Corp	Govt	Corp	Govt	Yield	Return	n/a	Total
Asia ex-Japan	194	196	230	0	0	0	0	0	0	0	0	0	620
Emerging Europe	243	0	147	0	0	0	0	0	0	0	0	0	390
Europe ex-UK	0	0	0	0	0	0	45	0	0	0	0	0	45
Global	0	0	0	259	502	160	544	17	54	204	56	80	1,876
GEM	745	3,494	1,178	0	0	0	0	0	0	0	0	0	5,417
Global ex-US	0	0	0	0	62	0	0	0	0	0	0	0	62
Latin America	24	529	24	0	0	0	0	0	0	0	0	0	577
Total	1,206	4,219	1,579	259	564	160	589	17	54	204	56	80	8,987
in %	13%	47%	18%	3%	6%	2%	7%	0%	1%	2%	1%	1%	100%

Equity funds: average portfolio allocation

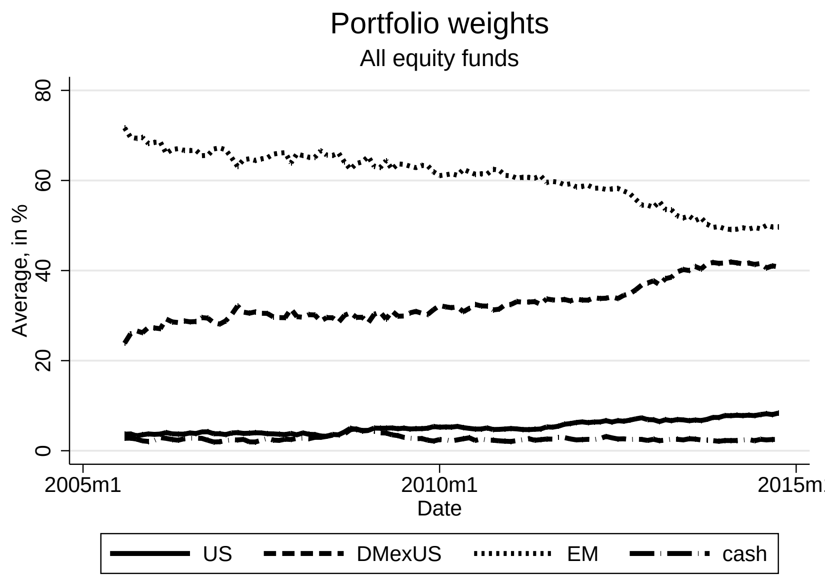


Figure 8:

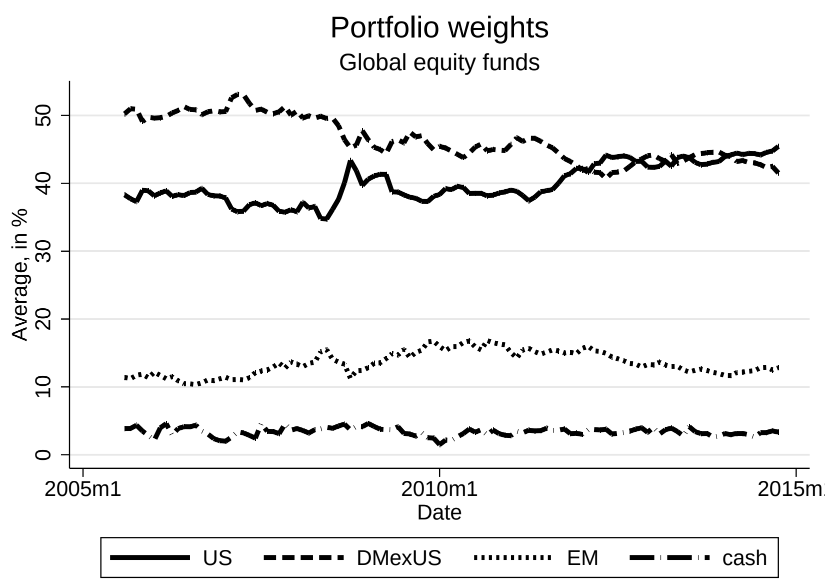


Figure 9:

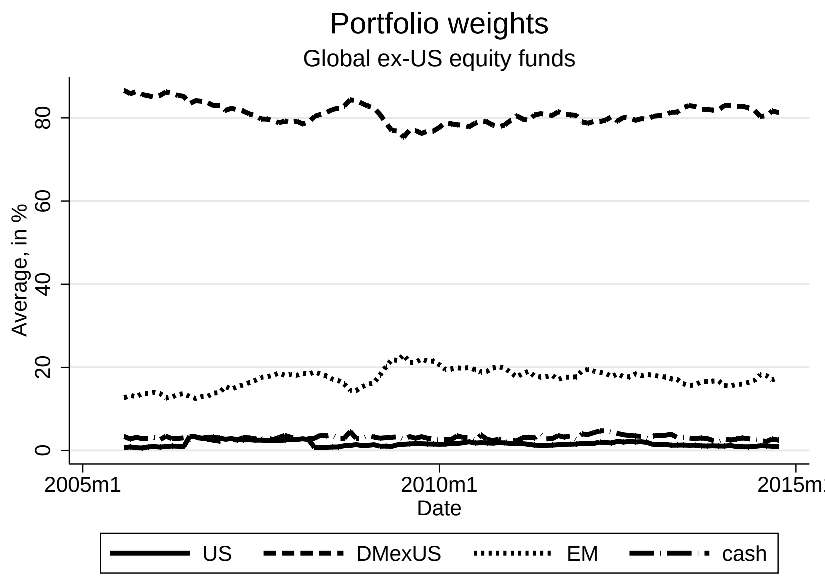


Figure 10:

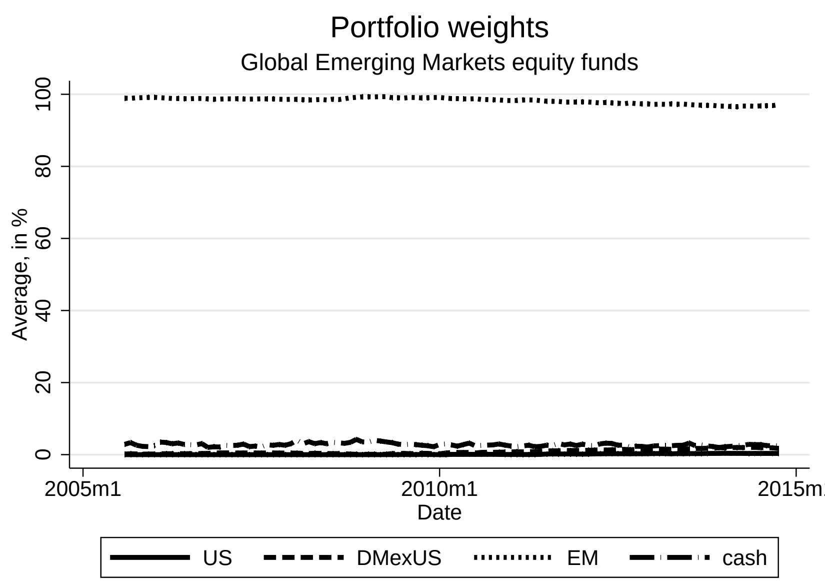


Figure 11:

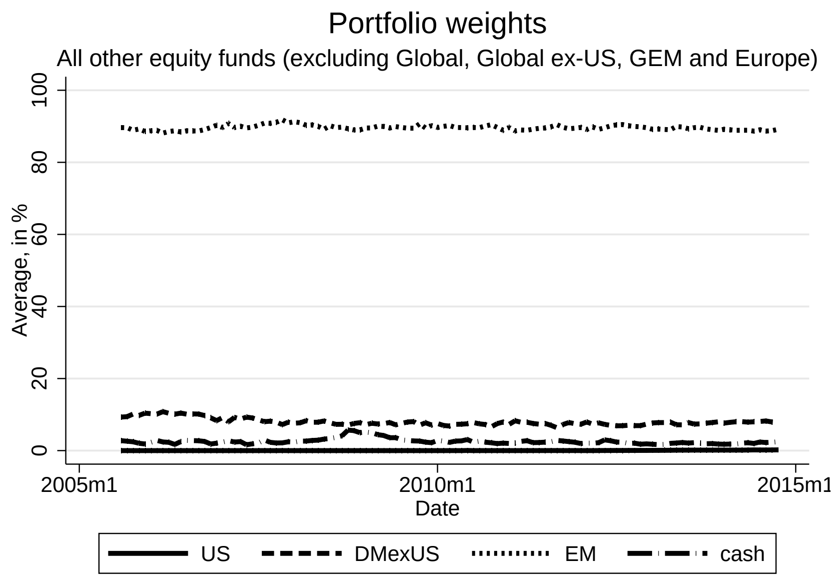


Figure 12:

Bond funds: average portfolio allocation

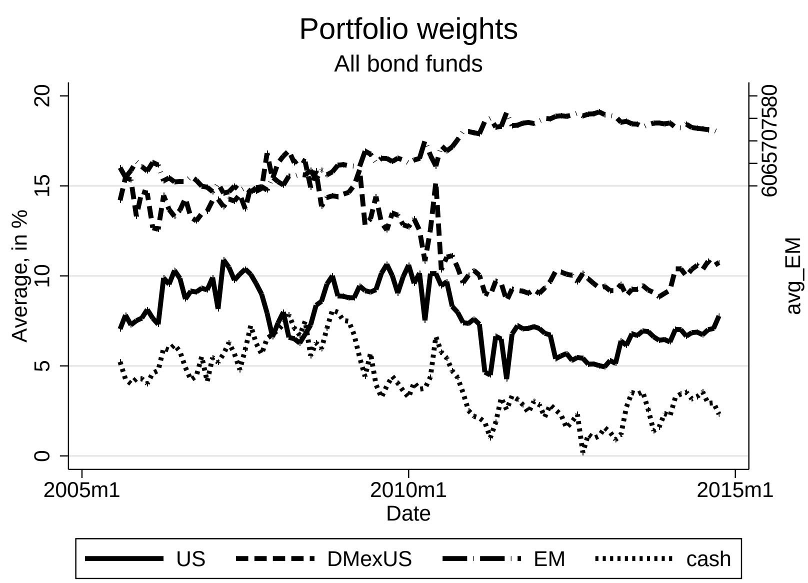


Figure 13:

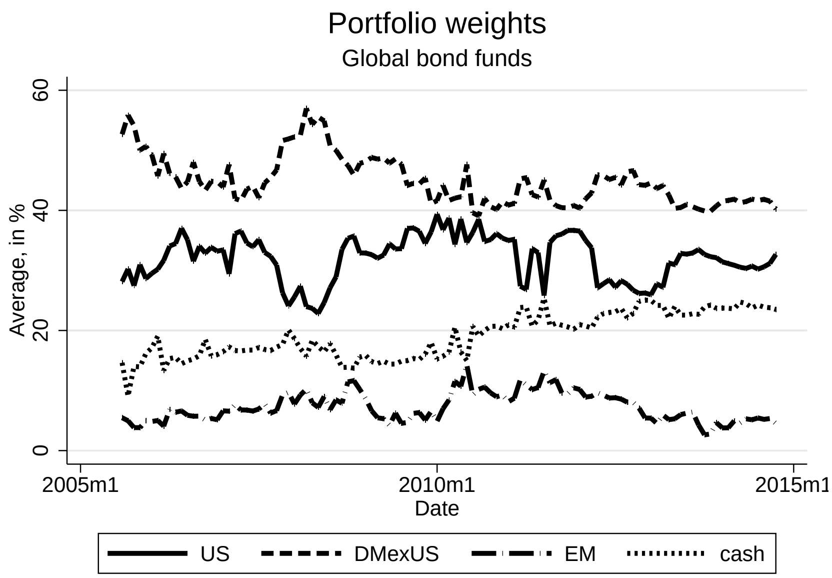


Figure 14:

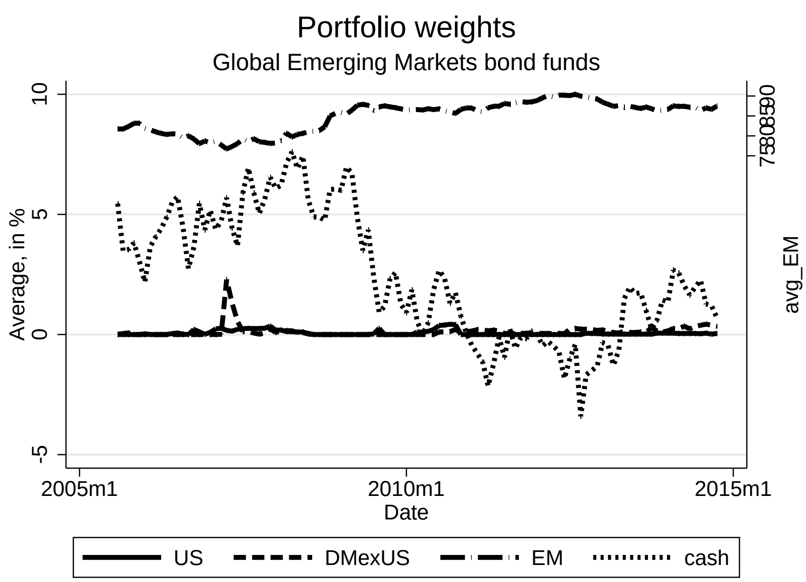


Figure 15:

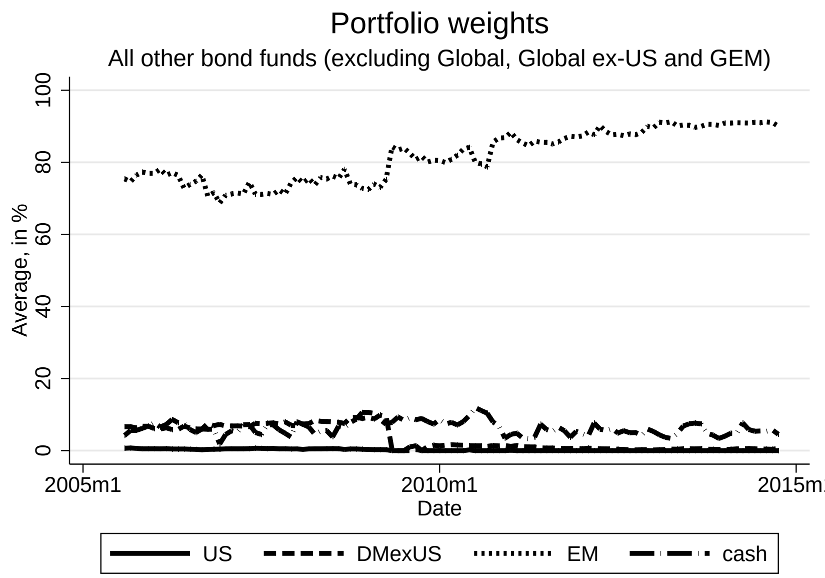


Figure 16:

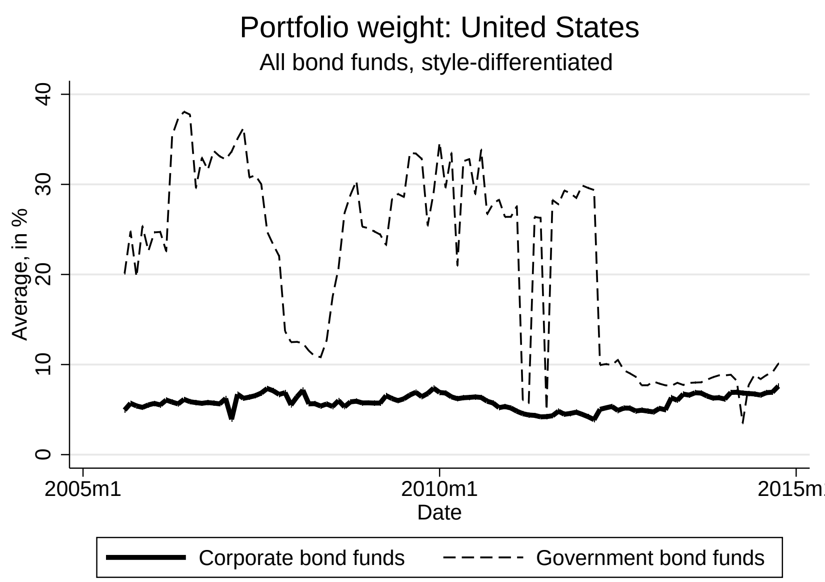


Figure 17:

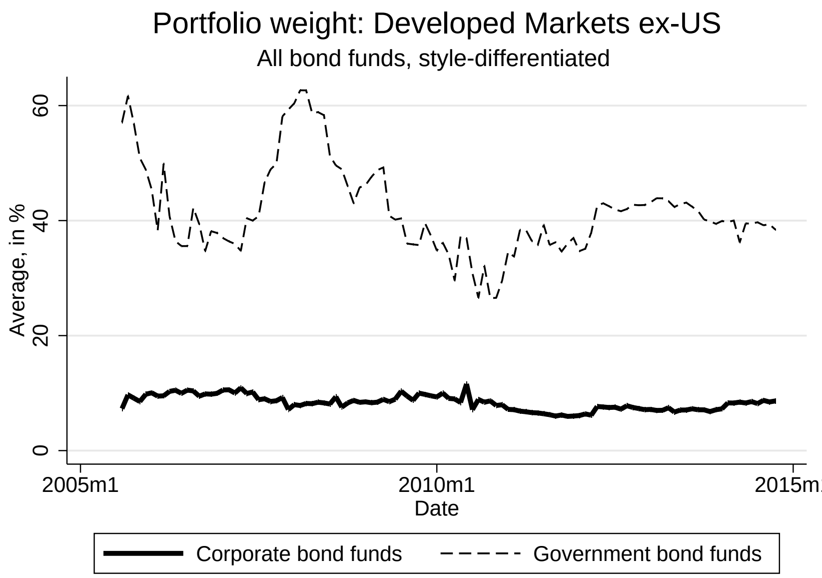


Figure 18:

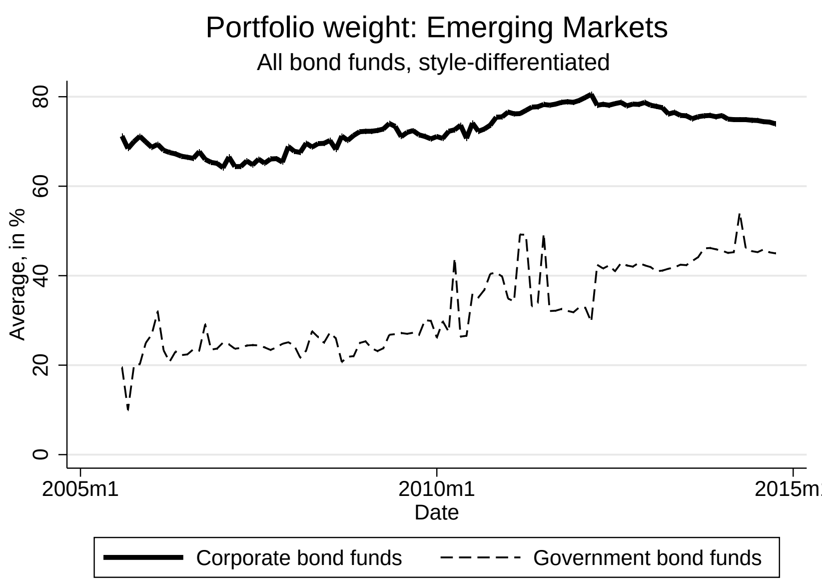


Figure 19:

9.4 Estimation results

The tables below the estimated effect of unconventional monetary policy operations and surprise announcements in the US and other explanatory variables on the weight of region X_{it} in the portfolio of fund i and month t:

$$X_{it} = \rho X_{it-1} + \beta \mathbf{MP}_t + \mu + \phi_i + \epsilon_{it}$$

$$\text{with } \mathbf{MP}_t = [asset\,purchases_t, policy\,surprises_t]$$

The variable X_{it} represents the log of portfolio weightings of fund i in month t of a country or a set of countries $X \in${US, Rest of the World excluding the US (ROW), Developed Markets excluding US (DMexUS)}.

We allow for fund-specific intercepts by including fund fixed-effects ϕ_i so as to account for unobserved time-invariant differences between funds.

The effects of unconventional monetary policy are measured by the coefficients on the policy variable $\mathbf{MP}_t$ which includes unconventional monetary policy surprises and operations. The coefficient β should pick up the indirect and direct effects of unconventional monetary policy on the portfolio weightings.

The portfolio weightings of all countries have been re-weighted to exclude a fund's cash holdings, which we report separately, and are expressed in percentage points. The functional form of the weighting in the benchmark specification is the portfolio weighting in log levels. A robustness check considers other forms such as the log weights in first-differences.

The set of explanatory variables consist of six elements. (1) A lagged dependent variable, whereby the weighting from the previous month (X_{it-1}) is included owing to the theoretical considerations described by the partial adjustment model. The monetary policy vector $\mathbf{MP}_t$ comprises (2) unconventional monetary policy operations in the form of asset purchases of mortgage-backed securities and agency debt (MBSAD) as well as Treasury securities purchases.

Full sample

Table 21: Equity Funds

VARIABLES	(1) US	(2) ROW	(3) DMexUS	(4) cash
Log lagged weight	0.663***	0.921***	0.868***	0.328***
	(0.0511)	(0.0128)	(0.0390)	(0.0206)
Fed Treasury purchases	-0.0358***	0.00342***	0.0136***	-0.0371
	(0.0129)	(0.000906)	(0.00341)	(0.0229)
Fed MBSAD purchases	0.0119	0.000560	-0.00185	0.00993
	(0.0106)	(0.000487)	(0.00275)	(0.0207)
Fed announcement	-0.00795	0.00330***	0.00387	0.00312
	(0.0174)	(0.000960)	(0.00473)	(0.0308)
Constant	0.901***	0.343***	0.498***	0.536***
	(0.135)	(0.0562)	(0.146)	(0.0176)
Observations	6,722	11,662	10,209	10,451
Number of fundid	262	288	282	285
Adjusted R-squared	0.556	0.854	0.764	0.108
Fund fixed effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 22: Bond Funds

VARIABLES	(1) US	(2) ROW	(3) DMexUS	(4) cash
Log lagged weight	0.882***	0.861***	0.710***	0.430***
	(0.0439)	(0.0358)	(0.0691)	(0.0485)
Fed Treasury purchases	0.00577	-0.00241	0.0271**	-0.0251
	(0.0202)	(0.00446)	(0.0117)	(0.0518)
Fed MBSAD purchases	0.00313	-0.00215	0.0117	-0.208***
	(0.00846)	(0.00426)	(0.00855)	(0.0475)
Fed announcement	-0.0162	0.00962	-0.0158	0.0814
	(0.0145)	(0.00798)	(0.0123)	(0.0946)
Constant	0.334***	0.605***	1.099***	1.026***
	(0.120)	(0.157)	(0.264)	(0.0949)
Observations	1,091	1,982	1,215	1,671
Number of fundid	39	51	40	47
Adjusted R-squared	0.736	0.732	0.510	0.219
Fund fixed effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Sub-samples: individual US QE programmes

Equity funds

Table 23: **Portfolio allocation to US**

	Log US Weight				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	All	QE1	QE2	Op.Twist	QE3
Log lagged weight	0.663***	0.531***	0.726***	0.542***	0.546***
	(0.0511)	(0.0220)	(0.0840)	(0.104)	(0.137)
Fed Treasury purchases	-0.0358***	-0.0549**	0.00758	-0.0359	0.0748***
	(0.0129)	(0.0235)	(0.0177)	(0.0442)	(0.0255)
Fed MBSAD purchases	0.0119	0.0220	0.0267	0.0694	-0.0358*
	(0.0106)	(0.0170)	(0.0378)	(0.0425)	(0.0207)
Fed announcement	-0.00795	-0.00180	0.0272	-0.122***	0.0414*
	(0.0174)	(0.0249)	(0.0450)	(0.0350)	(0.0222)
Constant	0.901***	1.366***	0.711***	1.268***	1.123***
	(0.135)	(0.0640)	(0.214)	(0.281)	(0.345)
Observations	6,722	1,327	1,041	1,396	2,958
Number of fundid	262	97	101	126	221
Adjusted R-squared	0.556	0.436	0.528	0.447	0.301
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Equity funds

Table 24: **Portfolio allocation to Rest of the World**

	Log ROW Weight				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	All	QE1	QE2	Op.Twist	QE3
Log lagged weight	0.921***	0.845***	0.869***	0.832***	0.757***
	(0.0128)	(0.0362)	(0.0650)	(0.0190)	(0.0356)
Fed Treasury purchases	0.00342***	0.00948***	-0.00444**	0.0226***	-0.0150***
	(0.000906)	(0.00180)	(0.00220)	(0.00759)	(0.00314)
Fed MBSAD purchases	0.000560	-0.00202*	-0.00439	-0.00186	0.00603**
	(0.000487)	(0.00122)	(0.00290)	(0.00327)	(0.00302)
Fed announcement	0.00330***	0.00336***	-3.75e-06	0.0168***	0.00487
	(0.000960)	(0.00111)	(0.00429)	(0.00450)	(0.00371)
Constant	0.343***	0.683***	0.582**	0.732***	1.059***
	(0.0562)	(0.159)	(0.286)	(0.0835)	(0.154)
Observations	11,662	2,698	2,031	2,567	4,366
Number of fundid	288	163	173	199	260
Adjusted R-squared	0.854	0.712	0.702	0.714	0.579
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Equity funds

Table 25: **Portfolio allocation to Developed Markets ex. US**

	Log DMexUS Weight				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	All	QE1	QE2	Op.Twist	QE3
Log lagged weight	0.868***	0.731***	0.512***	0.694***	0.892***
	(0.0390)	(0.0987)	(0.107)	(0.0523)	(0.0516)
Fed Treasury purchases	0.0136***	-0.000996	0.0621***	0.0491**	0.0217**
	(0.00341)	(0.00541)	(0.0105)	(0.0233)	(0.00890)
Fed MBSAD purchases	-0.00185	-0.00808	0.111***	-0.0209	0.00981
	(0.00275)	(0.00582)	(0.0197)	(0.0138)	(0.0120)
Fed announcement	0.00387	0.0123***	0.0816***	-0.00592	-0.0198
	(0.00473)	(0.00434)	(0.0154)	(0.0115)	(0.0192)
Constant	0.498***	1.064***	1.791***	1.127***	0.393**
	(0.146)	(0.393)	(0.390)	(0.192)	(0.196)
Observations	10,209	2,181	1,748	2,253	4,027
Number of fundid	282	149	157	181	250
Adjusted R-squared	0.764	0.441	0.504	0.544	0.569
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Bond funds

Table 26: **Portfolio allocation to US**

	Log US Weight				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	All	QE1	QE2	Op.Twist	QE3
Log lagged weight	0.882***	0.708***	0.757***	0.497***	0.513**
	(0.0439)	(0.0474)	(0.0955)	(0.0669)	(0.214)
Fed Treasury purchases	0.00577	0.0290	-0.0207	-0.0582	0.0565
	(0.0202)	(0.0307)	(0.0313)	(0.344)	(0.121)
Fed MBSAD purchases	0.00313	-0.0273	0.00158	-0.176	-0.0798
	(0.00846)	(0.0241)	(0.0411)	(0.120)	(0.114)
Fed announcement	-0.0162	-0.00991	0.00891	0.0853	0.00947
	(0.0145)	(0.0194)	(0.127)	(0.0664)	(0.0389)
Constant	0.334***	0.880***	0.744**	1.405***	1.346**
	(0.120)	(0.140)	(0.273)	(0.225)	(0.589)
Observations	1,091	314	197	198	382
Number of fundid	39	23	19	19	26
Adjusted R-squared	0.736	0.484	0.586	0.336	0.232
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Bond funds

Table 27: **Portfolio allocation to Rest of the World**

	Log ROW Weight				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	All	QE1	QE2	Op.Twist	QE3
Log lagged weight	0.861***	0.902***	0.355***	0.420**	0.710***
	(0.0358)	(0.0360)	(0.0899)	(0.159)	(0.1000)
Fed Treasury purchases	-0.00241	-0.00904	-0.00877	-0.00768	0.000182
	(0.00446)	(0.0104)	(0.0170)	(0.0227)	(0.00711)
Fed MBSAD purchases	-0.00215	-0.00106	-0.0341	0.0175	-0.00137
	(0.00426)	(0.00685)	(0.0420)	(0.0194)	(0.0119)
Fed announcement	0.00962	0.0127	-0.0275	-0.0164	0.00350
	(0.00798)	(0.0131)	(0.0467)	(0.0197)	(0.00724)
Constant	0.605***	0.421***	2.803***	2.529***	1.272***
	(0.157)	(0.153)	(0.389)	(0.692)	(0.437)
Observations	1,982	540	362	389	691
Number of fundid	51	34	33	33	40
Adjusted R-squared	0.732	0.731	0.130	0.247	0.527
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Bond funds

Table 28: **Portfolio allocation to Developed Markets ex. US**

	Log DMexUS Weight				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	All	QE1	QE2	Op.Twist	QE3
Log lagged weight	0.710***	0.665***	0.760***	0.481***	0.586***
	(0.0691)	(0.0805)	(0.0775)	(0.143)	(0.104)
Fed Treasury purchases	0.0271**	0.0164	0.0658**	-0.0416	0.148
	(0.0117)	(0.0242)	(0.0291)	(0.0554)	(0.0877)
Fed MBSAD purchases	0.0117	-0.000873	-0.0290	0.0196	-0.0200
	(0.00855)	(0.0140)	(0.0690)	(0.0414)	(0.0545)
Fed announcement	-0.0158	-0.00704	0.0853	0.0340	-0.0827*
	(0.0123)	(0.0136)	(0.0605)	(0.0410)	(0.0467)
Constant	1.099***	1.406***	0.899**	2.132***	1.362***
	(0.264)	(0.343)	(0.317)	(0.595)	(0.350)
Observations	1,215	310	207	221	477
Number of fundid	40	20	20	21	31
Adjusted R-squared	0.510	0.481	0.577	0.256	0.350
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

9.5 Robustness checks

Controlling for global ex-US QE

Table 29: *Equity funds*

	(1)	(2)	(3)
VARIABLES	US	ROW	DMexUS
Log lagged weight	0.663***	0.922***	0.866***
Fed Treasury purchases	-0.0334***	0.00278***	0.0103***
Fed MBSAD purchases	0.0138	8.25e-05	-0.00435
Fed announcement	-0.00524	0.00251***	8.29e-05
Global ex-US QE	0.00325*	-0.000900***	-0.00440***
Observations	6,722	11,662	10,209
Number of fundid	262	288	282
Adjusted R-squared	0.556	0.854	0.765
Fund fixed effects	Yes	Yes	Yes

Table 30: *Bond funds*

	(1)	(2)	(3)
VARIABLES	US	ROW	DMexUS
Log lagged weight	0.882***	0.860***	0.706***
Fed Treasury purchases	0.00820	-0.00434	0.0305**
Fed MBSAD purchases	0.00506	-0.00354	0.0147*
Fed announcement	-0.0122	0.00686	-0.0107
Global ex-US QE	0.00400	-0.00294	0.00553**
Observations	1,091	1,982	1,215
Number of fundid	39	51	40
Adjusted R-squared	0.736	0.733	0.511
Fund fixed effects	Yes	Yes	Yes

Expressing US Fed purchases as % of US GDP

Table 31: *Equity funds*

	(1)	(2)	(3)	(4)
VARIABLES	US	ROW	DMexUS	cash
Log lagged weight	0.664***	0.922***	0.867***	0.327***
	(0.0510)	(0.0127)	(0.0390)	(0.0206)
d_FedTreas_gdp	-0.0465**	0.00438***	0.0269***	-0.0893**
	(0.0202)	(0.00144)	(0.00632)	(0.0387)
d_FedMBSAD_gdp	0.0123	0.00136*	-0.00409	0.0314
	(0.0173)	(0.000767)	(0.00440)	(0.0336)
Fed announcement	-0.00456	0.00297***	0.00462	-0.00418
	(0.0176)	(0.000959)	(0.00474)	(0.0305)
Constant	0.897***	0.341***	0.498***	0.540***
	(0.135)	(0.0558)	(0.146)	(0.0178)
Observations	6,722	11,662	10,209	10,451
Number of fundid	262	288	282	285
Adjusted R-squared	0.556	0.854	0.764	0.108
Fund fixed effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 32: *Bond funds*

VARIABLES	(1) US	(2) ROW	(3) DMexUS	(4) cash
Log lagged weight	0.882***	0.861***	0.709***	0.431***
	(0.0441)	(0.0358)	(0.0690)	(0.0486)
d_FedTreas_gdp	0.00432	-0.00237	0.0454**	-0.0672
	(0.0373)	(0.00663)	(0.0206)	(0.0891)
d_FedMBSAD_gdp	0.00810	-0.00428	0.0217	-0.330***
	(0.0136)	(0.00731)	(0.0133)	(0.0763)
Fed announcement	-0.0178	0.0101	-0.0171	0.0814
	(0.0147)	(0.00801)	(0.0121)	(0.0944)
Constant	0.333***	0.606***	1.098***	1.026***
	(0.119)	(0.157)	(0.263)	(0.0953)
Observations	1,091	1,982	1,215	1,671
Number of fundid	39	51	40	47
Adjusted R-squared	0.736	0.732	0.510	0.219
Fund fixed effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Log weights in first-differences

Table 33: *Equity funds*

VARIABLES	(1) Δ US	(2) Δ ROW	(3) Δ DMexUS	(4) Δ cash
Lagged Δ in log weight	-0.0862*	-0.0278	0.0316	-0.427***
	(0.0491)	(0.0489)	(0.0335)	(0.0129)
Fed Treasury purchases	-0.00382	0.00225**	0.0110***	0.0138
	(0.00628)	(0.000907)	(0.00216)	(0.0188)
Fed MBSAD purchases	0.00743	0.000730	-0.00185	-0.0136
	(0.0112)	(0.000495)	(0.00165)	(0.0119)
Fed announcement	0.0138	0.00300***	0.00667	-0.0405
	(0.0160)	(0.000878)	(0.00517)	(0.0329)
Constant	0.00396	-0.00160***	-0.000926	-0.00744
	(0.00397)	(0.000285)	(0.000834)	(0.00653)
Observations	6,422	11,377	9,891	9,860
Number of fundid	257	288	282	283
Adjusted R-squared	0.007	0.002	0.002	0.182
Fund fixed effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 34: *Bond funds*

VARIABLES	(1) Δ US	(2) Δ ROW	(3) Δ DMexUS	(4) Δ cash
Lagged Δ in log weight	-0.110	-0.115***	-0.306***	-0.372***
	(0.0714)	(0.0228)	(0.0834)	(0.0333)
Fed Treasury purchases	-0.0120	-0.00561	0.0367**	0.0125
	(0.0162)	(0.00641)	(0.0147)	(0.0362)
Fed MBSAD purchases	0.00622	-0.00392	0.00310	0.0134
	(0.00479)	(0.00455)	(0.00496)	(0.0317)
Fed announcement	-0.0243	0.0113	-0.0150	-0.0731
	(0.0154)	(0.00735)	(0.0117)	(0.0984)
Constant	0.000235	0.00207	-0.00982**	-0.0122
	(0.00480)	(0.00289)	(0.00473)	(0.0150)
Observations	1,053	1,940	1,175	1,586
Number of fundid	37	51	40	46
Adjusted R-squared	0.010	0.015	0.103	0.140
Fund fixed effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

9.6 Pure signalling effects of LSAPs

Table 35: *Equity funds*

	(1)	(2)	(3)	(4)
VARIABLES	US	ROW	DMexUS	cash
Log lagged weight	0.663***	0.922***	0.867***	0.328***
	(0.0510)	(0.0128)	(0.0390)	(0.0206)
Fed Treasury purchases	-0.0339***	0.00301***	0.0132***	-0.0362
	(0.0123)	(0.000880)	(0.00339)	(0.0223)
Fed MBSAD purchases	0.0110	0.00105**	-0.00128	0.0107
	(0.00905)	(0.000482)	(0.00258)	(0.0203)
LSAP Announcement Dummy	0.0103*	0.000635	0.00149	0.0113
	(0.00607)	(0.000473)	(0.00269)	(0.0173)
Constant	0.898***	0.340***	0.498***	0.533***
	(0.135)	(0.0561)	(0.146)	(0.0180)
Observations	6,722	11,662	10,209	10,451
Number of fundid	262	288	282	285
Adjusted R-squared	0.556	0.854	0.764	0.108
Fund fixed effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 36: *Bond funds*

VARIABLES	(1) US	(2) ROW	(3) DMexUS	(4) cash
Log lagged weight	0.880***	0.861***	0.711***	0.430***
	(0.0433)	(0.0359)	(0.0687)	(0.0488)
Fed Treasury purchases	0.0115	-0.00361	0.0304**	-0.0320
	(0.0205)	(0.00491)	(0.0124)	(0.0518)
Fed MBSAD purchases	0.00150	-0.000611	0.00920	-0.194***
	(0.00981)	(0.00365)	(0.00804)	(0.0503)
LSAP Announcement Dummy	0.0173	0.00198	0.00404	0.0341
	(0.0113)	(0.00295)	(0.00644)	(0.0421)
Constant	0.332***	0.607***	1.093***	1.018***
	(0.117)	(0.157)	(0.262)	(0.0951)
Observations	1,091	1,982	1,215	1,671
Number of fundid	39	51	40	47
Adjusted R-squared	0.736	0.732	0.509	0.219
Fund fixed effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

9.7 Unconventional monetary policy by major central banks

Table 37: *Equity funds*

VARIABLES	(1) US	(2) US	(3) US	(4) US	(5) US
Lagged_log_weight	0.665***	0.666***	0.665***	0.665***	0.665***
	(0.0508)	(0.0507)	(0.0509)	(0.0508)	(0.0508)
GlobalAnn	-0.00418				
	(0.00332)				
FedAnn		0.0132			
		(0.0144)			
ECBAnn			0.00125		
			(0.00473)		
BoJAnn				-0.109***	
				(0.0404)	
BoEAnn					-0.0235
					(0.0270)
Constant	0.887***	0.885***	0.887***	0.886***	0.887***
	(0.134)	(0.133)	(0.134)	(0.134)	(0.133)
Observations	6,722	6,722	6,722	6,722	6,722
Number of fundid	262	262	262	262	262
Adjusted R-squared	0.555	0.556	0.555	0.556	0.555
Fund fixed effects	Yes	Yes	Yes	Yes	Yes
Major CB QE control	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 38: *Bond funds*

	(1)	(2)	(3)	(4)	(5)
VARIABLES	US	US	US	US	US
Lagged_log_weight	0.882***	0.882***	0.883***	0.882***	0.883***
	(0.0423)	(0.0425)	(0.0417)	(0.0423)	(0.0424)
GlobalAnn	-0.00292				
	(0.00301)				
FedAnn		-0.0245			
		(0.0154)			
ECBAnn			-0.0269		
			(0.0174)		
BoJAnn				-0.151**	
				(0.0689)	
BoEAnn					0.0714**
					(0.0310)
Constant	0.335***	0.336***	0.334***	0.334***	0.334***
	(0.121)	(0.122)	(0.120)	(0.121)	(0.121)
Observations	1,091	1,091	1,091	1,091	1,091
Number of fundid	39	39	39	39	39
Adjusted R-squared	0.736	0.736	0.737	0.737	0.738
Fund fixed effects	Yes	Yes	Yes	Yes	Yes
Major CB QE control	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 39: *Equity funds*

VARIABLES	(1) ROW	(2) ROW	(3) ROW	(4) ROW	(5) ROW
Lagged_log_weight	0.922***	0.923***	0.922***	0.923***	0.923***
	(0.0126)	(0.0125)	(0.0126)	(0.0126)	(0.0126)
GlobalAnn	0.000955***				
	(0.000202)				
FedAnn		0.00174*			
		(0.000977)			
ECBAnn			-0.000109		
			(0.000592)		
BoJAnn				0.0228***	
				(0.00438)	
BoEAnn					-0.00119
					(0.00121)
Constant	0.339***	0.338***	0.339***	0.337***	0.338***
	(0.0552)	(0.0549)	(0.0551)	(0.0550)	(0.0554)
Observations	11,662	11,662	11,662	11,662	11,662
Number of fundid	288	288	288	288	288
Adjusted R-squared	0.854	0.854	0.854	0.854	0.854
Fund fixed effects	Yes	Yes	Yes	Yes	Yes
Major CB QE control	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 40: *Bond funds*

VARIABLES	(1) ROW	(2) ROW	(3) ROW	(4) ROW	(5) ROW
Lagged_log_weight	0.860***	0.860***	0.860***	0.861***	0.862***
	(0.0369)	(0.0365)	(0.0369)	(0.0366)	(0.0358)
GlobalAnn	0.00164				
	(0.00119)				
FedAnn		0.0107			
		(0.00830)			
ECBAnn			0.00150		
			(0.00134)		
BoJAnn				0.0675**	
				(0.0282)	
BoEAnn					-0.0265**
					(0.0130)
Constant	0.608***	0.607***	0.607***	0.604***	0.601***
	(0.160)	(0.159)	(0.161)	(0.159)	(0.156)
Observations	1,982	1,982	1,982	1,982	1,982
Number of fundid	51	51	51	51	51
Adjusted R-squared	0.732	0.733	0.733	0.734	0.735
Fund fixed effects	Yes	Yes	Yes	Yes	Yes
Major CB QE control	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 41: *Equity funds*

VARIABLES	(1) DMexUS	(2) DMexUS	(3) DMexUS	(4) DMexUS	(5) DMexUS
Lagged_log_weight	0.867***	0.867***	0.867***	0.867***	0.867***
	(0.0392)	(0.0391)	(0.0391)	(0.0391)	(0.0391)
GlobalAnn	0.00161*				
	(0.000857)				
FedAnn		-0.00365			
		(0.00476)			
ECBAnn			-0.00178		
			(0.00209)		
BoJAnn				0.0339**	
				(0.0162)	
BoEAnn					0.0103**
					(0.00438)
Constant	0.505***	0.505***	0.505***	0.506***	0.505***
	(0.148)	(0.147)	(0.147)	(0.147)	(0.147)
Observations	10,209	10,209	10,209	10,209	10,209
Number of fundid	282	282	282	282	282
Adjusted R-squared	0.764	0.764	0.764	0.764	0.764
Fund fixed effects	Yes	Yes	Yes	Yes	Yes
Major CB QE control	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 42: *Bond funds*

VARIABLES	(1) DMexUS	(2) DMexUS	(3) DMexUS	(4) DMexUS	(5) DMexUS
Lagged_log_weight	0.709***	0.709***	0.709***	0.709***	0.708***
	(0.0695)	(0.0694)	(0.0689)	(0.0693)	(0.0693)
GlobalAnn	-0.00320				
	(0.00201)				
FedAnn		-0.0138			
		(0.0114)			
ECBAnn			0.0173		
			(0.0185)		
BoJAnn				-0.0250	
				(0.0335)	
BoEAnn					-0.00541
					(0.0116)
Constant	1.112***	1.112***	1.112***	1.112***	1.115***
	(0.265)	(0.265)	(0.263)	(0.265)	(0.265)
Observations	1,215	1,215	1,215	1,215	1,215
Number of fundid	40	40	40	40	40
Adjusted R-squared	0.508	0.508	0.508	0.507	0.507
Fund fixed effects	Yes	Yes	Yes	Yes	Yes
Major CB QE control	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

9.8 Different types of unconventional monetary policy announcements

9.8.1 LSAP Announcements

Table 43: *Equity funds*

	(1)	(2)	(3)	(4)	(5)
VARIABLES	US	US	US	US	US
Lagged_log_weight	0.665***	0.665***	0.665***	0.665***	0.665***
	(0.0509)	(0.0509)	(0.0509)	(0.0508)	(0.0509)
Global_LSAP	-0.000757				
	(0.00188)				
FedAnn_LSAP		-0.00614			
		(0.0151)			
ECBAnn_LSAP			-0.00394		
			(0.00516)		
BoJAnn_LSAP				-0.0937**	
				(0.0444)	
BoEAnn_LSAP					-0.0161
					(0.0144)
Constant	0.887***	0.887***	0.887***	0.887***	0.887***
	(0.134)	(0.134)	(0.134)	(0.134)	(0.134)
Observations	6,722	6,722	6,722	6,722	6,722
Number of fundid	262	262	262	262	262
Adjusted R-squared	0.555	0.555	0.555	0.555	0.555
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 44: *Bond funds*

VARIABLES	(1) US	(2) US	(3) US	(4) US	(5) US
Lagged_log_weight	0.882***	0.882***	0.882***	0.882***	0.881***
	(0.0425)	(0.0423)	(0.0417)	(0.0422)	(0.0426)
Global_LSAP	0.00254				
	(0.00239)				
FedAnn_LSAP		-0.00558			
		(0.0163)			
ECBAnn_LSAP			-0.0214		
			(0.0211)		
BoJAnn_LSAP				-0.0444	
				(0.134)	
BoEAnn_LSAP					0.0539*
					(0.0284)
Constant	0.337***	0.336***	0.336***	0.336***	0.337***
	(0.121)	(0.121)	(0.120)	(0.121)	(0.122)
Observations	1,091	1,091	1,091	1,091	1,091
Number of fundid	39	39	39	39	39
Adjusted R-squared	0.736	0.736	0.737	0.736	0.737
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 45: *Equity funds*

	(1)	(2)	(3)	(4)	(5)
VARIABLES	ROW	ROW	ROW	ROW	ROW
Lagged_log_weight	0.923***	0.923***	0.923***	0.923***	0.923***
	(0.0126)	(0.0126)	(0.0126)	(0.0126)	(0.0127)
Global_LSAP	0.000251*				
	(0.000133)				
FedAnn_LSAP		0.00233**			
		(0.000971)			
ECBAnn_LSAP			0.000193		
			(0.000605)		
BoJAnn_LSAP				0.0229***	
				(0.00633)	
BoEAnn_LSAP					0.00369***
					(0.00122)
Constant	0.338***	0.338***	0.337***	0.337***	0.338***
	(0.0553)	(0.0552)	(0.0552)	(0.0552)	(0.0554)
Observations	11,662	11,662	11,662	11,662	11,662
Number of fundid	288	288	288	288	288
Adjusted R-squared	0.854	0.854	0.854	0.854	0.854
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 46: *Bond funds*

VARIABLES	(1) ROW	(2) ROW	(3) ROW	(4) ROW	(5) ROW
Lagged_log_weight	0.861***	0.860***	0.860***	0.860***	0.862***
	(0.0363)	(0.0371)	(0.0365)	(0.0365)	(0.0351)
Global_LSAP	-0.000857				
	(0.000772)				
FedAnn_LSAP		0.00909			
		(0.0102)			
ECBAnn_LSAP			0.000991		
			(0.00122)		
BoJAnn_LSAP				0.0273	
				(0.0186)	
BoEAnn_LSAP					-0.0262**
					(0.0129)
Constant	0.607***	0.609***	0.608***	0.608***	0.603***
	(0.158)	(0.161)	(0.159)	(0.159)	(0.153)
Observations	1,982	1,982	1,982	1,982	1,982
Number of fundid	51	51	51	51	51
Adjusted R-squared	0.732	0.732	0.732	0.732	0.733
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 47: *Equity funds*

VARIABLES	(1) DMexUS	(2) DMexUS	(3) DMexUS	(4) DMexUS	(5) DMexUS
Lagged_log_weight	0.867***	0.867***	0.867***	0.867***	0.867***
	(0.0392)	(0.0391)	(0.0391)	(0.0392)	(0.0392)
Global_LSAP	0.000540				
	(0.000608)				
FedAnn_LSAP		-0.00108			
		(0.00481)			
ECBAnn_LSAP			-0.00218		
			(0.00225)		
BoJAnn_LSAP				-0.0275	
				(0.0188)	
BoEAnn_LSAP					0.00905
					(0.00586)
Constant	0.505***	0.506***	0.505***	0.506***	0.505***
	(0.147)	(0.147)	(0.147)	(0.148)	(0.148)
Observations	10,209	10,209	10,209	10,209	10,209
Number of fundid	282	282	282	282	282
Adjusted R-squared	0.763	0.763	0.763	0.764	0.764
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 48: *Bond funds*

VARIABLES	(1) DMexUS	(2) DMexUS	(3) DMexUS	(4) DMexUS	(5) DMexUS
Lagged_log_weight	0.709***	0.709***	0.710***	0.710***	0.709***
	(0.0694)	(0.0694)	(0.0687)	(0.0693)	(0.0694)
Global_LSAP	-0.00183				
	(0.00194)				
FedAnn_LSAP		-0.0185			
		(0.0139)			
ECBAnn_LSAP			0.0224		
			(0.0206)		
BoJAnn_LSAP				0.0547	
				(0.0770)	
BoEAnn_LSAP					8.10e-05
					(0.0145)
Constant	1.110***	1.111***	1.109***	1.109***	1.112***
	(0.265)	(0.265)	(0.262)	(0.265)	(0.265)
Observations	1,215	1,215	1,215	1,215	1,215
Number of fundid	40	40	40	40	40
Adjusted R-squared	0.507	0.508	0.509	0.507	0.507
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

9.8.2 Non-LSAP Announcements

Table 49: *Equity funds*

VARIABLES	(1) US	(2) US	(3) US	(4) US	(5) US
Lagged_log_weight	0.665***	0.665***	0.665***	0.665***	0.666***
	(0.0506)	(0.0509)	(0.0507)	(0.0509)	(0.0505)
Global_NonLSAP	-0.00624**				
	(0.00266)				
FedAnn_NonLSAP		0.0559			
		(0.0380)			
ECBAnn_NonLSAP			0.126***		
			(0.0256)		
BoJAnn_NonLSAP				-0.124**	
				(0.0582)	
BoEAnn_NonLSAP					-0.0405
					(0.0619)
Constant	0.885***	0.888***	0.886***	0.885***	0.885***
	(0.133)	(0.134)	(0.133)	(0.134)	(0.132)
Observations	6,722	6,722	6,722	6,722	6,722
Number of fundid	262	262	262	262	262
Adjusted R-squared	0.556	0.555	0.556	0.556	0.555
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 50: *Bond funds*

	(1)	(2)	(3)	(4)	(5)
VARIABLES	US	US	US	US	US
Lagged_log_weight	0.881***	0.882***	0.880***	0.883***	0.883***
	(0.0417)	(0.0425)	(0.0411)	(0.0421)	(0.0426)
Global_NonLSAP	0.00603				
	(0.00506)				
FedAnn_NonLSAP		-0.0944*			
		(0.0522)			
ECBAnn_NonLSAP			-0.187		
			(0.132)		
BoJAnn_NonLSAP				-0.171**	
				(0.0708)	
BoEAnn_NonLSAP					0.0943
					(0.0634)
Constant	0.339***	0.333***	0.342***	0.332***	0.337***
	(0.119)	(0.122)	(0.116)	(0.121)	(0.121)
Observations	1,091	1,091	1,091	1,091	1,091
Number of fundid	39	39	39	39	39
Adjusted R-squared	0.737	0.737	0.737	0.737	0.737
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 51: *Equity funds*

VARIABLES	(1) ROW	(2) ROW	(3) ROW	(4) ROW	(5) ROW
Lagged_log_weight	0.923***	0.923***	0.923***	0.923***	0.923***
	(0.0126)	(0.0126)	(0.0127)	(0.0125)	(0.0126)
Global_NonLSAP	0.000273				
	(0.000194)				
FedAnn_NonLSAP		0.00549*			
		(0.00328)			
ECBAnn_NonLSAP			-0.00412		
			(0.00406)		
BoJAnn_NonLSAP				0.0239***	
				(0.00541)	
BoEAnn_NonLSAP					-0.00797***
					(0.00259)
Constant	0.338***	0.338***	0.338***	0.337***	0.337***
	(0.0553)	(0.0552)	(0.0555)	(0.0549)	(0.0553)
Observations	11,662	11,662	11,662	11,662	11,662
Number of fundid	288	288	288	288	288
Adjusted R-squared	0.854	0.854	0.854	0.854	0.854
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 52: *Bond funds*

VARIABLES	(1) ROW	(2) ROW	(3) ROW	(4) ROW	(5) ROW
Lagged_log_weight	0.860***	0.861***	0.860***	0.861***	0.860***
	(0.0365)	(0.0367)	(0.0363)	(0.0369)	(0.0367)
Global_NonLSAP	-0.000516				
	(0.000596)				
FedAnn_NonLSAP		0.0126			
		(0.0130)			
ECBAnn_NonLSAP			0.0256*		
			(0.0143)		
BoJAnn_NonLSAP				0.0779**	
				(0.0351)	
BoEAnn_NonLSAP					-0.0213
					(0.0142)
Constant	0.609***	0.606***	0.610***	0.606***	0.609***
	(0.159)	(0.159)	(0.158)	(0.161)	(0.160)
Observations	1,982	1,982	1,982	1,982	1,982
Number of fundid	51	51	51	51	51
Adjusted R-squared	0.732	0.732	0.732	0.734	0.733
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 53: *Equity funds*

	(1)	(2)	(3)	(4)	(5)
VARIABLES	DMexUS	DMexUS	DMexUS	DMexUS	DMexUS
Lagged_log_weight	0.867***	0.867***	0.866***	0.866***	0.867***
	(0.0392)	(0.0392)	(0.0392)	(0.0391)	(0.0391)
Global_NonLSAP	0.000925				
	(0.000626)				
FedAnn_NonLSAP		0.00660			
		(0.00926)			
ECBAnn_NonLSAP			0.0208*		
			(0.0120)		
BoJAnn_NonLSAP				0.0604***	
				(0.0217)	
BoEAnn_NonLSAP					0.0169**
					(0.00793)
Constant	0.505***	0.505***	0.506***	0.507***	0.506***
	(0.147)	(0.147)	(0.148)	(0.147)	(0.147)
Observations	10,209	10,209	10,209	10,209	10,209
Number of fundid	282	282	282	282	282
Adjusted R-squared	0.764	0.763	0.764	0.764	0.764
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 54: *Bond funds*

VARIABLES	(1) DMexUS	(2) DMexUS	(3) DMexUS	(4) DMexUS	(5) DMexUS
Lagged_log_weight	0.709***	0.709***	0.709***	0.709***	0.709***
	(0.0695)	(0.0694)	(0.0695)	(0.0693)	(0.0692)
Global_NonLSAP	0.00202				
	(0.00265)				
FedAnn_NonLSAP		-0.0121			
		(0.0246)			
ECBAnn_NonLSAP			-0.124		
			(0.0867)		
BoJAnn_NonLSAP				-0.0539	
				(0.0334)	
BoEAnn_NonLSAP					-0.0240
					(0.0211)
Constant	1.112***	1.112***	1.114***	1.112***	1.110***
	(0.266)	(0.265)	(0.266)	(0.265)	(0.264)
Observations	1,215	1,215	1,215	1,215	1,215
Number of fundid	40	40	40	40	40
Adjusted R-squared	0.507	0.507	0.509	0.508	0.507
Fund fixed effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

List of countries and regions in the sample

Developed Markets

Australia Austria Belgium Canada Denmark Finland France Germany Greece Ireland Italy Japan Netherlands New Zealand Norway Portugal Spain Sweden Switzerland United Kingdom United States.

Emerging and Frontier Markets

Albania Algeria Angola Argentina Azerbaijan Bahrain Baltic Republics Bangladesh Belarus Bolivia Bosnia-Herzegovina Botswana Brazil Bulgaria Cambodia Chile China Colombia Congo-Kinshasa Costa Rica Croatia Cuba Cyprus Czech Republic Dominican Republic Ecuador Egypt El Salvador Estonia Gabon Georgia Ghana Guatemala Honduras Hong Kong Hungary Iceland India Indonesia Iran Iraq Israel Ivory Coast Jamaica Jordan Kazakhstan Kenya Korea North Korea South Kuwait Latvia Lebanon Liberia Libya Lithuania Macedonia Madagascar Malawi Malaysia Mauritius Mexico Moldova Mongolia Morocco Mozambique Namibia Nicaragua Nigeria Oman Pakistan Panama Papua New Guinea Paraguay Peru Philippines Poland Qatar Romania Russian Federation Rwanda Saudi Arabia Serbia Sierra Leone Singapore Slovakia Slovenia South Africa Sri Lanka Swaziland Taiwan Tajikistan Tanzania Thailand Trinidad and Tobago Tunisia Turkey Turkmenistan Uganda Ukraine United Arab Emirates Uruguay Venezuela Vietnam Yemen Zambia Zimbabwe.

Other Markets

Other Asian, Other Bond, Other Equity, Other European, Other Latin American, Other Middle Eastern and African.

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Chapter 3

Sovereign Debt Negotiations as a Macroeconomic Game with Strategic Interactions among Players

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Abstract

This paper aims to show that existing methods analysing games with more than two players can be usefully applied to macroeconomic games involving strategic interactions among three or more players. This is shown in the context of sovereign refinancing negotiations which are modelled as a bargaining game between three players: a debtor country in need of finance (player 1); its creditors from the international official-sector (player 2); and its foreign private-sector creditors in the form of international banks (player 3). The presence of a third player has important effects on the distribution of the gains from trade and the stability of the game if one allows for the possibility that any two players may form a coalition against another player. After deriving general results, the model is applied to the Greek sovereign debt crisis to provide an economic application and to show that the framework can be applied to a range of macroeconomic games.

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1 Introduction

The Greek sovereign debt crisis has sparked interest in the issue of sovereign finance and reignited academic interest in sovereign debt negotiations, as can be seen from Bulow and Rogoff (2015) and Aguiar and Amador (2014). In the following we build on the seminal contribution by Bulow and Rogoff (1988) and model sovereign refinancing negotiations as a bargaining game between three players: a debtor country in need of finance (player 1); its creditors from the international official-sector (player 2); and its foreign private-sector creditors in the form of international banks and financial institutions (player 3). In the case of the Greek sovereign debt crisis, the refinancing negotiations take place between the Greek government; the Eurogroup of finance ministers representing the euro-area creditor countries; and a bank advisory committee representing international private creditors.

There is a plethora of literature in microeconomics that analyses games with more than two players. The literature's main insight is that the presence of a third player has important effects on the bargaining situation if one allows for the possibility that any two players may form a coalition against another player. This paper aims to show that existing microeconomic methods, modelling such strategic outside options, can be usefully applied to issues in macroeconomics. This paper studies sovereign debt negotiations, but the model is applicable to a wide range of macroeconomic games, such as wage bargaining, agricultural trade policy, international tax competition, monetary policy coordination, currency wars, and other settings with strategic interactions among more than two players.

Modelling sovereign debt negotiations as a bargaining problem relates to the idea of multilateral bargaining in Bulow and Rogoff (1988). Our model differs from their approach in that we take account of the possibility that any two of the players may form a coalition against another player. The static model, in our paper, shows that the payoffs available via these strategic outside options affect the equilibrium distribution of the gains from trade. This idea, as developed by Compte and Jehiel (2010), is then embedded in the model by Bauso and Timmer (2009) which is a framework for analysing sequences of dynamic stochastic bargaining games under uncertainty. Dynamics and uncertainty are important elements of modern macroeconomics and the dynamic model shows how shocks, in the presence of uncertainty, can affect the outcome of the refinancing negotiations.

This paper presents a static and a dynamic model of sovereign refinancing negotiations. The main results are as follows.

The static model applies to the long-run, in which there are no shocks and there is complete information. The model shows that the equilibrium payoffs to the participants in the negotiations are affected by their strategic outside options. There are two extreme results: (1) When international banks, as a third player, are party to any credible outside option, they can play off the other players against one another and, in the limit, capture all the gains from trade. (2) The joint share of the gains from trade allocated to the international creditors is highest when they can credibly threaten to draw up an agreement between themselves and impose such imperfect agreement on the debtor country. This has the effect that the debtor country, e.g. Greece, has, in the limit, to concede all gains from trade to its international creditors from the foreign official- and private-sector.

The dynamic model applies to the short-run, which is characterised by the presence of shocks and uncertainty. The key results are two-fold: (1) Only in the presence of symmetrical bargaining strength do the creditors tolerate foregoing some amount of gains from trade in expectation of higher returns in the long-run. This idea by Bulow and Rogoff (2015) that creditors might be “willing to take smaller repayments now in exchange for structural reform that makes the [debtor] country more inclined to make larger payments in the future” applies only in part when the negotiations are characterised by bargaining strength asymmetries. (2) In contrast, in the presence of asymmetrical bargaining strength, sovereign debt negotiations often result in imperfect agreements. These are inefficient negotiation outcomes drawn up by the creditors and forced on the debtor country. They are inefficient because they include agreement only on that part of economic reforms that would leave the debtor country indifferent between rejecting and acceding to the imperfect agreement proposed by the creditors.

Underlying the dynamic model is the assumption that participants in these talks are partly influenced by regret. The motivation is that players in the sovereign debt negotiations are often subject to backward-looking assessments of their performance. Opinion polls ask the populace how they assess the past behaviour of their governments, the eurozone as a whole, or specific eurozone institutions such as the ECB. See the polls by Infratest (2012), Pew Research Global (2014) and the European Commission (2015). The Greek government is subject to similar ex-post assessments of its performance in the refinancing negotiations. Foreign private creditors, such as banks, are also subject to backward-looking assessments such as what a shareholder or client investor could have obtained, had they invested in a peer or comparative benchmark (Hunter et. al., 2014).

The influence of regret on economic and financial decision making is long-established and has been emphasised as early as in Savage (1954) and has sub-sequently been developed by Bell (1982, 1983) and Loomes and Sugden (1982, 1987) and, more recently, in Hart and Mas-Colell (2000, 2003).

Applications to decisions under uncertainty, such as investment, portfolio allocation or market participation include early studies such as Shefrin and Statman (1985), Odean (1996) and more recently Fogel and Berry (2006), while Muermann et al. (2006) and Michenaud and Solnik (2008) study related applications to empirical finance. The literature shows that investors delay realising capital losses, an indication of regret being a factor in investment decisions. The Bundesbank (2011) acknowledges the role of regret on financial decisions. Models analysing how regret affects investor decisions to enter or exit a market have been recently developed by Barberis, Huang, Thaler (2006) and Qin (2015).

1.1 Related Literature

The literature on sovereign debt can be composed into two approaches, both of which ask why a country would service its debt when it could simply default on its obligations.[1]

The first approach to sovereign debt lending and default, developed by Eaton and Gersovitz (1981) extends ideas by Hellwig (1971) and starts by pointing out that countries gain from accessing international capital markets. Borrowing from abroad allows a country to smooth consumption when output

[1] An overview of the use of game theory to the analysis of sovereign debt and default is found in Pitchford and Wright (2013). A general survey on the theory of sovereign debt and default is provided by Aguiar and Amador (2014). The discussion below builds on Bulow and Rogoff (2015).

is subject to shocks. The level of external debt is limited by an incentive compatibility constraint. The country defaults if the required debt servicing is too large relative to the benefit of retaining its reputation. Cole and Kehoe (1996) provide a more general model of transient and permanent beliefs about the reputation of a debtor country. In a further refinement, Grossman and van Huyck (1988) allow for partial default.

The second approach to sovereign debt lending and default, as developed by Bulow and Rogoff (1988, 1989), points out that creditors have rights to enforce repayment and make default costly by using the legal system in creditor countries. Punishments are direct restrictions on the ability of the debtor country to freely transact in financial and goods markets. The seminal paper by Bulow and Rogoff (1988), extended in Bulow and Rogoff (1989), allows the government of the creditor country to become involved in the negotiations if it needs to consent to side-payments to the other two players for the purpose of avoiding default by the debtor country. Whether the side-payment is positive, or negative, depends on how much the creditor country's taxpayers gain as consumers and exporters from uninterrupted trade by avoiding the default of the debtor country.

The literature on sovereign debt negotiations also suggests that there may be more than a single level of international bargaining. It is possible that there is a second level of bargaining relating to domestic implementation of what has been negotiated at the international level. The second level is palpably important in the Greek sovereign debt crisis in that there may also be conflict among the different groups each player represents such as conflict within (a) the debtor country, say between capital and labour, within (b) the international banks or between their shareholders with conflicting interests, and within (c) the creditor country between pensioners and exporters. The interested reader can consult the literature associated with Putnam (1988) on two-level games. Lehman and McCoy (1992) provide an illuminating two-level game analysis of Brazil's debt negotiations.

Recently, there have been papers that model sovereign debt negotiations as a sequential game between more than two players. Many of these papers built on the stochastic sequential model of Merlo and Wilson (1995) which allows for multilateral bargaining, but does not consider the effects of coalitions between any players. Applications of the Merlo-Wilson model to sovereign debt negotiations include Ghosal and Miller (2003) and Ghosal et. al. (2010). The framework is one of non-cooperative games, as opposed to a cooperative games, which implies that these models ignore the effect of strategic outside options in the form of any two, or more players forming a sub-coalition away from the grand coalition between all players. The same shortcoming applies to paper modelling the heterogeneity of the players engaged in sovereign debt negotiations, such as Haldane et. al. (2005), Weinschelbaum and Wynne (2007), and Pitchford and Wright (2012), which are briefly discussed.

In Haldane et. al. (2005), the $n > 2$ creditors facing the sovereign debtor are heterogeneous in their costs of rejecting the debt restructuring offer and holding out for a better deal. The motivation for modelling creditor heterogeneity is that some creditors such as, mutual bond funds, may have different investment horizons than other creditors, such as institutional investors including pension funds and insurance companies. Haldane et. al. (2005) note that "classes of creditors may differ in many ways including in the value of their outside options" yet they only considers *unilateral* outside options by any player singly. Their model, although allowing for more than two players, ignores strategic outside options by any two players jointly.

Weinschelbaum and Wynne (2007) explicitly model the official sector creditors. The paper considers the IMF as a “a strategic player that maximizes its own payoffs” and “as an institution responsible for representing a club of countries when deciding on a bailout in response to an international financial crisis.” However, there is no strategic interaction in the cooperative sense considered in our paper because debt negotiations are model the IMF as a *unilateral* first-mover in a sequential bargaining game.

Pitchford and Wright (2012) notionally allow for cooperative interaction by distinguishing between an individual and collective settle process for sovereign debt. In the individual settlement process, each creditor singly bargains with the sovereign separately according to a random-offers variant of the Rubinstein (1982) bargaining game. The collective settlement process is only notional as bargaining occurs only once when the sovereign bargains with one leading creditor representing all other creditors. The non-cooperative game theoretic framework does not allow for the possibility that there is more than one ’lead creditor’, which would be one method to introduce strategic interaction in the cooperative game theoretic sense in the model.

The rest of the chapter is structured as follows. Section 2 defines bargaining strength. Section 3 introduces the static model. Section 4 describes the dynamic model. Section 5 applies the model to the Greek sovereign debt crisis. A final section concludes.

2 Defining bargaining strength

This section reviews the Nash (1950) solution to the bargaining problem. We then introduce an extension to the Nash solution, as developed by Compte and Jehiel (2010), which allows for the presence of strategic outside options, i.e. the possibility of any two players forming a coalition against another player.

2.1 Exogenously determined bargaining strength

The Nash bargaining solution determines how the gains from economic interaction are shared between the players participating in the negotiations.

The Nash solution specifies a utility level u_i for each player $i = 1, 2, 3$ such that the Nash product is maximised while satisfying a resource constraint:

$$\max_{\{u_1, u_2, u_3\}} \quad (u_1 - d_1)^{\alpha_1} (u_1 - d_2)^{\alpha_2} (u_3 - d_3)^{\alpha_3} \tag{1}$$

$$\text{s.t.} \quad v_{123} = u_1 + u_2 + u_3. \tag{2}$$

The weight α_i signifies the bargaining strength of player i. The disagreement point d_i specifies what player i obtains if there is no agreement between the players regarding how to distribute the gains from trade. When there is agreement, the resulting economic interaction generates gains from trade v_{123}.

The Nash solution for player 1's share of the gains from trade is:

$$u_1^* \quad = \quad \alpha_1 \left(v_{123} + \frac{\alpha_2 + \alpha_3}{\alpha_1} d_1 - d_2 - d_3 \right) \tag{3}$$

and similarly, by symmetry, for the other players.

The disadvantage of the Nash solution is not only that the equilibrium allocation is partly determined by arbitrarily specified bargaining weights α_i. It also ignores the possibility of any two players forming a coalition against a third player, which, as outside options, could be used for leverage to extract a greater share of the gains from trade.

The Nash solution ignores such 'strategic' outside options because it considers the outcome of the negotiations to be either (i) a solid agreement between all entities, or (ii) disagreement, in which case each player receives what is obtainable in autarky $d_i = v_i$. This ignores the possibility that (iii) two players $\{ij\}$ may draw up an agreement between only the two of them, and assign the autarky value to the player k excluded from the agreement, rendering him indifferent between autarky and going along with the imperfect agreement imposed by the other two players.

It is important to consider such strategic dimensions in the context of sovereign debt negotiations, given that they often involve more than two parties in practice. It has been recognised as early as in Von Neumann and Morgenstern (1944) that the presence of more than two players has important effects given that "both players 1 and 2 would lose interest in a coalition with each other, and player 3 will become the desirable partner for each of them", predicting that this "will lead to a competitive bidding for [the third player's] cooperation."

For this reason, we choose to use the Coalitional Nash solution, developed in Compte and Jehiel (2010), because it pins down the allocation of the gains from trade without recourse to arbitrarily specified bargaining weights, and endogenously determines bargaining strength by differences in the payoffs available to each player via their strategic outside options.

2.2 Endogenously determined bargaining strength

The following briefly explains the Coalitional Nash solution, a multiplayer extension to the simple Nash solution.[2] It differs from the latter in considering strategic outside options in the form of any two players agreeing to form a coalition against another player.

Bargaining occurs between $N = 3$ players. When the negotiations result in an agreement between all players $\{123\}$, it yields gains from trade v_{123}. When the negotiations result in disagreement, each player resorts to autarky in which the gains from trade are zero $v_i = 0$.

The negotiations may, however, result in an agreement that is drawn up by only two of the players, i and j. This imperfect agreement may occur between either players $\{12\}$, $\{13\}$ or $\{23\}$. The value obtainable from an agreement of the subset of players $S \subset N$ is denoted by $v(S)$, or v_{ij}.

The player that is not party to drawing up the agreement will be assigned a payoff of zero, which is also his payoff in autarky. The player not party to drawing up such an imperfect agreement is thus made indifferent between resorting to autarky and accepting the other players' agreement. We assume that, given his indifference, the excluded player k will accede to the imperfect agreement drawn up by $\{ij\}$.

Imperfect agreements are imperfect in the sense the resulting gains from trade are less than that obtainable when all players are involved in drawing up the negotiation outcome, implying that $v_{ij} < v_{123}$. The motivation for this assumption is provided in Section 3.1.

Any two players excluding another player from drawing an agreement can

[2]This links to the idea in Binmore, Rubinstein, and Wolinsky (1986) who showed that the ordinary Nash (1950) solution is affected by the presence of *relevant* outside options.

serve as outside options which players can harness for the purpose of extracting a greater share of the gains from trade.

However, only 'credible' outside options will affect a player's equilibrium share of the gains v_{123}. An agreement drawn up between two players $\{ij\}$ is a credible outside option, and will thereby affect the distribution of the gains v_{123} resulting from an all-player agreement $\{123\}$, if such an outside option were to yield the two players involved a larger payoff compared to the all-player agreement. In order to satisfy players i and j's constraint for participating in the all-player agreement $\{123\}$, the third player k has to, therefore, accept a less than one-third of share of the gains from trade v_{123}.

As participation constraints for the all-player agreement $\{123\}$, credible outside options constrain the range of admissible bargaining solutions. The Coalitional Nash equilibrium distribution of the gains from trade

$$\max_{\{a_1, a_2, a_3\}} \quad a_1\ a_2\ a_3 \tag{4}$$

$$\text{s.t.} \quad v_{123} = a_1 + a_1 + a_3 \tag{5}$$

$$a(S) \geq v(S) \quad \text{for } S \subset N \tag{6}$$

takes this into account by the set of participation constraints (6), while also satisfying a resource constraint (5). The participation constraints ensure that no set of players has an incentive to block the formation of the all-player, perfect agreement $\{123\}$.[3]

[3]The result is an allocation that is in the Core of the bargaining problem, which relates to the contract curve in the Edgeworth box. In a standard pure exchange economy, with two goods and two agents, each player starts out with an initial input allocation. The allocation would be Pareto optimal if their indifference curves were tangent to each other. The contract set or, more commonly, the contract curve is the collection of all such optimal allocations. However, the initial allocation may not be optimal for example when, at the endowment point, the indifference curves are not tangent, but, instead, intersect one another, demarcating a lens-shaped area that indicates feasible Pareto improvements. The subset of the contract set,

The Coalitional Nash solution allows for relevant strategic outside options to affect a player's share of the gains from trade, which can be seen from the mathematical formulation of the solution for the distribution of the gains from exchange:

$$a_1^* (1 + m_1^\mu) = a_2^* (1 + m_2^\mu) = a_3^* (1 + m_3^\mu) \tag{7}$$

which relates a player's equilibrium allocation a_i^* to his endogenously determined bargaining strength $m_i^\mu \equiv \sum_{\widehat{S} \in S_i} \mu_{\widehat{S}}$ where $\mu = \left(\mu_{\widehat{S}}\right)_{\in Si}$ denotes the strength of a coalition of $S \subset N$ players.

In the absence of any credible outside option, each player receives one-third of the gains v_{123}, implying that the sum of any two players' share is two-thirds. Then, players i and j form a *credible* sub-coalition S, or outside option, where they could jointly obtain more than two-thirds outside the all-player agreement:

$$v_{ij} \geq \frac{2}{3} v_{123}. \tag{8}$$

In order to keep i and j in the all-player agreement, they have to jointly obtain at least as much as they could receive outside the perfect agreement.[4] The equilibrium share of v_{123} allocated to players $\{ij\}$ will yield the players:

$$a_i^* + a_j^* = v_{ij} \tag{9}$$

The stronger player i (and j) obtains a larger equilibrium allocation, relative to the strategically weaker player k, if $m_i^\mu < m_k^\mu$ such that $a_i > a_k$, as can be seen from (7). This occurs if player i has at his or her disposal a larger number

i.e. the section of the contract curve that lies within this lens-shaped area, describes the Core of an economy.

[4]In Section 3.4.2, it will be shown that Eq. 8 is a sufficient but not a necessary condition when there is more than one credible outside option.

of credible outside options, or the same number but stronger credible outside options.

Figure 1 illustrates the distribution of the gains from trade in the absence of credible outside options (symmetrical bargaining strength) and in the presence of one credible outside option (one of several possible cases of asymmetrical bargaining strength).[5] Later, in Section 3.4, when applying the model to sovereign debt negotiations, we simulate the model under both scenarios.

In the absence of credible outside options, all coalitions have zero strength $\mu = 0$. The gains from trade are split equally. Each player receives one-third of the gains from trade: $a_i = \frac{1}{3}$ for $\forall i$. In the presence of a credible outside option, the gains from trade will be split unequally, in favour of the stronger players.

Below it will be assumed that player 1 is strategically weaker relative to player 2 and 3. This is modelled as a coalition of the latter forming a credible coalition, resulting in players 2 and 3 jointly receiving a larger share of the gains from trade at the expense of the share allocated to player 1.

[5] In the next Section, we will allow for the presence of more than one credible coalition and show how the allocation to players depends on the relative strength of credible coalitions.

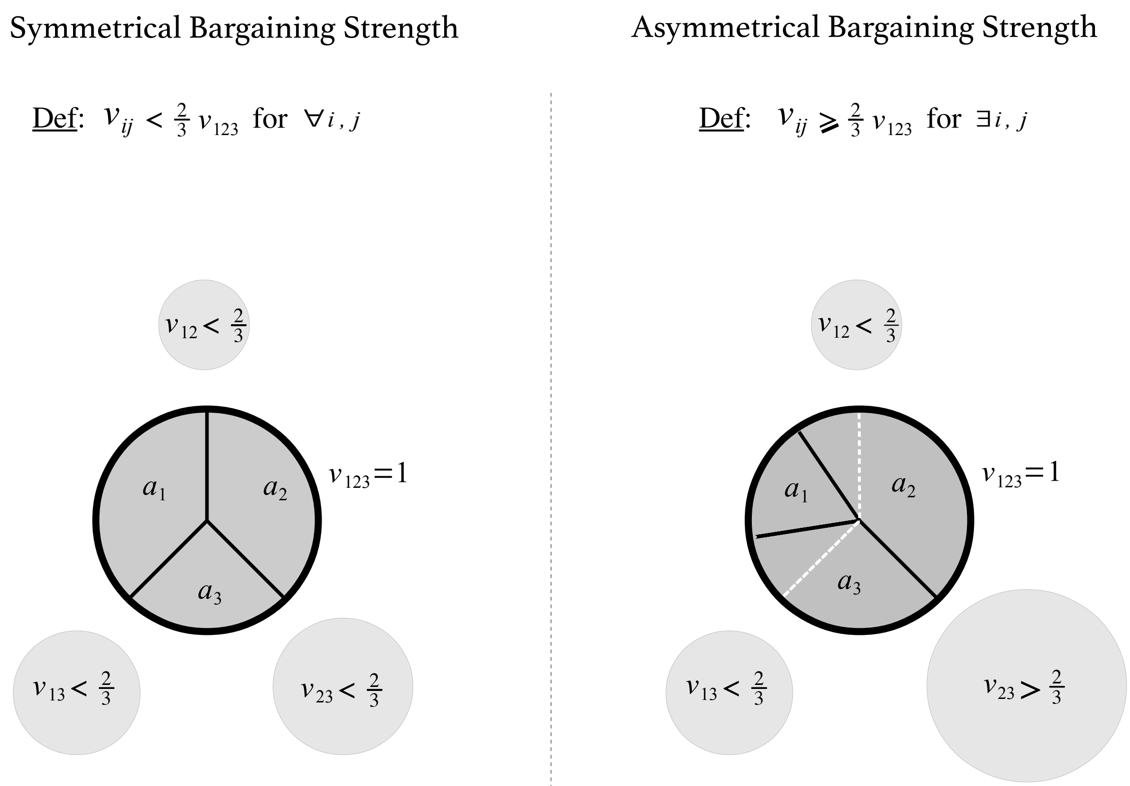


Figure 1: The distribution of the gains v_{123}, resulting from the economic interaction following agreement between all players $\{123\}$, is affected by relevant strategic outside options available to players. In the absence of credible outside options, each player receives $a_i = {}^1\!/_3$ (see the Figure, left-hand side). However, players 2 and 3 can receive a payoff superior to the equitable distribution, if they have the credible outside option of drawing up an agreement $\{23\}$ amongst only the two of them yielding them $v_{23} > \frac{2}{3}v_{123}$and would assign a zero payoff to the other Player 1 (see the Figure, right-hand side). The strategically weaker player 1 is forced to concede that players 2 and 3 obtain more than two-thirds of the gains, so as to avoid the strategically stronger players drawing up an agreement only amongst themselves. In equilibrium, $a_2^* + a_3^* = v_{23}$.

3 Static model

This Section illustrates how existing microeconomic methods for modelling games with three players can be usefully applied to the issue of sovereign refinancing negotiations, and, by extension, other macroeconomic contexts in which bargaining strength matters.

Players → Negotiation → **Agreement** → Activity → Output → Distribution

Figure 2: Static model

3.1 Model overview

We briefly provide an overview of the model. See Figure 2.

Players represent the three main types of economic agents participating in a game involving strategic interactions among the players. Examples of macroeconomic games include sovereign debt negotiations, wage bargaining, monetary policy coordination, tax competition, currency wars, competitive trade policy, among others. In the application to sovereign debt negotiations, one may think about the three players as follows: a debtor country in need of finance (player 1), the international official-sector creditors (player 2) and foreign private-sector creditors in the form of international banks (player 3).Given the heterogeneity in types, one cannot reduce many macroeconomic games with three, or more, distinct type of players to a game of two players without loss of generality.

The differences between the players imply the potential for a relationship, or exchange, between the players. Once the terms and conditions of such exchange have been agreed upon, the implementation of the agreement results in an activity, such as the provision of resources and services as well as the compliance with the terms and conditions specified in the agreement. This economic interaction results in an activity, generating gains from exchange, which may be thought of as the activity's output.

Negotiations are required to result in an agreement before the activity commences. The negotiations are about reaching an agreement regarding the terms under which the activity is to be carried out, including how the resulting output will be distributed among the players. Once an agreement is accepted, bargaining stops.[6]

Figure 3 shows that negotiations can result in disagreement or agreement. Following 'disagreement', the activity does not take place and each player i remains in autarky obtaining $v_i = 0$ for $\forall i$. If, however, there is an agreement jointly drawn up by all players $\{123\}$, such a mutual or 'perfect agreement' yields a maximum level of output v_{123}. When agreements are drawn up by only two players $\{ij\}$, then the resulting output v_{ij} is lower. Such 'imperfect agreements' are drawn up either between $\{12\}$, $\{13\}$ or $\{23\}$. The player k not party to drawing up such an imperfect agreement is assigned a payoff of zero, which is also his payoff in autarky, rendering him indifferent between resorting to autarky and acceding to the other players's agreement. It is assumed that player k will accede to the imperfect agreement such that the activity, or exchange, will go ahead.

Imperfect agreements are imperfect in that they are inefficient by a measure of $x_{k|ij} = v_{123} - v_{ij}$. This inefficiency reduces the resulting gains from exchange to less than what would be available under a perfect agreement such that: $v_{ij} < v_{123}$. Furthermore, some imperfect agreements imply a larger inef-

[6]We use the axiomatic approach to bargaining without specifying explicitly the negotiation protocol, which is specified in the sequential approach to bargaining. The equilibrium outcome of the negotiations are the same in both approaches in our context.

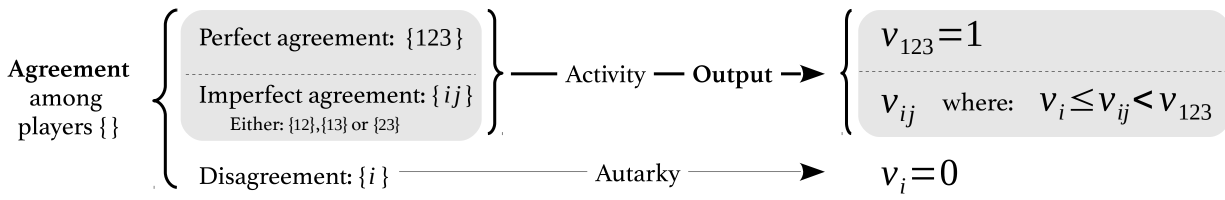


Figure 3: Negotiation outcomes

ficiency than other imperfect agreements.

A motivation for assuming that imperfect agreements involve a measure of inefficiency is as follows. The player excluded from drawing up the agreement will accede to the imperfect agreement and participate in the economic interaction. However, because imperfect agreements are drawn up by only two of the players, they do not resolve all the issues in dispute which would have realised all potential gains from trade. The issues that are not being resolved depend upon which of the players is excluded from drawing up the agreement. By the very virtue of representing different economic types, the players differ in the size of their contribution to the success of the sovereign debt negotiations such that excluding this player will lead to a greater inefficiency than excluding that player from drawing up the agreement.

We number the players in an ordinal fashion: not fully involving player 1 in an agreement results in the least amount of inefficiency, while excluding player 3 results in the largest loss of output, with the marginal contribution of player 2 being somewhere in between. The value, or output, generated by each of the imperfect agreements $\{ij\}$ takes the following ordering: $v_{12} < v_{13} < v_{23}$ where each $v_{ij} < v_{123}$.

While the perfect agreement is the equilibrium outcome, the potential of negotiations resulting in imperfect agreements will affect the equilibrium payoffs.[7] The outside option of any two players forming a sub-coalition against another player confers bargaining strength to these two players that are members of credible outside coalitions. Players can use this as leverage for extracting a greater share of the gains from trade.

3.2 Players

Sovereign debt negotiations can be considered as a bargaining game between the debtor country and its foreign creditors. This builds on the idea of Bulow and Rogoff (1988) who model sovereign debt negotiations as a multilateral bargaining game. Recall that the three players are: a debtor country in need of finance (player 1); its international official-sector creditors (player 2); and its foreign private-sector creditors in the form of international banks (player 3).

3.3 Negotiation outcomes

3.3.1 Disagreement

In the absence of agreement by any player, i.e. where neither the debtor country nor its creditors agree, each player resorts to autarky. Economic interaction does not occur and there are no gains from exchange:

$$v_i = 0 \quad \text{for } i = 1, 2, 3 \tag{10}$$

[7] Imperfect agreements cannot be the equilibrium outcome of the negotiations because they are Pareto-dominated by the perfect agreement. However, this it does not mean that non-equilibrium outcomes in the form of imperfect agreements do not occur in practice. Section 5 explains what imperfect agreements correspond to in the Greek sovereign refinancing negotiations.

Disagreement is conventionally specified as all players disagreeing. This is one of several possibilities.[8] In a bargaining game of alternating offers, disagreement can result either from bargaining indefinitely by continuously delaying agreement forever, or due to bargaining breaking down indefinitely when one player permanently exits the negotiations. However, it could also be the case that there is an imperfect agreement where two players draw up an agreement amongst themselves, assigning a payoff of zero to the third player who, having been made indifferent between autarky and the imperfect agreement, is assumed to accede to the imperfect agreement.

3.3.2 Perfect agreement

A perfect agreement is drawn up by all players $\{123\}$ in the sovereign debt negotiations. The agreement amounts to specifying a distribution of the gains from trade arising from creditors lending to the debtor country and the conditions of the agreement being implemented by all players. Perfect agreements yield a maximum of gains from trade, which are here normalised to unity:

$$v_{123} = 1. \tag{11}$$

The gains from trade are the proceeds of growth resulting from the debtor country appropriately using the funds obtained from the creditors for domestic investment. Akin to the agricultural system of share cropping, the crops (gains from trade) resulting as output from appropriate use of the land as a production input (loan) are to be shared between the tenant (debtor) and the landowners (creditors). As there are three different economic type of agents, in this

[8] See Binmore, Shaked and Sutton (1989).

analogy the land is a leasehold held by a private landowner on lease from a public owner, such as a city council, with the output being shared via a system of taxation.

Two comments are in order. Firstly, the gains from trade are treated as a primitive aspect of the model. For specific applications, the resulting gains from trade can be determined further by micro-foundations, as in Bulow and Rogoff (1988, 1989). Secondly, the level of the gains from trade are constant and known in the static model. In the dynamic model, the gains from trade vary over time and are subject to uncertainty, as explained in Section 4.

3.3.3 Imperfect agreements

In the literature on sovereign debt negotiations, Bulow and Rogoff (1988) argue, along with others, that negotiation participants have outside options that may improve their bargaining strength and thereby, their share of the gains from trade. Bulow and Rogoff (1988) consider *unilateral* outside options by any player singly, which in our model is autarky. We further consider strategic outside options by any two players jointly, as hinted at in Bulow and Rogoff (2015).

The strategic outside options take the form of a sub-coalition of two players $\{ij\}$ drawing up the agreement and consulting the other player k afterwards, who ends up going along with their offer. Such imperfect agreements can be drawn up between players $\{12\}$, $\{13\}$ or $\{23\}$. Players cannot strike two of these deals at once. The player excluded from drawing up the agreement is assigned a payoff of zero, which is also his autarky payoff, rendering him indifferent between remaining in autarky and accepting the other players's agreement. As he is indifferent, it is assumed that player k will accept the imperfect agreement such that the activity or exchange will go ahead.

An interpretation of what these outside options may correspond to in practice, in the context of sovereign debt negotiations, is provided in Section 5.

Imperfect agreements affect the equilibrium payoffs if they are credible threats. Recall that equilibrium payoffs to players result from the equilibrium negotiation outcome: a perfect agreement. Outside options would be irrelevant to the result of the negotiations if they were non-credible, for example when the inefficiency reduces the gains from trade to zero.

The strength of the threat of players $\{ij\}$ formulating the sovereign refinancing 'memorandum of understanding' without player k depends on the inefficiency resulting from not involving that player in the process. Instead of there being agreement on all issues, which would yield a maximal gains of trade, the imperfect agreement only settles those issues that would render player k indifferent between rejecting, or acceding to the agreement.

Some imperfect agreements $\{ij\}$ are associated with a larger inefficiency $x_{k|ij} = v_{123} - v_{ij}$ than other imperfect agreements. By virtue of being different economic types, the players differ in the size of their contribution to the success of the sovereign debt negotiations. Therefore, not including player k in drafting the agreement $\{ij\}$ might inflict an inefficiency

$$x_{k|ij} = 1 - v_{ij} \tag{12}$$

that is higher than the inefficiency of not involving player j in drafting an agreement drawn up by $\{ik\}$, inflicting a loss of $x_{j|ik} = 1 - v_{ik}$. If indeed the cost of excluding player k is higher than excluding player j, such that $x_{k|ij} > x_{j|ik}$, implying $v_{ij} < v_{ik}$, then player k occupies a strategically stronger position in the sovereign debt negotiations by virtue of the large inefficiency resulting from not involving him in drawing up the sovereign refinancing agreement. A sufficient condition for a sub-coalition of players $\{ij\}$ to be credible requires the inefficiency, resulting from excluding player k, to be less than one-third of the gains from trade $x_{k|ij} \leq \frac{1}{3}$, implying $v_{ij} \geq \frac{2}{3}$.

The higher the level of v_{ij}, the lower the inefficiency $x_{k|ij}$ of excluding player k from drafting the agreement, and, thus, the stronger the members of the sub-coalition $\{ij\}$, which will lead to players i and j receiving a larger equilibrium share of the gains from trade resulting from an all-player $\{123\}$ agreement. This nexus between bargaining strength and share of gains from trade will be established explicitly in Section 3.4.2.

Depending on what specific macroeconomic context the model is applied to, the negotiations may be characterised by either zero, one, two, or three credible outside options. Figure 4 illustrates the $2^3 = 8$ possible permutations: different sets of imperfect agreements may be non-credible (normal font) or credible (bold font). The size of the black circle represents the payoff to the members of the coalition.

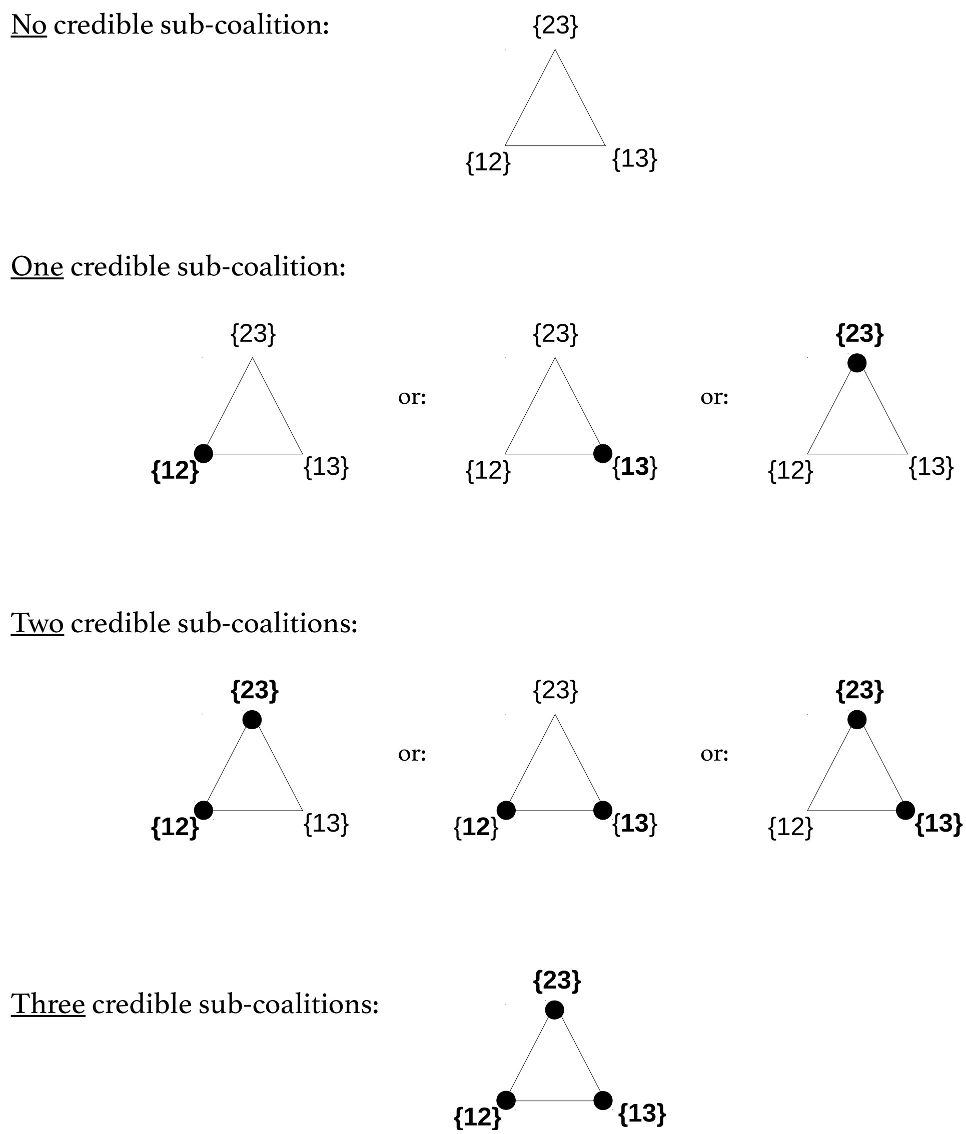


Figure 4: The set $\{ij\}$ represents players i and j drawing up an agreement amongst themselves, involving the other player k only to have the agreement signed. The threat of such imperfect agreements, as outside options to an all-player $\{123\}$ agreement, may be credible (bold font) or non-credible (normal font). This depends on the payoff v_{ij}, the size of the black circle, that players $\{ij\}$ obtain were they to implement their agreement, which could vary between different outside options. There are either none $\{\emptyset\}$; one [either $\{12\}, \{13\}$ or $\{23\}$]; two [either $\{12\&23\}, \{12\&13\}$ or $\{13\&23\}$]; or three $\{12\&13\&23\}$ such credible sub-coalitions as outside options, which will affect the distribution of the gains from trade.

3.4 Distribution

In the following comparative static exercise, we let v_{13} and v_{23} jointly vary between 0 and 1, in order to analyse how the equilibrium payoffs vary with the strength of the coalitions.

The equilibrium outcome of the negotiations is an agreement drawn up by all players $\{123\}$. Yet, the presence of such outside options, if they are credible, affects the equilibrium payoffs because players can use their credible outside options as leverage in order to extract a greater share of the gains from trade.

To foreshadow the results: The gains from trade are distributed equitably between the players, if none of the outside options are credible. If, however, the negotiations are characterised by the existence of bargaining strength asymmetries, in the form of the presence of at least one credible outside option, then the gains from trade will be distributed unequally. Moreover, when the negotiations are characterised by the presence of two credible coalitions, the distribution of the gains from trade will depend on their relative strength.

As we apply the model to negotiations about the refinancing needs of a small and dependent debtor country, we will assume that for any outside option to be credible, it must involve international banks, as they occupy a pivotal role in the negotiations: global financial institutions are the economic agent whose involvement in drafting an agreement contributes most to the success, or failure, of the sovereign debt negotiations.

Therefore, international banks (player 3) are party to any credible outside option, implying, that the agreement $\{12\}$ is not a credible threat. This assumption can be expressed, in the limit, by letting the inefficiency resulting from excluding banks be maximal, $x_3 = 1$, such that the coalition not involving foreign private-sector creditors (player 3) yields zero gains from trade: $v_{12} = 0$. A motivation for this, as part of the more general parameter restriction $v_{12} < v_{13} < v_{23}$, follows in Section 5.

3.4.1 Symmetrical bargaining strength

If all players have equal strength, the gains from trade will be distributed equally, with $a_i^* = \frac{1}{3}v_{123}$ for $\forall i$. This obtains if the set of credible coalitions is empty:

$$S = \{\emptyset\} : \qquad a^* = \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix} \tag{13}$$

where a_i^* represents player i's share of the gains from trade $v_{123} = 1$ resulting from the all-player agreement $\{123\}$. See Figure 6. For the negotiations to be characterised by symmetrical bargaining strength, the necessary as well as sufficient condition is:

$$v_{ij} \leq \frac{2}{3} \tag{14}$$

such that there is no set of players $S = \{\emptyset\}$ that could threaten to form a subcoalition to draw up an agreement yielding them more than two thirds of the gains from trade, which would be a payoff superior to the equal split of the gains from trade. See Figure 5.[9]

[9]Figure 5 is based on Figure 2 in Compte and Jehiel (2010). There seems to a typographical error in their manuscript for they specify $a^*_{2|13} = 1 - v_{12}$ instead of $a^*_{2|13} = 1 - v_{13}$ for $S = \{13\}$ in which case the allocation should be a function of v_{13} only.

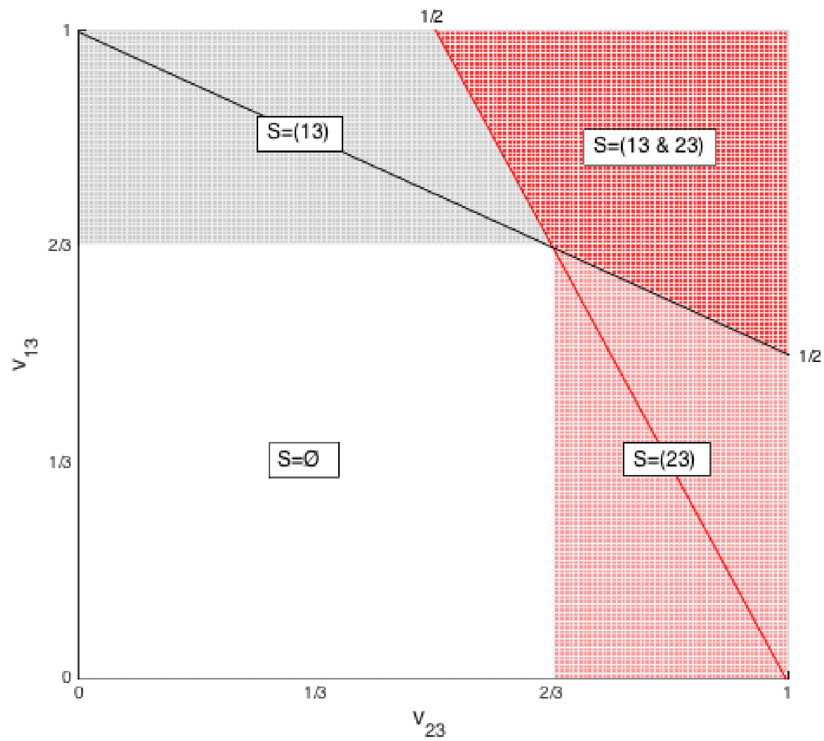


Figure 5: The set of credible outside options S. When all $v_{ij} \leq \frac{2}{3}$, no outside option yields any set of players more than two-thirds of the gains from trade $v_{123} = 1$. However, if one coalition is credible (Case A): assuming $v_{ij} \geq \frac{2}{3}$, the area below the black (red) line ensures that only $\{23\}$ (only $\{13\}$) is credible. The area above the red and black lines demarcates the parameter space where both coalitions are credible, of which player 3 is both a member. (See Case B.) [Note: This figure is based on Fig. 2 in Compte and Jehiel (2010).]

3.4.2 Asymmetrical bargaining strength

When the negotiations are characterised by the existence of bargaining strength asymmetries, in the form of the presence of at least one credible outside option, the gains from trade will be distributed unequally. There are two cases: A and B.

Case A: One credible outside option: $\{13\}$ **or** $\{23\}$

In Case A.1, the sub-coalition $\{13\}$ is the only credible outside option. In Case A.2, the sub-coalition $\{23\}$ is the only credible outside option. As both are symmetrical, we focus on describing the conditions for one of them in detail.

In Case A.2, the creditors from the international official sector (player 2) and international private investor-creditors (player 3) form the *only* credible outside option. The conditions for this to occur are:

$$v_{23} \geq \frac{2}{3} \qquad (15)$$

$$v_{13} \leq 1 - 0.5v_{23} \qquad (16)$$

with Eq. (16) being depicted as a black line in Figure 5.

These two conditions will be explained in turn.

Eq. (15), is sufficient for sub-coalition $\{23\}$ to be a credible threat against player 1. In the all-player equilibrium, players 2 and 3 receive at least as much as they could have obtained under agreement $\{23\}$. In other words, $a_2^* + a_3^* = v_{23}$. More specifically, the two will each receive half of their threat point, $a_2^* = a_3^* = 0.5v_{23}$, while the weaker player 1 obtains what is left over $a_1^* = v_{123} - v_{23}$, where $v_{123} = 1$. Therefore, the distribution of the gains is:

$$S = \{23\}: \qquad a^* = \begin{bmatrix} 1 - v_{23} \\ 0.5\, v_{23} \\ 0.5\, v_{23} \end{bmatrix} \tag{17}$$

where a_i^* represents the allocation to player i under the all-player agreement $\{123\}$, which is the equilibrium outcome of the negotiations. Note that we analyse how the share of the gains from trade in the all-player agreement is affected by varying the size of the credible outside option v_{23}.

Eq. (16) simply rules out the other outside option, namely $\{13\}$, from being credible. It is easy to see this by noting in (17) that the allocation to player 2 is $a_2^* = 0.5v_{23}$. The right-hand side of (16) represents $1 - a_2^*$, which can be thought of as the share of the gains from trade that are leftover and allocated to the remaining players such that: $1 - 0.5v_{23} = 1 - a_2^* = a_1^* + a_3^*$.

Therefore, the Eq. (16) as the second condition for creditors to be the only credible outside option, can be rewritten intuitively as:

$$v_{13} \leq a_1^* + a_3^* \tag{18}$$

which shows that the allocation to player 1 and 3 under the equilibrium agreement $\{123\}$, needs to be larger than or equal to the value players 1 and 3 could have obtained, had they chosen their outside option $\{13\}$ instead of staying in the all-player agreement $\{123\}$.

Why is Eq. (15) a sufficient but not a necessary condition for rendering a coalition credible?

It is very easy to see this by examining a corner solution. In Figure 5, consider the point where: $v_{23} = 1$ and $v_{13} = 0.5$. Then, according to Eq. (17), the gains from trade will be allocated such that $a_1^* = 0$, while the other players each receive $a_2^* = a_3^* = 0.5$. Holding constant at $v_{23} = 1$, as soon as $v_{13} > 0.5$, the condition (16) would be violated, implying that $\{13\}$ is a credible coalition, in addition to $\{23\}$.

In other words, in the presence of two credible coalitions, it can be the case that a coalition $\{ij\}$ is credible although $v_{ij} < \frac{2}{3}$. In this configuration, the equilibrium payoffs will be affected by the *relative* strength of each outside options, a scenario to which we turn to in Case B below.

Before proceeding, for purposes of completeness, we depict the conditions when $\{13\}$ is the only credible coalition. The conditions describing this case are symmetrical to the case depicted above. One has to only change the role of players 1 and 2. To see this, simply compare Equations (15)-(16) with the conditions:

$$v_{13} \geq \frac{2}{3} \tag{19}$$

$$v_{23} \leq 1 - 0.5v_{13} \tag{20}$$

Eq. (20) can, upon rearrangement, be expressed as $v_{13} \leq 2 - 2v_{23}$, which is depicted by the red line in Figure 5.

In this case, the distribution of the gains follows:

$$S = \{13\}: \qquad a^* = \begin{bmatrix} 0.5\,v_{13} \\ 1 - v_{13} \\ 0.5\,v_{13} \end{bmatrix} \tag{21}$$

Case B: Two credible outside options $\{13, 23\}$

Both coalitions are credible if the following conditions are satisfied:

$$v_{13} \geq 1 - 0.5v_{23} \quad (22)$$

$$v_{23} \geq 1 - 0.5v_{13} \quad (23)$$

The conditions (22) and (23) are simply the obverse of (16) and (20).

The reason for these conditions can be shown via proof by contradiction. Consider (22): pretending that $\{23\}$ is the only credible coalition, and distributing the gains from trade according to (17) denoted by $a_{i|\{23\}}$ for each player i, will not be an equilibrium distribution if $\{13\}$ is also credible coalition. The coalition of players 1 and 3 is credible if (22) holds, which can be rewritten as $v_{13} \geq a_{1|\{23\}} + a_{3|\{23\}}$, similar to (18). The same reasoning applies to (23).

The presence of credible strategic outside options, as participation constraints for the agreement between all three players, thus, constrain the range of admissible bargaining solutions, as explained in Section 2.2.

The allocation of the gains from trade in Case B is:

$$S = \{23, 13\} : \qquad a^* = \begin{bmatrix} 1 - v_{23} \\ 1 - v_{13} \\ v_{13} + v_{23} - 1 \end{bmatrix} \quad (24)$$

Player 1 obtains $a_1^* = 1 - v_{23}$, i.e. what is leftover from the gains from trade $v_{123} = 1$ that is not distributed to members of the credible coalition $\{23\}$ of which he is not a member. By symmetry, player 2 obtains $a_2^* = 1 - v_{13}$.

The allocation to Player 3 can be understood easily by noting that the allocation to all players needs to sum to the available gains from trade: $a_1^* + a_2^* + a_3^* = 1$.

Substituting the equilibrium allocations for the other players into this equations yields the equilibrium allocation $a_3^* = v_{13} + v_{23} - 1$.

Figure 6 depicts how a player's equilibrium share of the gains from trade, resulting from an all-player agreement in the sovereign refinancing negotiations, is influenced by his and other players' outside options.

Figure 7 adds up the equilibrium shares of any two players. It shows that Players $1\&2$ can jointly obtain at most a share of two-thirds of the gains from trade in the sovereign refinancing negotiations. This follows from the assumption that player 1 and 2 are in a strategically weaker position relative to Player 3 who is part of any credible outside option. In other words, player 3 is party to any imperfect agreement that could serve as a credible threat to undermine an agreement drawn up by all players.

One can make two further observations on Figure 7. Firstly, players $1\&3$'s joint share is highest when $v_{13} > \frac{2}{3}$ implying that the debtor country and international banks can bargain for side payments from the foreign official-sector. Secondly, players $2\&3$'s joint share is highest when $v_{23} > \frac{2}{3}$, implying that the international creditors can credibly threaten the debtor country with an agreement drawn up by the creditors. In the limit, the sovereign debtor has to surrender all the gains from trade to its foreign creditors.

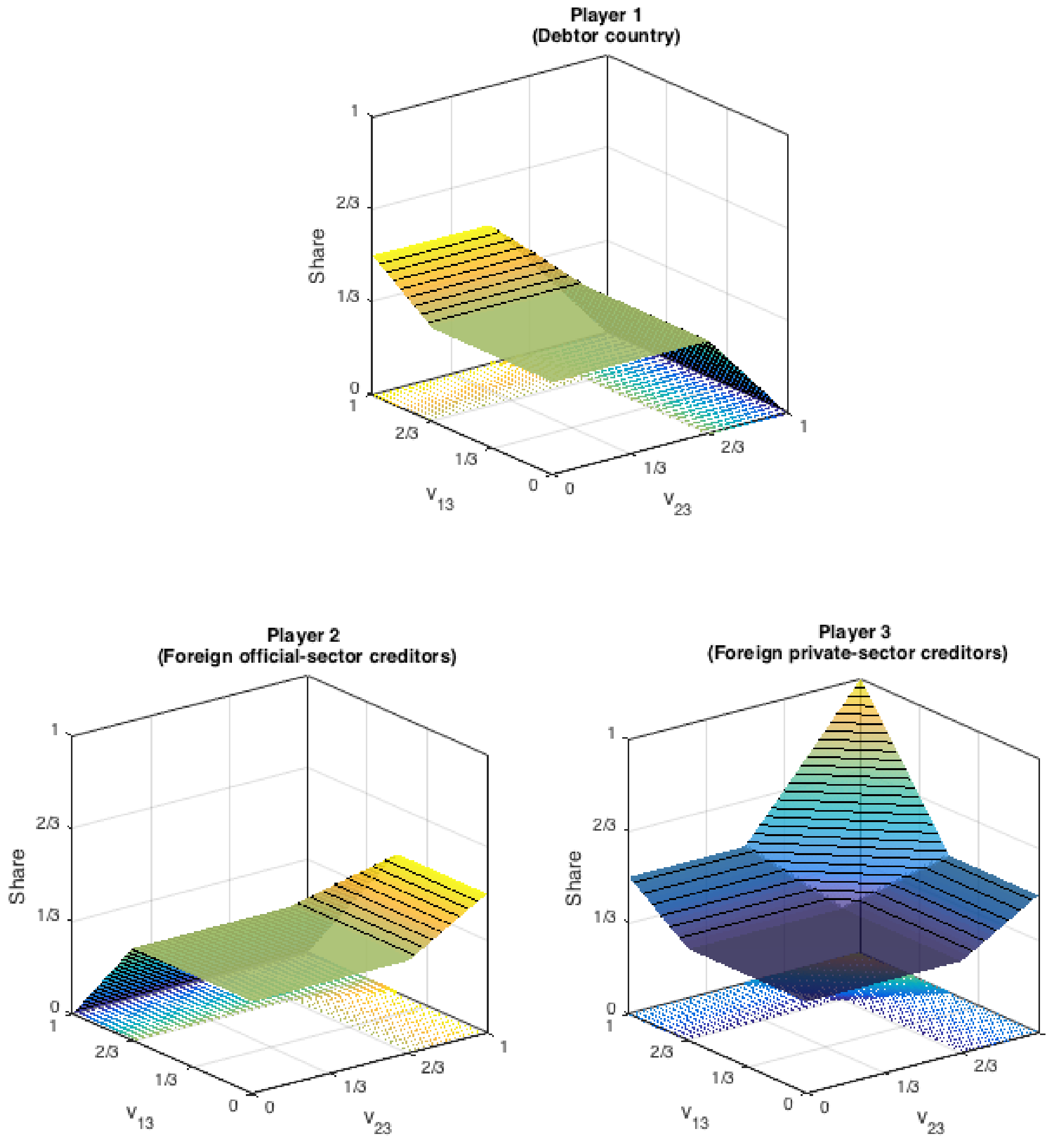


Figure 6: A player's equilibrium share of the gains from trade $v_{123} = 1$, resulting from an all-player agreement $\{123\}$ in the sovereign refinancing negotiations, is influenced by his and other players' outside options $\{ij\}$ and their relative strength v_{ij}. International banks are party to any credible outside option, while the other players are at most a member of one but not all credible threats. This puts international banks is a stronger bargaining position, with their strength being highest when both outside options are credible. In those circumstances, (see Case B), Player 3 can play off the two other players against one another and, in the limit as $v_{13} = v_{23} = 1$, capture all the gains from trade.

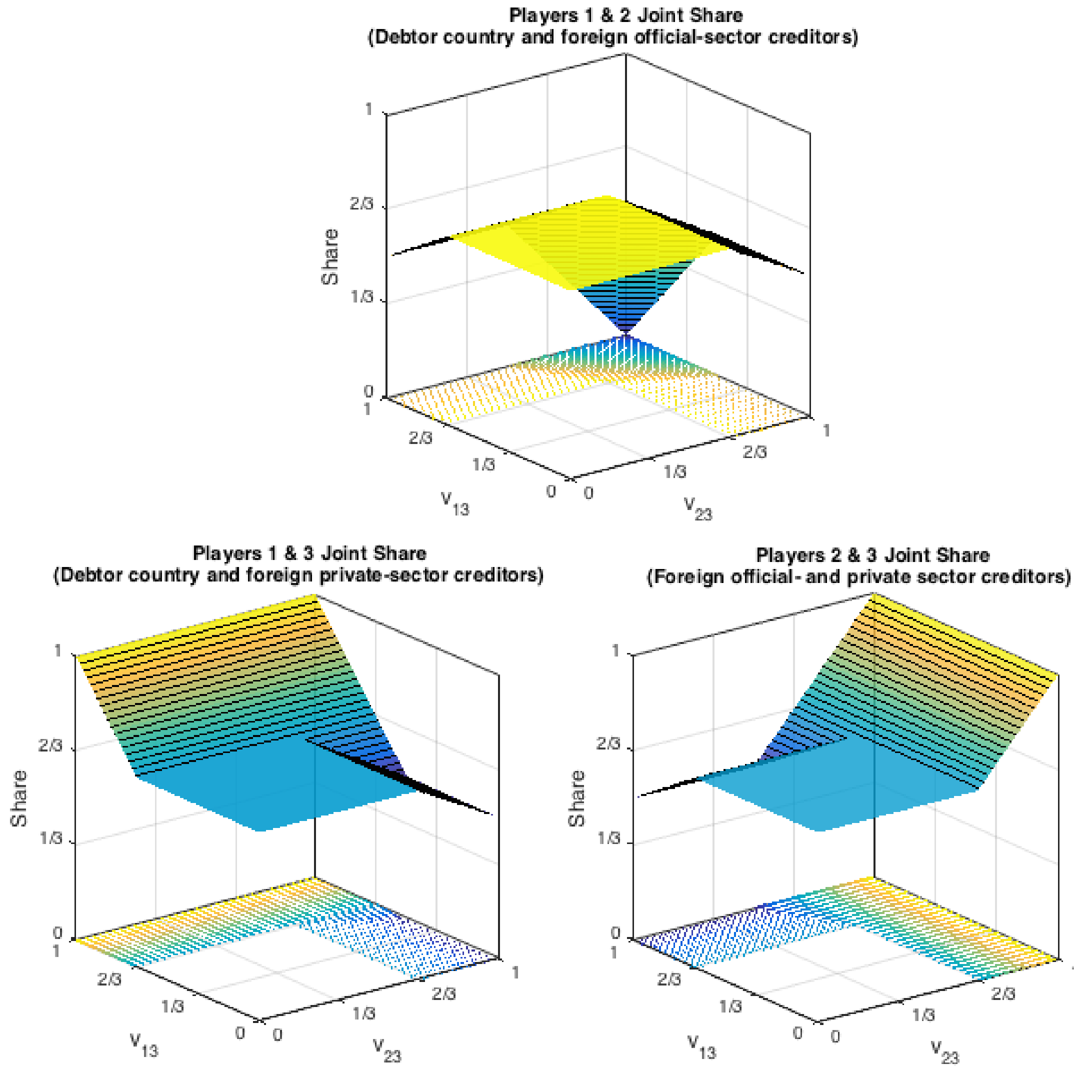


Figure 7: Players $1\&2$ can jointly obtain at most a share of two-thirds of the gains from trade in the sovereign refinancing negotiations. This follows from the assumption that player 1 and 2 are in a strategically weaker position relative to Player 3 who is part of any credible outside option. In other words, player 3 is party to any imperfect agreement that could serve as a credible threat to undermine an agreement drawn up by all players. Players $1\&3$'s joint share is highest when $v_{13} > \frac{2}{3}$, implying that the debtor country and the foreign private-sector creditors can bargain for side payments from the foreign official-sector creditors representing, for example taxpayers in the foreign creditor countries. Players $2\&3$'s joint share is highest when $v_{23} > \frac{2}{3}$, implying that the international creditors can credibly threaten the debtor country. This has, in the limit as $v_{23} = 1$, the effect of the sovereign debtor conceding all the gains from trade to its international creditors.

4 Dynamic model

The static model is insightful and appropriate for addressing the question of how the distribution of the gains from trade is affected by outside options in a bargaining situation featuring three players.

Recall that the equilibrium outcome of sovereign debt negotiations is a mutual agreement between all players and that a player's share of the output is affected by the outside options available to him. This is because, in the presence of three players, any player may form a coalition with another player.

4.1 Motivation

The static model is, however, unable to address a number of other questions that are important for macroeconomists. Here we focus on one application, namely that the static model is unable to capture the key intuition by Bulow and Rogoff (2015) that creditors might be "willing to take smaller repayments now in exchange for structural reform that makes the [debtor] country more inclined to make larger payments in the future." The static model is inappropriate for this purpose for the following three reasons.

Firstly, the static model considers sovereign debt negotiations as a static one-shot game. In practice, however, sovereign debt is constantly being renegotiated, a fact which, according to Bulow and Rogoff (2015), necessitates a "framework to understand the ’extend and pretend’ approach officials have adopted in the case of Greece" or in other sovereign debt negotiations. A dynamic model allows for such considerations, including forward- and backward-looking behaviour.

Secondly, the static model assumes that there is complete information. It is more likely, however, that sovereign refinancing negotiations are subject to uncertainty given that the value of any agreement is likely to be unknown at the time of striking a deal.

Thirdly, the static model predicts that negotiations will result in an imperfect agreement if the return from doing so dominates, even just marginally, the return from a mutual agreement. As the insight from Bulow and Rogoff (ibid) above indicates, it is more likely that players tolerate foregoing some amount of return for some time in expectation of higher returns in the long-run. Here we posit that players are willing to do so as long as they do not significantly regret having done so in the past. If players regret having been willing to take smaller payments in the past (because they could have obtained more had they enforced an imperfect agreement), only then might players be inclined to consider an imperfect agreement, even if such an outcome would be inefficient.

The main results of the dynamic model are as follows: (1) Under symmetrical bargaining strength, the outcome of the negotiations is always a mutual agreement between all players, such that there is never pressure for any coalition of players to force an imperfect agreement onto another player. (2) With asymmetrical bargaining strength, however, the international creditors, which are assumed to form the only credible coalition in the long-run, are in some periods inclined to force an agreement onto the debtor country. Model simulations show that creditors are inclined to adopt an imperfect agreement even though doing so is inefficient.

4.2 Model overview

Sovereign debt is frequently renegotiated in the course of the time leading up to the maturity of the debt contract. Bulow and Rogoff (2015) suggest that this can be thought of as a constant recontracting of sovereign debt, which is here modelled as a sequence of refinancing negotiations.

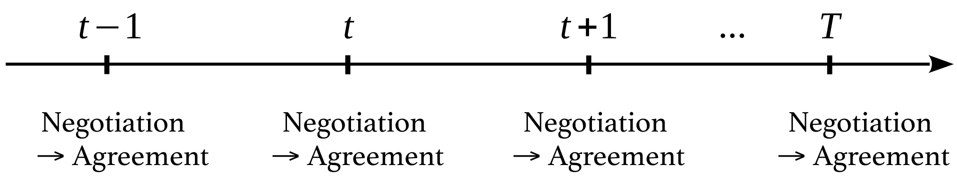


Figure 8: Dynamic model

Figure 8 illustrates the dynamic model. The recontracting of sovereign debt can be considered as a sequence of bargaining games in which the debtor country and its foreign creditors negotiate each working day $t < T$ how to split the gains from trade available from reaching an agreement in the negotiations. The date T can be thought of as the maturity date of the debt contract.

The model is first simulated over a horizon of $T = 3000$ days, that is about 8.5 years. This matches the average maturity at issue of new external government debt. The average maturity of public debt in the eurozone is about 9 years for France, Italy and Spain, compared with about 7 years for Ireland and Greece, as indicated by data from the BIS (2015).

4.2.1 Uncertainty

It is assumed that the value of any agreement is unknown at the time of striking a deal because the gains from trade, and the value of the players' outside options, are subject to shocks whose size is unknown in the current period.

The shocks are drawn from a standard-uniform distribution, with the long-run value of the shock being zero. More specifically, there are bounded but unknown disturbances to the value of any agreement, where the shocks are independent and identically distributed (i.i.d.) and are drawn from a standard-normal distribution:

$$\epsilon(t) \sim N(0,1). \tag{25}$$

As a result, the return available from any negotiation outcome varies over time according to

$$v(t) = v + \epsilon(t) \tag{26}$$

where v is the long-run value of any agreement. The value of disagreement, which results in autarky, is zero in all periods.

4.2.2 Forward-looking behaviour

The players know the long-average value of the coalitions. Therefore, players also know their share of the gains from trade they can expect to receive in the long-run. This serves as a reference point below which a player's allocation cannot fall by more than some small measure σ in any period in the short-run.

This imposes two constraints on the solution to the model.

First, the average allocation of the gains from trade should converge to the expected long-run equilibrium allocation, which is calculated when shocks are zero and the coalition values are equal to their long-run value, such that:

$$\lim_{t \to T} \overline{a}(t) = a^* \tag{27}$$

where a^* is the equilibrium distribution of the gains from trade in the long-run as determined by the static model.[10] The solution is a unique and efficient allocation of the gains from trade.[11]

[10] See Section 3.4

[11] See Section 2.2.

Second, the contemporaneous allocations in any period cannot deviate too far from this expected equilibrium allocation:

$$a_{min} \ \leq \ a(t) \ \leq \ a_{max} \tag{28}$$

where the bounds are $a_{min} = -\sigma a^*$ and $a_{max} = \sigma I$ with $0 < \sigma < 1$ and I being a column vector of ones with the same dimension as equilibrium distribution.

The motivation for specifying the lower bound as a function of the expected equilibrium allocation is to allow bargaining strength asymmetries, which affect the division of the long-run gains from trade, to influence how far the allocations can deviate from that long-run equilibrium in the short-run. This is important for our macroeconomic application in that we are interested in examining the relationship between bargaining strength asymmetries and the outcome of sovereign debt negotiations.[12]

4.2.3 Backward-looking behaviour

Due to uncertainty about the values of any agreement, players learn at period t about any difference between (a) the allocation they received in the previous period in $t-1$ and (b) what they could have obtained had the size of the shock and, thus, the return available from their outside options, been known at the time. The difference (a) - (b) is the ex-post regret experienced by players.

Players experience regret upon learning that their payoffs are less than what they could have obtained had they opted for an imperfect agreement in the preceding period. There is regret on the part of those players who negatively assess not having used their outside option in the previous periods.

[12] In the baseline model of Bauso and Timmer (2012), these bounds on the contemporaneous allocations are symmetrical.

The level of regret can be reduced by receiving more than what a player, or coalition, could have obtained via its best outside options in that period. In that sense, regret is an additive measure in the model. In the solution method, the social planner attempts to keep the regret of players bounded within some small measure epsilon because it is assumed that (i) players tolerate some level of regret but (ii) not too much regret.

As to (i), consider that the debtor country's international creditors might be willing to forego some gains from trade (which they could have captured by an imperfect agreement) in anticipation that they will be better off in the long-run from always reaching mutual agreement in the negotiations with the sovereign debtor. This captures the intuition of Bulow and Rogoff, mentioned earlier, that creditors might be willing to take smaller payoffs now, in exchange for larger payments in the long-run.

As to (ii), it can be noted that in any period in which there is significant regret on the part of the creditors about not having imposed their will via an imperfect agreement on the debtor country in past periods (if an imperfect agreement would have yielded the creditors a larger amount of the gains from trade than a perfect mutual agreement in those past periods), then, the international creditors will have an incentive to abandon trying to reach a mutual agreement and, instead, be inclined to force an imperfect agreement onto the debtor country in that period.

4.2.4 Solution method

We apply the solution method of Bauso and Timmer (2012) which satisfies the constraints that forward-looking behaviour imposes on the solution.[13]

[13] Appendix 7.1 provides a detailed description of the solution method.

4.3 Simulation

We simulate the model under asymmetrical bargaining strength (Scenario I), and symmetrical bargaining strength (Scenario II).

In each case, the model will be simulated $N = 100,000$ times or 'rounds'. The motivation for simulating the model N times is to draw out representative summary statistics that indicate the model's dynamic behaviour. Each simulation round has a horizon of $T = 3000$ days or about 8.5 years, which is the average maturity of new external sovereign debt in the eurozone.[14]

In case of the model with asymmetrical bargaining strength (Scenario I), the model will be simulated furthermore once $N = 1$ over a longer horizon of $T = 1$ million days. A sovereign bond with such a long horizon can be thought of as a government consol.

Asymmetrical bargaining strength (Scenario I)

For the negotiations to be characterised by asymmetrical bargaining strength, there needs to be at least one credible coalition of players. Here we assume that the international official-sector and foreign private-sector creditors, that is the set of players $\{23\}$, form the only credible outside option. This renders players 2 and 3 strategically stronger than the debtor country.[15]

The simulations of the model with bargaining strength asymmetries show that the international creditors are inclined to force an agreement onto the debtor country in most periods.

Table 1 presents summary results of the simulations of the model under asymmetrical bargaining strength. Consider Column (a): The overall probab-

[14] See data by the BIS (2015) and Eurostat (2015).
[15] The conditions for this scenario (Case A.2) were described in Section 3.4.2.

Table 1: Selected summary statistics for simulations of the model with asymmetrical bargaining strength where $T = 3,000$ days or about 8.5 years.

Episodes of imperfect agreements

	(a) Frequency (in % of maturity of sovereign bond)	**(b) Length**
Max.	99.80%	8.21 years
Mean	90.31%	1.53 years
Median	91.63%	1.5 months
Min.	54.17%	1 day

ility that creditors are inclined to adopt an imperfect agreement during the refinancing negotiations is very high in the presence of bargaining strength asymmetries. Even in the best circumstances, i.e. where there are mostly benign shocks, the minimum frequency of periods where creditors are inclined to force an imperfect agreement onto the debtor country represents more than half (54.17%) of the length to maturity of the sovereign bond.

Consider Column (b): Episodes of imperfect agreements, where the international creditors experience significant regret regarding having come to a mutual agreement with the debtor country in the past, are of short median duration. The average length of such episodes, however, is much longer, which, combined with the result from (a), suggests that these episodes tend to be long-lasting and persistent. This is in line with the fact that the mechanism driving these episodes in the model is regret, a process that has memory.

To illustrate and see this easily, consider one example of a simulation that leads to pressure for the mutual agreement between all players $\{123\}$ to break down. Figure 9 plots the level of regret x_{ij} for the set of players $\{ij\}$ over the course of the maturity of the bond, that is $T = 3000$ days or about 8.5

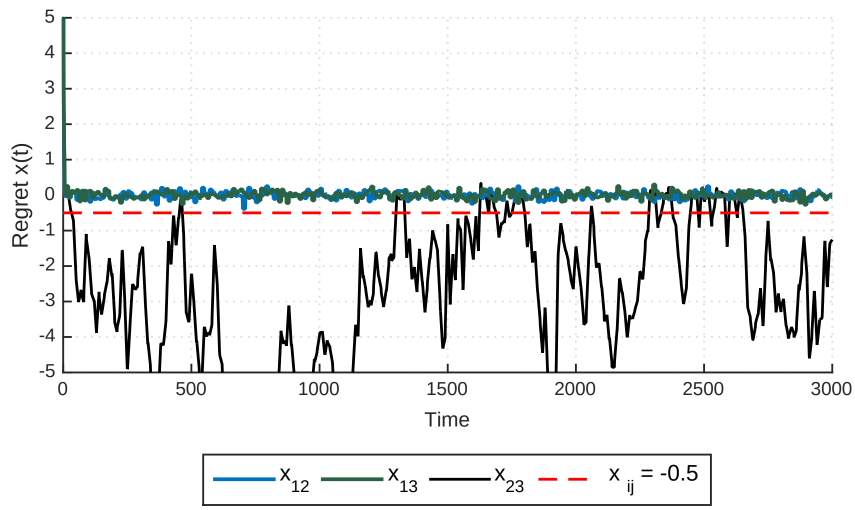


Figure 9: Example of one simulation round of the model with asymmetrical bargaining strength simulated over $T = 3,000$ periods. The level of regret x_{ij} for any set of players $\{ij\}$ varies over the course of the maturity of the bond. Here, under asymmetrical bargaining strength, in many periods the strong players $\{23\}$ experience regret $x_{23} < 0$ about not having used their outside option. The players 2 and 3 would like to abandon the mutual agreement and, instead, draw up an agreement amongst themselves and impose such an agreement on the debtor country if $x_{23}(t) < -0.5$.

years. The stronger players $\{23\}$ are inclined to abandon reaching a perfect agreement if the level of their regret (of not having used their outside option) falls below $\varepsilon = -0.5$. The regret of the non-credible coalitions remains above the threshold at all times.

The mechanism driving this result is that the strong coalition, by virtue of its bargaining strength, can credibly demand to receive in the short-run a payoff in each period that is at least as large as the payoff available from the expected long-run equilibrium allocation. Recall from Section 4.2.2 that the lower bound on the allocation to players in the short-run is a function of the expected long-run equilibrium allocation, which is affected by bargaining strength.

In the stochastic setting of the dynamic model, the payoff required to be allocated to strong players may not always feasible due to the presence of shocks. The regret of the international creditors tends to fall below the threshold ε when the aggregate gains from trade fall short of the level required to satisfy the strong coalition's demand. This tends to occur when there are large adverse shocks to the gains from trade $v_{123}(t)$, as will be seen below.

The simulations of the asymmetrical bargaining strength case above show that the model with bargaining strength asymmetries spends most of its time in periods where the creditors, players $\{23\}$, are inclined to abandon coming to a mutual agreement with the debtor country.

To further identify the mechanism driving this result, we need to analyse the distribution of shocks preceding the periods in which the creditors switch from (i) wanting to reach a mutual agreement with the debtor country to (ii) regret having done so in the past such that the creditors are inclined to abandon trying to reach a mutual agreement.

We are interested in isolating those periods in which players start to be inclined towards adopting an imperfect agreement. We do not model what occurs if an imperfect agreement were actually to be adopted. We simply record those time periods in which players have a sufficiently large level of regret (about having foregone opportune payments in the past) such that they switch to be inclined towards an imperfect agreement, while assuming that such an agreement is in fact never imposed.

The results from the simulations above have shown that within one simulation round, the system tends to be characterised by a few, long-lasting episodes during which creditors remain inclined towards an imperfect agreement, instead of the negotiations switching frequently back and forth between being inclined either towards one or the other type of agreement.

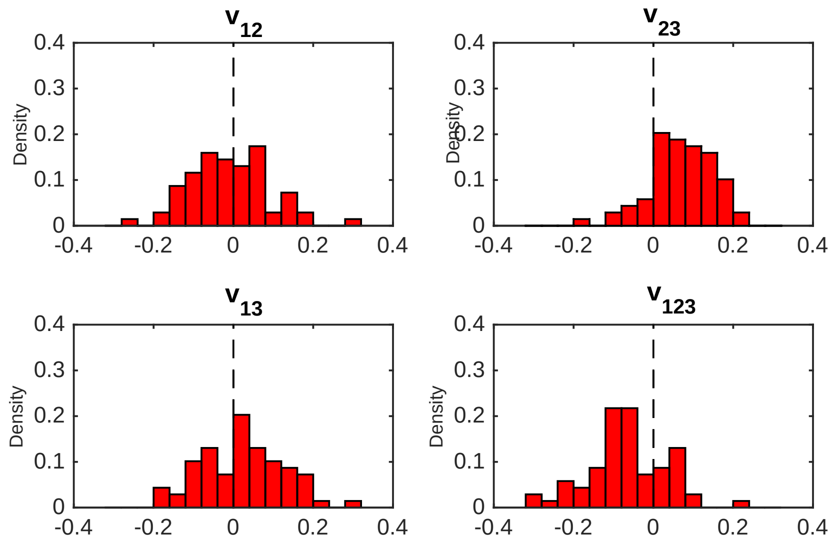


Figure 10: Distribution of the shocks to the negotiation outcomes when creditors (players 2 and 3) start to be inclined to force an imperfect agreement $\{23\}$ onto the debtor country (player 1), instead of reaching a mutual agreement among all players $\{123\}$.

Therefore, for the specific purpose of identifying a sufficiently large set of periods in which players switch towards wanting to adopt an imperfect agreement, the model with asymmetrical bargaining strength (Scenario I) will be simulated once more, now just for one single round $N = 1$ but over a longer horizon of $T = 1$ million days. Bonds of such length can be thought of as government consols.

Figure 10 plots the distribution of the shocks preceding the instances when creditors switch to being inclined to force an imperfect agreement on the debtor country. There are 4 shocks in the model: shocks to the value of the perfect agreement $v_{123}(t)$, and shocks to the value available from any of the three types of imperfect agreements $v_{12}(t)$, $v_{13}(t)$, and $v_{23}(t)$. Analysing the distribution of the shocks indicates that the most likely combination of shocks triggering creditors to be inclined to abandon reaching a perfect agreement in the negotiations is a positive shock to the payoff available from the creditors' outside option $v_{23}(t)$, combined with a negative shock to the available amount of aggregate gains from trade $v_{123}(t)$.

Interestingly, there are significant irregularities in the distribution of the shocks in the run up to periods where the creditors start to be inclined to abandon trying to reach a mutual and perfect agreement. If the shocks were perfectly random, the shock distribution would be centred around zero, which is the long-run value of the shocks. This is mostly the case for the shocks to the value of the imperfect agreements $\{12\}$ and $\{13\}$ but not for the other two shocks. (See left-hand side, Figure 10).

There is an irregular pattern for shocks to the value of the imperfect agreement of the creditors $\{23\}$ and the value of the perfect agreement $\{123\}$. The shock to the creditors' outside option $v_{23}(t)$ tends to be positive, while the shock to the gains from trade from mutual agreement among all players $v_{123}(t)$ tends to be negative in those periods where the international creditors want to abandon the perfect agreement. Furthermore, the two shocks are negatively correlated in those periods.

This implies that creditors in the sovereign debt negotiations tends to exhibit pressure to abandon reaching a mutual outcome when the gains from trade are below their expected long-run average, at the same time as when the return from forcing an outcome onto the debtor country is higher than average.

Another striking insight from the dynamic model is that sovereign debt negotiations tend to experience pressure towards an imperfect agreement even though such an outcome would be inefficient, including for the creditors. This is illustrated in Figure 11.

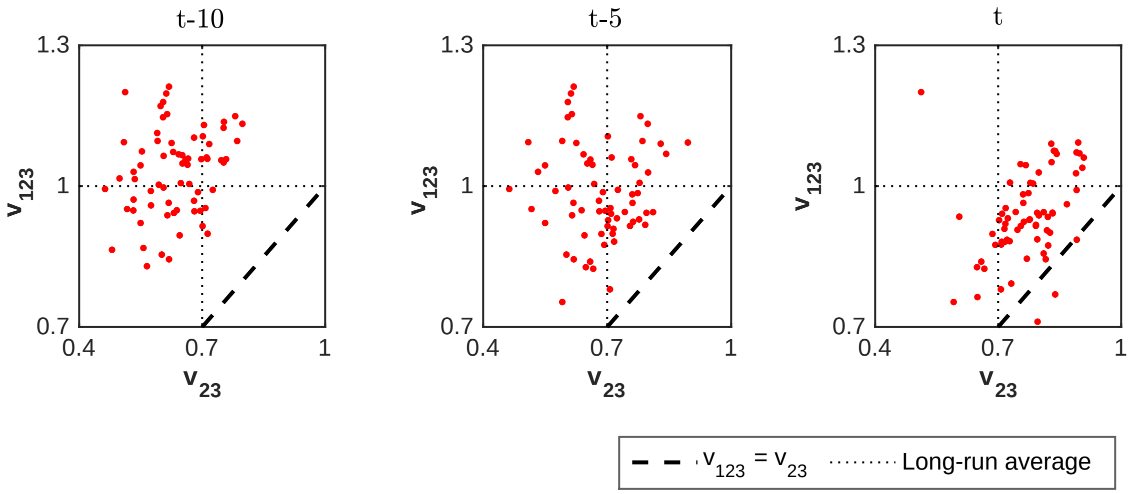


Figure 11: Values of negotiation outcomes preceding period t where creditors start to be inclined to force an imperfect agreement $\{23\}$ onto the debtor country (player 1), instead of reaching a mutual perfect agreement among all players $\{123\}$. The perfect agreement would still yield more gains from trade given that in almost all cases $v_{123} > v_{23}$ in period t. (Simulating the model with asymmetrical bargaining strength once, $N = 1$, over a long horizon of $T = 1$ million periods).

Figure 11 shows that the perfect agreement would yield more aggregate gains from trade in virtually all instances when, in period t, creditors start to be inclined towards abandoning a mutual agreement. This is because the inefficiency of the imperfect agreement, as measured by the difference $x_{23} = v_{123} - v_{23}$, is positive in period t, although it tends to grow smaller in the run-up to instances where creditors start to be disinclined towards reaching to a mutual agreement with the debtor country.

The last finding regarding the inefficiency of imperfect agreements suggests that attenuating bargaining strength asymmetries might concern policy makers. This is discussed in Section 4.4 below.

Symmetrical bargaining strength (Scenario II)

The simulations of the model without bargaining strength asymmetries exhibits no periods where players are inclined to force an imperfect agreement on another player.[16] Negotiation participants are inclined to reaching a mutual agreement between all participants over the entire duration of the sovereign debt negotiations. The regret of all coalitions of players is always above ε.

The result is that, under symmetrical bargaining strength, the sovereign debt negotiations are stable. None of the negotiation participants has an incentive to block a mutual agreement being drawn up between the debtor country and its foreign creditors.

This can be easily understood by considering a counter-example. If there was a strong coalition (as in Scenario I above), the stronger players could credibly demand to receive a payoff as large as the payoff available from their expected long-run equilibrium allocation. Due to the presence of shocks to the values of the agreements, it is not always feasible to satisfy the strong coalition's demand, such as when there are large adverse shocks to the aggregate gains from trade. This mechanism leads to episodes of pressure to reach an imperfect agreement in Scenario I, as seen above.

However, in the presence of symmetrical bargaining strength, this mechanism is inoperative. The allocation mechanism then has more slack in distributing the gains from trade such that the regret of all players remains small. No set of players is sufficiently frustrated by not having used their outside option. This is because such outside options would not have yielded any players much more than what they receive from a mutual agreement.

[16]The negotiations are characterised by symmetrical bargaining strength if no set of players can form a credible sub-coalition. See Section 3.4.1.

Therefore, under symmetrical bargaining strength, all players remain satisfied to keep reaching a perfect and mutual agreement in all periods of the sovereign debt negotiations.

To summarise the results of the simulations:

In Scenario I, when the negotiations are characterised by asymmetrical bargaining strength, the coalition of the strong players, i.e. the international creditors from the official- and private-sector, are inclined to abandon trying to come to a mutual agreement with the strategically weaker player, the debtor country, in most periods. The stronger players are inclined to abandon reaching a mutual perfect agreement when their regret (that is, the regret of not having used their outside option in the form of drawing up an agreement between themselves and imposing such an imperfect agreement on the debtor country) drops below a measure of ε.

In Scenario II, when there are no bargaining strength asymmetries, the sovereign refinancing negotiations always result in a mutual agreement between all players. There is no episode where any coalition of players is inclined to abandon reaching a mutual agreement.

4.4 Policy considerations

With the caveat that the model is highly stylised, we briefly draw out policy issues that have been considered in the discussions on sovereign debt negotiations.

The model suggests that the presence of bargaining strength asymmetries leads to potential instability in sovereign debt negotiations. These bargaining strength asymmetries can be removed in two complementary ways in the model.

Firstly, one can increase the long-run aggregate gains from trade v_{123}. This increases the payoff available from engaging in the debtor country's sovereign debt market and relates to the policy of raising economic growth in the debtor country, which would make reaching a mutual agreement more attractive to the international creditors.

Secondly, one can decrease the long-run value of the creditors' strategic outside option v_{23}, say by introducing some form of capital flow management controls. Measures raising the pecuniary costs of exiting the debtor country's sovereign debt market could reduce the incentive for foreign creditors to force an imperfect agreement on the debtor country.

However, it may be impractical for policy makers, in the short-run, to alter the long-run growth prospects of the debtor country, and thereby increase the aggregate gains from trade available from a mutual agreement. If this is the case, it might be possible for policy makers to reduce the likelihood of negative shocks to the growth of the debtor country by means of macroeconomic demand management. Yet, the presence of bargaining strength asymmetries continues to imply latent instability in the sovereign debt market.

5 Application to the Greek sovereign debt crisis

In the case of the Greek sovereign debt negotiations, the players can be thought of as the Greek government (player 1); the Eurogroup of finance ministers representing the interests of creditor countries and official-sector creditors in the Eurozone, led by Germany (player 2); and a bank advisory committee representing the interest of international private investor-creditors (player 3).

5.1 Empirical motivation

Modelling international private creditor-investors as one player is motivated by the fact that private creditor coordination occurred in practice in the Greek sovereign debt negotiations. A Private Creditor-Investor Committee (PCIC) for Greece was formed in November 2011. Its steering committee's co-chairmen are Charles Dallara, Managing Director of the International Institute of Finance (IIF), and Jean Lemierre, Senior Advisor to the Chairman of BNP Paribas. According to the IIF (2011), the aim of the private creditor-investor committee is to "conduct negotiations on a voluntary PSI [private sector involvement] for Greece with the Greek and Euro Area authorities."

Private creditor coordination, in the form of a committee representing private lenders in negotiations with a debtor country, has a long history, as pointed out by Sturzenegger and Zettelmeyer (2007). As described in Esteves (2007), one of the earliest and most successful examples of private creditor coordination was established in 1868 in the form of the British Corporation of Foreign Bondholders (CFB). Groups similar to the CFB were subsequently set up in France and Belgium (1898), Switzerland (1912), Germany (1927), and the US (1933).

The structure of private capital flows changed during the 1970s which led to a new form of private creditor coordination. Prior to the 1970s, according to Sturzenegger and Zettelmeyer (2007), most bonds were held by several thousand of investors in a few creditor countries, whose interest could be represented by a CFB-type group in each country. By the 1970s, however, most loans were provided by several hundred commercial banks from many countries, in addition to most bank lending becoming increasingly channelled through bank syndicates involving groups of ten or more international banks.

The internationalisation of sovereign lending required a new coordinated negotiating procedure for the restructuring of commercial bank debt. It emerged in the form of the "Bank Advisory Committee" (BAC), also known as the "London Club." According to Sturzenegger and Zettelmeyer (2007), a BAC is normally composed of a group of a dozen banks and represents several hundreds of bank creditors in debt restructuring negotiations.[17] The PCIC for Greece in 2011 is the latest example of such a unitary entity coordinating and representing private creditors in sovereign debt negotiations.

5.2 What does each player bring to the negotiating table?

Player 1 (the debtor country) provides access to the investment opportunity, putting the borrowed funds to appropriate use and satisfying the conditions outlined in an agreement. This could be servicing the debt repayments; achieving a primary budget surplus; collecting taxes and other liabilities; implementing reform packages such as changing the tax structure, labour law, accounting rules, financial regulation, and so forth. In corporate finance, such conditions are called debt covenants, which give creditors a level of control over borrowers.[18] *Negative* debt covenants specify what the debtor country is prohibited from doing, which may include not incurring additional long-term debt, increasing the salaries of some public-sector employees, or selling certain types of public assets. *Positive* debt covenants specify what the borrower is required to do, which may include maintaining certain minimum financial ratios, such as debt-to-GDP ratio, or implementing actions specified in cross-

[17] Rieffel (2003) provides a detailed account of BACs. The equivalent of BACs or the London Club for national creditors is the Paris Club, an organisation representing bilateral public sector creditor interests. See Rieffel (1985), Eichengreen and Portes (1995) for an overview over the Paris Club. For coordination between the London Club and Paris Club, see Hudes (1984). For conflicts between the IMF and the Paris Club, see Brown (2006). For a recent overview on sovereign debt, see Bowdler and Esteves (2013).

[18] See Graham and Smart, Ch.13 (2011).

default covenants.[19] It should be obvious that some of these conditions are demanded to be written into the agreement by the foreign private-sector creditors and others by the foreign official-sector creditors, to which we turn to next.

Player 2 (the creditors from the international official sector) being involved in any sovereign debt restructuring agreement is, firstly, conducive to maintaining a sound international regulatory, legal, and business climate for investment in and trade with the debtor country. This includes contributing to the enforcement of international property rights, bankruptcy and capital markets law. Secondly the foreign official-sector also provides bilateral loans, bail-out funds, as well as access to emergency liquidity via the lender of last resort. In the case of the Eurozone, this includes the ECB's holdings of Greek bonds, loans from the eurozone bail-out fund (EFSF) as well as access to the European Stability Mechanism (ESM) and the Emergency Liquidity Assistance (ELA) facility. Thirdly, involving the official-sector also ensures that the debtor country's domestic business and banks, as well as foreign banks', have continued access to the Target-2 interbank payment, clearing and settlement system which is an essential component of financial system architecture provided by the foreign official-sector.

Player 3 (international private-sector creditors) provide the debtor country with the access to market finance, including sovereign finance as well as trade finance, insurance and other financial services. Involving foreign banks in the refinancing talks ensures agreement for debt rollovers, i.e. maturity extensions for existing sovereign debt, additional funds and other forms of debt restructuring. International banks are important as they decide whether and,

[19] Cross-default clauses are stipulations within a loan agreement or bond indenture that considers the borrowing party in default once the borrower is in default on any other obligation.

if so, how much to increase the risk premium demanded from (i) borrowers in the debtor country and (ii) the sovereign borrower itself. If international banks are not fully involved in drawing up the sovereign debt restructuring agreement, then the international banks can declare the negotiation outcome as a sovereign credit event, which would send the debtor country's borrowing costs soaring. This has devastating effects for the economies of the debtor as well as the creditor countries.

The above modelling setup naturally abstracts from many aspects of the actual Greek refinancing talks, including (i) disagreements between the different constituencies among each player, such as conflicts between political factions within the Greek or German governments, or among the international financial institutions; we also abstract from (ii) the need for the international agreement to be ratified or approved domestically, say by a referendum in Greece or elections in Germany;[20] and we also ignore (iii) the role of a fourth player, such as the Russian government, which the Greek government reportedly approached for financial assistance.

5.3 The meaning of imperfect agreements

This section provides a crucial empirical motivation for the assumption that some negotiated agreements are associated with a larger inefficiency than others; more specifically, the assumption that an agreement not involving international banks is the least likely to be a credible threat, whereas an agreement forced on the small debtor country is most likely to be a credible threat. This is important as it indicates which of the cases of asymmetrical bargaining

[20]The literature studying two-level games suggests an interaction between the dynamics of domestic and international bargaining. See the seminal studies by Putnam (1988) and its enlightening application by Lehman and McCoy (1992) to the 1988 Brazilian debt negotiations.

strength depicted in the previous section is the most appropriate representation of the Greek bargaining situation.

In the dynamic model (Section 4) it will be assumed that Case A.2 applies, namely an agreement among the creditors forced on the debtor country is the only credible threat in the Greek refinancing negotiations.

Here it is argued that the imperfect agreement $\{23\}$ drawn up by the creditors is inefficient compared to a perfect agreement $\{123\}$ because the latter would involve the debtor country (player 1) in drawing up the agreement so that it includes the full list of prior actions specified by the eurozone institutions and the IMF to be performed by Greece in exchange for sovereign finance.[21] Under an imperfect agreement, however, only that part of the list of reforms is included in the agreement which would leave Greece indifferent between rejecting and acceding to the imperfect agreement proposed by the creditors.

It is assumed that the imperfect agreement $\{12\}$ excluding international banks (player 3) will result in the largest inefficiency, given that not involving global financial institutions in the debt restructuring agreed bilaterally between only Greece and its international official-sector creditors could lead international banks to consider such an 'involuntary' negotiation outcome as a sovereign default by Greece. This would lead to a much higher loss of gains from trade than other imperfect agreements such that: $v_{12} < v_{23}$.

A detailed illustration of what the different imperfect agreements may correspond to in practice in the Greek negotiations is provided below.

[21] See the IMF's list of prior actions from June 26, 2015. Also see the IMF's conditionality for sovereign loans which is available at: https://www.imf.org/external/np/exr/facts/conditio.htm

Agreement by $\{12\}$ forced on international banks (player 3)

The negotiated agreement $\{12\}$ is a negotiation outcome drawn up between Greece (player 1) and the eurozone institutions (player 2) which includes international banks (player 3), only in so far as to leaving foreign private-sector creditors indifferent between autarky and acceding to the agreement.

The Greek debt restructuring that took place in March 2012 closely resembles a negotiation outcome that was drawn up between Greece and foreign official-sector creditors, but did not fully involve foreign private-sector creditors.

The restructuring of Greek debt was marked by a voluntary participation of 85.8% of bond holders, while holders of 14.2% of the outstanding face value of Greek bonds either rejected the debt restructuring plan or failed to participate in the consultation process for drawing up the agreement.[22] Greece, in conjunction with official-sector creditors from the eurozone, such as the ECB as well as the IMF, imposed the debt restructuring on the holders of €177 billion worth of Greek bonds, thereby forcing it onto hold-out investors, who own €25 billion of Greek bonds which did not participate in formulating the final agreement.

The debt restructuring agreement was supported only by two of the largest eurozone banks, i.e. Deutsche Bank and BNP Paribas, which are both represented by the Private Creditor-Investor Committee for Greece (PCIC), i.e. the bank advisory committee. The PCIC noted that the debt restructuring represented "understandings reached between the [bank advisory committee] and the Greek authorities and the Euro Area official sector"[23] but did not men-

[22] See the PCIC's press release from March 9, 2012.
[23] PCIC press statement on March 9, 2012.

tion that the bank advisory committee does not represent the other thirteen international banks that are members of the International Swaps and Derivatives Association. This matters, because it is the whole set of banks sitting on the ISDA's Determination Committee that decide whether or not a negotiation outcome constitutes a sovereign credit event.[24]

Considering the agreement not fully involving international private-sector creditors as an imperfect agreement with a large inefficiency is supported by the fact that international banks, via the ISDA, decided on March 9th, 2012, that the Greek debt restructuring constituted a sovereign credit event. That decision triggered credit default swaps, which lead to rising sovereign spreads and falling credit ratings for the debtor country. It raises the cost of government borrowing, which, in turn, affects the debt capacity of the sovereign and may, in the limit, lead to a complete lack of access to capital markets. All of this reduces the overall available gains from trade resulting from an imperfect agreement $\{12\}$ forced on the foreign private-sector creditors.

Agreement by $\{13\}$ forced on foreign official-sector creditors (player 2)

The negotiated agreement $\{13\}$ is a bargaining outcome drawn up by Greece (player 1) and its foreign private-sector bond holders (player 3). The foreign official-sector creditors, most importantly German and other northern European taxpayers, would have to fund providing bilateral loans and financial assistance to the debtor country, including bailing out international banks.

Bulow and Rogoff (1988) note that a lack of agreement in the negotiations can harm third parties such as the international official-sector creditors so

[24] Decisions by the ISDA whether an action by a debtor constitutes a credit event is taken by its Determination Committee which consists of the main international financial institutions including the likes of Bank of America-Merrill Lynch, Barclays, BNP Paribas, Credit Suisse, Deutsche Bank, Goldman Sachs, JPMorgan Chase, Morgan Stanley, Société Générale and UBS.

much so that the debtor country and the foreign private-sector may extract side-payments from the international official-sector creditors. Bulow and Rogoff (2015) underline that "the bargaining for side-payments by third parties (e.g. the IMF or German taxpayers) are acutely illustrated by the recent Greek drama." Side-payments from the international official lenders could take the form of a haircut on Greece's IMF loans or a significant form of debt relief, akin to the London Agreement adopted in 1953 for post-Second World War Germany.

The inefficiency of such an imperfect agreement is that, in practice, sovereign bonds have cross-default clauses. These are stipulations within a loan agreement or bond indenture that considers the borrowing party in default once the borrower is in default on any other obligation. Neither international banks, via the ISDA, nor rating agencies have so far ruled Greece's failure to pay back a tranche to the IMF as constituting a credit event.[25] However, the uncertainty surrounding such an event it itself leads us to rule out Case A.1, namely the scenario where an agreement can credibly be forced on the foreign official-sector.[26]

Agreement by $\{23\}$ forced on the debtor country (player 1)

Finally, consider the agreement $\{23\}$ as requiring the debtor country to implement loan conditions drawn up by its creditors. More specifically, this agreement includes the debtor country (player 1) only in so far as to leaving it indifferent between rejecting and acceding to the agreement.

[25] See Bloomberg, June 30, 2015 "Default seen averted in swaps by Greek failure to pay IMF" and Reuters, May 1, 2015 "Ratings agencies say no default if Greece misses ECB, IMF payments."

[26] See Wall Street Journal, June 5, 2015, "Bundling IMF payments buys Greece time, but now what?" and Reuters, February 12, 2015, "Greek failure to pay official lenders could trigger CDS payments, according to lawyers.".

Bulow and Rogoff (1988, 1989) note that private creditors have legal rights in foreign creditor country courts. The coalition between the two creditors implies that international financial institutions draw upon the legal system provided by the creditor country. The agreement drawn up the creditors is most likely to be a credible threat because creditors can enforce compliance with the loan conditions, and make default costly to the debtor country by drawing upon the legal system in the creditor country.

International creditors can threaten the debtor country with commercial interference, directly or sub-rosa, which ranges from (i) making the debtor country's trade more difficult by threatening to seize or impound shipments of goods; (ii) interfering or blocking normal access to trade insurance and lines of trade credit as suggested in Lane (2004). Furthermore, creditors can (iii) prevent the debtor country, or some elements of its government, from holding assets in creditor countries for fear of seizure, as Bulow and Rogoff (1988) suggest. Foreign creditors can also (iv) enforce financial sanctions against the banking system of the debtor country as was observed in practice when in 2015 the ECB effectively asphyxiated the Greek banking system by limiting its provision of emergency liquidity assistance (ELA) facility.

There is empirical evidence indicating that a coalition between international private creditors and the foreign official sector creditors can damage the debtor country. Rose (2005) finds evidence for commercial interference following sovereign defaults, although ones notes the evidence by Gelos, Sahay and Sandlering (2011) who find limited evidence for strong punishment by capital markets, as Martinez and Sandleris (2011) and Mitchener and Weidenmier (2004) do. Hebert and Schreber (2015) report that equity returns of Argentinian firms react negatively to court rulings in the US regarding Argentine sovereign debt. Importantly “such actions, can, in principle, substantially interfere with a country’s gains from trade”, as noted by Bulow and Rogoff (2015), suggesting that the question is ”as to whether creditors can really make threats to interfere with a country’s international commerce and trade credible, especially when the creditor must bear substantial costs to implement them.”

This underlines that creditor identity matters, as pointed out by Bulow and Rogoff (2015). If player 2 were another type of private creditor, such as hedge funds, then the coalition of $\{23\}$ might not be credible because it lacks legal backing from the creditor country. Also if player 2 were an insignificant creditor country, with poor legal rights as well as inefficient enforcement of capital markets law, the inefficiency of forcing an agreement onto the debtor country might be prohibitively large so as to render $\{23\}$ a non-credible threat.

However, given that we apply the model to the Greek sovereign debt negotiations, it is assumed here that the foreign official- and private-sector creditors forcing a negotiation outcome onto the debtor country is a credible threat during the negotiations.

5.4 Application to other macroeconomic games

Applying the model to the Greek sovereign debt negotiations, we assume that the implementation of any agreement is particularly sensitive to full agreement by international banks. In other words, it is assumed here that only agreements involving international banks, i.e. outside options $\{13\}$ and $\{23\}$, can be credible threats. An agreement excluding private investor-creditors, i.e. $\{12\}$ is not a credible threat. This implies that we restrict the analysis of the eight theoretically possible cases, enumerated above in Figure 4, to four cases when the model is applied to the Greek sovereign debt negotiations: there are either none $\{\emptyset\}$, a single [$\{13\}$ or $\{23\}$] or two [$\{13, 23\}$ jointly] credible threats characterising the Greek sovereign debt negotiations.

The model is sufficiently general to be applied to other types of debt negotiations. One case is when the debtor country is a large economy, such as the United States, not small as Greece, in which case any agreement drafted by the US as the debtor country and its foreign official-creditors, say China or Japan, could be a credible outside option excluding international banks.

The role of international banks also depends on the ownership and maturity structure of sovereign debt. A greater share of bonds with long maturities should improve the bargaining position of the debtor country, assuming that the bonds are not due soon. It also helps the debtor country if a greater share of bonds are held by domestic residents. In Greece more than 90% of government debt is owned by foreigners. In contrast, the share of overseas holdings of UK gilts amounts to only 25%, according to the UK's Debt Management Office.[27]

The model lends itself to other macroeconomic applications, i.e. when the bargaining problem is about the question of how to share costs of, the clean up following an offshore oil spill. This cost is to be shared between the country whose coastline is directly affected, a foreign oil company, and the possibly the government where the oil company has its headquarters. Another application is to let the players be a resource rich country, foreign private investors and a third player representing foreign state investors, in the form of a state-owned enterprise, such as a national oil company, a sovereign wealth fund, or a development bank. The bargaining problem would then be framed as how to

[27]Data available at: www.dmo.gov.uk/index.aspx?page=publications/Quarterly_Reviews

distribute the gains from resource extraction.

The above suggests many possible applications of how microeconomic methods modelling games with three players, and allowing for strategic outside options can be usefully applied to a variety of macroeconomic contexts in which bargaining strength matters.

6 Concluding remarks

The paper aims to show that methods analysing games with more than two players can be usefully applied to and shed light on macroeconomic games where there are three different types of economic agents interacting in a strategic setting. Sovereign debt negotiations are one of many possible macroeconomic applications.

The static model showed that the equilibrium outcome of sovereign debt negotiations is a mutual agreement between all players and that a player's share of the resulting gains from exchange is affected by the outside options available to him. This is because, in the presence of three players, any player may form a coalition with another player for the purpose of capturing a larger share of the gains from trade.

The dynamic model showed that, if there are no bargaining strength asymmetries, the sovereign refinancing negotiations always result in a mutual agreement between all players. Symmetrical bargaining strength implies that none of the players has an incentive to block a mutual agreement between the debtor country and its creditors. If, however, the negotiations are characterised by asymmetrical bargaining strength, in most periods the stronger players are inclined to abandon trying to come to a mutual agreement with the strategically weaker player. When applied to the Greek case, this occurs when its creditors, which are assumed to form the only credible sub-coalition in the long-run, record significant regret about having foregone forcing an imperfect agreement on the debtor country in the preceding periods.

There are several extensions to the model that have not been considered here. First, one could apply the model to other types of sovereign debt negotiations, such as when the sovereign borrower is a large country such as the United States. Second, it would be insightful to add a second layer of bargaining between the different constituencies among each player. This would allow one to analyse the interaction between the dynamics of domestic and international bargaining. Finally, the model is not restricted to studying issues of sovereign refinancing but might be applied to other issues in macroeconomics, such as negotiations about how to distribute the gains from resource extraction between a resource rich country, a foreign state-owned enterprise, and international private investors. The model is potentially applicable to a large set of macroeconomic games, such as trade policy, international tax competition, wage bargaining, monetary policy coordination, currency wars, and other settings with strategic interactions among more than two players.

7 Appendix

7.1 Solution

The solution of the model is an allocation that describes how the gains from trade are divided in the presence of uncertainty.

This section outlines the solution method of Bauso and Timmer (2009). It satisfies two properties. *First*, the average allocation of the gains from trade should converge to the expected long-run equilibrium allocation, which is calculated when shocks are zero and the coalition values are equal to their long-run value. *Second*, the contemporaneous allocations in any period cannot deviate too far from this expected equilibrium allocation.

My contribution is a refinement of these two solution properties that befits our macroeconomic application.

Firstly, in Bauso and Timmer (2009) any division of the gains from trade is an equilibrium if the allocation is in the set of Core allocations. I refine this by requiring the equilibrium to be a unique allocation in the Core, as defined by the Coalitional Nash solution outlined in Section 2.2. The motivation for this refinement is that, besides equilibrium uniqueness possibly being a desirable property in itself, the refined equilibrium characterises an efficient allocation, in the sense of maximising the product of all players' payoffs. From the perspective of macroeconomists, uniqueness and efficiency are attractive equilibrium properties.

Secondly, the bounds on the contemporaneous allocations are pre-specified in Bauso and Timmer (2012). I refine this by letting the lower bound be a function of the expected equilibrium allocation such that, in any period, the contemporaneous allocation cannot deviate too far below the expected equilibrium allocation. The motivation for this refinement is that it allows bargaining strength asymmetries, which affect the division of the long-run gains from trade, to influence how far the allocations are allowed deviate from the expected allocation in the short-run. This is important for our macroeconomic application in that we are interested in examining the relationship between bargaining strength asymmetries and the stability of sovereign debt negotiations.

Resource constraint

The solution method needs to observe the resource constraint in each period. The total amount allocated to the players cannot exceed the available amount. Given the uncertainty about the contemporaneous values of the coalitions, the solution could attempt to mistakenly allocate more than which is actually available.

Ensuring that the amount allocated to the players does not exceed the available amount is implemented in Bauso and Timmer (2009) by specifying that allocations to players are made at a higher rate than the rate at which the coalition values change.

The length of time between two successive draws of coalition values $v(t)$ and $v(t+1)$ is equal to 1, which is the rate of change between coalition values. Let the solution method make allocations to players at the higher rate of $1/\Theta$ where $0 < \Theta < 1$ indicates the length of time between successive allocations. For example when $\Theta = 1/2$, then each period t, in which the coalition values change, is associated with two periods, k and $k+1$, in which allocations are made.[28]

[28] In the main body of the paper, the notation t is used instead of k for ease of comprehension.

For example, the value $v(t)$ in the interval $(t-1,\, t]$ is distributed equally over the two allocation periods, with $v(k) = \frac{1}{2}v(t)$ for period k and $v(k+1) = \frac{1}{2}v(t)$ for period $k+1$. The coalition value $v(t)$ is divided into

$$v(k) = \Theta\, v(t) \tag{29}$$

for $k = \frac{t-1}{\Theta} + 1,\ ...,\ \frac{t}{\Theta}$ and $t = 1, 2, ...$

Any erroneous allocations made in period k can be reversed subsequently in period $k+1$. Errors occur when the amount intended to be allocated to the players of a coalition exceeds or falls short of the value of the coalition, with the latter defining its participation constraint. Errors and thus violations of participation constraints occurs because of the uncertainty regarding the contemporaneous value of the coalitions and the gains from trade.

Participation constraints

The solution to the division of the gains from trade needs to meet the participation constraints of the players and coalitions. Equation (6) describes the participation constraints which are a set of inequalities. Bauso and Timmer (2009) introduce a non-negative over-allocation, or surplus variable that allows the participation constraints to be expressed as a set of equalities.

The division of the gains from trade is an allocation vector assigning a payoff $a_i(k)$ to each player i in each period k. The difference between the sum of the payoffs assigned to the members of a coalition and the value of the coalition, i.e. the payoff the players could have obtained as a coalition, is referred to as the over-allocation or surplus of the coalition.

The overallocation or surplus s_S to coalition $S \subset N$, with N denoting the coalition of all players, is the difference between the sum of the payoffs to the players of that coalition and the actual value of the coalition:

$$s_S(k) \equiv \sum_{i \in S} a_{i\in S}(k) - v_S(k). \tag{30}$$

The overallocation to the coalitions, $s = [\ s_1 \quad s_2 \quad s_3 \quad s_{12} \quad s_{13} \quad s_{23}\ ]'$, are non-negative given that each coalition must receive at least as much as the value of the coalition. Autarky has a value of zero, such that the overallocation to a single player is simply his allocation: $s_i = a_i$. The over-allocation or surplus of the coalition of all three players s_{123} is undefined given that, in equilibrium, the available gains from trade are distributed fully.

Having defined the surplus to coalitions, the allocation of the gains from trade can be rewritten as the augmented allocation $u(k)$:

$$u(k) = \begin{bmatrix} a(k) \\ s(k) \end{bmatrix}. \tag{31}$$

Importantly, finding an allocation $a(k)$ that satisfies the participation constraints of the players is equivalent to finding an allocation $u(k)$ that satisfies $Au(k) = v(k)$ which describes the participation constraints of the players.

We are now in a position to explicitly state the properties which the division of the gains from trade has to satisfy in order to qualify as a solution.

Solution properties

The solution is an allocation $u(k)$ dividing the gains from trade among the players. The solution method of Bauso and Timmer (2009) satisfies two properties.

First, the average allocation converges to the expected long-run equilibrium allocation u^* such that:

$$\lim_{k \to T} \overline{u}(k) = u^*. \tag{32}$$

Second, the contemporaneous allocation does not deviate too far from the expected equilibrium allocation in any period

$$u_{min} \ \leq \ u(k) \ \leq \ u_{max} \tag{33}$$

where the bounds are $u_{min} = -\sigma u^*$ and $u_{max} = \sigma \mathsf{u}$ with $0 < \sigma < 1$ and u being a pre-specified array of the same dimension as u^*.

The motivation for specifying the lower bound u_{min} as a function of the expected equilibrium u^* is to allow bargaining strength asymmetries, which affect the division of the long-run gains from trade, to influence how far the allocations can deviate from that equilibrium in the short run.

Finally, the contemporaneous allocations need to satisfy the constraint:

$$Au(k) \ = \ v(k) \tag{34}$$

to ensure the continued participation of all players in the negotiations.

Backward-looking behaviour

Recall that the coalition values, describing the payoff available from the strategic outside options of a player or coalition of players, defines their participation constraint. As they are subject to shocks, their current value $v(k)$ is unknown. In the presence of uncertainty about the contemporaneous values of the strategic outside options, the division of the gains from trade can, ex-post, be erroneous in measure of how far the allocation deviates from satisfying the participation constraints.

When an element of the allocation vector $u(k)$ fails to satisfy the participation constraints defined by the condition $Au(k) = v(k)$, the allocation can be considered to be erroneous. For example, when $u_{ij}(k) > v_{ij}(k)$ the coalition of players $\{i, j\}$ has been allocated “too much” or “too little: if instead $u_{ij}(k) < v_{ij}(k)$. The notion of an excess (shortfall) in the payoff to a player or coalition measures how far the allocation exceeds (falls short of) strictly satisfying their participation constraints.

The errors are recorded in the variable $x(k)$ which sums up the size of the erroneous allocations that occurred in all periods up to k. It evolves according to:

$$x(k+1) = x(k) + Au(k) - v(k). \tag{35}$$

The error measures the extent to which the allocations to players and coalitions have been insufficient, or excessive, in terms of satisfying the players’ or coalitions’ participation constraints in the periods up to k. For example, a negative value indicates a level of dissatisfaction of a player or coalition regarding how the gains from trade have been divided.

The First Best solution is to keep the error to zero in all periods, which is impossible due to the current coalition values being unknown. The Second Best solution is to keep the error within a margin $|\varepsilon|$. The reason for Bauso and Timmer (2009) wanting to keep the error bounded is that the cost of dynamic uncertainty should be distributed among the players, rather than falling consistently on any one player or coalition. Sovereign debt negotiations break down when a player’s or set of players’ dissatisfaction exceeds the threshold $|\varepsilon|$.

Next we describe how the Bauso and Timmer (2009) solution to the division of the gains from trade satisfies the properties, outlined in Section 7.1, while also ensuring that the error is bounded given certain conditions. In game-theoretic terminology, the sequence of games need to be balanced, instead of being unbalanced.

Solution method

The following outlines the solution method of Bauso and Timmer (2009) which yields a running average allocation thats converges to the expected equilibrium allocation while, given the condition that the game is balanced, keeping the error bounded.

At any period k, the current coalition values $v(k)$ are unknown, while their long-run value v and the current coalition excess or error $x(k)$ are known. Under this specification of the information set, Bauso and Timmer (2009) suggest a solution in form of a feedback rule that reverses erroneous allocations and deviations from the targeted equilibrium allocation. This is done by defining a new state variable:

$$z(k) = \begin{bmatrix} x(k) \\ y(k) \end{bmatrix} \tag{36}$$

Where $x(k)$ track the errors, while $y(k)$ keeps track of deviations of the current allocation from the target expected equilibrium allocation. The variable evolves according to the equation

$$z(k+1) = z(k) + u(k) - Dv(k). \tag{37}$$

The solution method assigns allocations to players such that any errors and deviations from the target allocation are reversed:

$$u(k) = -z(k). \tag{38}$$

The solution is akin to a feedback rule that reverses any shortfalls (or excess) in the allocations as well as any deviations from the expected equilibrium allocation.

The allocation needs to observe the constraints specified by (33), placing the following bounds on the allocation rule

$$u_i(k) = \begin{cases} u_{i,\min} & \text{if} \quad u_{i,\min} > -z_i(k) \\ -z_i(k) & \text{if} \quad u_{i,\min} \leq -z_i(k) \leq u_{i,\max} \\ u_{i,\max} & \text{if} \quad -z_i(k) > u_{i,\max} \end{cases} \tag{39}$$

By letting the lower bound of the contemporaneous allocation be a function of the long run equilibrium allocation, the bargaining strength of players affects the way in which the costs of dynamic uncertainty will be distributed among the the players.

7.2 Simulation

This section simulates the model under two scenarios in order to highlight the role of bargaining strength asymmetries in sovereign debt negotiation breakdown.

In the first scenario, there are no bargaining strength asymmetries between the debtor country and its foreign creditors.

In the second scenario, there are bargaining strength asymmetries by assuming that the debtor country, Greece in our example, is in a strategically weaker bargaining position relative to its creditors.

Simulations of the model with no bargaining strength asymmetries show that sovereign debt negotiations do not break down in the absence of bargaining strength asymmetries. This contrasts with simulations of the model with bargaining strength asymmetries in which sovereign debt negotiations occasionally break down.

The mechanism driving this key result is that the presence of a strong coalition places a constraint on the distribution of the gains from trade that, in practice, is infeasible to be satisfied in all periods. The creditors, by virtue of their bargaining strength, can credibly demand to receive a payoff that is at least as large as the payoff available from their outside option. The payoff required to be allocated to the members of the strong coalition, however, is not feasible when the aggregate gains from trade may, due to large adverse shocks in some periods, fall short of the level required to satisfy the strong coalition's demand arising from the return available from its outside option.

Analysing the distribution of the shocks at the time of sovereign debt negotiation breakdown indicates that the most likely combination of shocks triggering a breakdown in negotiations is a positive shock to $v_{23}(t)$, the payoff available from the creditors' outside option, combined with a negative shock to $v_{123}(t)$, the available amount of aggregate gains from trade.

Simulation settings

Table 2 describes the simulation settings. The simulation horizon is set to $T = 300$ and the length of time between allocations is $1/\Theta = 0.1$. The resulting number of allocation periods is $K = 3000$. The parameter binding the lower and upper bound on the contemporaneous allocations is set to $\sigma = 0.5$. A

Parameter	Value
T	300
Θ	10
K	3000
σ	0.5
ε	-0.5

Table 2: Simulation settings

sovereign debt crisis occurs when the dissatisfaction regarding the divisions of gains from trade to any player or coalition of players grows larger than or equal to a measure of $\varepsilon = |-0.5|$.

Model with no bargaining strength asymmetries

This section simulates the model with no bargaining strength asymmetries.

Bargaining strength asymmetries can be removed from the model by changing the numerical specification of the coalition values such that the coalition between the euro-area creditor countries and international banks, i.e. players $\{2, 3\}$, is no longer a strong coalition. Any choice of the value of the strategic outside option v_{23} that satisfies $v_{23} < \frac{2}{3}v_{123}$ will remove the asymmetry in bargaining strength. Only the relative size of the strategic outside option matters as a measure of relative bargaining strength. In the example here, we select $v_{23} = 0.6$, compared to $v_{23} = 0.7$ in the model with strength asymmetries, to remove the strategic strength of the debtor country's creditors. The full numerical specification of the coalition values is:

$$v_i = 0 \qquad \begin{array}{c} v_{12} = 0.25 \\ v_{13} = 0.3 \\ v_{23} = 0.6 \end{array} \qquad v_{123} = 1. \tag{40}$$

Under symmetrical bargaining strength, the gains from trade will, in the long-run, be divided equally between the debtor country and its creditors. The long-run equilibrium allocation designates a share of $a_i^* = \frac{1}{3}$ of the gains from trade to each player.

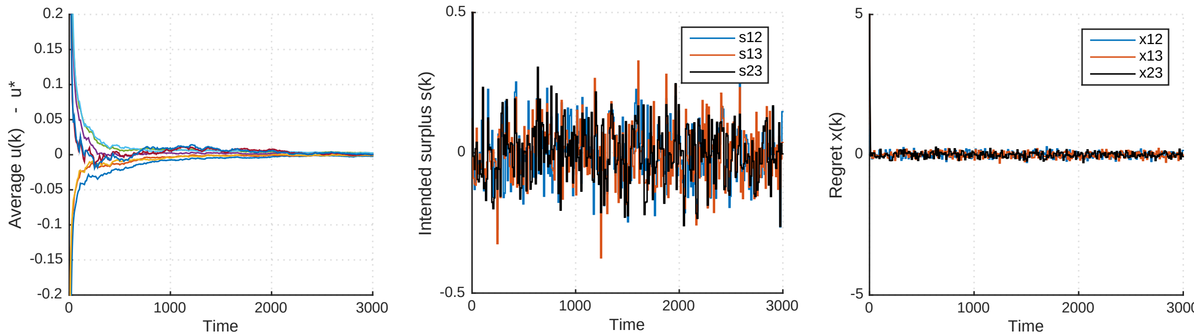
As explained in Section 7.1, the allocation implies a surplus s_S^* for each coalition S. The surplus measures the difference between the sum of the payoffs allocated to the players of the coalition $\sum_i a_{i \in S}$ and the actual value of the coalition v_S.

The augmented equilibrium allocation $u^* = [a^* \, s^*]'$ is:

$$a_i^* = s_i^* = \frac{1}{3} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \qquad s_{ij}^* = \frac{1}{3} \begin{bmatrix} 1.25 \\ 1.10 \\ 0.20 \end{bmatrix}. \tag{41}$$

The size of equilibrium allocation, particularly those of the surpluses s_{ij}, matters because it affects how, in any period k, the allocation $u(k)$ can deviate from the equilibrium at any period $k < T$ in the short-run. Recall from Section 7.1 that the long-run equilibrium imposes the following restrictions on the SR allocation $u(k)$:

$$-0.5u^* \;\leq\; u(k) \;\leq\; 0.5. \tag{42}$$



(a) Average allocation (b) Intended surplus (c) Dissatisfaction

Figure 12: Simulation of model with no bargaining strength asymmetries

Given this restriction, as long as all entries in the equilibrium vector u^* are non-zero, all elements of the allocation vector $u(k)$ can fall below the equilibrium allocation in any period k. Note that all elements of the equilibrium allocation in (41) are positive. This is necessary for the solution to the model to be feasible in keeping the error within a margin $|\varepsilon|$. Crucially, as will be seen below, this is not case in the model with bargaining strength asymmetries, characterised by the presence of a strong coalition whose equilibrium surplus s_{23} is zero.

Figure 12 reports the simulation results for the model with no bargaining strength asymmetries. Plot 12a shows that the average allocation $u(k) = [a(k)\ s(k)]'$ converges to the equilibrium allocation u^*. Plot 12b shows how the allocation mechanism adjusts the surplus $s(k)$ intended for a player or coalition of players in order to achieve an average allocation that converges to the target equilibrium allocation and to contain the level of erroneous allocations. Plot 12c illustrates the level of erroneous allocations $x(k)$, a measure that sums the difference between the intended surplus and the actual surplus over all periods up to k. The error measures the net deviations of the actual allocation from the intended allocation. If it is negative, the error for a player or coalition of players indicates their level of dissatisfaction with the division of the gains up in all periods up to k.

All the elements of the error $x(k)$ are bounded within a margin of error $\varepsilon = -0.5$. Negotiations never break down as the level of dissatisfaction of any player and coalition of players never falls below $|\varepsilon|$ during any period.

Model with bargaining strength asymmetries

We now simulate the model with bargaining strength asymmetries.

Assume that the debtor country is strategically weaker than its creditors. In our example of the Greek negotiations, this means that the euro-area creditor countries including Germany (player 2) and the international private sector creditors (player 3) are in a strategically stronger bargaining position than Greece (player 1).

The numerical specification of the coalition values is

$$v_i = 0 \qquad \begin{matrix} v_{12} = 0.25 \\ v_{13} = 0.3 \\ v_{23} = 0.7 \end{matrix} \qquad v_{123} = 1 \tag{43}$$

which differs from the model with no bargaining strength asymmetries in that here $v_{23} > \frac{2}{3}v_{123}$. This condition implies that the foreign official sector creditors (player 2) and international private creditors (player 3) could jointly obtain a larger share of the distribution of the gains from trade by virtue of their strategic outside option v_{23} being a credible threat. Any other coalitions of players $\{i, j\}$ are weaker because $v_{ij} < \frac{2}{3}v_{123}$.

Asymmetrical bargaining strength leads to the gains from trade being divided unequally. In the absence of bargaining strength asymmetries, each player receives $a_i^* = \frac{1}{3}\,1.00$. But here in the presence of bargaining strength asymmetries, the equilibrium allocation designates a smaller share $a_1^* = \frac{1}{3}\,0.90$ to the debtor country and a larger share $a_2^* = a_3^* = \frac{1}{3}\,1.05$ to each of the creditors.

The equilibrium allocation $u^* = [a^*\, s^*]'$ in the model with bargaining strength asymmetries thus is

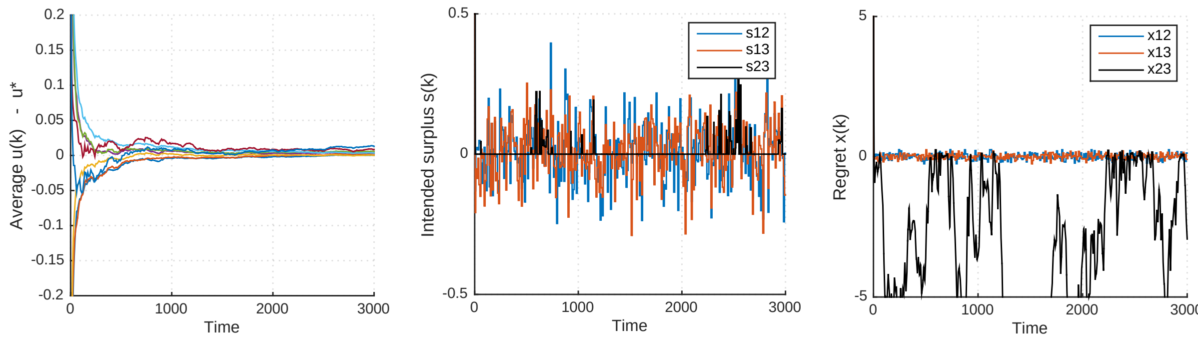
$$a_i^* = s_i^* = \frac{1}{3}\begin{bmatrix} 0.90 \\ 1.05 \\ 1.05 \end{bmatrix} \qquad s_{ij}^* = \frac{1}{3}\begin{bmatrix} 1.20 \\ 1.05 \\ 0 \end{bmatrix}. \tag{44}$$

Importantly, note that the equilibrium surplus for the strong coalition is zero, $s_{23}^* = 0$ implying $a_2^* + a_3^* = v_{23}$. This can be interpreted as the participation constraint of the strong coalition $\{2, 3\}$ to be binding strictly, while the participation constraints of the weaker coalitions $\{1, 2\}$ and $\{1, 3\}$ are slack, meaning $a_1 + a_2 \geq v_{12}$ and $a_1 + a_3 \geq v_{13}$.

The equilibrium allocation u^*, particularly the surpluses s_{ij} matter as they affect how far the allocation $u(k)$ can deviate from the equilibrium. The restriction

$$-\,0.5u^* \;\leq\; u(k) \;\leq\; 0.5 \tag{45}$$

implies that, as long as all entries in the equilibrium vector u^* are positive, the allocation $u(k)$ can fall below the equilibrium allocation. However, because $s_{23}^* = 0$, the intended surplus to the strong coalition can never fall below the equilibrium allocation. Yet the possibility of a deviation below as well as above the equilibrium allocation is necessary for the solution to the model to correct



(a) Average allocation (b) Intended surplus (c) Dissatisfaction

Figure 13: Simulation of model with bargaining strength asymmetries

past erroneous allocations and, thereby, contain the level of error $x(k)$.

Recall, that in the presence of uncertainty about the coalition values, the allocation mechanism produces erroneous allocations $x(k)$ which the solution method subsequently reverses by increasing (decreasing) the intended surplus to those players and coalition of players that have received too little (too much) revenue of the gains from trade in the previous period. This solution method, discussed in Section (7.1), ensures that the average allocation converges to the expected equilibrium allocation while keeping the error within the band $|\varepsilon|$.

Figure 13 reports the simulation results for the model with bargaining strength asymmetries. Plot 13a shows that the average allocation $u(k) = [a(k)\ s(k)]'$ converges to the equilibrium allocation. Plot 13b shows how the allocation mechanism adjusts the intended surplus $s(k)$ for a player or coalition of players in order to achieve an average allocation that converges to the target equilibrium allocation. The strong coalition constrains the allocation mechanism's flexibility to correct past errors in the allocations to the strong coalition. This is because in (45) the lower bound on the surplus to the strong coalition requires it to be non-negative $s_{23}(k) \geq 0$.

As will be seen below, the allocation mechanism results in sovereign debt negotiations that occasionally break down. The dissatisfaction, or negative level of the error $x(k)$, cannot be contained above the admissible threshold $|\varepsilon|$. The strong players do not take account of the negative externality that their bargaining strength exerts on the stability of the sovereign debt negotiations.

Plot 13c illustrates the level of erroneous allocations, a measure which sums the difference between the intended surplus and the actual surplus that occurred in all periods up to k. The error measures the net deviations of the actual allocation from the intended allocation. A negative value of the error $x(k)$ can be thought to reflect the level of dissatisfaction of a player or set of players about the distribution of the gains from trade over all periods up to k. One can see that the error for the international banks x_3, as well as the coalition between the debtor country and the international banks x_{13} can no longer be contained above $\varepsilon = -0.5$. In periods where either x_{13} or x_3 are already exceeding this threshold, the error for the coalition between the creditors x_{23} also exceeds the dissatisfaction threshold.

In the presence of bargaining strength asymmetries, sovereign debt negotiations can break down. Negotiations break down when a player or set of players' dissatisfaction with how the gains from trade have been distributed, as measured by the level of erroneous allocations, exceeds a threshold $|\varepsilon|$.

Definition: *Sovereign debt negotiations break down if any participant or set of participants in the negotiations are significantly dissatisfied how the gains from trade have been allocated over the course of the maturity of the sovereign bond. There is pressure to abandon reaching a perfect agreement if the regret of a player or set of players, denoted by* $x(k) < 0$*, falls below the threshold* $|\varepsilon|$.

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