FINESS

SEVENTH FRAMEWORK PROGRAMME

Project funded under the Socio-economic Sciences and Humanities

European Commission

Working Paper D.4.4

International Consumption Risk Sharing and Monetary Policy

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December 2009

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Very preliminary and incomplete.
Comments welcome.

Abstract

This project aims at analyzing the impact of monetary policy on the international allocation of risk in a two-country dynamic stochastic general equilibrium model with sticky prices and international portfolio choice. The model features endogenous firms entry which influences the evolution of equity in each country and alters real exchange rate dynamics. Preliminary results show that there may be substantial deviations from efficient consumption risk sharing in the presence of monetary policy when there are frictions in goods as well as asset markets.

Keywords: International portfolio choice, consumption risk sharing, monetary policy, frictions

JEL Classification: F32, F42, E44

*Financial support from the European Commission (7^{th} Framework Programme, Grant Agreement No. 217266) is gratefully acknowledged.

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1 Introduction

The past two decades where accompanied by a significant increase in international capital flows. Economies have greatly benefited from the effects of financial liberalization as it facilitated an efficient allocation of economic risks across countries. Yet, especially in the light of the current financial and economic crisis, the question emerges how monetary authorities influence the size and composition of cross-border capital flows and how this, in turn, affects macroeconomic dynamics.

This project aims at analyzing the role of monetary policy for international consumption risk sharing. To this end, I develop a dynamic stochastic general equilibrium model with frictions in goods and asset markets and nominal price rigidities in a two-country framework. The model helps analyzing the impact of monetary policy on countries' portfolio allocation. Transaction costs impede international trade in financial markets. Frictions in goods markets are modeled via iceberg-type trade costs and home bias in consumption. In addition, the model features endogenous firm entry.

Implementing a role for monetary policy in a model with international portfolio choice is important for at least three reasons. First, Marcel Fratzscher and Straub (2008) show empirically that US monetary policy shocks substantially influence the dynamics and the composition of US capital flows. In addition, they find that stock and bond returns react quite differently on changes in monetary policy. Second, the optimal design of monetary policy hinges on the structure of international financial markets. Obstfeld and Rogoff (2002) and Benigno (2009) show theoretically that price stability may be inefficient in the context of incomplete financial markets. However, Devereux and Sutherland (2008) find that this result critically depends on the degree of market incompleteness. If some risks can be shared via cross-border trade in nominal bonds, price stability is optimal as it replicates the flexible price equilibrium and leads to full international risk sharing. Third, monetary policy rules alter the impact of other shocks on the economy. In a recent issue of the IMF's World Economic Outlook (2009), the authors analyze the consequences of financial markets and technology shocks under different monetary policy regimes within a New Keynesian framework and find significant differences in the dynamics of the other variables of the system.

To assign a nontrivial role to monetary policy in this model, nominal price rigidities are introduced following Rotemberg (1982). Firms face quadratic costs when adjusting their prices at home and abroad. In addition, the model features endogenous firm entry. As a consequence, the value of equity in each country may not only change because of valuation effects due to changes in asset prices and the real exchange rate, but also because of the endogenously evolving number of firms, that are financed by households. Moreover, as product varieties available to households may change over time, endogenous firm entry impinges on the price indices at home and abroad which crucially influences real exchange rate rate dynamics. This, in turn, may affect the extent of international consumption risk sharing measured by the correlation of relative consumption growth across countries and changes in the real exchange rate as advocated by Backus and Smith (1993).

The model also incorporates frictions in goods and in asset markets. Frictions in goods markets, such as trade costs, make consumption smoothing with help of foreign goods more expensive. As a consequence, domestic consumption is more closely linked to domestic output and therefore more vulnerable to shocks originating at home. Frictions in financial markets, such as transaction costs or information asymmetries, directly impede households' ability to diversify their portfolios. Obstfeld and Rogoff (2000) show theoretically that trade costs alone can go far in explaining deviations from perfect consumption risk sharing. In her empirical study, Fitzgerald (2007) finds that both type of frictions are necessary to explain the apparent failure of perfect risk sharing.

This paper is related to recent work that endogenously solves for portfolio positions in a dynamic stochastic equilibrium framework. Evans and Hnatkovska (2005) combine continuous time approximations with numerical solution techniques to analyze dynamic portfolio choices in an international setting. Devereux and Sutherland (2007) and Tille and Wincoop (2007) propose an approximation method based on higher order Taylor series expansions. Here, I follow Ghironi, Lee, and Rebucci (2007) and introduce quadratic costs on portfolio holdings to solve for portfolio allocations and to induce model stationarity.

The setup presented here shares many features of the models by Ghironi and Stebunovs (2008) and Bilbiie, Ghironi, and Melitz (2007). Ghironi and Stebunovs (2008) analyze the effects of endogenous entry in an international setting. However, there is no international portfolio choice and prices are fully flexible. Bilbiie, Ghironi, and Melitz (2007) examine the role of monetary policy in a model with price rigidities in a closed economy framework. The purpose of this draft is to present the basic model setup. The rest of this paper is structured as follows. Section 2 presents the theoretical framework of optimizing firms and households. The structure of the aggregate economy is given in Section 3. Some first preliminary results are presented in Section 4. Section 5 concludes.

2 The model

This section presents the main elements of the two-country framework. The model is a two-country version of the sticky price model by Bilbiie, Ghironi, and Melitz (2007) with international portfolio choice and frictions in both, goods as well as asset markets. Foreign variables are denoted by an asterisk.

2.1 Households' preferences and demand

In each country, there is a unit mass of identical households. The representative home household supplies L hours of labor inelastically. Labor is immobile across countries and remunerated at the nominal wage rate W_t.[1] The household maximizes expected lifetime utility discounting period utility from consumption with its subjective discount factor $\beta \in (0,1)$:

$$E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}\frac{C_s^{1-\gamma}}{1-\gamma}\right], \tag{1}$$

with the coefficient of relative risk aversion $\gamma > 0$.

The household consumes a CES basket that consists of a continuum of goods Ω. Each good is tradable. However, as in Ghironi and Stebunovs (2008), households have a preference for goods produced at home,

$$C_t = \left(\phi^{\frac{1}{\theta}}(c_{D,t})^{\frac{\theta-1}{\theta}} + (1-\phi)^{\frac{1}{\theta}}(c_{X,t})^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}},$$

where $\phi > 0.5$ governs the degree of consumption home bias and θ is the symmetric elasticity of substitution across goods. Consumption of home and foreign goods is given by

$$c_{D,t} = \left(\int_{\omega\in\Omega} c_{D,t}(\omega)^{\frac{\theta-1}{\theta}}d\omega\right)^{\frac{\theta}{\theta-1}}, \quad \text{and} \quad c_{X,t} = \left(\int_{\omega^*\in\Omega} c_{X,t}(\omega^*)^{\frac{\theta-1}{\theta}}d\omega^*\right)^{\frac{\theta}{\theta-1}},$$

respectively. In each period only a subset of goods is available $\Omega_t \subset \Omega$. The consumption

[1] Since households are identical in each country, I omit an identifier for an individual households for convenience.

price index is given by

$$P = \left(\phi(P_{D,t})^{\theta-1} + (1-\phi)(P_{X,t})^{\theta-1}\right)^{\frac{1}{1-\theta}},$$

with the price index for home goods

$$P_{D,t} = \left(\int_{\omega\in\Omega_t} p_{D,t}(\omega)^{1-\theta} d\omega\right),$$

and the price index for imported goods

$$P^*_{X,t} = \left(\int_{\omega^*\in\Omega_t} p_{X,t}(\omega^*)^{1-\theta} d\omega^*\right), \tag{2}$$

where $p_{D,t}(\omega)$ and $p^*_{X,t}(\omega^*)$ are the price for a single home and foreign variety, respectively. Export prices are denominated in the currency of the destination market. Demand for home and foreign goods are then given by

$$c_{D,t}(\omega) = \phi\left(\frac{p_{D,t}(\omega)}{P_t}\right)^{-\theta} C_t, \quad \text{and} \quad c_{X,t}(\omega^*) = (1-\phi)\left(\frac{p^*_{X,t}(\omega^*)}{P_t}\right)^{-\theta} C_t.$$

Foreign households' intratemporal choices are symmetric with the same parameters for subjective time preference, β, relative risk aversion, γ, elasticity of substitution, θ, and domestic bias in goods, ϕ. Note that the subset of goods available in the foreign country, $\Omega^*_t \subset \Omega$, is the same as in the home country.

2.2 Firms

In each country, there is a continuum of monopolistically competitive firms each producing a differentiated good ω with labor as the sole input factor. Technology of a home firm is given by $y_t(\omega) = Z_t l_t(\omega)$, with individual labor demand $l_t(\omega)$ and aggregate labor productivity Z_t. Labor productivity reflects the effectiveness of labor per worker and is stochastic. Foreign firms' technology is symmetric. Firms at home and abroad set prices as a markup over marginal costs. For home firms these are given by w_t/Z_t in units of the consumption basket, where w_t denotes the real wage rate. Marginal costs for foreign firms measured in units of the foreign consumption basket are given by w^*_t/Z^*_t.

In every period there is a mass of potential entrants in both countries. Before entering the market, firms face a sunk entry cost $f_{E,t}$ in effective labor units. Since each start-up hires $f_{E,t}/Z_t$ domestic workers to cover these costs, these are equal to $w_t f_{E,t}/Z_t$ in units of the home consumption good. Entrants maximize their discounted expected future profits after entering the market taking the probability of a death shock into account. Since equity is traded internationally, firms use the stochastic discount factor of home and foreign shareholders weighted by households' share in home equity as discount factor when optimizing. There is an incentive to enter until the average firm value is equalized with the entry cost, *i.e* the free entry condition is given by $v_t(\omega) = w_t f_{E,t}/Z_t$. Costs for entering the foreign market are given by $w_t^* f_{E,t}^*/Z_t^*$ leading to the free entry condition $v_t^*(\omega^*) = f_{E,t}^* w_t^*/Z_t^*$.

Firms that enter the market today do not start producing until tomorrow, which leads to a time-to-build lag. In addition, any firm, already operating in the market or just entering, may be hit by an exogenous shock that forces market exit. This death shock occurs at the very end of each period with probability δ and is identical for the foreign country. Both assumptions imply that the total number of firms producing at home, N_t, evolves according to $N_t = (1-\delta)(N_{t-1} + N_{E,t-1})$, where $N_{E,t-1}$ denotes the number of entrants at time $t-1$.

Each good ω and ω^* is tradable. However, exporting is costly. There are iceberg-type trade costs $\tau \geq 1$ and $\tau^* \geq 1$ when shipping home and foreign goods, respectively.

Given households' demand with elasticity θ, firms set the nominal prices as a markup over marginal costs. Nominal prices for goods sold at home and for goods that are shipped abroad are denoted as $p_{D,t}(\omega)$ and $p_{X,t}(\omega)$, respectively. Prices are expressed relative to the price index of the destination market. As in the model by Bilbiie, Ghironi, and Melitz (2007), firms have to pay quadratic costs when adjusting their prices as advocated by Rotemberg (1982).

$$pac_{D,t}(\omega) = \frac{\psi}{2}\left(\frac{p_{D,t}(\omega)}{p_{D,t-1}(\omega)} - 1\right)^2 \frac{p_{D,t}(\omega)}{P_t} y_{D,t}^D(\omega) \tag{3}$$

with $\psi \geq 0$ reflecting the degree of the price rigidity. Bilbiie, Ghironi, and Melitz (2007) interpret these costs as marketing materials needed for changing prices as these costs are proportional to real revenues from purchases at home $\frac{p_{D,t}(\omega)}{P_t} y_{D,t}^D$, where $y_{D,t}^D(\omega)$ is home demand for variety ω. Price adjustment costs for home firms in the foreign market are given as

$$pac_{X,t}(\omega) = \frac{\psi}{2}\left(\frac{p_{X,t}(\omega)}{p_{X,t-1}(\omega)} - 1\right)^2 \frac{p_{X,t}(\omega)}{P_t^*} Q_t y_{X,t}^D(\omega) \tag{4}$$

with the real exchange rate $Q_t = \mathscr{E}_t P_t^*/P_t$ that reflects home consumption in terms of foreign consumption and the nominal exchange rate $\mathscr{E}_t$ in price quotation.

Any new firm that enters the market in $t-1$ and starts producing at time t, faces price adjustments costs relative to the average nominal prices in the home and foreign market $p_{D,t-1}$ and $p_{X,t-1}$. Since all firms are symmetric, these average prices are the same for each variety in equilibrium, *i.e.* $p_{D,t-1} = p_{D,t-1}(\omega)$ and $p_{X,t-1} = p_{X,t-1}(\omega)$ for every good ω.

As marketing materials have the same composition as the consumption basket, total demand for variety ω in the home and in the foreign market are given by

$$y_{D,t}^D(\omega) = \left(\frac{p_{D,t}(\omega)}{P_t}\right)^{-\theta}(C_t + PAC_{D,t}), \quad \text{and} \quad y_{X,t}^D(\omega) = \left(\frac{p_{X,t}(\omega)}{P_t^*}\right)^{-\theta}(C_t^* + PAC_{X,t}).$$

Using the symmetry across firms in equilibrium, aggregate demand to cover price adjustment changes in the home and foreign market are $PAC_{D,t} = N_t pac_{D,t}(\omega)$ and $PAC_{X,t} = N_t pac_{X,t}(\omega)$.

Firms maximize the real value of the firm by choosing the amount of labor needed for production and prices at home and abroad, *i.e.* they maximize the expected discounted profit streams taking the probability of survival in each period into account

$$v_t(\omega) = E_t\left[\sum_{s=t+1}^{\infty} (\Omega_{t,s}(1-\delta))^{s-t} d_s(\omega)\right], \tag{5}$$

where total profits, $d_s(\omega)$, are given by the sum of profits earned from domestic activity, $d_{D,s}(\omega)$, and profits from exporting, $d_{X,s}(\omega)$. $\Omega_{t,s}$ equals home and foreign households' stochastic discount factor weighted by their respective shares in home equity.[2]

Optimal behavior leads to the following real prices in the home and in the foreign market

$$\rho_{D,t}(\omega) \equiv \frac{p_{D,t}(\omega)}{P_t} = \mu_{D,t}(\omega)\frac{w_t}{Z_t}, \qquad \text{and} \qquad \rho_{X,t}(\omega) \equiv \frac{p_{X,t}(\omega)}{P_t^*} = \mu_{X,t}(\omega) Q_t^{-1} \tau \frac{w_t}{Z_t}. \tag{6}$$

[2]See the next subsection for details.

Time-varying markups differ for prices in the home and in the foreign market and are given by

$$\mu_{D,t}(\omega) = \theta\left[(\theta-1)\left[1-\frac{\psi}{2}\left(\frac{p_{D,t}(\omega)}{p_{D,t-1}(\omega)}-1\right)^2\right]+\psi\Upsilon_{D,t}\right]^{-1}, \text{ with} \tag{7}$$

$$\Upsilon_{D,t} = \frac{p_{D,t}(\omega)}{p_{D,t-1}(\omega)}\left(\frac{p_{D,t}(\omega)}{p_{D,t-1}(\omega)}-1\right) - E_t\left[\Omega_{t,t+1}\frac{y^D_{D,t+1}}{y^D_{D,t}}\frac{P_t}{P_{t+1}}\frac{p_{D,t+1}(\omega)}{p_{D,t}(\omega)}\left(\frac{p_{D,t+1}(\omega)}{p_{D,t}(\omega)}-1\right)\right]$$

Similarly, the markup for the price for the foreign market is given by

$$\mu_{X,t}(\omega) = \theta\left[(\theta-1)\left[1-\frac{\psi}{2}\left(\frac{p_{X,t}(\omega)}{p_{X,t-1}(\omega)}-1\right)^2\right]+\psi\Upsilon_{X,t}\right]^{-1}, \text{ with} \tag{8}$$

$$\Upsilon_{X,t} = \frac{p_{X,t}(\omega)}{p_{X,t-1}(\omega)}\left(\frac{p_{X,t}(\omega)}{p_{X,t-1}(\omega)}-1\right) - E_t\left[\Omega_{t,t+1}\frac{y^D_{X,t+1}}{y^D_{X,t}}\frac{P^*_t}{P^*_{t+1}}\frac{Q_{t+1}}{Q_t}\frac{p_{X,t+1}(\omega)}{p_{X,t}(\omega)}\left(\frac{p_{X,t+1}(\omega)}{p_{X,t}(\omega)}-1\right)\right].$$

Note that both markups reduce to the familiar constant $\theta/(\theta-1)$ if there are no price changes or ψ is equal to zero. Price adjustment costs and profit maximization are symmetric for foreign firms.

2.3 Household's intertemporal choices

The representative domestic household consumes and receives income from labor, portfolio investments that consist of holdings of a bond that is only traded domestically and home and foreign equity that is traded across borders.

In each country, domestic equity is bundled in a mutual fund and issued in the respective market. The home mutual fund consists of $N_t + N_{E,t}$ home firms and the foreign mutual fund consist of $N^*_t + N^*_{E,t}$ foreign firms existing at time t. In each period the household purchases $x_{H,t+1}$ shares in the home mutual fund and $x_{F,t+1}$ shares in the foreign mutual fund. Fund managers in both countries do not distinguish between exporting firms and firms operating for the domestic market only. Each fund returns a dividend equal to total profits of all firms in each country. However, since firms exit the market with a probability of δ at the end of period t, only $N_{t+1} = (1-\delta)(N_t + N_{E,t})$ firms in the home market and $N^*_{t+1} = (1-\delta)\left(N^*_t + N^*_{E,t}\right)$ firms in the foreign market will produce in $t+1$ and pay dividends. The price in real terms of a share in the home and foreign mutual fund for the home household is equal to the real present discounted value of future profit streams of firms in each country expressed in home consumption units, *i.e.* v_t and $Q_t v_t^*$.

The portfolio holdings of domestic and foreign equity chosen in period t are given by

$$\alpha_{H,t+1}\mathscr{P}_{t+1} = x_{H,t+1}\left(N_t + N_{E,t}\right)v_t \text{ and } \alpha_{F,t+1}\mathscr{P}_{t+1} = x_{F,t+1}Q_t\left(N_t^* + N_{E,t}^*\right)v_t^*, \tag{9}$$

where $\alpha_{H,t+1}$ and $\alpha_{F,t+1}$ are the portfolio shares of domestic and foreign equity, respectively, and $\mathscr{P}_{t+1}$ denotes the real value of the portfolio at the end of period t.

When holding home and foreign equity, households have to pay quadratic fees to financial intermediaries as in Ghironi, Lee, and Rebucci (2007). Besides introducing frictions in financial markets, these convex costs solve the problem of indeterminacy of the portfolio composition as they pin down portfolio shares in a non-stochastic steady state and ensure stationarity in response to stochastic shocks.[3] Financial costs for holding home and foreign equity are given by

$$\frac{\xi_{H,t}}{2}\left(\alpha_{H,t+1}\mathscr{P}_{t+1}\right)^2 \quad \text{and} \quad \frac{\xi_{F,t}}{2}\left(\alpha_{F,t+1}\mathscr{P}_{t+1}\right)^2. \tag{10}$$

The scaling parameters $\xi_{H,t}$ and $\xi_{F,t}$ reflect the extent of frictions in financial markets. These fees are redistributed from financial intermediaries to the household in a lump-sum fashion equal to

$$\bar{F_t} = \frac{\xi_{H,t}}{2}\left(\alpha_{H,t+1}\mathscr{P}_{t+1}\right)^2 + \frac{\xi_{F,t}}{2}\left(\alpha_{F,t+1}\mathscr{P}_{t+1}\right)^2. \tag{11}$$

The household takes this redistribution as given when maximizing utility. There are no transaction costs on bonds, since these are traded only domestically so that equilibrium bond holdings are zero in the aggregate.

The intertemporal budget constraint of the representative home household is then given by

$$\begin{aligned}&\mathscr{P}_{t+1} + \frac{\xi_{H,t}}{2}\left(\alpha_{H,t+1}\mathscr{P}_{t+1}\right)^2 + \frac{\xi_{F,t}}{2}\left(\alpha_{F,t+1}\mathscr{P}_{t+1}\right)^2 \\ &= \left(\alpha_{H,t}R_{H,t} + \alpha_{F,t}R_{F,t} + (1-\alpha_{H,t}-\alpha_{F,t})R_{B,t}\right)\mathscr{P}_t + w_t L - C_t + \bar{F_t},\end{aligned} \tag{12}$$

where $R_{B,t}$ is the real return on the riskless bond. $R_{H,t}$ and $R_{F,t}$ denote the return on domestic and foreign equity, respectively, expressed in home consumption units. Keeping

[3]In addition to convex portfolio costs, Schmitt-Grohé and Uribe (2003) explore alternative ways to achieve stationarity in a setting with incomplete asset markets.

in mind that only a fraction $(1-\delta) = N_t/(N_{t-1}+N_{E,t-1})$ of all pre-financed firms in $t-1$ produces and earns non-zero profits in t, these returns can be written as

$$R_{H,t} = \frac{v_t + d_t}{v_{t-1}}(1-\delta) \quad \text{and} \quad R_{F,t} = \frac{Q_t}{Q_{t-1}}\frac{v_t^* + d_t^*}{v_{t-1}^*}(1-\delta). \tag{13}$$

Maximization of lifetime utility (1) with respect to the intertemporal budget constraint (12) leads to the following set of Euler equations:

$$1 = E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma} R_{B,t+1}\right] \tag{14}$$

$$1 = E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma} \frac{R_{H,t+1}}{1+\xi_{H,t}\alpha_{H,t+1}\mathscr{P}_{t+1}}\right] \tag{15}$$

$$1 = E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma} \frac{R_{F,t+1}}{1+\xi_{F,t}\alpha_{F,t+1}\mathscr{P}_{t+1}}\right]. \tag{16}$$

As in Ghironi, Lee, and Rebucci (2007), transaction costs link portfolio holdings to the growth rates of marginal utility.[4] Using (13), the Euler equations for domestic and foreign equity can be rewritten in terms of the average firm values and total profits as

$$v_t = (1-\delta)E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma} \frac{v_{t+1}+d_{t+1}}{1+\xi_{H,t}\alpha_{H,t+1}\mathscr{P}_{t+1}}\right] \tag{17}$$

$$v_t^* = (1-\delta)E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma} \frac{Q_{t+1}}{Q_t}\frac{v_{t+1}^*+d_{t+1}^*}{1+\xi_{F,t}\alpha_{F,t+1}\mathscr{P}_{t+1}}\right]. \tag{18}$$

In an analogous manner, optimal behavior of the representative foreign households, leads to Euler equations for home and foreign equity given by

$$v_t = (1-\delta)E_t\left[\beta\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\gamma} \frac{Q_t}{Q_{t+1}}\frac{v_{t+1}+d_{t+1}}{1+\xi_{H,t}^*\alpha_{H,t+1}^*\mathscr{P}_{t+1}^*}\right] \tag{19}$$

$$v_t^* = (1-\delta)E_t\left[\beta\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\gamma} \frac{v_{t+1}^*+d_{t+1}^*}{1+\xi_{F,t}^*\alpha_{F,t+1}^*\mathscr{P}_{t+1}^*}\right]. \tag{20}$$

Note that these Euler equations are consistent with firms' present discounted value of expected profits, described in the previous section if home firms' discount factor is given

[4]Transversality conditions for bonds and shares are omitted.

by

$$\Omega_{t,s} = x_{H,s} \frac{\beta^{s-t}(C_s)^{-\gamma}}{(C_t)^{-\gamma}(1+\xi_{H,s-1}\alpha_{H,s}\mathscr{P}_s)} + x^*_{H,s} \frac{\beta^{s-t}(C^*_s)^{-\gamma}}{(C^*_t)^{-\gamma}(1+\xi^*_{H,s-1}\alpha^*_{H,s}\mathscr{P}^*_s)}, \text{ with } s > t. \tag{21}$$

Firms discount expected profits with the sum of home and foreign household's intertemporal marginal rate of substitution adjusted for marginal transaction costs and weighted by the respective share in the home mutual fund. A similar discount factor is used by foreign firms.

3 Aggregation and model summary

The main equations of the model for the home as well the foreign country are summarized in Table 1. Symmetry implies that firms in each country set the same prices at home and abroad. The model is closed using net foreign assets and the equilibrium on the labor market.

Net foreign assets

Equity market clearing implies that home and foreign holdings in each mutual fund sum to one. Since bond holdings are zero in the aggregate, portfolio shares of home foreign equity in each country also equal one:

$$x_{H,t} + x^*_{H,t} = 1, \quad x_{F,t} + x^*_{F,t} = 1 \tag{22}$$

$$\alpha_{H,t} + \alpha_{F,t} = 1, \quad \alpha^*_{F,t} + \alpha^*_{H,t} = 1 \tag{23}$$

Because financial fees are redistributed to the household, the aggregate budget constraint for the home country can be written as

$$\mathscr{P}_{t+1} = (\alpha_{H,t}R_{H,t} + \alpha_{F,t}R_{F,t})\,\mathscr{P}_t + w_tL - C_t. \tag{24}$$

Substituting the value of each portfolio position (9) and the definition of returns (13), equation (24) can be expressed as

$$\begin{aligned} & x_{H,t+1}\,(N_t + N_{E,t})\,v_t + Q_t x_{F,t+1}\left(N^*_t + N^*_{E,t}\right)v^*_t \\ & = x_{H,t}N_t\,(v_t + d_t) + Q_t x_{F,t}N^*_t\,(v^*_t + d^*_t) + w_tL - C_t. \end{aligned} \tag{25}$$

Each portfolio position may not only change because of fluctuations in asset prices and the exchange rate. In this setup, valuation effects may also arise because of the endogenously evolving number firms in each country. For the foreign country the aggregate budget constraint looks similar

$$\begin{aligned} & x^*_{F,t+1}\left(N^*_t + N^*_{E,t}\right)v^*_t + Q^{-1}_t x^*_{H,t+1}\left(N_t + N_{E,t}\right)v_t \\ & = x^*_{F,t}N^*_t\left(v^*_t + d^*_t\right) + Q^{-1}_t x^*_{H,t}N_{D,t}\left(v_t + d_t\right) + w^*_t L^* - C^*_t. \end{aligned} \tag{26}$$

Multiplying (26) by the real exchange rate and subtracting the foreign budget constraint in terms of home consumption from (25) yields an expression for home's net foreign assets that depend on home and foreign equity holdings, consumption and labor income

$$\begin{aligned} & Q_t x_{F,t+1}\left(N^*_t + N^*_{E,t}\right)v^*_t - x^*_{H,t+1}\left(N_t + N_{E,t}\right)v_t \\ & = -x_{H,t+1}\left(N_t + N_{E,t}\right)v_t + Q_t x^*_{F,t+1}\left(N^*_t + N^*_{E,t}\right)v^*_t \\ & + \left(x_{H,t} - x^*_{H,t}\right)N_t\left(v_t + d_t\right) + Q_t\left(x_{F,t} - x^*_{F,t}\right)N^*_t\left(v^*_t + d^*_t\right) \\ & + w_t L - Q_t w^*_t L^* - C_t + Q_t C^*_t. \end{aligned} \tag{27}$$

Labor market clearing

Labor demand in the home country is given

$$L_t = N_t\left(l_{D,t} + l_{X,t}\right) + \frac{f_{E,t}}{Z_t}N_{E,t}$$

The first term on the right hand side gives the number of workers hired for production of all domestic firms, where $l_{D,t}$ and $l_{X,t}$ are labor demand for producing goods for the home and for the foreign market, respectively. The second term captures labor employed to cover sunk entry costs. Using firms' profits of selling their goods at home and abroad, $d_{D,t}$ and $d_{X,t}$, and given that labor is supplied inelastically by households and immobile across borders, equilibrium in the labor market is then given by

$$L = N_t \left[d_{D,t} \left[\rho_{D,t} Z_t \left(1 - \frac{\psi}{2} \left(1 - \frac{p_{D,t}}{p_{D,t-1}} \right)^2 \right) - w_t \right]^{-1} \right.$$
$$\left. + d_{X,t} \left[\rho_{X,t} Z_t Q_t \tau^{-1} \left(1 - \frac{\psi}{2} \left(1 - \frac{p_{X,t}}{p_{X,t-1}} \right)^2 \right) - w_t \right]^{-1} \right]$$
$$+ \frac{f_{E,t}}{Z_t} N_{E,t}. \tag{28}$$

Labor demand and supply is similar for the foreign country.

4 Model dynamics

The calibration of model parameters follows Bilbiie, Ghironi, and Melitz (2007) and Ghironi and Stebunovs (2008) summarized in Table 2. The model is log-linearized around a symmetric, non-stochastic steady state, where $\tau = \tau^*$ $L = L^*$, $Z = Z^*$, $f_E = f_E^*$.

Two scenarios with different degrees of financial integration are examined. First, I consider the empirically more relevant case of domestic equity bias in both countries. Frictions in financial markets are assumed to be $\xi_{H,t} = \xi_{F,t}^* = 0.01$ and $\xi_{F,t} = \xi_{H,t}^* = 0.03$ implying that each country's access to its own equity is less costly than purchasing equity abroad. Second, this domestic equity bias scenario is contrasted with a setting where countries are more financially integrated. Frictions are assumed to be small and equal across countries: $\xi_{H,t} = \xi_{F,t} = \xi_{F,t}^* = \xi_{H,t}^* = \xi = 0.0025$.[5]

As in Bilbiie, Ghironi, and Melitz (2007), monetary policy follows a simple interest rate rule that responds to expected consumer price inflation, given by

$$\mathsf{i}_t = 1.5 E_t \pi_{t+1}^{cpi}.$$

Here, i_t denotes the percentage deviation of the nominal exchange rate from steady state, and π_t^{cpi} is the deviation of (gross) consumer price inflation from steady state.

In principle, the model allows for various shock scenarios: shocks to aggregate labor productivity, Z and Z^*, changes in entry costs, f_E and f_E^*, which are interpreted as deregulation, shocks to financial market access, ξ_H, ξ_F, ξ_F^*, and ξ_H^* and monetary policy shocks.

[5]This number still is large enough to achieve stationarity in response to transitory shocks.

In addition, different policy rules of the monetary authority may be analyzed. For the rest of this draft, however, I concentrate on the impact of a permanent home technology shock on efficient consumption risk sharing. Further scenarios will analyzed in a future version.

In Figure 1, periods are interpreted as quarters. All responses are given in percentage deviations from the initial steady state. The responses of the endogenous variables in the case of more integrated financial markets are denoted by a dashed line. The responses in the case of domestic equity bias are denoted by a solid line.

With a positive shock to home labor productivity, entering the home market becomes more attractive, because workers are more productive. The number of entrants in the home country, $N_{E,t}$, increases. These new entrants are financed by both, home as well as foreign households. The value of home equity held by home and foreign households, $\alpha_{H,t+1}\mathscr{P}_t$ and $\alpha^*_{H,t+1}\mathscr{P}^*_t$, increases. This effect is even more pronounced if financial markets are less integrated, as foreign households hold less home equity in the initial steady state, but want to share the benefits from the favorable shock in the home economy. As it is less costly for both countries to hold home equity, the number of home entrants is higher if financial markets are more integrated in the long run.

In contrast, in the foreign country, the number of entrants $N^*_{E,t}$ initially is below its initial steady state level as it is more attractive to enter the home country. The number of foreign firms decreases as well. Households in both countries shift their portfolio allocation towards home equity, $\alpha_{H,t+1}$ and $\alpha^*_{H,t+1}$ increase whereas $\alpha_{F,t+1}$ and $\alpha^*_{F,t+1}$ decrease. As a consequence, net foreign assets in the home country decrease and foreign net foreign assets increase.

Since the number of firms operating at home, N_t, steadily increases, but labor is supplied inelastically and is immobile across countries wages, w_t, must rise. As expected, wages are higher if financial markets are more financially integrated in the long run.

Consumption at home increases for two reasons. First, labor income improves due to rising wages and, second, because of higher income from portfolio investments. The increase in profits of firms, d_t and d^*_t, and the steady increase in firm values v_t and v^*_t, raises the return on home and foreign equity, $R_{H,t}$ and $R^*_{F,t}$, and boost the value of the portfolio in the home country. In the long run the value of the portfolio is even higher if markets are less financially integrated, as home households hold more home equity in this scenario.

Foreign households share the consumption benefits from the permanent increase in home productivity and consumption in the foreign country grows. As consumption in the home country increases, demand for foreign goods also increases, despite home bias in consumption. To meet this demand, foreign output is higher in the long run compared to the initial steady state.[6] As a consequence, wages in the foreign country, w_t^*, rise as well, leading to an increase in labor income in the foreign country. Interestingly, foreign consumption is even higher if there is domestic equity bias, as home households are wealthier and their demand for foreign goods is even more pronounced.

To evaluate the extent to which this model generates deviations from efficient consumption risk sharing in the presence of shocks, I draw on a frequently used measure going back to Backus and Smith (1993). For two *ex ante* symmetric countries and additive separable utility with constant relative risk aversion as in (1) that trade a full set of state-contingent securities, efficient risk sharing implies that $(C_t/C_t^*)^\gamma = Q_t$.[7] This condition holds irrespective of frictions in the goods markets as long as financial markets are complete and fully integrated. Of course, in this setup, in addition to frictions in goods markets that lead to deviations from purchasing power parity, financial markets are neither complete, as only two assets are traded, nor fully integrated, as engagement in financial markets is subject to transaction costs. However, deviations from the Backus-Smith-condition reflect the degree of how much financial markets imperfections impede consumption risk sharing in the presence of goods market imperfections. The impulse responses show that there is a positive deviation from this benchmark, which implies that consumption risk sharing is only partial throughout the transmission process. As expected, this deviation is larger if there is home bias in equities.

5 Conclusion

This project analyzes the impact of monetary policy on international consumption risk sharing within a two-country dynamic stochastic equilibrium model with sticky prices, building on the models by Bilbiie, Ghironi, and Melitz (2007) and Ghironi and Stebunovs (2008). The model also features endogenous firms entry which influences the evolution of equity in each country and alters real exchange rate dynamics. Preliminary results show that there may be substantial deviations from efficient consumption risk sharing in the

[6] Home (foreign) output is defined as $y \equiv w_t L + N_{D,t} d$ ($y^* \equiv w_t^* L^* + N_{D,t}^* d^*$).

[7] If countries are asymmetric in steady state, this condition holds times a constant. Tille (2005) explores the role of this wedge. Since this model is solved around a symmetric steady state, this constant equals one.

presence of monetary policy when there are frictions in goods as well as asset markets. A future draft will analyze further shock scenarios and investigate the role of different monetary policy rules on international risk sharing.

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Table 1: Model Summary

Price indexes	$\phi N_t\left(\rho_{D,t}\right)^{1-\theta}+(1-\phi)N_t^*\left(\rho_{X,t}^*\right)^{1-\theta}=1$ $\phi N_t^*\left(\rho_{D,t}^*\right)^{1-\theta}+(1-\phi)N_t\left(\rho_{X,t}\right)^{1-\theta}=1$
Profits	$d_t=d_{D,t}+d_{X,t}$ $d_t^*=d_{D,t}^*+d_{X,t}^*$
Domestic prices	$\rho_{D,t}=\mu_{D,t}\frac{w_t}{Z_t}$ $\rho_{D,t}^*=\mu_{D,t}^*\frac{w_t^*}{Z_t^*}$
Export prices	$\rho_{X,t}=\tau Q_t^{-1}\mu_{X,t}\frac{w_t}{Z_t}$ $\rho_{X,t}^*=\tau^* Q_t\mu_{X,t}^*\frac{w_t^*}{Z_t^*}$
Number of firms	$N_t=(1-\delta)\left(N_{t-1}+N_{E,t-1}\right)$ $N_t^*=(1-\delta)\left(N_{t-1}^*+N_{E,t-1}^*\right)$
Firm entry	$v_t=w_t\frac{f_{E,t}}{Z_t}$ $v_t^*=w_t^*\frac{f_{E,t}^*}{Z_t^*}$
Euler equations for bonds	$1=E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(R_{B,t+1}\right)\right]$ $1=E_t\left[\beta\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\gamma}\left(R_{B,t+1}^*\right)\right]$
Euler equations for home equity	$1=E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\frac{R_{H,t+1}}{1+\xi_{H,t}\alpha_{H,t+1}\mathscr{P}_{t+1}}\right]$ $1=E_t\left[\beta\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\gamma}\frac{R_{H,t+1}^*}{1+\xi_{H,t}^*\alpha_{H,t+1}^*\mathscr{P}_{t+1}^*}\right]$
Euler equations for foreign equity	$1=E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\frac{R_{F,t+1}}{1+\xi_{F,t}\alpha_{F,t+1}\mathscr{P}_{t+1}}\right]$ $1=E_t\left[\beta\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\gamma}\frac{R_{F,t+1}^*}{1+\xi_{F,t}^*\alpha_{F,t+1}^*\mathscr{P}_{t+1}^*}\right]$

Continued.

Table 1 continued.

Return on home equity	$R_{H,t+1} = (1-\delta)\frac{v_{t+1}+d_{t+1}}{v_t}$ $R^*_{H,t+1} = (1-\delta)\frac{Q_t}{Q_{t+1}}\frac{v_{t+1}+d_{t+1}}{v_t}$
Return on foreign equity	$R_{F,t+1} = (1-\delta)\frac{Q_{t+1}}{Q_t}\frac{v^*_{t+1}+d^*_{t+1}}{v^*_t}$ $R^*_{F,t+1} = (1-\delta)\frac{v^*_{t+1}+d^*_{t+1}}{v^*_t}$
Net foreign assets	$\alpha_{F,t+1}\mathscr{P}_{t+1} - Q_t\alpha^*_{H,t+1}\mathscr{P}^*_{t+1} = -\alpha_{H,t+1}\mathscr{P}_{t+1}$ $+Q_t\alpha^*_{F,t+1}\mathscr{P}^*_{t+1} + (\alpha_{H,t}R_{H,t} + (1-\alpha_{H,t})R_{F,t})\,\mathscr{P}_t$ $-Q_t\left(\alpha^*_{F,t}R^*_{F,t} + (1-\alpha^*_{F,t})R^*_{H,t}\right)\mathscr{P}^*_t$ $+w_tL - Q_tw^*_tL^* - C_t + Q_tC^*_t$
Labor market clearing	$L = N_t\left(l_{D,t} + l_{X,t}\right) + \frac{f_{E,t}}{Z_t}N_{E,t}$ $L^* = N^*_t\left(l^*_{D,t} + l^*_{X,t}\right) + \frac{f^*_{E,t}}{Z^*_t}N^*_{E,t}$

Table 2: Model Calibration

Subjective time preference factor β	0.99
Relative risk aversion γ	2
Elasticity of substitution θ	3.8
Consumption home bias ϕ	0.75
Trade costs τ, τ^*	1.3
Sunk entry costs f_E, f^*_E	1
Probability of market exit δ	0.025
Degree of price rigidity ψ	77
Labor supply L, L^*	1

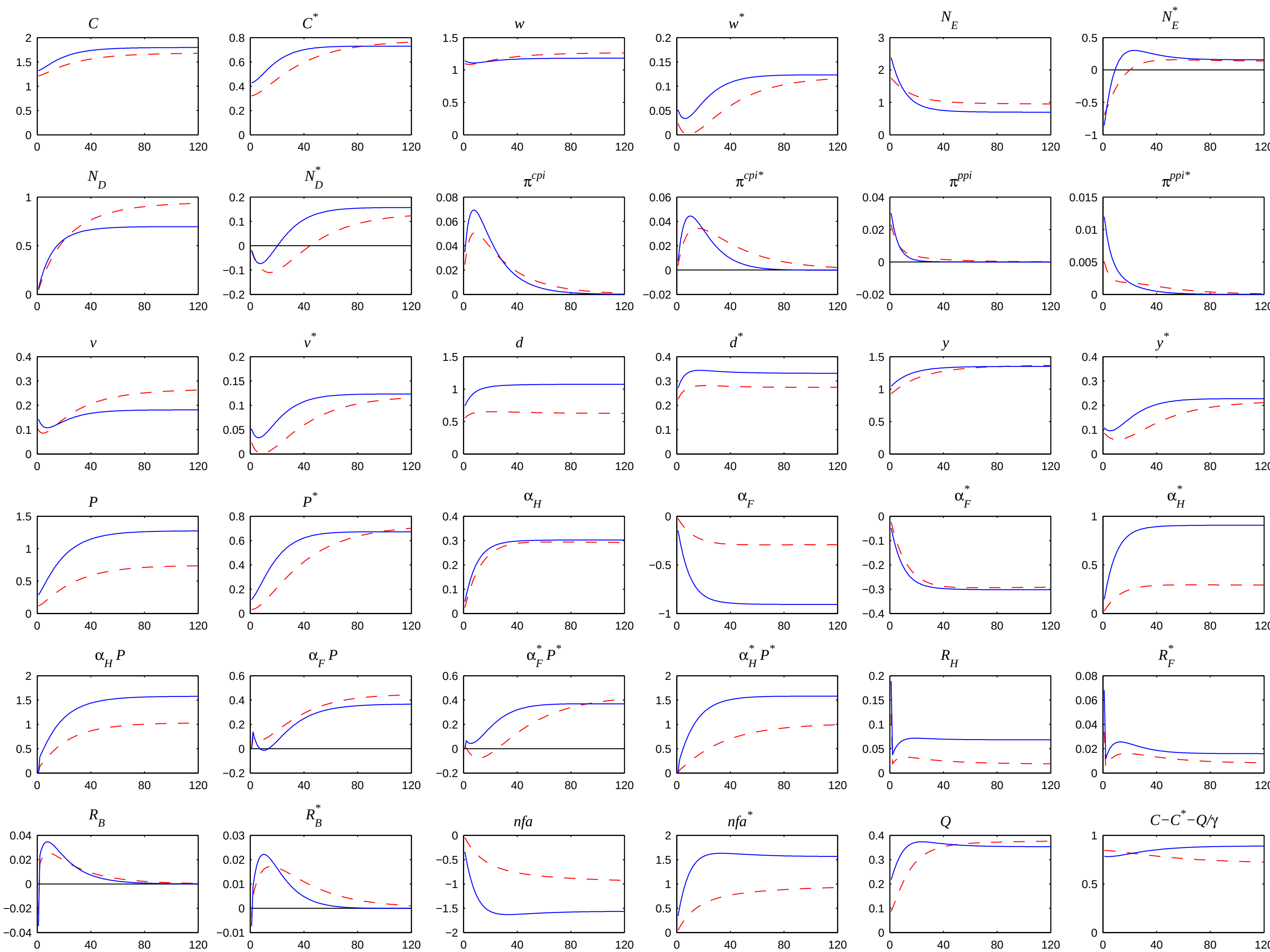

Figure 1: Permanent technology shock. (*Notes*: The solid line denotes the domestic equity bias scenario, the dashed line denotes financially more integrated economies.)