International Business Cycles and Financial Frictions

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Abstract

This paper builds a two-country DSGE model with financial frictions to study the business cycle comovement when the leveraged investor has foreign asset exposure. The investor holds capital in both countries and faces a leverage constraint on her debt. This foreign exposure along with financial frictions lead to an amplification of transmission of shocks between countries. When a negative technology shock hits the home country, it leads to a decline in the home country's asset price which in turn tightens the leverage constraints of investor in both countries. Thus, borrowing is reduced globally and this leads to another round of sell-off of the asset. I calibrate this model to match data of the US and an aggregate of industrialized countries. Simulation shows three important results: First, the model does better in accounting for business cycle comovement. The model can explain two thirds of the output correlations in the data. The employment correlation matches exactly the correlation in the data and the correlation of investment gets closer to the data compared to the model without constraint. Second, when the investor has more foreign asset exposure of the other country, the output correlation between the two increases. This result is consistent with the evidence documented in Imbs (2006) that the output correlations rise with financial integration. Third, substantial differences exist in impulse response functions between the model with financial frictions and the model without them.

1 Introduction

The central question this paper addresses is the quantitative impact of financial frictions on the business cycle comovement between countries when the leveraged investors have foreign asset exposure. The 2008 financial turmoil which started with the US housing market crisis transformed into a global crisis. This strong global interdependence draws attention to the effect of asset prices on the balance sheet of highly leveraged multinational financial institutions. It is reasonable to conjecture that the financial frictions, along with degree of exposure to foreign assets, may influence the international transmission of shocks. However, despite the importance of this question, it has not been studied quantitatively in the literature. This paper fills this gap and concludes that by including financial frictions, the model does a better job in accounting for the correlations of output, investment and employment in the data. Moreover, the model also shows that as foreign asset exposure increases, business cycles becomes more synchronized.

I build a two-country model where credit contracts are imperfectly enforceable. The investor can hold capital stock in both countries. However, she faces a leverage constraint because she cannot promise to repay her debt. The leverage constraint limits her loans to be smaller than a portion of the market value of her total capital holdings. I calibrate this model to match data of the US and the rest of the world (an aggregate of 19 European countries, Canada and Japan). This model is then taken to examine whether the existence of financial frictions in a world where constrained investor holds cross country portfolios can improve the model's ability to account for key features of the data. To be specific, I check if the model can improve the cross country correlations of output, investment and labor.

I find that incorporating financial frictions into open economy business cycle models does help to improve the fit of the model. The model mimics an "international finance multiplier" mechanism which drives up output correlations across countries through the financial channel instead of the traditional trade channel. When a negative technology shock hits the domestic market, the demand for capital in the home country falls, which in turn forces down investment and the price of domestic capital. This leads to a tightening of investors' leverage constraint in both countries. Borrowing is reduced globally and therefore demand for capital in the foreign country also declines which pushes down the price of foreign asset, leading to another round of credit tightening. The kind of multiplier effect arises, since the decline in investment lowers asset prices and investor's net worth, further pushing down investment. By considering foreign exposure, the foreign asset price has an immediate effect on the balance sheet of domestic investor. Along with the presence of the financial frictions, the technology shock is spilled over from one country to another and thus drives up the business cycle correlations.

The model is evaluated quantitatively by calibrating to the data between the US and the rest of the world. Three important results are found. First, the simulation results show that the presence of financial frictions improve the business cycle comovement along all dimensions : the calibrated model produces positive correlations of output, investment and employment. The model can explain two thirds of the output correlations in the data. The employment correlation matches exactly the correlation in the data and the correlation of investment gets closer to the data compared to the model without constraint. Second, when the investor increases her foreign asset exposure, the output correlation increases. This result is consistent with the evidence documented in Imbs (2006) that the output correlations rise with financial integration. Third, substantial differences exist in IRFs between models with and without financial frictions. After a negative shock hits country 1, in the model with no financial frictions country 2's output goes up because of resources reallocation according to the relative efficiency of production. However, in the model with financial frictions, country 2's output declines due to the transmission mechanism.

This paper relates to several strands of literature. The first strand addresses the comovement of the international business cycles. Backus, Kehoe and Kydland (1992) showed that in a complete market model, output, investment and labor are negatively correlated because of efficient allocation of resources across countries. Baxter and Crucini (1995), Kollmann(1996), and Heathcote and Perri (2002) introduced incomplete market. However, they find that incomplete market does not help much to match the business cycle correlations in the data, because there is little need for

insurance markets.

The second strand is a recent and growing literature analyzing financial frictions in an open economy context, including Gertler, Gilchrist and Natalucci (2007), Faia (2007) and Devereux and Yetman (2009). Gertler, Gilchrist and Natalucci (2007) builds a small open economy model with credit frictions to explore the connection between the exchange rate regime and financial distress in the case of 1997 Korea crisis. Faia (2007) studies financial frictions in a two-country DSGE model showing that business cycle synchronization increases when the economies have similar financial structures, while it decreases with the degree of financial openness. However, these two papers and the previous literature did not study the impact of the financial frictions when the constrained agents have foreign asset exposure. As will be shown later in this paper, the introduction of foreign exposure reverse the direction of business cycle synchronization: when taking into the account of foreign exposure, the business cycles are more synchronized when the financial integration increases.

The paper by Devereux and Yetman (2009) is the closest to my work in that it studies financial frictions and capital portfolio choice in a two-country model. In contrast to my paper, their model lacks capital accumulation and endogenous labor choice which are the key ingredients for business cycle fluctuations.¹

The third strand is the international portfolio choice literature, pioneered by Van Wincoop and Tille (2007) and Devereux and Sutherland (2008) with recent contribution made by Heathcote and Perri (2009). This literature uses higher order perturbation in solving optimal portfolio allocations in DSGE models.

The paper is organized as follows. In Section 2 we describe the model economy. In Section 3 we discuss how this model is calibrated and solved. In Section 4, the main results are presented and analyzed. In Section 5, we provide further robustness checks. Section 6 concludes.

¹Dedola and Lombardo (2010) studied a similar problem with financial accelerator as in Bernanke et al. (1999). However, they did not provide any moments from the model to judge the model's fit.

2 Model

In this section I outline a two-country, one-good international business cycle model. The world economy consists of two countries, home (country 1) and foreign (country 2). The countries are of the same size and each of them is populated with two types of infinitely lived agent: investor and saver. I assume that capital is mobile across the countries but labor is immobile across the countries. The following subsections detail the economic choice faced by agents in the two economies, the structure of production and the relevant market clearing conditions.

2.1 Household

There are two types of household in the model. The first type can buy the capital stocks installed both domestically and abroad. He can also trade one period bond at the national level. We refer to this type of households as investors. Investors account for a fraction n of all households. The rest of the households only participate in the domestic bond market and we refer to them as savers. Similar to the assumption made in Bernanke, Gertler and Gilchrist (1999), I assume that the investors have the ability to transform the capital into a factor that can be used in the market good production. However, since the savers donot have this ability, they will only purchase capital to be used in the home production.

2.1.1 Investor

For investor in each country i, he chooses consumption c_{it}^{I} , provides labor services l_{it}^{I} , and makes a portfolio choice among risk free debt, domestic capital and foreign capital. His utility is given by the following expression:

$$E_t \sum_{t=0}^{\infty} \left[\beta(C_{it}^I, L_{it}^I) \right]^t \frac{1}{1-\gamma} \left(\left(c_{it}^I - \psi^I \frac{(l_{it}^I)^{1+\theta}}{1+\theta} \right)^{1-\gamma} - 1 \right) \qquad i = 1, 2$$
(1)

The Greenwood-Hercowitz-Huffman (GHH) preference is widely used in the open economy literature, early work includes Correia, Neves and Rebelo (1995). GHH preference is chosen because there is no wealth effect on labor supply. As a result, only substitution effect operates on hours and suggests that the path of hours will follow closely that of output². To ensure a stationary equilibrium, I follow Mendoza (1991) to assume an endogenous discount factor.

$$\beta(C_{it}^I, L_{it}^I) = \left(1 + C_{it}^I - \psi^I \frac{(L_{it}^I)^{1+\theta}}{1+\theta}\right)^{-\omega^I}$$

The discount factor is external in the sense that household takes $\beta(C_{it}^{I}, L_{it}^{I})$ as exogenous. (C_{it}^{I} and L_{it}^{I} are aggregate level of consumption and hours of investor.) As shown in Schmitt-Grohe and Uribe (2003), internalizing the discount factor makes negligible quantitative differences.

The period budget constraint of a representative investor is given by

$$c_{it}^{I} + q_{it}^{k} k_{ii,t+1}^{I} + q_{jt}^{k} k_{ij,t+1}^{I} = w_{it} l_{it}^{I} + q_{it}^{b} B_{it+1}^{I} - B_{it}^{I} + ((1-\delta)q_{it}^{k} + R_{it}^{k})k_{ii,t}^{I} + ((1-\delta)q_{jt}^{k} + R_{jt}^{k} - \tau_{t})k_{ij,t}^{I}$$
(2)

Here q_{it}^k denotes price of capital in country i, q_{it}^b denotes price of bond in country i $(q_{it}^b = \frac{1}{1+R_{it}^b}$ where R_{it}^b is the risk-free rate), k_{ijt+1}^I denotes the capital in country jholding by investor from country i. In each period, the investor receives a return R_{it}^k (R_{jt}^k) by renting the capital to the market production firm in country i (j). He also receives labor income by supplying labor to the domestic market production firm. He then sells the capital after depreciation at price q_{it}^k (q_{jt}^k). By assumption, the investor is less patient than the saver, therefore he will borrow from the saver at the risk-free rate to finance the purchase of capital for next period.

Following Devereux and Sutherland (2009), I assume that there is some uncertainty in the return of capital that investor gets from foreign market. For convenience, I call it cost to invest aboard. Specifically, the return from foreign country that the agent receives is subject to an iceberg cost τ_t^3 . This cost is second-order to ensure a

 $^{^{2}}$ GHH preferences are commonly used in the open economy literature, dating back to Devereux, Gregory and Smith (1992). Recent examples include Aguiar and Gopinath (2006), Raffo (2008) and Boileau and Normandin (2008).

³It is quite common to introduce exogenous financial frictions, such as Till and Van Wincoop

well-behaved portfolio allocation.

$$\tau_t \sim N(0, \chi \sigma^2)$$

Since by assumption the investor cannot commit to repay on the debt, he faces a leverage constraint of the form

$$B_{it+1}^{I} \le \kappa (q_{it}^{k} k_{ii,t+1}^{I} + q_{jt}^{k} k_{ij,t+1}^{I})$$
(3)

Here B_{it+1}^{I} denotes the amount of debt that he can borrow from the saver and κ controls the leverage ratio. The leverage constraint is imposed directly as in the models with endogenous credit constraints examined by Kiyotaki and Moore (1997), Aiyagari and Gertler (1999) and Kocherlakota (2000). Since the debt level is linked directly to investor's total asset value, any fluctuation in either country's capital price will have an immediate impact on the borrowing capacity of the investors in both countries. Therefore, both the leverage constraint and the foreign capital exposure are the key ingredients that help the transmission of technology shocks across countries.

2.1.2 Saver

Consider a saver with GHH preference described by

$$E_0 \sum_{t=0}^{\infty} \left[\beta(C_{it}^S, L_{it}^S) \right]^t u\left(c_{it}^{SM}, c_{it}^{SH}, l_{it}^{SM} l_{it}^{SH} \right)$$

$$\tag{4}$$

where

$$u\left(c_{it}^{SM}, c_{it}^{SH}, l_{it}^{SM} l_{it}^{SH}\right) = \frac{1}{1 - \gamma} \left(\left(c_{it}^{S} - \psi^{S} \frac{(l_{it}^{S})^{1+\theta}}{1 + \theta}\right)^{1-\gamma} - 1 \right)$$
(5)

and

$$c_{it}^{S} = \left(\lambda \left(c_{it}^{SM}\right)^{e} + \left(1 - \lambda\right) \left(c_{it}^{SH}\right)^{e}\right)^{1/e}$$

(2007) and Devereux and Sutherland (2006). Other papers, such as Martin and Rey (2004), Coeurdacier (2005) and Coeurdacier and Guibaud (2005).

$$l_{it}^S = l_{it}^{SM} + l_{it}^{SH}$$

The instantaneous utility function, u, is defined over four arguments at each date: c_{it}^{SM} is consumption of market-produced commodity in country i, c_{it}^{SH} is consumption of a home produced commodity, l_{it}^{SM} is labor time spent in market production and l_{it}^{SH} is labor time spent in the home production. The elasticity of substitution between c_{it}^{SM} and c_{it}^{SH} is given by $\frac{1}{1-e}$. The discount factor is defined similarly to that of investor

$$\beta(C_{it}^{S}, L_{it}^{S}) = \left(1 + C_{it}^{S} - \psi^{I} \frac{(L_{it}^{S})^{1+\theta}}{1+\theta}\right)^{-\omega}$$

where ω^S represents the elasticity of the discount factor to the composite $1 + C_{it}^S - \psi^I \frac{(L_{it}^S)^{1+\theta}}{1+\theta}$.

At each date, the saver is subject to a market budget constraint that allocates total income between two uses: the purchase of the market consumption good and the purchase of the household capital. Capital is resold to capital producer after using in the home production. I assume the capital depreciates at rate δ , for simplicity, I assume it to be the same as the depreciation rate in market production sector. The saver also receives interest payment on the bond he purchased and his labor income by supplying labor to the market production firm If w_{it} is the wage rate, q_{it}^b is the price for bond, then the budget constraint can be written as

$$c_{it}^{SM} + q_{it}^k k_{ii,t+1}^S = w_{it} l_{it}^{SM} + (1-\delta) q_{it}^k k_{ii,t}^S + q_{it}^b B_{it+1}^S - B_{it}^S$$
(6)

The saver is also subject to the home production constraint at each date

$$c_{it}^{SH} = G(k_{ii,t}^S, l_{it}^{SH})$$
(7)

I assume that the home production has a Cobb-Douglas production technology of the form

$$G(k_{ii,t}^{S}, l_{it}^{SH}) = (k_{ii,t}^{S})^{\alpha_2} (l_{it}^{SH})^{1-\alpha_2}$$
(8)

2.2 Capital Producer

In each country, there is one representative capital producer who operates in a perfectly competitive market. At the end of period t, the capital producer purchases final goods i_{it} and the undepreciated physical capital, $(1 - \delta)k_{i,t}$, that has been used in period t production cycle. The capital producer uses these inputs to produce new installed capital k_{it+1} using the following constant return to scale production technology

$$k_{i,t+1} = (1-\delta)k_{i,t} + \phi\left(\frac{i_{i,t}}{k_{i,t}}\right)k_{i,t}$$

I assume that the construction of new capital goods is subject to adjustment costs whereas the repair of old capital goods is not. The following specification for adjustment cost is adopted

$$\phi\left(\frac{i_{i,t}}{k_{i,t}}\right) = \frac{g_1}{1-\pi} \left(\frac{i_{i,t}}{k_{i,t}}\right)^{1-\pi} + g_2$$

where $\phi(\cdot)$ is a positive, concave function. I denote the price of the new capital to be $q_{i,t}^k$, then the parameter π controls the elasticity of the investment to capital ratio with respect to $q_{i,t}^k$. This specification allows the shadow price of installed capital to diverge from the price of an additional unit of capital, i.e., it permits variation in the price $q_{i,t}^k$. As in Kiyotaki and Moore(1997), the idea is to have asset price variability contribute to volatility in investor's balance sheet.

Since the marginal rate of transformation from previously installed capital to new capital is unity, the price of old capital is also $q_{i,t}^k$. The firm's profits at time t is

$$\Pi_{i,t} = q_{i,t}^k k_{i,t+1} - q_{i,t}^k (1-\delta) k_{i,t} - i_{i,t}$$

The capital producer therefore solves

$$\max_{k_{t}, i_{t}} \Pi_{i,t} = q_{i,t}^{k} k_{i,t+1} - q_{i,t}^{k} (1-\delta) k_{i,t} - i_{i,t}$$

s.t. $k_{i,t+1} = (1-\delta) k_{i,t} + \phi \left(\frac{i_{i,t}}{k_{i,t}}\right) k_{i,t}$

Solving the maximization problem above leads to the following optimality condition

$$q_{i,t}^{k} = \frac{1}{\phi_{1}(i_{i,t}, k_{i,t})k_{i,t}} = \frac{1}{\phi'\left(\frac{i_{i,t}}{k_{i,t}}\right)}$$
(9)

Moreover, the new installed capital produced in each country is brought by three types of agents: domestic investor, foreign investor and domestic saver. To be specific,

$$k_{1t} = nk_{11t}^{I} + nk_{21t}^{I} + (1-n)k_{11t}^{S}$$
$$k_{2t} = nk_{12t}^{I} + nk_{22t}^{I} + (1-n)k_{22t}^{S}$$

The aggregate stock of physical capital evolves as follow

$$k_{it+1} = (1-\delta)k_{it} + \phi\left(\frac{i_{it}}{k_{it}}\right)k_{it}$$

2.3 Production

The structure of market production firm is straight forward. The firm only lives for one period and has a Cobb-Douglas production function in capital and labor. The market good production is subject to a stochastic technology shock.

$$F(k_{i,t}^{I}, l_{it}) = e^{z_{it}} (k_{i,t}^{I})^{\alpha_{1}} (l_{it})^{1-\alpha_{1}}$$
(10)

The firm rents capital from domestic and foreign investor

$$k_{i,t}^{I} = n(k_{ii,t}^{I} + k_{ji,t}^{I})$$
(11)

and it also rents labor from domestic investor and domestic saver

$$l_{it} = n l_{it}^{I} + (1 - n) l_{it}^{SM}$$
(12)

The optimality conditions for the firm are

$$w_{it} = F_L(z_{it}^m, k_{i,t}^I, l_{it})$$
(13)

$$R_{it}^{k} = F_{K}(z_{it}^{m}, k_{i,t}^{I}, l_{it})$$
(14)

We assume that the law of motion for the technology shock is given by a stationary VAR of the form

$$\begin{bmatrix} z_{1t}^m \\ z_{2t}^m \end{bmatrix} = \begin{bmatrix} \rho_1^m & \rho_2^m \\ \rho_2^m & \rho_1^m \end{bmatrix} \begin{bmatrix} z_{1t-1}^m \\ z_{2t-1}^m \end{bmatrix} + \begin{bmatrix} \epsilon_{1t}^m \\ \epsilon_{2t}^m \end{bmatrix}$$
(15)

where ρ_1^m represents the persistence of the technology shock and ρ_2^m represents the spill-over effect of the technology shock. The innovation follows

$$\begin{bmatrix} \epsilon_{1t}^m \\ \epsilon_{2t}^m \end{bmatrix} \sim N(0, \Sigma) \text{ with correlation matrix } \begin{bmatrix} \sigma_1^m \\ \phi^m & \sigma_2^m \end{bmatrix}$$
(16)

where ϕ^m is the correlation between the two technology shocks.

2.4 Market Clearing

There are two sets of market clearing conditions: the bond market clearing and the good market clearing. Since the bond market is domestic, the total bond within a country is zero which gives the following conditions,

$$nB_{1t+1}^{I} + (1-n)B_{1t+1}^{S} = 0 (17)$$

$$nB_{2t+1}^{I} + (1-n)B_{2t+1}^{S} = 0 (18)$$

Now we develop the aggregate resource constraint for this economy.

$$nc_{1t}^{I} + (1-n)c_{1t}^{SM} + nc_{2t}^{I} + (1-n)c_{2t}^{SM} + \overline{\tau}_{t} + i_{1t} + i_{2t} = F(k_{1t}^{I}, l_{1t}) + F(k_{2t}^{I}, l_{2t})$$
(19)

The market good clearing gives that the total market output is used in three aspects: total market consumption, total investment and the sum of the portfolio cost $\overline{\tau}_t$.

2.5 Equilibrium

A competitive equilibrium is defined as a sequence of allocations $\{c_{it}^{I}, c_{it}^{SM}, c_{it}^{SH}, k_{ii,t+1}^{I}, k_{ii,t+1}^{S}, k_{ii,t+1}^{I}, l_{it}^{I}, l_{it}^{SM}, l_{it}^{SH}, B_{it+1}^{I}, B_{it+1}^{S}\}$ and prices $\{q_{it}^{k}, q_{it}^{b}, w_{it}, R_{it}^{k}, \mu_{it}\}$ (i = 1, 2) such that both the representative household and the firm maximize and market clears. The set of equilibrium conditions that characterize the time paths for the allocation and prices are given by the first order conditions for the households and the firm that follows, together with the market clearing conditions and the stochastic process for the technology. To save space, only equilibrium conditions for country 1 are shown below

$$c_{1t}^{I} + q_{1t}^{k} k_{11,t+1}^{I} + q_{2t}^{k} k_{12,t+1}^{I} = w_{1t} l_{1t}^{I} + q_{1t}^{b} B_{1t+1}^{I} - B_{1t}^{I}$$
(20)

$$+((1-\delta)q_{1t}^{k}+R_{1t}^{k})k_{11,t}^{I}+((1-\delta)q_{2t}^{k}+R_{2t}^{k}-\tau_{t})k_{12,t}^{I}$$
(21)

$$B_{1t+1}^{I} \le \kappa (q_{1t}^{k} k_{11,t+1}^{I} + q_{2t}^{k} k_{12,t+1}^{I})$$
(22)

$$q_{1t}^k U_{c_{1,t}}^I = \beta(C_{1t}^I, L_{1t}^I) E_t U_{c_{1,t+1}}^I ((1-\delta)q_{1t+1}^k + R_{1t+1}^k) + \kappa \mu_{1t} q_{1t}^k$$
(23)

$$q_{2t}^{k}U_{c_{1,t}}^{I} = \beta(C_{1t}^{I}, L_{1t}^{I})E_{t}U_{c_{1},t+1}^{I}((1-\delta)q_{2t+1}^{k} + R_{2t+1}^{k} - \tau_{t+1}) + \kappa\mu_{1t}q_{2t}^{k}$$
(24)

$$q_{1t}^b U_{c_1,t}^I = \beta(C_{1t}^I, L_{1t}^I) E_t U_{c_1,t+1}^I + \mu_{1t}$$
(25)

$$c_{1t}^{SM} + q_{1t}^k k_{11,t+1}^S = w_{1t} l_{1t}^{SM} + (1-\delta) q_{1t}^k k_{11,t}^S + q_{1t}^b B_{1t+1}^S - B_{1t}^S$$
(26)

$$c_{1t}^{SH} = G(k_{11,t}^S, l_{1t}^{SH}) \tag{27}$$

$$q_{1t}^k U_{c_m,t}^S = \beta(C_{1t}^S, L_{1t}^S) E_t \left(U_{c_m,t+1}^S (1-\delta) q_{1t+1}^k + U_{c_h,t+1}^S G_K(k_{11,t+1}^S, l_{1t+1}^{SH}) \right)$$
(28)

$$q_{1t}^b U_{c_m,t}^S = \beta(C_{1t}^S, L_{1t}^S) E_t U_{c_m,t+1}^S$$
(29)

$$w_{1t} = \psi^I (l_{1t}^I)^\theta \tag{30}$$

$$w_{1t} = \frac{\psi^S (l_{1t}^{SM} + l_{1t}^{SH})^{\theta}}{(c_{1t}^S)^{1-e} \lambda (c_{1t}^{SM})^{e-1}}$$
(31)

$$G_L(k_{11,t}^S, l_{1t}^{SH}) = \frac{\psi^S(l_{1t}^{SM} + l_{1t}^{SH})^\theta}{(c_{1t}^S)^{1-e} (1-\lambda) (c_{1t}^{SH})^{e-1}}$$
(32)

$$w_{1t} = F_L(k_{1,t}^I, l_{1t}) \tag{33}$$

$$R_{1t}^k = F_K(k_{1,t}^I, l_{1t}) \tag{34}$$

$$q_t = \frac{1}{\phi_1(i_t, k_t)k_t} \tag{35}$$

where μ_{it} is the Lagrange multiplier associated with the leverage constraint in country i and the total capital used in country 1 is

$$k_{1t} = nk_{11t}^{I} + nk_{21t}^{I} + (1-n)k_{11t}^{S}$$

The capital used by market production in country 1 is

$$k_{1t}^I = nk_{11t}^I + nk_{21t}^I$$

The law of motion for total capital in country 1 is

$$k_{1t+1} = (1-\delta)k_{1t} + \phi(\frac{i_{1t}}{k_{1t}})k_{1t}$$

The world market clearing condition is

$$nc_{1t}^{I} + (1-n)c_{1t}^{SM} + nc_{2t}^{I} + (1-n)c_{2t}^{SM} + \overline{\tau}_{t} + i_{1t} + i_{2t} = F(k_{1t}^{I}, l_{1t}) + F(k_{2t}^{I}, l_{2t})$$

By Walras Law, the world market clearing condition is redundant.

3 Calibration

We now proceed to choose parameter values, setting some numbers on the basis of a priori information and setting others according to the steady state conditions. A period in the model corresponds to one quarter. The sample period in the data is from 1972:1 to 2008:4. Table 1 gives a summary of the calibration.

3.1 Preference and Production Parameters

The intertemporal elasticity of substitution (IES) is set to 0.5 which is standard in the literature. The parameter ω^S which controls saver's discount factor is set to 0.039 to match an annual interest rate of 4%. Following Bernanke, Gertler and Gilchrist (1999), I use the investor's discount factor to match an interest premium on borrowed funds of 2%, approximately the historical average spread between the prime lending rate and the six-month Treasury bill rate. This gives ω^I the value of 0.112. The implied steady state discount factor for the saver is 0.99 and the implied steady state discount factor for the investor is 0.97. There is no consensus on the estimation of the elasticity of labor supply. A reasonable bound for the elasticity of labor supply is from 0.3 to 2.2. In line with Greenwood, Hercowitz and Huffman (1988), I choose the elasticity to be 1.7 which corresponds to $\theta = 0.6$.

The depreciation rate, δ , is set to 0.025, corresponding to an annual depreciation rate of 10%. We now use $\alpha_1, \alpha_2, \psi^I, \psi^S$ and λ to match the following five observations: the market capital-to-output ratio, the home capital-to-output ratio, the market hours for the investor, the market hours for the saver and the home hours for the saver. According to Greenwood, Rogerson and Wright (1995), the home capital to output ratio is 5 where the home capital is defined as consumer durables plus residential structures. Since the total capital to output ratio is around 12 given by Cooley and Precsott (1995), the market capital to output ratio is set to 7. I choose the hours worked for market production to be 0.33 and the time spend on home production to be 0.25. This calibration gives a capital share of market production to be 0.29 and a capital share of home production to be 0.40. The only preference parameter that is left unspecified is e, the elasticity of substitution between the market and home consumption good. Higher values of e means that the saver is more willing to substitute consumption of one sector's output for consumption of the other sector's output. In New Keysian literature, it is a convention to pick 10 to be the elasticity of substitution between two goods. By analogy, we pick 10 as the an elasticity of substitution between the home and market goods for the benchmark model, implying a value of 0.9 for e. In what follows we will also consider several

alternative values of e for robustness test.

There are two parameters controlling for different costs: the investment adjustment cost, π and the portfolio cost χ . The elasticity of the capital price with respect to the investment capital ratio, π , is taken to be 0.25, following Bernanke, Gertler and Gilchrist (1999). This is one of the key parameters in the model since the capital price is crucial for determine the loans of investor and hence the global investment level. However, there is no firm consensus in the literature about what this parameter value should be. Reasonable assumption about the adjustment cost suggest that the value should lie within a range from 0. to 0.5^4 . The parameter χ controls the variance of the portfolio cost. When this cost is absent, only 14% of investor's asset are domestic, exhibiting substantial bias against the home asset. This observation is consistent with theory since when agent's labor income is correlated with his home capital return, to diversify this risk, the agent will take more position in the foreign country. We set χ to be 0.14 such that 75% of the capital used in one country's market production is rented from their domestic investor and the rest 25% of the capital comes from the foreign investor.

When the leverage constraint is binding the leverage ratio is $\frac{1}{1-\kappa}$ for a given κ . In this model, I calibrate the leverage ratio to be 3, according to Dedola and Lombardo (2010). This number is higher than the leverage ratio used in Bernanke, Gertler and Gilchrist (1999), since I consider the investors to not only include non-financial firms but also financial firms.

The share of saver is calibrated to be 50% according to Campbell and Mankiw (1989) where they have the rule of thumb consumer who makes up of half of the population. The rule of thumb consumer is a more extreme assumption as the agent doesnot have access to the financial market at all. It has been used in various papers in explaining the macroeconomic effects of fiscal policy (Gali, Lopez-Salido and Valles 2007), equity premium (Weil 1990) and recently it is used in some open economy paper as well (Corsetti, Meier and Muller 2009). Here I still shut down the saver's

⁴Jermann (1998) uses a value of 0.23 and King and Wolman (1996) reports a value of 2.0. Christensen and Dib (2008) give an estimate of 0.59 by Bayesian estimation. Meier and Muller (2006) report an estimate of 0.65, close to Christensen and Dib (2008).

access to equity market, however, I allow the saver to have saving technology.

3.2 Technology Parameters

For the benchmark calibration, we follow the estimates from Heathcote and Perri (2004). They estimate the productivity process by first computing and then subtracting a common deterministic growth trend from productivity. In this case, the productivity shocks still display high persistence and positively correlated innovations, but we no longer find evidence of spillovers. This gives the following estimates

$$\begin{bmatrix} z_{1t}^m \\ z_{2t}^m \end{bmatrix} = \begin{bmatrix} 0.91 & 0. \\ 0. & 0.91 \end{bmatrix} \begin{bmatrix} z_{1t-1}^m \\ z_{2t-1}^m \end{bmatrix} + \begin{bmatrix} \epsilon_{1t}^m \\ \epsilon_{2t}^m \end{bmatrix}$$

where

$$\begin{bmatrix} \epsilon_{1t}^m \\ \epsilon_{2t}^m \end{bmatrix} \sim N(0, \Sigma) \text{ with correlation matrix } \begin{bmatrix} 0.006 \\ 0.25 & 0.006 \end{bmatrix}$$

As a robustness check, I also use the productivity estimates from Backus, Kehoe and Kydland (1992) where there is some evidence of spillover. The estimates are

$$\begin{bmatrix} z_{1t}^m \\ z_{2t}^m \end{bmatrix} = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix} \begin{bmatrix} z_{1t-1}^m \\ z_{2t-1}^m \end{bmatrix} + \begin{bmatrix} \epsilon_{1t}^m \\ \epsilon_{2t}^m \end{bmatrix}$$

and we maintain the same covariance matrix as in Heathcote and Perri (2004).

4 Results

In this section, we analyze the quantitative implications of our model. First, we report the moments generated by the model and compare them with the data. Second, we look at the impulse response functions (IRFs) of technology shock to analyze the model mechanism.

4.1 Moments

The results of our simulations under the benchmark calibration are summarized in Table 2. The first column of Table 2 shows the statistics calculated from the data. panel (A) and (B) are calculated from US time series for the period of 1972:1 to 2008:4. The statistics from panel (C) represent the correlation of US series with series of rest of the world (which is an aggregate of Europe, Japan and Canada). The details of the aggregation of the rest of the world data is shown in Appendix. Except for net export, all series are logged and filtered by Hodrick-Prescott filter with a smoothing parameter of 1600.

The third column of Table 2, "Constraint Model", is our benchmark model with calibrations documented in Section 3. The second column of Table 2, "No Constraint Model", is exactly the same as the "Constraint Model" except that now the investor does not face the leverage constraint. The fourth column "Diversified Constraint" is the model where instead of imposing 75% home bias, we let the investor fully diversify his portfolio such that, as shown in the calibration, he only holds 14% of the capital in the domestic market.

As we see from the model predictions in Table 2, in general the model with constraint gives moments that are closer to the moments in the data. The constrained economy replicates the level of output volatility in the data, however, the output in unconstrained economy (2.54 percent) is more volatile than the constrained economy (1.92 percent). The high volatility of the unconstrained economy is introduced by the frequent substitution between market and home consumptions. In terms of relative volatility, both model over predicted the volatility of consumption and in the mean while under predicted the volatility of investment in the data. For the within country correlations, both models give positive correlations of net export with output while we see negative correlations in the data.

We next turn to the cross country correlations, the unconstrained economy predicts a consumption correlation and a output correlation that are too low, relative to the data. The constrained economy does better, predicting a higher level of output correlation. Although it overshoots the consumption correlation, we are still closer to the data than the unconstrained economy. In terms of investment and employment, both models predict positive correlations, while the constrained economy is closer to the moments in the data.

Overall, the model with constraint performs better in terms of the cross country correlations. The presence of the leverage constraint increases the correlation of consumption, labor and output while decreases the correlation of investment. As will be shown in Section 4.2, those improvements are introduced exactly by the financial frictions.

We then compare the difference induced by financial exposure. Investor in the constrained model holds 75% of capital in domestic market while investor in the diversified constraint model holds 14% of capital in domestic capital market. The later one has a larger foreign asset exposure. The impact of this foreign asset exposure on the business cycle comovement is immediate. If we look at the cross country correlations, output correlation increases from 0.4 to 0.53, which is fairly close to the data. Consumption and labor also rise because of the increased synchronization of output. Investment correlation is apparent once we review the leverage constraint of investor. As foreign capital exposure increases, foreign asset price will have a more profound impact on the debt level of the investor which in turn influence the domestic investment and output. Hence, the output correlation is driven up by increased foreign asset exposure.

4.2 Impulse Responses

In this section, I explain why the behavior of the three models differ. I analyze the response of the two-country economy to a one standard deviation negative shock in country 1 under the benchmark calibration. As in all the subsequent figures, the time units on the graphs are to be interpreted as quarters.

4.2.1 Technology Shock

Figure 1-4 shows the impact of a one standard deviation decline in country 1's technology shock. The upper panel shows country 1's response to the shock and the lower panel shows country 2's response. In each plot, the solid line corresponds to the impulse response in the constrained economy and the dash line corresponds to the unconstrained economy.

Leverage Constraint We first analyze the response of the model with leverage constraint. When the negative shock hits, the demand for capital in country 1 immediately falls around 0.16%, leading to a decline in the investment in country 1. Following the weak demand for capital, the price of capital in country 1 also falls. Since the investors hold leverage portfolio across countries, the decline in the asset price of country 1 leads to a shrinking of total wealth of investors in both countries. Therefore, the leverage constraints are tightened globally and the debts that the investors are eligible to loan are reduced. Now not only investor in country 1 has a weak demand for capital, so does investor in country 2. Hence, the investment and the capital price fall in country 2 as well. Another round of asset sell-off begins and the investment is dampened further.

Since the decline in the capital demand reduces the income of the investor, the investor's consumption falls, with country 1 investor's consumption falling by 0.9% and country 2 investor's consumption falling by 0.11%. As the savers suffers from their wage income, the savers' consumption are also reduced. Overall, the total market consumption in country 1 falls around 1% and that of country 2 falls around 0.06%.

As seen from Figure 1, the debt held by investor in country 1 declines more than 0.7% and because of the transmission mechanism introduced by the leverage constraints, the debt held by investor in country 2 also declines around 0.2%. We also see an increase in the capital used in the home production, because the domestic saver holds a portfolio of domestic capital and bond, a decline in the demand for bond makes the saver shifts his assets to domestic capital, therefore, the capital used in the home production increases.

Upon the negative shock to productivity, the investor and saver's labor supply to market production firm reduces immediately in country 1. Since there is no wealth effect on investor's labor for GHH preference, the investor's labor supply in country 2 also falls because of lower wage. However, the saver faces the trade off between wealth effect and substitution effect⁵. When the shock hits, wealth effect dominate substitution effect and saver in country 2 increases his market labor supply. However, this effect is minimum as it only leads to a 1 basis point movement. Next period, the substitution effect becomes larger and saver's market labor supply falls. The output of market production in country 1 falls by 1.4% in next period and through the transmission mechanism introduced by the leverage constraint, the output of market production in country 2 falls by around 0.1%.

No Leverage Constraint When the investor is not constrained, an unexpected 1 standard deviation decline in productivity leads to a fall in demand of capital in country 1 and so does investment. Thus asset price in country 1 declines. Because of the decline in the asset prices, the investor from country 2 suffers from his investment loss in country 1. However, because he doesn't face any form of collateral constraints, he can increase his debt to compensate his investment loss. Therefore, from Figure 3, we observe an increase in the debt level in country 2. There is a decline in the purchase of home capital, because the increase in the debt level in country 2 indicates an increase in the bond holdings of saver in country 2, as the saver holds more bond, he rebalances his portfolio by reducing his exposure to the home capital.

Because of the declining in the productivity in country 1's market sector, country 2 now looks more productive. Market capital flows from country 1 to country 2, thus Figure 2 shows an increase in the market capital in country 2. However, as there is also a fall in the demand for home capital, overall we see a 0.3% decline in the total investment in the country. Since the demand for capital is weak, the price level in country 2 also declines. Market output in country 2 follows a similar pattern as

⁵From Equation (31) and (32) we see that consumption shows up in the F.O.C. for saver's labor, therefore affecting saver's labor decision.

market capital: the market output in country 2 increases after the shock.

One thing that is left to be explained is the change in the investment under these two economies. As shown in Figure 1, the investment in country 2 falls less in the constrained economy than in the unconstrained economy. The reason is the following, the investment here is the total investment in the country which means that it is the sum of investment for market production and investment for home production. In the constrained economy, the investment of market sector falls because of the tightened leverage constraint for investor. However, the investment of home sector rises because the saver shifts his portfolio from bond to home capital. These two forces works against each other and the fall in the market investment overweighed the increase in the home investment, leading to a overall decline of investment. In the unconstrained economy, the market investment in country 2 rises because the relative productivity in country 1 now is higher. At the same time, the investment of home sector declines because now the saver shifts his portfolio from home capital to bond. These two forces results in a decline in the total investment level in country 2 and the magnitude is larger than the constrained economy.

Comparison After examining the two scenarios separately, now we put them together for comparison. There are several points to note. First, upon a negative technology shock to country 1, the market output in country 2 declines in the constrained economy whereas it increases in the unconstrained economy. The response of the unconstrained economy is similar to the situation of a standard complete market (or bond market): the capital flows into the more productive country, leading to negative responses of the production factors. The effect of the financial frictions becomes apparent when we look at the response of the constrained economy. The presence of the leverage constraint limits the investors' ability to invest in both countries. Since they are constrained from getting more loans, they do not have much resource to invest, therefore, although country 2's investment opportunity is better, the market capital in country 2 still declines.

Second, the decline of consumption in country 2 in the constrained economy is near three times as much in the unconstrained economy. For the unconstrained economy, country 2's consumption only has a 0.06% decline, because the investor are not constraint, they can borrow from the saver to cushion their investment loss, therefore, their consumption is barely affected. However, for the constrained economy, investor cannot borrow as much as he wants, hence consumption is affected to a bigger degree, leading to a 0.18% decline.

Third, the investment in country 2 falls less in the constrained economy than in the unconstrained economy. The reason is the following, the investment here is the total investment in the country which means that it is the sum of investment for market production and investment for home production. In the constrained economy, the investment of market sector falls because of the tightened leverage constraint for investor. However, the investment of home sector rises because the saver shifts his portfolio from bond to home capital. These two forces works against each other and the fall in the market investment overweighed the increase in the home investment, leading to a overall decline of investment. In the unconstrained economy, the market investment in country 2 rises because the relative productivity in country 1 now is higher. At the same time, the investment of home sector declines because now the saver shifts his portfolio from home capital to bond. These two forces results in a decline in the total investment level in country 2 and the magnitude is larger than the constrained economy.

To briefly sum up, the differences discussed above are exactly introduced by the financial frictions. The financial frictions drives up output, consumption and employment correlations while drives down the investment correlation.

Diversified Leverage Constraint In this section, we look at the effect of different degree of foreign exposure. Figure 5-8 shows the impact of a one standard deviation decline in country 1's technology shock. The upper panel shows country 1's response to the shock and the lower panel shows country 2's response. In each plot, the solid line corresponds to the impulse response in the partially diversified economy and the dash line corresponds to the fully diversified economy. Investors face leverage constraints in both economies.

Given the same level of decline in capital prices in country 1 for both economies

(Figure 6), it is straightforward to see that for investors who face leverage constraint, the more foreign capital he holds, the more he suffers from debt decline. This idea is confirmed in Figure 7 which shows the response of the debt level in country 2. We notice that when the investor is fully diversified (holding 86% foreign capital), his debt level falls more than three times than the case where he is partially diversified (holding 25% foreign capital). The debt level further influences other economic activities, output and consumption decrease. Therefore, through a larger balance sheet exposure of the foreign asset, the business cycles is more synchronized between the two countries.

5 Sensitivity Analysis

In this section, we report the results of a sensitivity analysis with respect to some key parameters in the model. Specifically, we explore some alternative values for the investment adjustment cost, leverage ratio, shock process and elasticity of substitution between home and foreign goods.

5.1 Adjustment Cost

The parameter π controls the elasticity of the capital price with respect to the investment capital ratio. As discussed in the calibration, the estimate of this elasticity varies a lot. Recent paper by Christensen and Dib (2008) etimates π to be 0.59 using data on investment. Other paper such as Meier and Muller (2006) gives a even higher value of 0.65. Therefore, as a robustness check, we set π to 0.5 implying a larger investment adjustment cost and a slower response of investment. We also set π to 100, in this case the adjustment cost is so large that investment does not move at all. The model is then reduced to a version where capital is fixed in each country which is similar to the setup of Devereux and Yetmann (2010)⁶. We argue that

⁶However, the two models are still not the same since this one has endogenous labor. Capital in this case can be interpret as land which are not mobile across countries but nevertheless can be owned by different investors.

significant difference exists between the model with and without capital accumulation. When capital cannot move across country, the business cycle synchronization becomes stronger.

Table 3 shows the simulations results when π is 0.25, 0.5 and 100 respectively. As π increases and as we move from left to right of the table, we see an increase of the cross country correlations in all the macro variables. The important role that π plays in the "international finance multiplier" mechanism become apparent. When the investment adjustment cost becomes higher, the capital price responds to technology shock to a greater extent. Since the capital price has an immediate impact on the investor's balance sheet, it influences the level of loans and investor's future investment decision. Therefore, when investment adjustment cost, on the other hand, also implies the investment to be less responsive to shocks. Therefore, we see a decline of the investment volatility.

5.2 Leverage Ratio

Now we experiment with higher leverage ratio for the investor's leverage constraint. As shown in previous section, the leverage constraint serves as an important channel for the propagation of the technology shocks. From equation (36), we see that as κ becomes bigger, the bigger impact the investor's asset value has on the eligible loans.

$$B_{it+1}^{I} \le \kappa (q_{it}^{k} k_{ii,t+1}^{I} + q_{jt}^{k} k_{ij,t+1}^{I})$$
(36)

Since many financial firms have higher leverage ratios, we set κ to 0.8, corresponding to a leverage ratio of 5. As seen from Table 4, the output volatility increases compared to lower leverage economy. There is also an uniform increase in the cross country correlations. Consumption correlation increases 0.06, while output correlation and labor correlation increase 0.07.

5.3 Different Shock Process

In the benchmark calibration, there is no spillover between the two technology shocks. Therefore we now conduct sensitivity analysis regarding the spillovers. The calibration for the technology shock is taken from Backus, Kehoe and Kydland (1992) (BKK) where the persistence of the shock is 0.906 and the spillover is 0.088. The covariance matrix for the innovation remains the same.

From the last column of Table 2, we observe an increase in the consumption correlation. The consumption correlation increases from 0.53 to 0.63. This is because that a negative shock to one country signals that the other country's output will also decline in the future. Consumer in that country takes this into account and lowers his current consumption. Therefore, consumption correlation goes up when technology is spilled over from one country to the other.

5.4 ES of Goods

Since there is no firm concensus on the elasticity of substitution between home and market good, we experiment with different values of e: 0.9, 0.5 and 0.1. As e gets smaller, it is more difficult to substitue between the two goods. Table 5 shows the simulation results from different value of e. When e is smaller, consumption becomes less correlated across countries.

[TO BE COMPLETED]

6 Conclusions

In this paper, I studied the quantitative impact of financial frictions on the business cycle comovement across countries. In particular, I have focused on the scenario where the agents have foreign asset exposure. I build a two-country DSGE model where the investor can hold cross country portfolios and faces leverage constraint on his debt. This paper argues that financial frictions are important in open economy models because it changes the propagation of technology shock across countries through the balance sheet of leveraged investors.

The paper concludes that by incorporating financial frictions, the model does a better job in accounting for the business cycle correlations across countries. The model can explain two thirds of the output correlations in the data. The employment correlation matches exactly the correlation in the data and the correlation of investment gets closer to the data compared to the model without constraint. Moreover, the model also shows that, consistent with the data, when the investors have more foreign asset exposure of the other country, the output correlation between the two increases.

My study reaffirms the growing attention in the open economy literature on integrating financial market frictions in otherwise standard two-country models. I documented the importance of including financial frictions and foreign asset exposure in the analysis. Since this model is able to replicate some key facts of international business cycle, I believe that this framework is promising to conduct further research, particularly on welfare analysis and the design of monetary and fiscal policies.

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A Computation

This appendix describes an algorithm for computing the equilibrium portfolios in open economy DSGE models. To a large extent, existing open economy models ignore portfolio composition, analyzing financial linkage between countries in terms of net foreign assets, with no distinction made between assets and liabilities. There is a growing literature which tries to develope methods to solve portfolio problems in these models. These work are pioneered by Devereux and Sutherland (2009) and Till and Wincoop (2007) with a recent development by Heathcote and Perri (2009). The idea of these three methods are essentially the same: If we have more than one assets, then the asset returns in the steady state are the same. Therefore, the portfolios are indeterminate in the steady state. In order to use perturbation method to solve the model, we need a steady state portfolio shares to perturb around. In general, we use information from second order perturbation to determine the steady state portfolios.

To be specific, in my model the steady state returns to capital in market production are the same across country. Therefore, although the total amount of capital used in market production is known, the distribution is indeterminate: the home and foreign investors can hold an arbitrary portion of the total market capital. I use the algorithm developed by Heathcote and Perri (2009) in solving this model.

Step 1 : Calculate the non-stochastic symmetric steady state equilibrium. We denote the steady state as $[\lambda_{11}, \lambda_{22}, X, Y]$ where λ_{11} is the market capital in country 1 holding by country 1 investor, λ_{22} is the market capital in country 2 holding by country 2 investor. X is the steady state of non-portfolio state variables and Y is the steady state of non-portfolio control variables. The first order conditions pin down the value of X and Y, while any value of $\lambda_0 = \lambda_{11} = \lambda_{22}$ is consistent with the equilibrium.

Step 2: Compute the decision rules $\lambda_{11,t+1} = g_1(\lambda_{11,t}, \lambda_{22,t}, X_t),$

 $\lambda_{22,t+1} = g_2(\lambda_{11,t}, \lambda_{22,t}, X_t), X_{t+1} = g_3(\lambda_{11,t}, \lambda_{22,t}, X_t, \epsilon_{t+1}), Y_t = g_4(\lambda_{11,t}, \lambda_{22,t}, X_t)$ up to second order around the steady state. The decision rules are computed using methods by Schmitt-Grohe and Uribe (2004). In order to apply their methods, a small quadratic adjustment cost is added for changing the portfolio from its steady state. However, we do not know whether the steady state portfolio λ_0 we guessed is the same as the average equilibrium portfolio in the true stochastic economy.

Step 3: Simulate the model for a large number of periods using the computed decision rules from Step 2. Compare the average portfolio shares with the steady state portfolio. If they are different, then we update the steady state portfolio with the average portfolio and return to Step 2. If the difference between them is within a certain tolerance level, then that means the initial steady state λ_0 is a good approximation of the long run portfolio holdings and we take it as the solution to our model.

This algorithm is tested in Heathcote and Perri (2009) by comparing it to the model solution where analytical form of the portfolio is known. The comparison shows that this algorithm gives a good approximation to the model and enjoys a rapid convergence.

B Data

The data series come from the OECD Quarterly National Account (QNA). For the US, GDP, consumption and investment correspond to Gross Domestic Product, Private plus Government Final Consumption Expenditure and Gross Fixed Capital Formation (all at constant prices). The employment data, coming from OECD Main Economic Indicators, uses the (deseasonalized) civilian employment index series. The imports and exports series at constant prices are from OECD Quarterly National Accounts.

For the data of rest of the world, we construct an aggregate of Canada, Japan and 19 European countries. The 19 European countries include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Norway, Netherlands, Portugal, Spain, Sweden, Switzerland, Turkey and United Kingdom. For the GDP, consumption and investment, I aggregate all the countries to create a single fictional non-US country by first rebasing each series in 2005 national currency constant prices and then expressing everything in 2005 US dollars using PPP exchange rates.

Employment for the rest of the world is aggregated using constant weights that are porportional to the number of employed persons in each area in 2005. An employment series for Europe 19 is not available before 2001, therefore I use employment for Austria, Finland, France, Germany, Italy, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom between 1984:1 and 2000:4. While for the period 1972:1 to 1983:4, I use aggregated employment data from the same set of countries as between 1984:1 and 2000:4 less Portugal. For the period of 1962:1 to 1971:4, I use aggregated data from Finland, Germany, Italy, Sweden and United Kingdom. These were the only European countries for which we could find consistent and comparable employment series.

C Table and Figures

Table 1 Benchmark Calibration				
Parameter	Description	Value		
γ	inverse of IES	2		
ω^{I}	controls investor's discount factor	0.112		
ω^S	controls saver's discount factor	0.039		
θ	controls elasticity of labor supply	0.6		
α_1	capital share of market production	0.29		
α_2	capital share of home production	0.40		
ψ^{I}	controls level of investor's labor	3.08		
ψ^S	controls level of saver's labor	1.32		
λ	share of market good consumption	0.57		
e	elasitcity of substitution between home and market good	0.9		
δ	depreciation	0.025		
π	invesment adjustment cost	0.25		
χ	variance of transportation cost	0.14		
n	measure of investors	0.5		
к	controls leverage ratio	2/3		

Table 2 Model Moments - Benchmark Model						
	Data	No Constraint	Constraint	Diversified Constraint		
(A) Standard Deviation in %						
Output	2.06	2.54	1.92	1.78		
Net Export	0.39	0.29	0.17	0.16		
(B) Standard Deviation relative to Ouput						
Consumption	0.63	1.07	1.05	0.99		
Investment	2.82	0.59	0.77	0.77		
Labor	0.67	0.73	0.72	0.71		
(C) Cross Correlation with Output						
Consumption	0.82	0.99	0.99	0.98		
Labor	0.86	1	1	1		
Investment	0.95	0.84	0.76	0.96		
Net Export	-0.45	0.60	0.53	0.46		
(D) Cross Country Correlations						
Consumption	0.44	0.29	0.53	0.75		
Output	0.61	0.24	0.40	0.53		
Investment	0.46	0.82	0.64	0.30		
Labor	0.43	0.23	0.41	0.55		

Table 3 Sensitivity Analysis - Adjustment Cost				
		Benchmark Model	Sensitivity Test	
	Data	$\pi = 0.25$	$\pi = 0.5$	$\pi = 100$
(A) Standard	(A) Standard Deviation in %			
Output	2.06	1.92	2.04	2.41
Net Export	0.39	0.17	0.25	0.34
(B) Standard	Deviatio	on relative to Ouput		
Consumption	0.63	1.05	1.10	1.21
Investment	2.82	0.77	0.49	0.00
Labor	0.67	0.72	0.72	0.73
(C) Cross Cor	(C) Cross Correlation with Output			
Consumption	0.82	0.99	0.99	0.99
Labor	0.86	1	1	1
Investment	0.95	0.76	0.77	0.80
Net Export	-0.45	0.53	0.50	0.42
(D) Cross Country Correlations				
Consumption	0.44	0.53	0.61	0.78
Output	0.61	0.40	0.46	0.62
Investment	0.46	0.64	0.79	0.93
Labor	0.43	0.41	0.48	0.63
Capital	N/A	0.78	0.85	0.94

Table 4 Sensitivity Analysis - Leverage and Shocks				
		Benchmark Model	Sensitivity Test	
	Data		High Leverage	BKK
(A) Standard Deviation in %				
Output	2.06	1.92	2.31	1.67
Net Export	0.39	0.17	0.23	0.30
(B) Standard Deviation relative to Ouput				
Consumption	0.63	1.05	1.13	1.13
Investment	2.82	0.77	0.57	0.45
Labor	0.67	0.72	0.73	0.70
(C) Cross Correlation with Output				
Consumption	0.82	0.99	0.99	0.98
Labor	0.86	1	1	1
Investment	0.95	0.76	0.77	0.72
Net Export	-0.45	0.53	0.50	0.57
(D) Cross Country Correlations				
Consumption	0.44	0.53	0.59	0.63
Output	0.61	0.40	0.46	0.34
Investment	0.46	0.64	0.72	0.58
Labor	0.43	0.41	0.48	0.32
Capital	N/A	0.78	0.77	0.61

Table 5 Sensitivity Analysis - IE of Goods					
		Benchmark Model	Sensitivity Test		
	Data	e = 0.9	e = 0.5	e = 0.1	
(A) Standard	(A) Standard Deviation in %				
Output	2.06	1.92	1.55	1.45	
Net Export	0.39	0.17	0.21	0.22	
(B) Standard	(B) Standard Deviation relative to Ouput				
Consumption	0.63	1.05	0.88	0.83	
Investment	2.82	0.77	0.98	1.05	
Labor	0.67	0.72	0.57	0.52	
(C) Cross Corr					
Consumption	0.82	0.99	0.99	0.99	
Labor	0.86	1	1	0.99	
Investment	0.95	0.76	0.84	0.85	
Net Export	-0.45	0.53	0.56	0.57	
(D) Cross Country Correlations					
Consumption	0.44	0.53	0.49	0.48	
Output	0.61	0.40	0.34	0.32	
Investment	0.46	0.64	0.72	0.73	
Labor	0.43	0.41	0.28	0.23	
Capital	N/A	0.78	0.85	0.87	











Figure 3 Comparison: unconstrained vs constrained















Figure 7 Different degree of foreign exposure



Figure 8 Different degree of foreign exposure