Country Portfolios, Collateral Constraints and Optimal Monetary Policy*

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Abstract

This paper develops a model where financial market imperfections, in the form of cross-border collateral constraints, generate international shock transmission which is inefficient from a welfare point of view. We demonstrate how, in this context, optimal monetary policy deviates from inflation targeting in order to deal with these financial market distortions. We find that the optimal monetary rule includes a strong feedback from the credit spread and that optimal policy delivers non-trivial welfare gains relative to inflation targeting. A comparison between cases with and without international financial trade shows that the risk-sharing role of asset trade appears to outweigh its role in shock transmission. So, despite the presence of collateral constraints, international financial integration appears to reduce the risk-sharing role of optimal monetary policy. This is true even when there are large and persistent shocks to collateral constraints.

Keywords: Optimal monetary policy, Financial market structure, Country portfolios, Collateral constraints

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1 Introduction

Prior to the financial crisis in 2008 there was a general consensus amongst economists and policy makers about the following two propositions: (i) that international financial market integration improves cross-country risk-sharing; and (ii) that monetary policy should focus on inflation stabilisation. The 2008 financial crisis shook the consensus around both propositions. The rapid transmission of the 2008 financial crisis from the USA to the rest of the world suggested that international financial markets, rather than providing risk sharing, actually created and transmitted economically inefficient shocks across countries. At the same time, concerns developed that the pre-crisis monetary policy framework (with its main focus on inflation stabilisation) was inappropriate in the face of financial market shocks. In this paper we develop a model which shows how financial market imperfections, in the form of cross-border collateral constraints, can generate international shock transmission similar to that observed during the 2008 crisis, and we demonstrate how, in this context, it is optimal for monetary policy to deviate from inflation targeting in order to deal with distortions arising in international financial markets.

Our starting point is the model developed by Devereux and Yetman (2010) and Devereux and Sutherland (2011b). These authors show that collateral constraints, in conjunction with international trade in equities and bonds, can imply that asset trade, while providing international risk-sharing, also creates a route by which inefficient shocks are transmitted across countries. This is because cross-border collateral constraints imply that, following a negative shock, 'fire sales' of assets in one country (which are required to meet the collateral constraint) cause parallel fire-sales (and asset price declines) in other countries.[1]

[1] The extensive closed-economy literature on financial frictions (which has greatly expanded since the 2008 crisis) emphasises a number of possible types of financial market imperfection. One line of literature emphasises collateral constraints, which arise because of *imperfect enforcement* (i.e. the inability of lenders to enforce full repayment of loans). The literature on imperfect enforcement was initiated by Kiyotaki and Moore (1997). A second important line of literature emphasises the role of *asymmetric information*. This builds on the work of Bernanke and Gertler (1989). See Quadrini (2011) for an extensive survey of the literature on both limited enforcement and asymmetric information. The Devereux and Yetman (2010) and Devereux and Sutherland (2011b) model is based on the limited enforcement literature. Dedola and Lombardo (2012) develop an alternative model, based on an asymmetric information friction, which also shows

The Devereux and Yetman (2010) and Devereux and Sutherland (2011b) model is a flexible price framework where there is no explicit role for monetary policy, so the first task of our paper is to develop an extended version of the model which incorporates sticky nominal prices. We use this extended model to analyse optimal monetary policy in the presence of international trade in equities and bonds in combination with cross-border collateral constraints.

Our central finding is that collateral constraints imply that optimal monetary policy should deviate from strict inflation targeting. We find that the optimal monetary rule implies a strong feedback from the *credit spread* (i.e. the spread between equity returns and the return on borrowing) to monetary policy. Thus optimal monetary policy tends to stabilise the credit spread. It also tends to reduce the inefficient fluctuations in the capital stock that are triggered by collateral constraints. Significantly, we find that the optimal monetary rule implies non-trivial welfare gains relative to inflation targeting. These results demonstrate that, in the presence of cross-border collateral constraints and trade in equities and bonds, optimal monetary policy is required to deviate from inflation targeting in order to offset distortions arising in international financial markets.

Our results have a close parallel in the closed economy literature on financial mark distortions. Curdia and Woodford (2010), who add an *ad hoc* form of financial friction into an otherwise standard closed economy new Keynesian model, show that optimal monetary policy should respond to the credit spread. Carlstrom *et al* (2010) demonstrate similar results in a closed economy model where firms are subject to collateral constraints that limit their ability to acquire working capital. Likewise, de Fiore and Tristani (2013) find that optimal monetary policy should respond to the credit spread in a closed economy model which incorporates asymmetric information between borrowers and lenders. In contrast to these papers, our paper analyses monetary policy in a framework which allows for the international transmission of financial market distortions and shocks, which we argue is a key feature of the 2008 financial crisis.

Turning to the recent open economy literature, the links between imperfections in international financial markets and optimal monetary policy have been analysed by Corsetti *et al* (2010, 2011). The main focus of these papers, rather than on collateral constraints, is on the lack of a full set of contingent assets to allow perfect

how financial markets can cause the inefficient international transmission of shocks.

risk sharing. Corsetti *et al* (2010, 2011) show that financial market incompleteness (in the extreme form of financial autarky or bond-only economies) can imply that monetary policy has a strong welfare role as a risk sharing device. There are thus potentially large welfare gains to be achieved by departing from strict inflation targeting. It is important to emphasise however, that the Corsetti *et al* (2010, 2011) model has a very limited ability to capture the key features of financial markets that appeared to play such an important role in the 2008 financial crisis. In the Corsetti *et al* (2010, 2011) model the only form of financial market imperfection is the absence of a full set of state contingent assets. Unlike the model presented below, this form of imperfection does not explain the way that the 2008 crisis was transmitted across countries. More generally, it is not clear that models based on autarky or bond-only economies are a good representation of present-day international financial markets.

In another related contribution to the open-economy literature, Senay and Sutherland (2016) show that an extended form of the Corsetti *et al* (2010, 2011) model, which allows for international trade in equities and bonds, while still short of financial completeness, tends to imply that optimal monetary policy is very close to strict inflation targeting and there is no significant role for monetary policy as a risk-sharing device. The key difference between the current paper and Senay and Sutherland (2016) is that our current paper combines cross-border collateral constraints with trade in equities and bonds whereas the Senay and Sutherland (2016) model does not include collateral constraints. The contrast between the main result reported in the current paper and the results in Senay and Sutherland (2016) thus demonstrate the implications of adding collateral constraints into a model with international trade in bonds and equities. Our results show that the addition of collateral constraints creates a significant imperfection in international financial markets which, in contrast to Senay and Sutherland (2016), implies that optimal monetary policy deviates significantly from inflation targeting.

The main focus of our analysis is on the implications of financial market imperfections for optimal monetary policy. But we can also use our model to consider an alternative question, namely the implications of *international financial integration* in a world which is subject to collateral constraints. We achieve this by comparing our benchmark case (which combines collateral constraints with asset trade) with a version of the model which combines collateral constraints with financial autarky. In performing this comparison, we find that optimal monetary policy in the financial autarky version of our model implies a larger deviation from inflation targeting and larger welfare gains relative to inflation targeting. This latter result shows that international asset trade implies lower welfare gains from monetary policy optimisation even when there are collateral constraints. In other words, despite the presence of collateral constraints, the risk sharing role of asset trade appears to outweigh its role in shock transmission.

One final contribution of our analysis relates to solution methodology. A key feature of the Devereux and Sutherland (2011b) model is that, within the collateral constraint, borrowers have a portfolio choice over home and foreign equities. The full analysis of optimal policy within our model must therefore combine welfare analysis of monetary policy with analysis of optimal portfolio choice by borrowers. Senay and Sutherland (2016) show how this combined analysis can be conducted in a model without collateral constraints. An important contribution of this paper is to extend this combined analysis to a model with collateral constraints.[2]

This paper proceeds as follows. The model is described in Section 2. We briefly illustrate the dynamic properties of the model in Section 3. Our specification of monetary policy and welfare is described in Section 4 and our approach to solving for asset market equilibrium and optimal policy is outlined in Section 5. The results are presented and discussed in Section 6, while Section 7 concludes the paper.

2 The Model

The model economy consists of two countries, home and foreign. As is standard in the literature on limited enforcement and collateral constraints it is necessary to assume that there are two types of households (within each country), borrowers and savers. Borrowers are less patient than savers.

[2] We solve the model assuming that the collateral constraint is always binding. Devereux and Yu (2014) and Devereux *et al* (2015) analyse related models where the collateral constraint is assumed to be occasionally binding. Devereux and Yu (2014) analyse the positive and welfare implications of international financial integration. In particular, they show how financial integration in the presence of collateral constraints can have both risk sharing and shock transmission effects. Devereux *et al* (2015) analyse optimal monetary and capital control policy in anticipation of and in response to sudden stops.

Borrowers hold real capital which they rent to intermediate goods firms. Savers also hold real capital and produce intermediate goods but, crucially, they are only able to access technology which is less productive than that available to borrowers. Final goods are produced using intermediate goods as the only input. Final goods are produced by imperfectly competitive firms which are subject to Calvo (1983) pricing.

All borrowing and lending takes the form of trade in real non-contingent bonds. In the benchmark version of the model there is an integrated world bond market, so borrowers and savers in both countries trade bonds in this single integrated bond market.

We assume that equity trade takes the form of trade in the ownership of real capital. Savers are assumed to hold only capital located in their own country and thus do not have access to international equity markets. Borrowers, however, can hold real capital in both countries and are able to trade in equity holdings in capital with borrowers in the other country.

Borrowers are subject to a collateral constraint which implies that, for individual borrowers, borrowing cannot exceed a fraction of the value of the borrower's total equity holdings. In our simulations we choose values for discount rates and technology to ensure that collateral constraints are binding in the steady state. Furthermore, in our stochastic and deterministic simulations we assume that the constraints are binding in all states of the world.

We analyse the effects of real and financial market shocks. Each country is subject to shocks to total factor productivity and shocks that directly affect collateral constraints. The later shocks represent random changes to borrowing terms caused, for instance, by exogenous variations in the perceptions of default risk. Collateral constraint shocks are emphasised in Jermann and Quadrini (2012) who show, via a variance decomposition, that shocks of this type are able to explain a significant proportion of GDP fluctuations.

Below we describe in turn the details of borrows' and savers' decision problems, intermediate goods production, final goods production and capital goods production.

2.1 Borrowers

Borrower h in the home country maximizes a utility function of the form

$$U_{b,t} = E_t \sum_{i=0}^{\infty} \beta_{b,t+i} \frac{C_{b,t+i}^{1-\rho}(h)}{1-\rho} \tag{1}$$

where $\rho > 0$, $C_b(h)$ is the consumption of borrower household h and β_b is the discount factor, which is determined as follows

$$\beta_{b,t+i+1} = \bar{\beta}_b \beta_{b,t+i} \left(1 + C_{b,t+i}\right)^{-\eta}, \ \beta_{b,t} = 1 \tag{2}$$

where $0 < \eta < \rho$, $0 < \bar{\beta}_b < 1$, C_b is aggregate home consumption of borrowers.[3]

C is a basket of final goods which we assume is identical across savers and borrowers in both countries. Thus we assume there is no home-bias in consumption and the real exchange rate is equal to unity. We can therefore use the final goods basket as a numeraire.

In the benchmark version of the model we assume that borrower households can hold capital located in either country. In this case the flow budget constraint of the home country borrower household is

$$\begin{aligned} & P_t C_{b,t} - P_t B_t + P_t z_t K_{H,t} + P_t z_t^* K_{F,t} \\ = \ & -R_{t-1} P_t B_{t-1} + (1-\delta) P_t z_t K_{H,t-1} + P_t x_t K_{H,t-1} \\ & +(1-\delta) P_t z_t^* K_{F,t-1} + P_t x_t^* K_{F,t-1} \end{aligned} \tag{3}$$

where P is the consumer price index, B is the stock of borrowing, K_H is home capital owned by borrowers, K_F is the foreign capital owned by borrowers, z is the price of home capital goods (in terms of final goods), z^* is the price of foreign capital goods (in terms of final goods), R is the real rate of interest on borrowing and x and x^* are the rental rates of home and foreign capital (in terms of final goods). δ is the depreciation rate of real capital. It is assumed that all labour is supplied by saver households so borrower households have no labour income.

As stated above, borrowing takes the form of bonds, so B is the stock of bonds issued by home country borrowers. As also stated above, equity holdings are in the form of real capital, so zK_H and z^*K_F are home country borrowers' holdings of home and foreign equities.

[3] Following Schmitt-Grohe and Uribe (2003), β_b is assumed to be taken as exogenous by individual decision makers. The impact of individual consumption on the discount factor is therefore not internalized.

The central feature of the model is that borrowing is subject to a collateral constraint which limits the amount of borrowing relative to the value of capital (equity) holdings. The collateral constraint is assumed to take the following form

$$B_t \leq \kappa_t \left(z_t K_{H,t} + z_t^* K_{F,t} \right) \tag{4}$$

where κ is a 'capital constraint shock.' We assume $\kappa_t = \bar{\kappa} \exp(\hat{\kappa}_t)$ where $0 < \bar{\kappa} < 1$, $\hat{\kappa}_t = \eta_\kappa \hat{\kappa}_{t-1} + \varepsilon_{\kappa,t}$ and $0 \leq \eta_\kappa < 1$ and $\varepsilon_{\kappa,t}$ is a zero-mean normally distributed i.i.d. shock with $Var[\varepsilon_\kappa] = \sigma_\kappa^2$.

The first order conditions for borrowers imply

$$\beta_{b,t} C_{b,t}^{-\rho} = E_t \left[\beta_{b,t+1} C_{b,t+1}^{-\rho} R_{t+1} \right] + \beta_{b,t} \mu_t \tag{5}$$

$$\beta_{b,t} C_{b,t}^{-\rho} = E_t \left[\beta_{b,t+1} C_{b,t+1}^{-\rho} r_{H,t+1}^e \right] + \beta_{b,t} \kappa_t \mu_t \tag{6}$$

$$\beta_{b,t} C_{b,t}^{-\rho} = E_t \left[\beta_{b,t+1} C_{b,t+1}^{-\rho} r_{F,t+1}^e \right] + \beta_{b,t} \kappa_t \mu_t \tag{7}$$

where μ_t is the Lagrange multiplier associated with the collateral constraint and

$$r_{H,t+1}^e = \frac{\left[(1-\delta) z_{t+1} + x_{t+1} \right]}{z_t} \qquad r_{F,t+1}^e = \frac{\left[(1-\delta) z_{t+1}^* + x_{t+1}^* \right]}{z_t^*}$$

are the rates of return on home and foreign capital.

Notice that the borrower has a portfolio decision to make over the composition of the capital holdings located in the two countries. Equations (6) and (7) can be combined to yield the following optimality condition for portfolio allocation

$$E_t \left[\beta_{b,t+1} C_{b,t+1}^{-\rho} \left(r_{H,t+1}^e - r_{F,t+1}^e \right) \right] = 0 \tag{8}$$

As shown by Devereux and Sutherland (2011b), despite the presence of the collateral constraint, this condition is in a form which allows the application of the Devereux and Sutherland (2011a) portfolio solution methodology. The application of this solution methodology will be discussed in more detail below.

Notice also that if the collateral constraint is not present the Lagrange multiplier, μ_t, would be zero in equations (5), (6) and (7). This implies that, up to a first order approximation, $E_t \left[r_{H,t+1}^e \right] = E_t \left[R_{t+1} \right]$, i.e. the rate of return on capital is equated to the cost of borrowing. The presence of the collateral constraint breaks this equality and therefore introduces a premium, or a *spread*, between the return on capital and the cost of borrowing, thus $E_t \left[r_{H,t+1}^e \right] - E_t \left[R_{t+1} \right] > 0$. It is useful to define

$$SPR_t = E_t \left[r_{H,t+1}^e - R_{t+1} \right]$$

to be the *spread*. The monetary policy rule specified below will include a feedback term that responds to this spread.

In the analysis reported below we also consider a version of the model where there is no international trade in financial or real assets. In this alternative case borrowers can only hold capital located in their own country. The home budget constraint therefore takes the form

$$\begin{aligned} & P_t C_{b,t} - P_t B_t + P_t z_t K_{H,t} \\ = \quad & -R_{t-1} P_t B_{t-1} + (1-\delta) P_t z_t K_{H,t-1} + P_t x_t K_{H,t-1} \end{aligned} \tag{9}$$

and the collateral constraint is

$$B_t \leq \kappa_t z_t K_{H,t}$$

In this alternative formulation of the model borrower households do not have any portfolio decision and equations (7) and (8) are irrelevant.

2.2 Savers

Savers are assumed to be more patient than borrowers. In addition they do not have access to international equity markets (i.e. they cannot trade in home and foreign capital holdings) and they cannot rent capital to intermediate goods firms. Their asset choices are thus limited to bonds and local holdings of real capital. Their holdings of real capital can only be used in the 'back-yard' production of intermediate goods using a technology which is less productive than that available to intermediate goods firms.

Home country saver household h maximises a utility function of the form

$$U_{s,t} = E_t \sum_{i=0}^{\infty} \beta_{s,t+i} \frac{C_{s,t+i}^{1-\rho}(h)}{1-\rho} \tag{10}$$

where $\rho > 0$, $\phi > 0$, $C_s(h)$ is the consumption of saver household h and β_s is the discount factor, which is determined as follows

$$\beta_{s,t+i+1} = \bar{\beta}_s \beta_{s,t+i} \left(1 + C_{s,t+i}\right)^{-\eta}, \ \beta_{s,t} = 1 \tag{11}$$

where $0 < \eta < \rho$, $0 < \bar{\beta}_s < 1$, C_s is aggregate home consumption of savers. Savers are assumed to be more patient than borrowers so $\bar{\beta}_s > \bar{\beta}_b$.

The flow budget constraint of the home country saver household is

$$P_tC_{s,t} + P_tS_t + P_tz_tK_{s,t} = R_{t-1}P_tS_{t-1} + (1-\delta)P_tz_tK_{s,t-1} + P_tq_tY_{s,t} + P_tw_tH + P_t\Pi_t \quad (12)$$

where S is the stock of savings (i.e. holdings of bonds), K_s is the capital stock owned by savers, Y_s is the output of intermediate goods produced by savers, H is the labour supply of savers (which, for simplicity, is assumed to be exogenous and constant) and w is the real wage (in terms of final goods). Π_t is the profits of capital producing firms plus the profits of final goods producers (to be defined in more detail below).

Savers produce intermediate goods using the following technology

$$Y_{s,t} = \bar{A}_sA_tK_{s,t-1}^{1-\varphi_s}$$

where total factor productivity is $\bar{A}_sA_t$ and A_t is a shock (defined below) which is common to both borrower and saver production technologies.

In the benchmark version of the model we assume that the market for borrowing and lending (i.e. the international market for bonds) is integrated across the two countries. Equilibrium therefore implies

$$S_t + S_t^* = B_t + B_t^*$$

The first order conditions for savers imply

$$\beta_{s,t}C_{b,t}^{-\rho} = E_t\beta_{s,t+1}C_{s,t+1}^{-\rho}R_{t+1} \quad (13)$$

$$\beta_{b,t}C_{b,t}^{-\rho} = E_t\beta_{b,t+1}C_{b,t+1}^{-\rho}r_{s,t+1}^e \quad (14)$$

where

$$r_{s,t+1}^e = \frac{\left[(1-\delta)z_{t+1} + q_{t+1}(1-\varphi_s)\bar{A}_sA_{s,t+1}K_{s,t}^{-\varphi_s}\right]}{z_t}$$

is the rate of return on capital owned by savers in the home country.

Equilibrium in the market for borrowing and lending implies

$$E_t\left[R_{t+1}\right] = E_t\left[R_{t+1}^*\right] \quad (15)$$

In an alternative version of the model we assume that the market is segmented across the two countries so equilibrium in the two separate markets for borrowing and lending implies

$$S_t = B_t \qquad S_t^* = B_t^*$$

2.3 Final goods consumption

We define $C_{i,t}$ $(i = s, b)$ to be a consumption basket which aggregates Home and Foreign final goods according to:

$$C_i = \left[\frac{1}{2}^{\frac{1}{\theta}} C_{H,i}^{\frac{\theta-1}{\theta}} + \frac{1}{2}^{\frac{1}{\theta}} C_{F,i}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{16}$$

where C_H and C_F are baskets of individual home and foreign produced final goods. The elasticity of substitution across individual goods within these baskets is $\nu > 1$. The parameter θ in (16) is the elasticity of substitution between home and foreign goods. Note that the home and foreign baskets are equally weighted so, as stated above, there is no 'home bias' in preferences. The assumption of no home bias, combined with the assumption of producer currency pricing implies that the real exchange rate (in terms of final goods prices) is unity.

The price index associated with the consumption basket C_t is

$$P_t = \left[\frac{1}{2} P_{H,H,t}^{1-\theta} + \frac{1}{2} P_{F,H,t}^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{17}$$

and where $P_{H,H}$ is the price index of home goods for home consumers and $P_{F,H}$ is the price index of foreign goods for home consumers. The corresponding prices for foreign consumers are $P_{H,F}$ and $P_{F,F}$.

Note that the terms of trade for the home country can be defined as follows

$$\tau = \frac{P_{F,F}}{P_{F,H}}$$

2.4 Intermediate goods firms

Intermediate goods firms operate in a perfectly competitive market with flexible prices and use the following technology

$$Y_{b,t} = \bar{A}_b A_t K_{b,t-1}^{1-\varphi_b} L_{b,t}^{\varphi_b}$$

where $K_{b,t} = K_{H,t} + K_{H,t}^*$ is total capital used by intermediate firms (i.e. the sum of home capital owned by home and foreign borrowers and rented to firms) and L_b is labour input. $\bar{A}_b A_{b,t}$ is total factor productivity (TFP) where A_t is a TFP shock determined as follows

$$\log(A_t) = \eta_A \log(A_{t-1}) + \varepsilon_{A,t}$$

where $0 \leq \eta_A < 1$ and $\varepsilon_{A,t}$ is a zero-mean normally distributed i.i.d. shock with $Var[\varepsilon_A] = \sigma_A^2$.

As stated above, we assume that intermediate goods firms have access to technology which is more productive than the technology available to savers. We therefore assume $\bar{A}_b > \bar{A}_s$.

Profits are given by

$$q_t Y_{b,t} - x_t K_{b,t} - w_t L_{b,t}$$

where q is the price of intermediate goods (in terms of final goods), w is the real wage rate (in terms of final goods) and x is the rental rate of home capital.

The first order conditions for employment of labour and capital are

$$x_t = q_t (1 - \varphi_b) \bar{A}_b A_{b,t} K_{b,t-1}^{-\varphi_b} L_{b,t}^{\varphi_b}$$

$$w_t = q_t \varphi_b \bar{A}_b A_{b,t} K_{b,t-1}^{1-\varphi_b} L_{b,t}^{\varphi_b - 1}$$

2.5 Final goods firms

Each firm in the final goods sector produces a single differentiated product. Sticky prices are modelled in the form of Calvo (1983) contracts with a probability of re-setting price given by $(1 - \lambda)$. We assume producer currency pricing (PCP).

If firms use the discount factor Ω_t to evaluate future profits, then firm z chooses its prices for home and foreign buyers, $p_{H,H,t}(z)$ and $p_{H,F,t}(z)$, in home currency to maximize

$$E_t \sum_{i=0}^{\infty} \Omega_{t+i} \lambda^i \left\{ y_{H,H,t+i}(z) \frac{[p_{H,H,t}(z) - q_{t+i}]}{P_{t+i}} + y_{H,F,t+i}(z) \frac{[p_{H,F,t}(z) - q_{t+i}]}{P_{t+i}} \right\} \quad (18)$$

where $y_{H,H}(z)$ is the demand for home good z from home buyers and $y_{H,F}(z)$ is the demand for home good z from foreign buyers and q is the price of the intermediate good.

For completeness we assume that final goods producers are owned by saver households who therefore receive the profits arising from final goods production.

2.6 Capital producers

Final goods are converted into real capital by perfectly competitive, profit maximising firms and sold at price z where the cost of producing I units of real capital is given by

$$I + F(I)$$

in terms of final consumption goods where $F(0) = 0$, $F'(.) > 0$, $F''(.) > 0$. We assume

$$F(I) = \frac{\psi}{2} \frac{\left(I - \bar{I}\right)^2}{\bar{I}}$$

where $\bar{I}$ is steady state I.

The first order condition for producers of capital goods is

$$z_t = 1 + \varphi'(I_t)$$

and the capital stock follows the accumulation process

$$K_{b,t} + K_{s,t} = (1 - \delta)(K_{b,t-1} + K_{s,t-1}) + I_t$$

Again, for completeness we assume that capital goods producers are owned by saver households who therefore receive the profits arising from capital goods production.

2.7 Aggregation and Market clearing

Total home demand for final goods is

$$D_t = C_{b,t} + C_{s,t} + I_t + F(I_t)$$

where home demand for home final goods is given by

$$D_{H,H,t} = \frac{1}{2} D_t \left(\frac{P_{H,H,t}}{P_t}\right)^{-\theta}$$

and foreign demand for home final goods is given by

$$D_{H,F,t} = \frac{1}{2} D_t^* \left(\frac{P_{H,F,t}^*}{P_t^*}\right)^{-\theta}$$

Equilibrium in the intermediate goods market implies

$$Y_{b,t} + Y_{s,t} = V_{H,H,t} D_{H,H,t} + V_{H,F,t} D_{H,F,t}$$

where $V_{H,H,t}$ and $V_{H,F,t}$ are measures of price dispersion in final goods markets.

2.8 Portfolio allocation

Apart from the existence of the collateral constraint, a key distinguishing feature of the above model, that sets it apart from much of the existing literature on optimal monetary policy in open economies, is that it allows for international trade in *multiple* assets. Recently developed solution techniques (Devereux and Sutherland, 2011a) make it possible to solve for equilibrium portfolio allocation in models of this type and Devereux and Sutherland (2011b) show how these new techniques can be employed in the case where a collateral constraint is binding.

It is simple to show that the borrower's budget constraint (3) and the home and foreign collateral constraints (equation (4) and its foreign equivalent) can be re-written so that the borrower's portfolio decision appears in a format consistent with the Devereux and Sutherland approach. Using the definitions of $r^e_{H,t}$ and $r^e_{F,t}$, the borrower budget constraint can be written as follows

$$\begin{aligned} & z_t K_{H,t} + z^*_t K_{F,t} - B_t \\ = \; & r^e_{H,t} z_{t-1} K_{H,t-1} + r^e_{F,t} z^*_{t-1} K_{F,t-1} - R_{t-1} B_{t-1} - C_{b,t} \end{aligned}$$

Define Ψ_t and Ψ^*_t to be the total capital holdings of respectively home and foreign borrowers, i.e.

$$\Psi_t = z_t K_{H,t} + z^*_t K_{F,t} \qquad \Psi^*_t = z_t K^*_{H,t} + z^*_t K^*_{F,t}$$

and define X_t to be the share of foreign capital in the home borrower's portfolio

$$X_t = \frac{z^*_t K_{F,t}}{z_t K_{H,t} + z^*_t K_{F,t}}$$

so the budget constraint becomes

$$\Psi_t - B_t = r^e_{H,t} \Psi_{t-1} + \left(r^e_{F,t} - r^e_{H,t} \right) X_{t-1} \Psi_{t-1} - R_{t-1} B_{t-1} - C_{b,t} \tag{19}$$

Note that home and foreign holdings of capital must sum to home and foreign capital stocks, i.e.

$$K_{b,t} = K_{H,t} + K^*_{H,t} \qquad K^*_{b,t} = K_{F,t} + K^*_{F,t}$$

so

$$\Psi^*_t = z_t K_{b,t} + z^*_t K^*_{b,t} - \Psi_t$$

The home and foreign collateral constraints can now be written in terms of D_t as follows

$$B_t \leq \kappa_t \Psi_t \qquad B_t^* \leq \kappa_t^* \left(z_t K_{b,t} + z_t^* K_{b,t}^* - \Psi_t \right) \tag{20}$$

The budget constraint written in the form of (19) is in a format which allows the Devereux and Sutherland approach to be applied while the collateral constraints in the form of (20) do not contain any portfolio allocation variables. Portfolio variables therefore only appear in the borrower's budget constraint (as assumed in the Devereux and Sutherland approach). Note that in (19) the portfolio excess return is given by

$$\left(r_{F,t}^e - r_{H,t}^e \right) X_{t-1} \Psi_{t-1}$$

3 Inflation Targeting and the Dynamic Response to Shocks

Before we describe our approach to evaluating welfare and analysing optimal policy, it is useful first to describe the properties of the above model in the case where monetary policy is exclusively focused on targeting producer price inflation. This allows us to demonstrate the way that collateral constraints create a powerful mechanism which transmits the effects of TFP and financial market shocks from one country to another. It also allows us to show how collateral constraints act as an amplification mechanism which increases the impact of TFP shocks.

We discuss the properties of the model with reference to the impulse response functions in Figures 1 and 2. These impulse responses are based on the benchmark parameter set shown in Table 1.

The parameters of the discount factors are chosen to imply a steady state discount rate of approximately 1% per quarter for savers and 1.5% for borrowers. Following Devereux and Sutherland (2011b) and Mendoza and Smith (2006) η is set equal to 0.022. The trade elasticity, θ, is set equal to 1.5, which matches the value in Backus et al (1992). The share of real capital in production is set equal to 0.3 for both borrowers and savers, whereas steady state TFP ($\bar{A}_b$ and $\bar{A}_s$) is assumed to be unity for intermediate goods firms and 0.5 for savers (thus, as explained above, implying that borrowers have access to a more productive technology than savers). The depreciation rate of real capital, δ, is set at 0.025 while the parameter of the adjustment cost function, ψ, implies a standard deviation of

Table 1: Benchmark Parameter Values

Discount factors	$\bar{\beta}_b = 0.988$, $\bar{\beta}_s = 1.027$, $\eta = 0.022$
Elasticity of substitution: individual goods	$\nu = 10$
Risk aversion	$\rho = 1$
Trade elasticity	$\theta = 1.5$
Steady state TFP	$\bar{A}_b = 1$, $\bar{A}_s = 0.5$
Share of capital in production	$1 - \varphi_b = 1 - \varphi_s = 0.3$
Depreciation	$\delta = 0.025$
Capital adjustment costs	$\psi = 0.2$
Calvo price setting	$\lambda = 0.75$
Collateral constraint parameter	$\bar{\kappa} = 0.75$
TFP shocks	$\eta_A = 0.9$, $\sigma_A = 0.005$
Collateral constraint shocks	$\eta_\kappa = 0.9$, $\sigma_\kappa = 0.011$

investment which is approximately twice that of output. The Calvo pricing parameter, λ, is set at 0.75 and the elasticity of substitution between individual goods, ν, is set equal to 10. These values are typical in the New Keynesian literature. The steady state collateral constraint parameter, $\bar{\kappa}$, is set at 0.75, which matches the value used in Devereux and Sutherland (2011b). The parameters of the shock processes for TFP and the collateral constraint are those used in Devereux and Sutherland (2011b) (which are based on Jermann and Quadrini (2012)).

Impulse responses to the two shocks (TFP and the collateral constraint) are shown in Figures 1 and 2. The line marked with triangles in each plot shows the impulse response in the benchmark case (i.e. where there is international trade in equities and bonds and collateral constraints are binding). For comparison we also show impulse responses (marked with circles) for the case where there is no international trade in equities and bonds (but collateral constraints bind within each country), and impulse responses (marked with asterisks) for the case where there is international trade in equities and bonds but collateral constraints are absent.

Figure 1 shows the effect of a negative TFP shock in the home country. In the absence of the collateral constraint the TFP shock lowers output, investment, consumption and equity prices. The fall in investment leads to a gradual fall in the capital stock for both savers and borrowers.

The collateral constraint (both with and without international asset trade) tends to magnify these effects. The fall in equity prices tightens the collateral constraint and causes a shift of real capital from borrowers to savers. The fall in borrowing puts downward pressure on the real interest rate, while the fall in equity prices implies a upward shift in expected equity returns. The spread between equity returns and borrowing therefore rises. These results show that the overall effect of the collateral constraint is to create a financial accelerator effect which magnifies the effect of the shock on investment. There is also a small magnifying effect on output.

The main contrast between the cases with and without financial trade are in terms of the cross country effects. In the case where there is no international asset trade the main impact of the shock, and the amplification effect of the collateral constraint, is concentrated on the home country. Thus equity prices fall more in the home country than the foreign country, there is a larger effect on the spread in the home country than in the foreign country and larger shift of capital from borrowers to savers in the home country than in the foreign country. This contrasts with the case where there is international asset trade. In this latter case the amplification effect of the collateral constraint is quite evenly spread across the two countries. This reflects the transmission effects of the collateral constraint. The fall in equity prices in the home country tightens the collateral constraint for both home and foreign borrowers (because both home and foreign borrowers hold home equity). This forces both home and foreign borrowers to reduce capital holdings in both home and foreign countries and this implies that the initial shock (and the amplification effect of the collateral constraint) is transmitted to *both* countries.

Figure 2 shows the impulse response to a negative collateral constraint shock to the home country (i.e. a negative shock to κ in equation (4)). Collateral constraint shocks are obviously only relevant in the case where the collateral constraint exists so Figure 2 shows only two plots, representing the cases with and without international asset trade (in both cases with a binding collateral constraint). Figure 2 shows that a negative shock to κ (which represents a tightening of the collateral constraint) leads to an initial fall in the home equity price, a fall in the cost of borrowing, a rise in the rate of return on equities and a rise in the credit spread. There is a consequent shift in real capital from borrowers to savers and a fall in output. These effects all go into reverse as the shock decays.

The main contrast between the cases with and without asset trade is again in terms of the transmission of the shock between countries. When there is trade in assets the tightening of the collateral constraint in the home country forces home borrowers to reduce their holdings of both home and foreign capital. The fall in home equity prices also tightens the collateral constraint for foreign borrowers and they are also forced to reduce their holdings of both home and foreign capital. These effects imply that a shock to the home collateral constraint is quite evenly spread across the two countries when there is asset trade but are strongly concentrated on the home country when there is no asset trade.

Figures 1 and 2 illustrate how the collateral constraint both acts as an amplification mechanism and as a source of shocks. The figures also illustrate how the collateral constraint can become a cross country transmission mechanism when there is international asset trade.

4 Welfare and the Monetary Policy Rule

We now turn to the analysis of optimal monetary policy in the above model. In this section we describe our welfare criterion and our approach to representing monetary policy.

As in Senay and Sutherland (2016), the particular welfare measure on which we focus is the unconditional expectation of aggregate period utility. For the home economy this is defined as follows

$$U = E\frac{C^{1-\rho}}{1-\rho} \tag{21}$$

where time subscripts are omitted to indicate that this is a measure of unconditional expectation. Damjanovic *et al* (2008) argue that unconditionally expected utility provides a useful alternative to Woodford's (2003) 'timeless perspective' when analysing optimal policy problems. For the purposes of this paper, unconditional expected utility provides a simple and convenient way to compute welfare in a context where portfolio allocation is endogenous. The next section provides a more detailed discussion of the complications that arise in the simultaneous computation of welfare and equilibrium portfolios.

Welfare in each country is the sum of borrower and saver utility

$$W = U_b + U_s$$

where

$$U_b = E\frac{C_b^{1-\rho}}{1-\rho}, \qquad U_s = E\frac{C_{s,}^{1-\rho}(h)}{1-\rho}$$

Because there are two types of households in each country (i.e. savers and borrowers), monetary policy may have distributional consequences. This implies that welfare comparisons between monetary policy rules are more complicated than is the case in standard open economy models. To overcome this problem we choose a simple and natural principle, which is to restrict attention to monetary policy rules which are (weakly) Pareto improving relative to strict inflation targeting, i.e. rules which are (weakly) welfare superior to inflation targeting for both saver and borrower households.

In common with Corsetti *et al* (2010, 2011) and much of the previous literature, we focus on co-operative policy in the sense that policy rules for each country are simultaneously chosen to maximise global welfare, i.e. the sum of the home and foreign welfare measures.

We model monetary policy in the form of a 'targeting rule'.[4] In general the optimal targeting rule is model dependent. Corsetti *et al* (2010, 2011) show that the optimal targeting rule typically includes a measure of inflation and a number of welfare gaps. Because of the complicated interaction between policy and portfolio choice we do not derive the fully optimal policy rule for our model. Instead we

[4] As argued by Woodford (2003), a 'targeting rule' is a convenient way to capture the welfare trade-offs faced by policy makers. It allows policy to be specified in terms of an optimal equilibrium relationship between various welfare 'gaps'. Once policy is specified in this way there is no need explicitly to model policy in terms of the optimal setting of a policy instrument (such as the nominal interest rate). However, an implied optimal rule for the policy instrument can easily be derived once the optimal equilibrium has been derived.

postulate that the optimal rule can be approximated in the following form

$$
\begin{aligned}
(\hat{P}_{Y,t} - \hat{P}_{Y,t-1}) + \delta_Y(Y_{G,t} - Y_{G,t-1}) + \delta_\tau(\tau_{G,t} - \tau_{G,t-1}) \\
+\delta_{SPR}(SPR_t - SPR_{t-1}) + \delta_B(\mathcal{D}_{b,t} - \mathcal{D}_{b,t-1}) \\
+\delta_S(\mathcal{D}_{s,t} - \mathcal{D}_{s,t-1}) + \delta_x(\mathcal{D}_{x,t} - \mathcal{D}_{x,t-1}) = 0
\end{aligned}
\tag{22}
$$

where Y_G, τ_G, $\mathcal{D}_b$, $\mathcal{D}_s$ and $\mathcal{D}_x$ are defined as follows

$$Y_G = \hat{Y} - \hat{Y}^{fb}$$

$$\tau_G = \hat{\tau} - \hat{\tau}^{fb}$$

$$\mathcal{D}_b = -\rho\left(\hat{C}_b - \hat{C}_b^*\right)$$

$$\mathcal{D}_s = -\rho\left(\hat{C}_s - \hat{C}_s^*\right)$$

$$\mathcal{D}_x = -\rho\left(\hat{C}_s - \hat{C}_s^*\right) - \rho\left(\hat{C}_b - \hat{C}_b^*\right)$$

and where a hat over a variable represents its log deviation from the non-stochastic steady state and the superscript fb indicates the first best value of a variable. Thus Y_G is a measure of the output 'gap' and τ_G is a measure of the terms of trade 'gap.' As will be explained in more detail below, $\mathcal{D}_{b,}$ $\mathcal{D}_s$ and $\mathcal{D}_x$ are measures of the deviation from full risk sharing. There is an analogous targeting rule for the foreign economy.

The targeting rule in (22) contains seven terms. The first term depends on producer price (PPI) inflation. The central role of inflation stabilisation in optimal policy in New Keynesian models is a well-known consequence of staggered price setting. In essence, staggered price setting implies that inflation causes distortions in relative prices between goods. Inflation is thus (other things equal) welfare reducing.

The second term in (22) measures the welfare-relevant output gap. Again the role of the output gap in optimal targeting rules in New Keynesian models is well-known and needs no further explanation.

The third term in the targeting rule measures the welfare-relevant terms-of-trade gap. As Corsetti *et al* (2010, 2011) explain in detail, in an open economy, because there are different baskets of goods produced in different countries, shocks may have distortionary effects on the relative price of these different baskets. These distortions are welfare reducing in the same way as the within-country price distortions generated by inflation are welfare reducing. The terms of trade gap therefore plays the same role in the monetary policy rule as the PPI inflation term.

The fourth term in (22) measures the impact of the credit spread. In the absence of the collateral constraint the credit spread is zero. The size of the credit spread therefore captures the welfare distortion that is caused by the presence of the collateral constraint and the fourth term in the targeting rule captures the welfare trade-off between using monetary policy to stabilise the credit spread relative to other welfare gaps.

The fifth, sixth and seventh terms in the targeting rule are measures of deviations from full risk sharing. These terms capture the welfare reducing effects of incomplete financial markets. (Corsetti *et al* (2010, 2011) refer to these as 'demand imbalances'.) To understand these terms note that, if a complete set of financial instruments were available for trade (within and between countries), equilibrium in financial markets would imply that the ratio of marginal utilities (for savers and borrowers) across countries would equal the relative price of consumption baskets, i.e.

$$\frac{C_{b,t}^{*-\rho}}{C_{b,t}^{-\rho}} = \frac{C_{s,t}^{*-\rho}}{C_{s,t}^{-\rho}} = 1$$

and the ratio of marginal utilities across savers and borrowers within each country would be constant, i.e.

$$\frac{C_{b,t}^{-\rho}}{C_{s,t}^{-\rho}} = \mathcal{X}, \qquad \frac{C_{b,t}^{*-\rho}}{C_{s,t}^{*-\rho}} = \mathcal{X}^*$$

where $\mathcal{X}$ and $\mathcal{X}^*$ are constants. In terms of log-deviations these conditions imply

$$-\rho\left(\hat{C}_b - \hat{C}_b^*\right) = 0$$

$$-\rho\left(\hat{C}_s - \hat{C}_s^*\right) = 0$$

$$-\rho\left(\hat{C}_b - \hat{C}_s\right) = 0$$

$$-\rho\left(\hat{C}_b^* - \hat{C}_s^*\right) = 0$$

It is thus clear that $\mathcal{D}_b$, $\mathcal{D}_s$ and $\mathcal{D}_x$ in (22) are measures of deviations from full risk sharing. And it is clear that these terms in the monetary policy rule capture the extent to which monetary policy is adjusted in order to achieve greater risk sharing.

Note that producer price inflation targeting is can be represented by policy rule (22) with $\delta_Y = \delta_\tau = \delta_{SPR} = \delta_b = \delta_s = \delta_x = 0$.

The seven terms in the policy rule capture a range of potential welfare trade-offs that feature in the optimal setting of monetary policy. Internal (i.e. with-in country) trade-offs are captured by the inflation term, the output gap, the credit spread and the risk-sharing gap between savers and borrowers. External (i.e. open economy) trade-offs are captured by the terms of trade gap and terms measuring deviations from international risk sharing. The object of the analysis presented below is to determine the optimal values of the parameters of the policy rule and thus to determine the role of asset market trade and collateral constraints in the optimal setting of monetary policy.

5 Portfolio Choice and Model Solution

Our objective in this paper is to analyse optimal monetary policy in the above specified model. A key distinguishing feature of the above model is that it allows for international trade in multiple assets. Our analysis therefore uses the portfolio solution techniques developed in Devereux and Sutherland (2011a) to solve for equilibrium portfolios.

As explained in Senay and Sutherland (2016), the simultaneous analysis of optimal policy and endogenous portfolio choice presents some new technical challenges. These challenges arise because there is an interaction between policy choices and portfolio choices. Portfolio choices depend on the stochastic properties of income and the hedging properties of available assets. Monetary policy affects the stochastic behaviour of income and the hedging properties of assets and therefore affects optimal portfolio choice. In turn, the equilibrium portfolio affects consumption and production choices and thus affects macroeconomic outcomes and welfare. Thus, in addition to the standard routes via which policy affects the macro economy, the optimal choice of monetary policy must take account of the welfare effects of policy that occur via the effects of policy on portfolio allocation.

Our solution approach follows the recent portfolio literature based on Devereux and Sutherland (2011a) in computing equilibrium portfolios using a second order approximation to the portfolio selection equations for the home and foreign country in conjunction with a first order approximation to the home and foreign budget constraints and the vector of excess returns. In Senay and Sutherland (2016) we showed how to combine this portfolio solution approach with an analysis of optimal monetary policy. In this paper we extend this joint analysis to also include collateral constraints.

As already explained, we model monetary policy as targeting rule (22). We optimise the choice of parameters in the targeting rule by means of a grid search algorithm. Each grid point represents a different setting of the parameters of the targeting rule and for each grid point there is an equilibrium portfolio allocation and a corresponding general macroeconomic equilibrium and level of welfare. We use the Devereux and Sutherland portfolio solution approach to evaluate the equilibrium portfolio at each grid point. This equilibrium portfolio is then used to compute macroeconomic equilibrium and a second order approximation of welfare at each grid point.

To be specific, our policy optimisation problem involves a grid search across the six coefficients of the policy rule in (22), i.e. δ_Y, δ_τ, δ_{SPR}, δ_b, δ_s and δ_x, in order to identify the parameter combination which maximises the unconditional expectation of period welfare (as defined in (21)).[5]

It should be noted that this methodology does not compute fully optimal policy because fully optimal policy may involve more inertia than is embodied in the above specified targeting rule (as is shown in Corsetti *et al* (2010, 2011) in some cases). Our optimal rule is therefore the optimal rule within the restricted class of rules defined by (22). The focus on a non-inertial targeting rule is a convenient simplification given the extra complications and computational burden arising from the endogenous determination of equilibrium portfolios.

6 Optimal Policy

6.1 The Benchmark Case

The numerical results for the optimal policy rule for the benchmark set of parameter values are shown in Table 2.

The figures reported in the first column show the results for the case where

[5] Given that the model is symmetric, the foreign country has a similarly defined targeting rule and the coefficients of that rule are assumed to be identical to the coefficients of the home rule, with appropriate changes of sign.

there is international trade in equities and bonds and the collateral constraint binds. The first six rows in the table show the coefficients of the optimised policy rule. Note that, judging from the size of the optimised coefficient, the credit spread appears to be a particularly significant term in the optimal policy rule. The seventh row in Table 2 shows the welfare gain from the optimal policy rule relative to strict (producer price) inflation targeting. This welfare gain is measured in terms of percentage equivalent steady state consumption units so the gain from policy optimisation is approximately 0.11% of steady state consumption.

The eighth row in Table 2 shows the portfolio share of foreign equity in the home portfolio when policy is set optimally. So, in the benchmark case, the home country has a very small bias (i.e. has a portfolio weight just over 50%) towards foreign equity (and the foreign country has an identical bias towards home equity).

The remaining rows of Table 2 compare the volatility of a number of variables arising from optimal policy and inflation targeting. Optimal policy implies that the standard deviation of PPI inflation is 0.12% per quarter (compared to 0 in the case of inflation targeting). Optimal policy implies a very small reduction in the volatility of the output gap and a somewhat larger reduction in the volatility of the credit spread. The latter effect obviously reflects the significance of the coefficient on the credit spread in the optimised policy rule.

The effects of optimal policy relative to inflation targeting are further illustrated in the impulse responses plotted in Figures 3 and 4. The line marked the triangles in each panel shows the impulse response in the case of inflation targeting for the benchmark case while the line marked with the circles shows the impulse response when policy is set according to the optimal rule. Figure 3 shows the response to a TFP shock and Figure 4 shows the response to a collateral constraint shock. Figures 3 and 4 show that optimal policy tends to dampen the response of the credit spread, equity prices, the return on equity and the real return on borrowing. It also tends to stabilise investment and the capital stock held by both borrowers and savers.

As a point of comparison the second column in Table 2 reports results for the case where there is asset trade but where there are no collateral constraints. In this case the optimal policy rule is only marginally different from inflation targeting and the welfare gains from optimisation relative to inflation targeting are virtually zero.

A comparison of the first and second columns of Table 2 shows that the presence of binding collateral constraints has quite a significant impact on optimal policy. There are non-trivial welfare gains from optimal policy (relative to inflation targeting) when there are collateral constraints. But the welfare gains are trivial when there are no collateral constraints.

6.2 Comparison with Autarky

A second important point of comparison is with the case where binding collateral constraints are present but there is no international trade in equities or bonds. The third column in Table 2 shows the results for this case. The coefficients of the optimised policy rule are quite similar to the case with international asset trade but it is now apparent that the welfare gains from policy optimisation are significantly higher than in the case with asset trade. The welfare gain from optimisation is now approximately 0.21% of steady state consumption, which is almost twice the welfare gain when there is asset trade.

The volatility results reported in the third column of Table 2 show that optimal policy (compared to inflation targeting) marginally reduces the standard deviation of the output gap and the terms of trade gap and, as in the asset trade case, has a significant effect on the volatility of the credit spread.

A comparison of the first and third columns of Table 2 shows the impact of asset trade on the welfare gains from optimal policy. In the context of this model, where collateral constraints create a channel for the transmission of shocks from one country to another, a relevant question is whether asset trade results in a greater role for active policy in order to offset real shocks. The fact that the optimal policy rule is quite similar in the cases illustrated in columns one and three in Table 2, while the welfare gain from policy optimisation is lower in column one than in column three, suggests that asset trade tends to reduce the role of monetary policy optimisation in the face of real shocks. In other words, the shock transmission mechanism created by collateral constraints does not offset the risk sharing benefits of asset trade.

As outlined above in the introduction, Corsetti *et al* (2010, 2011) show that imperfect asset markets imply that optimal monetary policy should deviate from inflation targeting in order to improve risk sharing. Senay and Sutherland (2016) show that this role declines sharply when there is trade in bonds and equities.

Table 2: Benchmark Results

		Asset trade with collateral constraint	Asset trade without collateral constraint	Financial autarky with collateral constraint
Policy rule	δ_Y	-0.068	0	-0.616
	δ_τ	0	0	-0.250
	δ_{SPR}	-0.301	0	-0.300
	δ_b	-0.007	0	-0.001
	δ_s	-0.042	-0.018	0.007
	δ_x	0.014	0	0.013
Welfare difference		0.108	0.00004	0.211
Portfolio share		0.5014	0.5013	–
Standard Deviations				
CPI Inflation	(optimal)	0.12	0.0011	0.16
Output gap	(optimal)	0.0086	0.0	0.012
	(inf tar)	0.0096	0.0	0.013
ToT gap	(optimal)	0	0.0	0.011
	(inf tar)	0	0.0	0.012
Spread	(optimal)	0.42	0.0	0.59
	(inf tar)	0.47	0.0	0.66

Devereux and Sutherland (2011b) show that trade in bonds and equities can create a strong shock transmission mechanism when combined with collateral constraints. As explained above, this raises the question of whether asset trade may increase the role of monetary policy as a risk sharing device rather than reduce it, when combined with collateral constraints. The results reported in Table 2 suggest that this is not the case. However, these results show an important role remains for monetary policy even when there is trade in equities and bonds (in contrast to the results reported in Senay and Sutherland (2016)).

6.3 Parameter variations

Table 3 shows the welfare results for a number of parameter variations.

The first row shows a case where the trade elasticity, θ, is less than unity. The welfare difference between optimal policy and inflation targeting is shown for the same three asset market structures as reported in Table 2 for the benchmark case. The welfare differences are almost identical to the benchmark case so it appears that the value of θ has no significant quantitative or qualitative effect on the welfare comparison.

The second, third and fourth rows of Table 3 show cases where, respectively, the variance of collateral constraint shocks is larger than the benchmark case, the persistence of collateral constraint shocks is higher than in the benchmark case, and the variance of collateral constraint shocks is set to zero (so the only source of shocks is TFP). It is apparent that the presence, size and persistence of collateral constraint shocks have significant effects on the size of the welfare difference between optimal policy and inflation targeting. The larger and more persistent are collateral constraint shocks the larger are the welfare differences. But it is also apparent that the ordering and relative size of the welfare differences when compared across financial market structures is little affected by the size and persistence of collateral constraint shocks. In all three cases the welfare difference is very small when there are no collateral constraints (i.e. column two) and the welfare difference is much larger in the case of financial autarky (when combined with collateral constraints) than in the case of asset trade (combined with collateral constraints), i.e. the comparison between columns three and one. Thus the general qualitative conclusions stated in the benchmark case appear to be unaffected by the size and persistence of collateral constraint shocks.

The fifth row of Table 3 shows a case where capital adjustment costs (represented by the parameter ψ) are higher than in the benchmark case. This is an interesting case to consider because the more costly it is to vary the total capital stock the more important is the transfer of the existing capital stock between savers and borrowers in response to shocks. A higher value for ψ will therefore tend to magnify the financial accelerator effects of collateral constraints. The welfare differences shown in row five of Table 3 confirm that the welfare benefits of policy optimisation are higher than in the benchmark case. However, as with the other parameter variations shown in Table 3, the ordering and relative size of the welfare differences across financial market structures are very similar to the benchmark case.

The last row of Table 3 shows a case where the steady state leverage ratio is higher than that in the benchmark case (i.e. κ is higher). This tends to reduce the welfare benefits of policy optimisation (relative to inflation targeting) but again does not appear to alter to relative ranking of welfare benefits when compared across financial market structures.

All the parameter variations shown in Table 3 thus appear to confirm the conclusions illustrated in the benchmark case.

7 Conclusion

This paper develops a model which shows how financial market imperfections, in the form of cross-border collateral constraints, generate international shock transmission which is inefficient from a welfare point of view. We demonstrate how, in this context, it is optimal for monetary policy to deviate from inflation targeting in order to deal with distortions arising in international financial markets. We find that the optimal monetary rule implies a strong feedback from the *credit spread* to monetary policy. Thus optimal monetary policy tends to stabilise the credit spread. Significantly, we find that the optimal monetary rule implies non-trivial welfare gains relative to inflation targeting.

The main focus of our analysis is on the implications of financial market imperfections for optimal monetary policy. But we can also use our model to consider an alternative question, namely the implications of *international financial integration* for optimal monetary policy in a world which is subject to collateral constraints.

Table 3: Parameter variations: welfare difference

	Asset trade with collateral constraint	Asset trade without collateral constraint	Financial autarky with collateral constraint
Low trade elasticity ($\theta = 0.85$)	0.108	0.000009	0.210
Larger collateral shocks ($\sigma_\kappa = 0.022$)	0.416	0.00004	0.826
More persistent collateral shocks ($\eta_\kappa = 0.95$)	0.124	0.00004	0.258
No collateral shocks ($\sigma_\kappa = 0$)	0.0064	0.00004	0.0072
Higher capital adjustment costs ($\psi = 1.0$)	0.300	0.00003	0.558
Higher steady state leverage ($\kappa = 0.8$)	0.248	0.00004	0.483

We achieve this by comparing our benchmark case (which combines collateral constraints with asset trade) with a version of the model which combines collateral constraints with financial autarky. In making this comparison we find that optimal monetary policy in the financial autarky case implies a larger deviation from inflation targeting than in the case with international financial trade. Furthermore, we find that the welfare gains from optimal policy (relative to inflation targeting) are larger in the autarky case than in the financial trade case. These results imply that the risk-sharing role of international asset trade appears to outweigh its role in international shock transmission, so, despite the presence of collateral constraints, financial integration appears to reduce the risk-sharing role of optimal monetary policy. This is true even when there are large and persistent shocks to collateral constraints.

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Figure 1: TFP shock, comparison of financial market structures

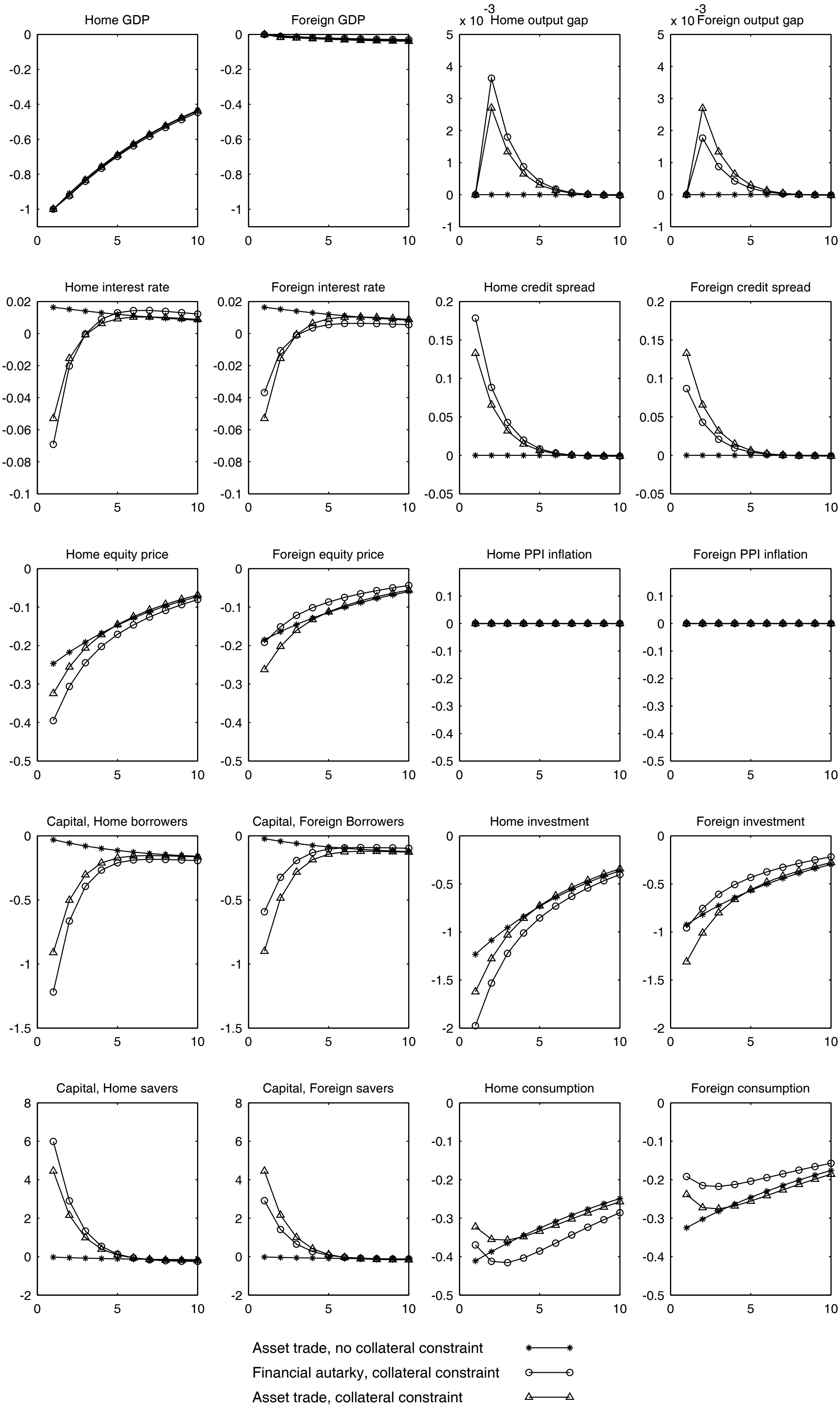

Figure 2: Collateral constraint shock, comparison of financial market structures

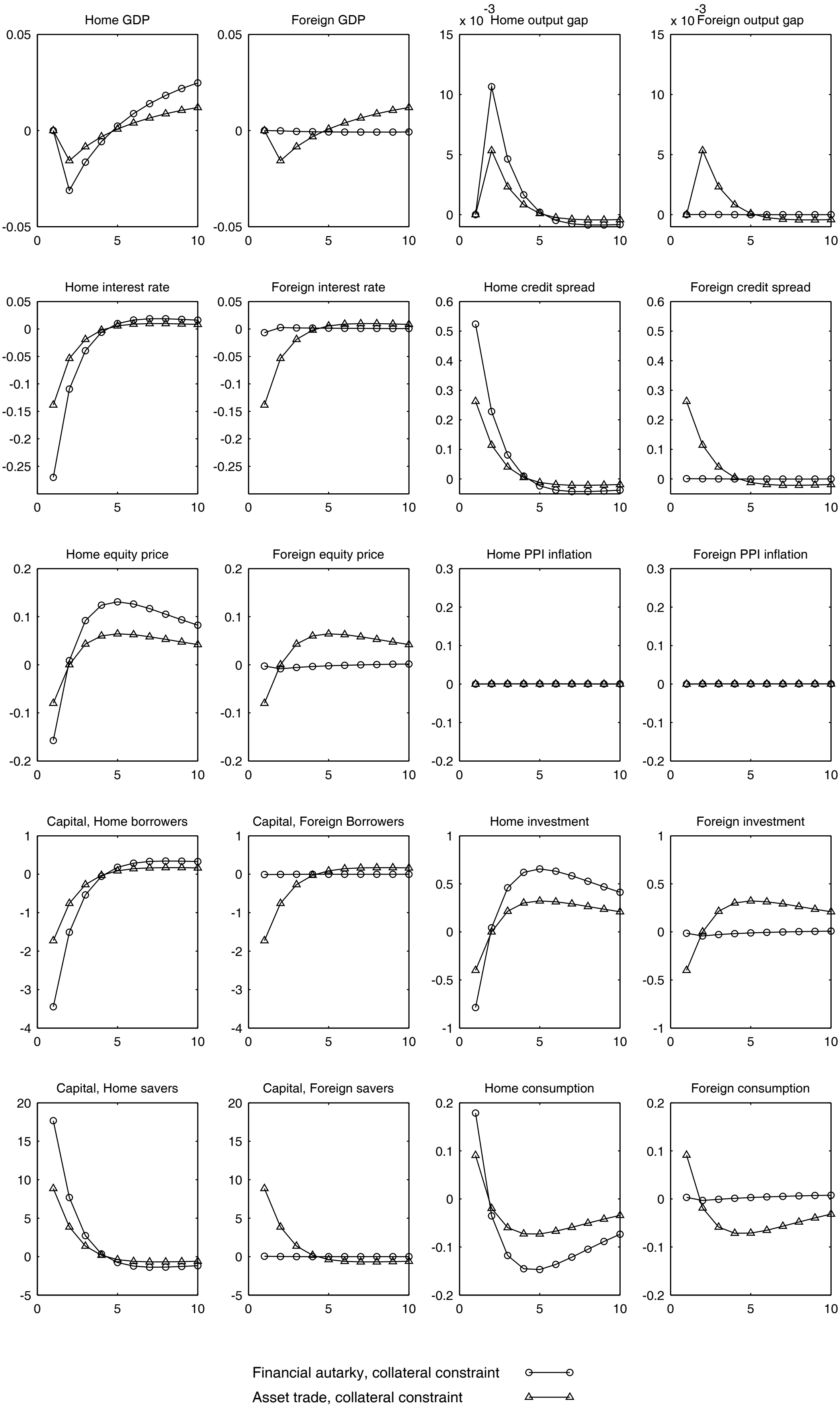

Figure 3: TFP shock, optimal policy versus inflation targeting

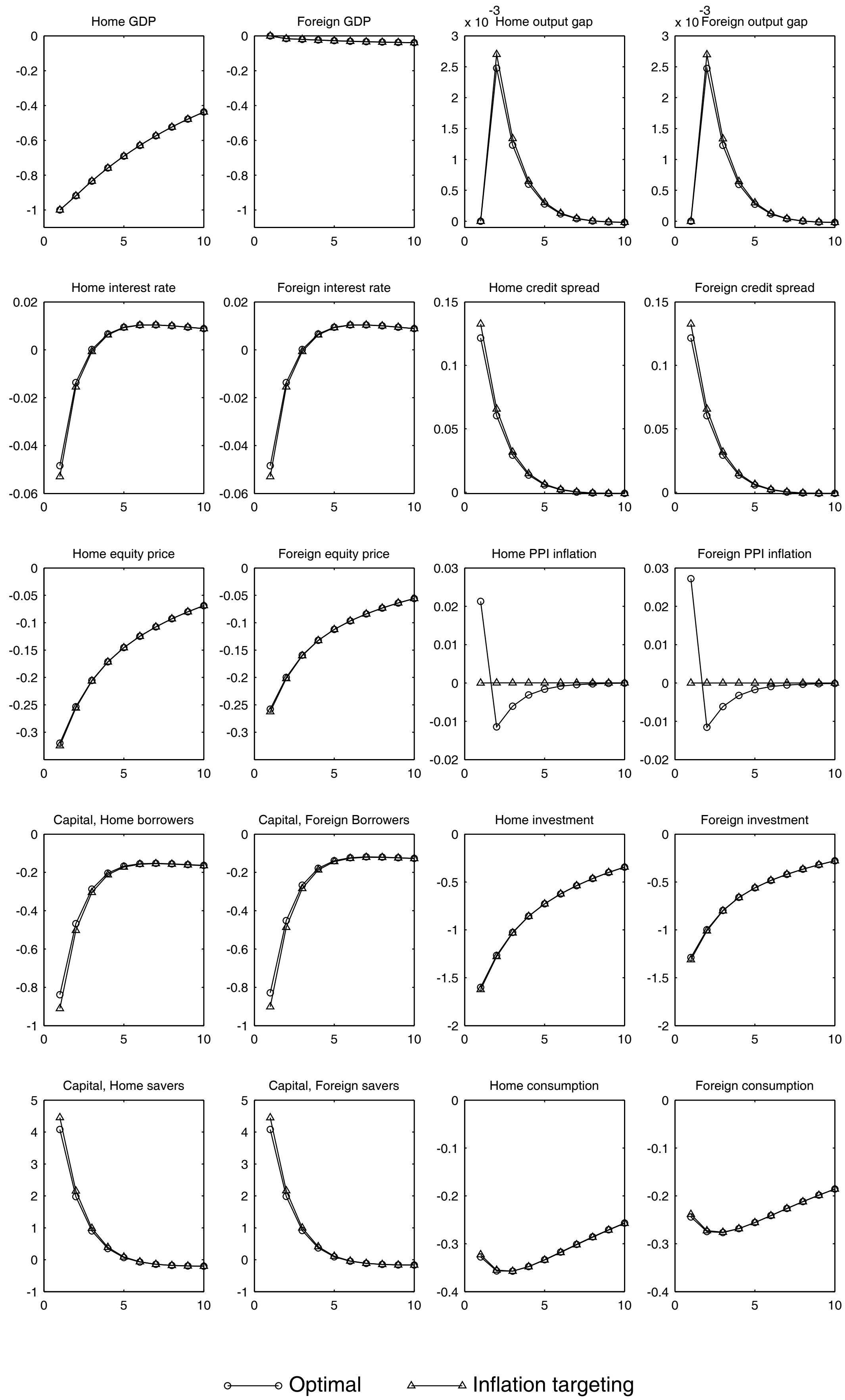

Figure 4: Collateral constraint shock, optimal policy versus inflation targeting