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International Risk Sharing and Land Dynamics

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Abstract

While business cycles of industrialized countries have become more synchronized in the past decade, the gap between cross-country correlations in output and in consumption, known as the *quantity anomaly*, has widened on average. A two-country real business cycle model with national endogenous borrowing constraints and frictionless international financial markets can account for these stylized facts that are related to international risk sharing. When preferences are non-separable between consumption and leisure, the borrowing mechanism brings about an internal *labor wedge* that interacts with the efficient international allocation. This *labor wedge* is also fundamental to explain the *Backus-Smith puzzle* or consumption—real-exchange-rate anomaly. Technology shocks contribute to explain international co-movements, whereas country-specific financial shocks to borrowing capacity allow the model to replicate the lack of international risk sharing. When the model is augmented with an additional sector, real estate, international co-movements are matched more closely.

JEL identification: E44, F34, F44
Keywords: international risk sharing, real estate dynamics, borrowing constraints, labor wedge, financial shocks

1 Introduction

Synchronization of business cycles across industrialized countries has risen over the past decade to levels that have culminated with the Great Recession. Additionally, during this period of enhanced financial globalization and sophistication, empirical evidence points to a widening gap between international co-movements of output and consumption, also known as the *quantity anomaly*. This

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is one of many inconsistencies that Backus, Kehoe, and Kydland (1992) (hereafter BKK) note between their model that stands as a benchmark in the international real business cycle (IRBC) literature and the data. The level of cross-country correlation in output is important because, as Baxter (2012) argues, if synchronization increases there is less room for international risk sharing. The negative cross-country correlations in inputs (hours worked and investment) generated by BKK's baseline model are also at odds with the data and that has led Baxter (1995) to call this the *international co-movement* puzzle. Finally, Backus and Smith (1993) identify another inconsistency that is important for the degree of international risk sharing and that pertains to international prices. In the literature, it is known as the *Backus-Smith* puzzle or the *consumption—real exchange rate anomaly.*

In order to shed light on synchronization and these long-standing puzzles, I introduce real estate into an international real business cycle (IRBC) model, augmented with national endogenous borrowing constraints. I show that the introduction of a real estate sector allows the model to match international co-movements and moments of output, consumption, investment and hours worked. One of real estate's key features, that is not shared with physical capital, is its non-tradability. Real estate also fulfills multiple functions; it is (i) an input in the production of an expenditure good, (ii) a consumption good, and (iii) a collateral asset.[1] Reallocation of land from the productive to the residential sector plays a key role for the mechanism examined in this paper.

Moreover, the inclusion of financial shocks to borrowing capacity helps to bring the gap between cross-country correlations in output and consumption and the correlation between real exchange rate growth and relative consumptions growth closer to what they are in the data. Since firms in this environment also have working capital requirements, these shocks affect directly the *labor wedge* corresponding to the difference between the marginal rate of substitution between consumption and leisure (MRS) and the marginal product of labor (MPN). Jermann and Quadrini (2012) show that this mechanism helps to generate more volatility in labor demand thereby accounting for a great share of output fluctuations. In this paper, financial frictions and non-separable preferences result in a *labor wedge* that is central to replicating the lack of international risk sharing.[2]

Perri and Quadrini (2011) also rely on working capital requirements and financial shocks to account for the international transmission of the financial crisis. However, the channels of propagation differ from mine. They assume that investors are shareholders of both Home and Foreign firms, and since liquidation costs are the same across countries this is equivalent to having one international investor that faces identical financial shocks, whether they emanate from the Home

[1]The reader should note that throughout this paper, I use real estate and land, but since there is not a housing nor commercial construction sector in my model, these two variables are interchangeable.

[2]Since this *labor wedge* arises because firms that do not pay wages to the value of their marginal product, it differs from Karabarbounis (2012) who emphasizes the consumption of non-market goods and its effects on the MRS.

or the Foreign economies. Hence, the transmission of shocks across countries takes place through this mechanism. In contrast, I do not allow for cross-border dividend streams, so that I do not consider international portfolios in my analysis.[3]

Since real estate markets are idiosyncratic, the calibration of the persistence and volatility of the shocks in my model is not based on a group of countries, but on two of the world's largest financial hubs: the United States and the United Kingdom. I focus on a period of stronger financial linkages internationally (1988-2007) that also coincides with a period of low aggregate volatility. In my baseline model, the two countries are linked internationally via two markets: the goods and assets markets. I follow Backus, Kehoe, and Kydland (1994)'s approach, so that each country specializes in the production of one intermediate good but the final consumption good is an aggregate of these two goods. This structure creates important terms of trade effects. I also assume that the only asset which countries can trade is a risk-less, non-contingent international bond, or that financial markets are incomplete.

These two international market linkages have been examined in the literature. For example, on the international linkages of the goods market, Ambler, Cardia, and Zimmermann (2002) build a model in which countries have multiple sectors and sector-specific shocks in order to generate greater positive co-movement in output. The two-good market structure embedded in my model also increases output co-movement across countries through terms of trade effects, but these effects are small compared to the ones generated by a borrowing mechanism. There has also been much work in order to explain the low level of cross-country correlations in consumption. One approach has been to rely on incomplete asset markets as in Baxter and Crucini (1995) and Kollmann (1996).[4] However, financial frictions in my model take place within countries rather than at the international level. Another approach has been to introduce non-separable preferences between consumption and leisure that are based on the work of Greenwood, Hercowitz, and Huffman (1988) (hereafter GHH). This type of preferences play a much more important role. With this type of preferences, stochastic discount factors (SDFs) depend not only on consumption levels, as is the case for separable preferences, but also on leisure decisions. The use of GHH preferences is widespread in the open economy literature, see *e.g.* Correia, Neves, and Rebelo (1995), Devereux, Gregory, and Smith (1992), and Mendoza (1991).

[3]Other papers that examine financial frictions in a two-country environment are divided into the Bernanke, Gertler, and Gilchrist (1999)'s financial accelerator and Kiyotaki and Moore (1997)'s enforcement constraint. For the former category of papers, Faia (2007) and Ueda (2012) show the importance of international portfolio and banking globalization, whereas, in the second category, Devereux and Yetman (2010), Paasche (2001), and Iacoviello and Minetti (2006) present models that aim at replicating various international stylized facts.

[4]Following the closed-economy literature on optimal dynamic contracts, Kehoe and Perri (2002) and Bai and Zhang (2012) also have an endogenously determined incomplete asset market structure that they introduce through a limited enforcement problem so that countries can default on their loans. They show that these distortions in international credit markets are important to explain the *quantity anomaly* and the degree of international risk sharing.

Another approach consists in augmenting BKK's workhorse model with non-tradable goods. Stockman and Tesar (1995) show that this extension generates positive cross-country correlations in consumption and in investment, and the correlation of the trade balance with output that is generated by the model is closer to the data. Benigno and Thoenissen (2008) show that the combination of incomplete financial markets and non-tradable goods can explain the *Backus-Smith* puzzle in a theoretical framework in which the non-tradable price ratio drives the correlation. Corsetti, Dedola, and Leduc (2008) also have some success in replicating the "puzzle" using a model in which non-tradable goods are considered both as final goods and as distribution services for tradable goods. In my model, real estate is also non-tradable, but since it accounts for a very small fraction of private consumption expenditures, that feature cannot explain the lack of international risk sharing.

Similar to my work, Iacoviello and Minetti (2006) also embed real estate into a two-country framework in which a fraction of agents are borrowing-constrained. They show that they can raise the co-movement of output by introducing different liquidation costs that depend on the lender's origin. In contrast, I do not allow for any international borrowing besides the international bond, so that this channel is non-existent in my framework. Reallocation of land from one sector to another within the same country matters most for my results. As stated above, the two-good structure in my model allows for terms of trade dynamics that amplify output co-movements. Terms of trade effects are also amplified by credit constraints in the model of Paasche (2001), but his framework differs from mine, since it features two small open economies that export to a large country. Moreover, he examines the effects of terms of trade shocks, that are, in contrast, endogenously determined in my model.

Working capital requirements are central to the propagation mechanism. Since firms need to pay their factors of production and dividends to shareholders before receiving their revenues, they contract an *intra-period loan* from the workers. The debt renegotiation problem comes about because firms can default on their obligations of that loan, although in equilibrium it will not be optimal to do so. In the event of a default, workers would be able to repossess a fraction of the firm's collateral composed of real estate and physical capital. Moreover, since investors have a lower discount factor than workers, firms also incur some *inter-period debt*. Their total liabilities, consisting of the sum of the *intra-period loan* and *inter-period debt*, cannot be greater than the expected value of their collateral multiplied by a stochastic exogenous parameter that corresponds to the financial shock.

Consider the impact of a temporary positive shock to the Home country's production technology. This effectively increases firms' production directly from the Solow residual and, indirectly, from a greater demand of capital and land. Since the capital share in output is greater than land share, firms sell their land, and, from the proceeds of their sale, invest and accumulate capital. Hence, their overall borrowing constraint that also corresponds to a fraction of the value of their collateralized assets increases. The increase in the *intra-period loan* is greater than the increase in the value of their collateralized assets, so that the level of *inter-period debt* is reduced and that results in a lower interest rate.

Internationally, partially integrated financial markets ensure that uncovered interest parity holds, so that, facing a lower interest rate, Home workers prefer to lend to Foreign workers. It results that Foreign firms borrow more to increase output and, in a similar fashion to Home firms, invest and accumulate capital by selling land. The presence of borrowing-constrained firms allows for an *investment wedge* to arise which ensures that, contrary to the benchmark two-country model of Backus, Kehoe, and Kydland (1992), a greater marginal product of capital does not lead to a greater interest rate. Therefore, *technology shocks* contribute to explain synchronization of economic activity across countries.

Consider the impact of a temporary positive financial shock to the Home country's borrowing capacity. Since firms have working capital requirements, the labor demand schedule shifts up quite significantly so that hours worked increase. Foreign workers lend to Home workers and from a relaxed borrowing constraint to Foreign firms. This ensures that the labor demand schedule shifts up in both countries. Since labor's share in output is important, output responses are positive and the cross-country correlation in output is positive. From higher lending rates, Foreign workers prefer to save and delay their consumption, so that the cross-country correlation in consumption and response of Foreign consumption are both negative. Hence, *labor wedges* contribute to explain the *quantity anomaly*.

Partially integrated international financial markets also imply that changes in the real exchange rate correspond to changes in the inverse of relative marginal utilities. Assuming separable preferences results in a correlation of one between the growth in the real exchange rate and in relative consumptions, that is contrary to data estimations, and, thus, has been denoted as the *Backus-Smith* puzzle. Following financial shocks, hours worked increase significantly due to the presence of a *labor wedge* and the utility generated by non-separable preferences in consumption and leisure drops more for the Home country than the Foreign country, so that the real exchange rate decreases. Since the ratio of consumptions increase, I find that financial shocks contribute to explain the *Backus-Smith* puzzle.

The rest of this paper is organized as follows. In section 2, I discuss some international business cycle stylized facts with regards to synchronization and risk sharing for industrialized countries and, in particular, the United States and the United Kingdom. In section 3, I present the baseline model that features endogenous borrowing constraints for firms. In section 4, I characterize the persistence

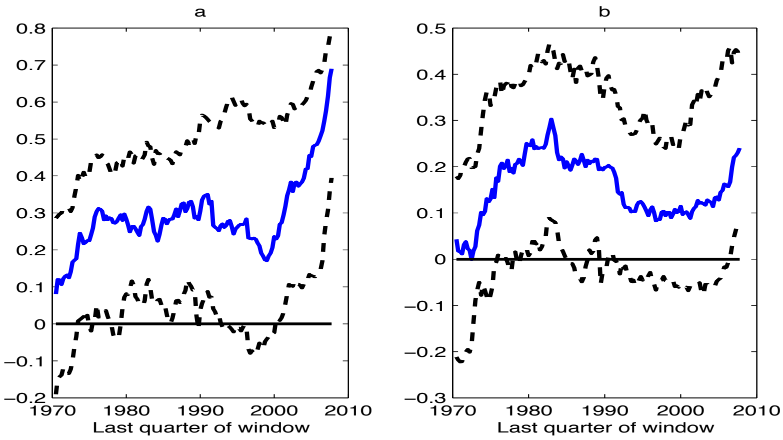

Figure 1: Panel a: Cross-country correlations in output for twenty-three OECD countries (rolling 40 quarter estimates, 1961Q1-2007Q4). Panel b: Difference between cross-country correlations in output and consumption. The *solid blue* line corresponds to the median and the *dashed black* lines to the first and third quartiles.

and volatility of the technology and financial shocks and calibrate the rest of the parameters. In section 5, I evaluate the effects of those shocks and display my results. Section 6 concludes and offers some new potential paths for further research on financial shocks in an international context.

2 International risk sharing stylized facts

BKK identify many properties of international business cycle co-movements between the United States and other industrialized countries and find some interesting anomalies. In this section, I assess whether the evidence still persists for a more recent period of time that coincides with greater financial integration. I estimate rolling cross-country correlations of the United States and twenty-three other OECD countries so that corresponds to 253 correlations.[5] I follow the method presented by Ambler, Cardia, and Zimmermann (2004) and proceed to a *GMM* estimation. In order to be consistent with previous studies, all series are logged and de-trended using the Hodrick-Prescott filter.

In panel a of Figure 1, each point on the lines correspond to the quartiles of cross-country correlations in output from a sample of twenty-three OECD countries, so that it corresponds to the last quarter of a forty-quarter window. Business cycle synchronization has increased strikingly since 2000: the average cross-country correlation in output is 0.27 from 1961Q1 to 1999Q4, whereas it is

[5]Due to data availability of series for some countries, the number of cross-country correlations is smaller in earlier periods of the sample. I refer the reader to Appendix B for a detailed description of the data.

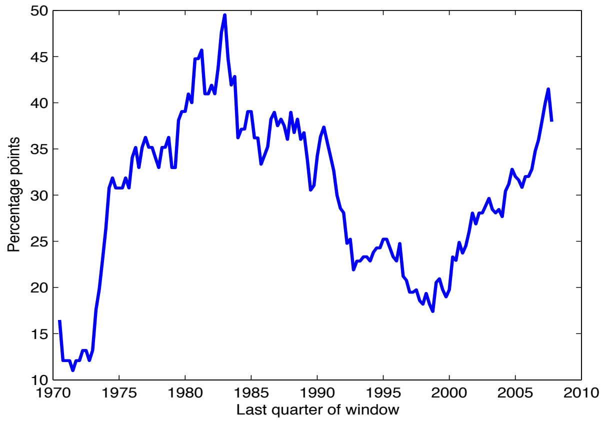

Figure 2: Percentage of differences between cross-country correlations in output and consumption that are statistically significant at 10% level (rolling 40 quarter estimates, 1961Q1-2007Q4).

0.72 from 2000Q1 to 2007Q4, that is a period excluding the financial crisis. In panel b of the same figure, the inconsistency between the baseline model of BKK and the data is exhibited that is the quartiles of the differences between cross-country correlations in output and in consumption. The average gap between these two correlations has widened: from 0.17 between 1961Q1 and 1999Q4 it has gone up to 0.4 between 2000Q1 and 2007Q4. Figure 2 presents the percentage of differences between these correlations that are statistically significant at 10% level.[6] For both figures, the same conclusion can be reached: the widening gap of the decade 2000's has taken place in spite of an explosion in international financial transactions and more sophisticated international financial markets that would have seemingly brought better risk sharing.

BKK and most work that features two-country frameworks estimate international correlations between the United States and Europe. However, since I evaluate the importance of real estate markets in international synchronization and those markets are rather idiosyncratic, I study co-movements between the United States and the United Kingdom. I pick the U.K. because it is large on both economic and financial dimensions. Data limitations also restrict the time period to 1987Q4-2007Q4: a period characterized by relatively low volatility of macroeconomic variables. Although, the U.K. business cycle is more synchronized with that of the U.S. when compared to the average of OECD countries, there is a clear upward trend for the co-movement of output in the last decade that is presented in Figure 3. The gap between cross-country correlations in output and in consumption has also enlarged in the decade 2000's.

The persistence of the inconsistency between the data and the results of the baseline model

[6]In order to test the significance of differences, correlations undergo a Fisher-z transformation that is the following: $\rho^z = 0.5 \log \frac{1+\rho}{1-\rho}$. The variance of these correlations is then approximated by $\sigma^2_{\rho^z} = 1/(N-3)$.

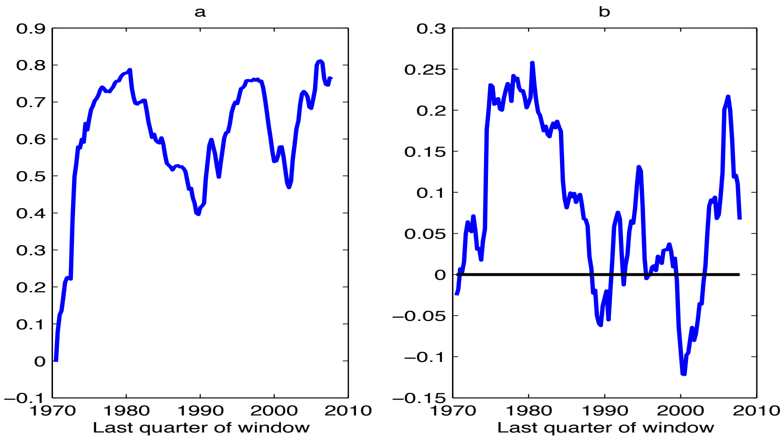

Figure 3: Panel a: Cross-country correlation in output between the United States and the United Kingdom (rolling 40 quarter estimates, 1961Q1-2007Q4). Panel b: Difference between the cross-country correlation in output and consumption between the United States and the United Kingdom.

suggests that financial globalization has not provided more international risk sharing. However, it has to be clear that there is no consensus in empirical work as whether or not industrialized countries have experienced more or less international risk sharing.[7] As for the evidence of the *Backus-Smith* puzzle, Corsetti, Dedola, and Viani (2012) find that the real exchange rate is significantly negatively correlated with relative consumption for many industrialized countries pairings at a business cycle frequency, but that the puzzle is less prominent at higher frequencies. In fact, it is negative and significantly different from zero for 12 countries out of 19 for correlations vis-à-vis the United States and for 14 countries out of 20 vis-à-vis the rest of the world.

3 The business-cycle model

The baseline model presented in this paper augments the incomplete financial markets version of Backus, Kehoe, and Kydland (1994) and the *bond economy* of Heathcote and Perri (2002)'s work on several dimensions. The class of preferences over consumption and leisure are similar to those proposed by Greenwood, Hercowitz, and Huffman (1988). Real estate is embedded in the model both in production and workers' preferences. Finally, there are two types of agents, investors and workers, that have different discount factors, where investors have the lowest discount factor, and

[7]See Kose, Prasad, and Terrones (2009) for a discussion of many works on that topic. For example, Bai and Zhang (2012) observe that financial globalization has not led to better international risk sharing. From a sample of 21 industrialized countries, they regress consumption growth on output growth for each country, controlling for world consumption and output growth. Their main finding is that they cannot reject the hypothesis indicating that the coefficient of that regression is equal to zero and is the same for the following time periods: 1970-1986 and 1987-2004. If perfect risk sharing would prevail, consumption growth would not be expected to depend on output growth.

therefore borrow from workers. Their borrowing is constrained by the value of their collateral and there are also working capital requirements in similar fashion to the borrowing constraints examined by Hart and Moore (1994) and Perri and Quadrini (2011).

The structure of the model is a two-country one, similar to Iacoviello and Minetti (2006), in which the world is populated by investors and workers that live either in the Home (H) country or in the Foreign (F) country. Optimization problems of both types of agents are expressed in per-capita terms in the following section. A fraction $\varpi \in (0, 1)$ of households are investors and the remaining $1 - \varpi$ are workers. I assume investors consume a final good, whereas only workers derive utility from housing services. The final good is a composite of the differentiated intermediate goods produced locally and abroad and can also be used for investment purposes. The factors of production for the intermediate good consist of labor provided by workers, capital and holdings of commercial real estate. I refer to real estate as land, a fixed asset that can have productive uses but from which workers also derive utility via housing services.

Agents of the two countries are linked in two ways: trade and finance. First, intermediate goods can be imported in order to produce the final good. Second, I adopt an incomplete financial market structure, so that workers trade an international non-contingent bond. I do not allow for foreign ownership of land. I opt for non-separable preferences in order to exploit the fact that there are no wealth effects on labor supply and this will turn out to be important when considering the international transmission of financial shocks. GHH preferences may be derived from the reduced-form of a model that would comprise home production.

3.1 Firms

Intermediate goods are produced according to a Cobb-Douglas production function (where $i = \{H, F\}$):

$$y_{it} = A_{it} h_{it-1}^{P\nu} k_{it-1}^{\mu} n_{it}^{1-\nu-\mu} \tag{1}$$

where factor shares for productive real estate h_{it-1}^{P} and capital k_{it-1} correspond respectively to ν and μ. Since the production function exhibits constant return to scale, the share of labor n_{it} is $1 - \nu - \mu$. Total factor productivity A_{it} is an exogenous shock to the production function. Home specializes in the production of intermediate good a and Foreign in the production of intermediate good b.

The final good in each country is a composite of these two intermediate goods and they are aggregated à la Armington by final good firms:

$$
\begin{aligned}
G(a_{Ht}, b_{Ht}) &= \left[\omega^{\epsilon+1} a_{Ht}^{-\epsilon} + (1-\omega)^{\epsilon+1} b_{Ht}^{-\epsilon}\right]^{-\frac{1}{\epsilon}}, &(2)\\
G(a_{Ft}, b_{Ft}) &= \left[(1-\omega)^{\epsilon+1} a_{Ft}^{-\epsilon} + \omega^{\epsilon+1} b_{Ft}^{-\epsilon}\right]^{-\frac{1}{\epsilon}} &(3)
\end{aligned}
$$

where a_i and b_i denote respectively the quantity of intermediate good a and b used in the production of country i's final goods. Here $\omega > 0.5$ represents home bias in the production intensity of the local intermediate good. Note that intermediate goods market clearing implies that

$$
a_{Ht} + a_{Ft} = y_{Ht}, \tag{4}
$$

$$
b_{Ht} + b_{Ft} = y_{Ft}. \tag{5}
$$

The elasticity of substitution between Foreign and Home intermediate goods is given by $\sigma = 1/(1+\epsilon)$. Final good firms generate important terms of trade effects for output synchronization, but it is really the optimization problem of intermediate good firms that is key.[8]

At the beginning of each period, firms have an inter-temporal debt $R_{it-1}e_{it-1}^P$ contracted from workers, capital k_{it-1} and real estate h_{it-1}^P, and a quadratic reallocation adjustment cost $\Psi_{h_{it}^P}(h_{it}^P, q_{it}, h_{it-1}^P)$ that proxies a transaction cost that arises when changes in land zoning occur. I follow Iacoviello (2005) so that this conversion cost is expressed as follows:

$$
\Psi_{h_{it}^P}(h_{it}^P, q_{it}, h_{it-1}^P) = \frac{\phi_h}{2}\left(\frac{h_{it}^P - h_{it-1}^P}{h_{it-1}^P}\right)^2 h_{it-1}^P q_{it}.
$$

where ϕ_h is a parameter chosen to control the level of that cost.[9]

The choice of labor input n_{it}, investment x_{it}, new real estate $q_{it}\Delta h_{it}^P$, dividends d_{it}, and the next period debt level e_{it}^P are made before production. The representative firm's budget constraint is given by:

$$
p_{iit}y_{it} + e_{it}^P = d_{it} + x_{it} + q_{it}(h_{it}^P - h_{it-1}^P) + \Psi_{h_{it}^P} + R_{it-1}e_{it-1}^P + w_{it}n_{it}. \tag{6}
$$

All variables are expressed in terms of the final good, so that the price of the intermediate good is p_{iit}. Since payments of the wage bill $w_{it}n_{it}$ to workers, of dividends d_{it} to investors, investment expenses x_{it}, land acquisitions $q_{it}\Delta h_{it}^P$ and adjustment costs $\Psi_{h_{it}^P}$ are all made before the revenues

[8] In the rest of this section, I use firms to implicitly refer to intermediate good firms.

[9] Note that workers also face that cost. An equivalent formulation would be to make firms bear all the costs, so that workers that workers' costs would be reflected in the price of land.

are realized, the firm contracts an *intra-period loan* l_{it}:

$$l_{it} = R_{it-1}e^P_{it-1} - e^P_{it} + d_{it} + x_{it} + q_{it}(h^P_{it} - h^P_{it-1}) + \Psi_{h^P_{it}} + w_{it}n_{it}. \tag{7}$$

From the budget constraint this loan must be equal to output. However, the contract is not perfectly enforceable, and defaulting can occur with some positive probability. In the case of a default, the lender can liquidate the firm's capital and commercial real estate for a stochastic fraction $\lambda_{it}\iota_k$ of the value of its capital holdings and λ_{it} of its real estate, where $\iota_k \in [0, 1]$ allows for a smaller fraction of physical capital to be collateralized, since it can be harder to liquidate machinery and equipment than real estate.[10] Hence, the recovery value if a default occurs is $\lambda_{it}E_{it}(\iota_k k_{it} + q_{it+1}h^P_{it})$. Since the total liabilities of the firm are $l_{it} + e_{it}$, in order to prevent any defaults the borrowing constraint is as follows:[11]

$$\lambda_{it}E_{it}(\iota_k k_{it} + q_{it+1}h^P_{it}) \geq l_{it} + e^P_{it}. \tag{8}$$

Equation (8) can also be expressed as:

$$\lambda_{it} \geq \frac{e^P_{it}}{E_{it}\left(\iota_k k_{it} + q_{it}h^P_{it}\right)} + \frac{l_{it}}{E_{it}\left(\iota_k k_{it} + q_{it}h^P_{it}\right)}.$$

The first term corresponds to a loan-to-value ratio for which capital and commercial real estate play the roles of collateral.

The equity value of the firm, defined as $\bar{V}_{it}(\mathbf{s_{it+1}}; k_{it+1}, h^P_{it+1}, e^P_{it+1})$, is measured at the end of the period after paying dividends to its shareholders, investing in physical capital and choosing its land share. By definition, the equity value is just the sum of future discounted dividends d_{it}, starting to be payable in the next period such that:

$$\bar{V}_{it}(\mathbf{s_{it+1}}; k_{it+1}, h^P_{it+1}, e^P_{it+1}) = E_{it}\sum_{j=1}^{\infty} m_{it+j}d_{it+j}$$

where m_{it+j} corresponds to the stochastic discount factor that will be derived from the entrepreneur's problem.

I also assume that capital accumulation is subject to depreciation and an adjustment cost

[10] Liu, Wang, and Zha (2011) argue that real estate is an important collateral asset, since for non-financial corporate firms it corresponds, on average from 1952 to 2010, to 58% of total tangible assets.

[11] This problem is based on Hart and Moore (1994) and I assume that the borrower has all the bargaining power. I refer the reader to Appendix A of Perri and Quadrini (2011) for a complete derivation of the debt renegotiation problem.

similar to that described in Jermann (1998) that serves the purpose of reducing the volatility of investment:

$$k_{it} = (1-\delta)k_{it-1} + \left(\left(\frac{g_1}{1-\phi_k} \right) \left(\frac{x_{it}}{k_{it-1}} \right)^{1-\phi_k} + g_2 \right) k_{it-1} \tag{9}$$

where $1/\phi_k$ corresponds to the elasticity of investment with respect to Tobin's q and δ corresponds to the depreciation rate. The other parameters g_1 and g_2 are set to steady-state targets so that $\partial k_{it}/\partial x_{it} = 1$ and so that Tobin's q is equal to 1.

3.1.1 Recursive Formulation of the Firms' Problem

The firm's problem can also be formulated recursively as follows:

$$\begin{aligned} V(\mathbf{s_i}; k_i, x_i, h_i^P, e_i^P) &= \max_{d_i, n_i, k_i', h_i^{P'}, e_i^{P'}} \left\{ d_i + Em_i' V(\mathbf{s_i'}; k_i', h_i^{P'}, e_i^{P'}) \right\} \\ & \text{subject to:} \\ & q_i h_i^P + Y_i + e_i^{P'} - w_i n_i = d_i + x_i + q_i h_i^{P'} + \Psi_{h_i^P} + R_i e_i^P, \\ & \lambda_i E(q_i' h_i^{P'} + \iota_k k_i') \geq e_i^{P'} + Y_i, \\ & k_i' = (1-\delta)k_i + \left(\left(\frac{g_1}{1-\phi_k} \right) \left(\frac{x_i}{k_i} \right)^{1-\phi_k} + g_2 \right) k_i. \end{aligned} \tag{10}$$

The recursive formulation is instructive because it shows the value of the firm as the sum of the discounted stream of dividends. Y_i refers to output in terms of the final good price, so that $Y_i = \frac{p_{ii}}{P_i} y_i$. The first order conditions are with respect to n_i, $e_i^{P'}$, h_i^P, x_i and k_i' and ϑ_i and Q_i correspond respectively to Lagrange multipliers on the borrowing constraint and on the capital accumulation equation.

$$Y_{ni} = \frac{w_i}{1-\vartheta_i}, \tag{11}$$

$$1 = Em_i'(R_i' + \vartheta_i), \tag{12}$$

$$q_i + \Psi'_{h_i^P} = Em_i' \left(q_i' + Y_{h_i^{P'}}(1-\vartheta_i') + \lambda_i \vartheta_i q_i' + \Psi'_{h_i^{P'}} \right), \tag{13}$$

$$Q_i = g_1 \left(\frac{k_i}{x_i} \right)^{\phi_k}, \tag{14}$$

$$Q_i = \lambda_i \iota_k \vartheta_i + Em_i' \left(\begin{array}{l} Y_{k'i}(1-\vartheta_i')+ \\ Q_i' \left[1 - \delta + g_2 + g_1 \left(\frac{\phi_k}{1-\phi_k} \right) \left(\frac{x_i}{k_i} \right)^{1-\phi_k} \right] \end{array} \right). \tag{15}$$

Equation (11) corresponds to the derivative with respect to labor. In a representative agent model without a borrowing constraint, wages would correspond to the marginal product of labor. Working capital requirements create a *labor wedge* between the marginal rate of substitution between consumption and leisure and the marginal product of labor. A relaxed borrowing constraint leads to lower levels of the Lagrange multiplier ϑ_i that directly affect the labor demand schedule. Equation (12) refers to a standard Euler equation for a borrowing-constrained model. The Lagrange multiplier ϑ_i also affects the inter-temporal substitution of consumption as the marginal utility of consumption decreases while the borrowing constraint is relaxed. Equations (13-15) show real estate and capital dynamics and highlight the importance of capital and land as collateral.

3.2 Investors

The description of the firm's problem is not sufficient, because investors own the firms from which they receive dividends d_{it} and have the following utility function: $E_0 \sum_{t=0}^{\infty} \gamma^t \ln c_{it}^P$. As shareholders of the firms, their budget constraint is as follows:

$$s_{it}(d_{it} + p_{it}^s) = c_{it}^P + p_{it}^s s_{it+1} \tag{16}$$

where s_{it} corresponds to the equity shares and p_{it}^s to their market price of those shares. As investors maximize over their consumption level and shares' quantity, the first order condition is this following one:

$$\frac{p_{it}^s}{c_{it}^P} - \gamma \frac{E_t(d_{it+1} + p_{it+1}^s)}{c_{it+1}^P} = 0 \tag{17}$$

By forward substitution, it is possible to find a value for the market price of shares:

$$p_{it}^s = E_t \sum_{j=1}^{\infty} \left(\frac{\gamma^j c_{it}^P}{c_{it+j}^P} \right) d_{t+j}$$

Hence, as in Jermann and Quadrini (2012), the effective discount factor that is consistent with the firms' problem is: $m_{it+1} = \gamma E_t u_c(d_{it+1})/u_c(d_{it})$.

3.3 Workers

I have motivated above the choice of GHH preferences, but they are not standard in this model, since housing services are included. I assume that the elasticity of substitution between the standard non-separable preferences and housing services is equal to one in each country, i where $i = \{H, F\}$.

$$E_0 \sum_{t=0}^{\infty} \beta_{it}^t U(c_{it}^W, h_{it}^W, n_{it})$$

where

$$U(c_{it}^W, h_{it}^W, n_{it}) = \ln \left(c_{it}^W - \frac{\zeta}{\eta} n_{it}^{\eta} \right) + j \ln h_{it}^W. \tag{18}$$

so that c_{it} corresponds to the consumption of the final good, n_{it} to the hours worked and h_{it}^W to the fraction of land owned by the household for residential purposes. In the utility function, the parameter j corresponds to the weight of housing in the household's utility, such that $\frac{j}{j+1} \times 100$ is the percentage of that share. In order to ensure stationarity in an incomplete financial market, I adopt Mendoza (1991)'s approach and render the discount factor endogenous[12] as follows

$$\beta_{it} = \left(1 + \exp(U(c_{it}^W, h_{it}^W, n_{it}))\right)^{-\varsigma_W}.$$

At the beginning of each period, workers have a housing stock h_{it}^W and bond holdings coming to maturity. After production occurs they get their loan and the interest on that loan back for the ones made to firms $R_{Ht-1}e_{Ht-1}^W$ and the ones made internationally to Foreign workers $Z_t R_{t-1} f_{Ht-1}$. They are also paid for the hours they work $w_{it}n_{it}$ over the time period. They allocate their revenues by either buying more bonds, selling or buying some part of the real estate or they can modify their consumption. The budget constraint for Home-country workers is as follows :

$$R_{Ht-1}e_{Ht-1}^W + Z_t R_{t-1} f_{Ht-1} + w_{Ht}n_{Ht} = c_{Ht}^W + q_{Ht}\Delta h_{Ht} + \Psi_{h_{Ht}^W} + e_{Ht}^W + Z_t f_{Ht}.$$

Workers also face a similar adjustment cost of land reallocation to the ones firms face:

$$\Psi_{h_{it}^W}(h_{it}^W, q_{it}, h_{it-1}^W) = \frac{\phi_h}{2} \left(\frac{h_{it}^W - h_{it-1}^W}{h_{it-1}^W} \right)^2 h_{it-1}^W q_{it}.$$

The budget constraint for Foreign workers is similar, but since their pricing of the currency is in terms of their own final good, the real exchange rate term does not show up.

[12] Bodenstein (2011) shows that an endogenous discount factor of this type always implies a unique steady state in two-country models. The adoption of an endogenous discount factor is strictly for technical reasons as its shifts are very small.

3.3.1 Workers' First Order Conditions

From the equilibrium conditions and the workers' optimization problem, combining first order conditions leads to:

$$\frac{U_{c^W_{Ht}}}{E_t(U_{c^W_{Ht+1}})} = \frac{\beta_{Ht}}{\beta_{Ft}} \frac{U_{c^W_{Ft}}}{E_t(U_{c^W_{Ft+1}})} \frac{E_t(Z_{t+1})}{Z_t}, \tag{19}$$

$$E_t\left(\frac{Z_t}{Z_{t+1}} R_{Ht}\right) = R_{Ft} = R_t, \tag{20}$$

$$\zeta n_{it}^{\eta-1} = w_{it}, \tag{21}$$

$$U_{c^W it}\left(q_{it} U_{h^W_{it}} + \Psi'_{h^W_{it}}\right) = \beta_{it} E_t\left(U_{c^W_{it+1}}\right)\left(q_{it+1} U_{h^W_{it+1}} + \Psi'_{h^W_{it+1}}\right). \tag{22}$$

The combination of first order conditions with respect to consumption and to the international bond for both Home and Foreign workers leads to equation (19). Therefore, expected changes in marginal utilities of consumption are proportional to expected changes in real exchange rates under incomplete asset markets, since variations in discount factors β_{Ht} and β_{Ft} are negligible. The *Backus-Smith* puzzle is that the correlation between the expected growth in real exchange rate and the expected growth in relative consumptions is low and negative in the data. As for equation (20), it results from the combination of first order conditions for the international and *inter-period bonds*. Equation (21) refers to labor supply. In contrast with logarithmic preferences, consumption does not show up with GHH preferences, so that income effects are dampened. Finally, the fourth condition (22) relates the stochastic discount factor of workers to the expected change in their marginal utility of land, the expected changes in land prices, and changes in the adjustment costs of land reallocation.

3.4 Shocks

There are two financial and two technology shocks that follow a multivariate autoregressive process as follows:

$$\Omega_t = \Gamma \Omega_{t-1} + \varepsilon_t,\ \varepsilon_t \sim N(0, \Sigma) \tag{23}$$

where $\Omega_t = [A_{Ht}, A_{Ft}, \lambda_{Ht}, \lambda_{Ft}]'$ and $\varepsilon_t = [\varepsilon_{A_{Ht}}, \varepsilon_{A_{Ft}}, \varepsilon_{\lambda_{Ht}}, \varepsilon_{\lambda_F}]'$. Elements off the diagonal in matrix Γ are defined as spill-overs. The variance-covariance matrix is given by: $E(\varepsilon_t \varepsilon_t') = \Sigma$.

3.5 Market Clearing

For the final goods' market, the production of the goods is equal to the domestic absorption:

$$c_{it}^{P} + c_{it}^{W} + x_{it} = G(a_{it}, b_{it}) \text{ where } i = \{H, F\}. \tag{24}$$

$$(1-\varpi)e_{it}^{P} + \varpi e_{it}^{W} = 0 \tag{25}$$

The international bonds market clearing condition is:

$$Z_t f_{Ht} + f_{Ft} = 0, \tag{26}$$

Moreover, since land is a fixed asset, its supply is normalized to one, so that:

$$h_{it}^{P} + h_{it}^{W} = 1. \tag{27}$$

3.6 Recursive competitive equilibrium

Definition 1. *In each country (where $i = \{H, F\}$ and $j = H, F$, but $i \neq j$) a recursive competitive equilibrium is defined as a set of functions for*

(i) workers' policies $c_i^W(\boldsymbol{s})$, $n_i(\boldsymbol{s})$, $h_i^W(\boldsymbol{s})$, $f_i(\boldsymbol{s})$, $e_i^W(\boldsymbol{s})$;
(ii) investors' policies $c_i^P(\boldsymbol{s})$
(iii) firms' policies $d(\boldsymbol{s}; k, h^P, e_i)$, $l(\boldsymbol{s}; k, h^P, e_i)$, $k(\boldsymbol{s}; k, h^P, e_i)$, $h^P(\boldsymbol{s}; k, h^P, e_i^P)$ and $e_i^P(\boldsymbol{s}; k, h^P, e_i^P)$;
(iv) firms' value $V(\boldsymbol{s}; k, h^P, e_i^P)$;
(v) aggregate prices for each country $w(\boldsymbol{s})$, $R(\boldsymbol{s})$, $R_i(\boldsymbol{s})$, $p_{ii}(\boldsymbol{s})$, $p_{ij}(\boldsymbol{s})$, $P_i(\boldsymbol{s})$, $q(\boldsymbol{s})$ and $m(\boldsymbol{s}, \boldsymbol{s}')$;
(vi) law of motion for the aggregate state $s' = \Psi(s)$.

Such that:

(i) workers' policies satisfy conditions (19-22);
(ii) investors' policies satisfy conditions 17;
(iii) firms' policies are optimal and $V(\boldsymbol{s}; k, h^P, e_i^P)$ satisfies the Bellman's equation (10);
(iv) the wage, interest rates and prices clear the labor, bond markets, housing markets ($h^P + h^W = 1$), goods markets(4) and (5), and $m(\boldsymbol{s}, \boldsymbol{s}') = \gamma U_{c^{P'}}/U_{c^P}$;
(v) the resource constraint (24) is satisfied;
(vi) the law of motion in each country $\Psi(s)$ is consistent with individual decisions and the stochastic processes for A_i and λ_i.

3.7 Prices, Terms of Trade and Real Exchange Rate

Under the assumption of perfect competition for firms, the equilibrium prices of goods a and b in terms of the Home final good correspond to the marginal products of these two goods. For prices the first position of the subscript determines the production location of the intermediate good and the second position of the subscript where it is used for the production of the final good. Hence, p_{HHt} corresponds to the price of good a in the Home country with $i = \{H, F\}$

$$p_{Hit} = \partial G(a_{it}, b_{it})/\partial a_{it}, \quad p_{Fit} = \partial G(a_{it}, b_{it})/\partial b_{it}. \tag{28}$$

The price level of the final good is an aggregate of the Home and the Foreign country intermediate good, so that

$$P_{Ht} = \left(\omega p_{HHt}^{\frac{\epsilon}{1+\epsilon}} + (1-\omega) p_{FHt}^{\frac{\epsilon}{1+\epsilon}}\right)^{\frac{1+\epsilon}{\epsilon}} \tag{29}$$

Terms of trade are defined as the price of good b in terms of the price of good a and also correspond to the marginal rate of substitution:

$$\begin{aligned} TOT_t &= \frac{p_{FHt}}{p_{HHt}} = \frac{1-\omega}{\omega}\left(\frac{a_{Ht}}{b_{Ht}}\right)^{1+\epsilon} \\ &= \frac{p_{FFt}}{p_{HFt}} = \frac{\omega}{1-\omega}\left(\frac{a_{Ft}}{b_{Ft}}\right)^{1+\epsilon} \end{aligned} \tag{30}$$

The real exchange rate is defined as the ratio of the price of final goods in the Foreign country over the price of the same final goods in the Home country[13]

$$Z_t = \frac{P_{Ft}}{P_{Ht}} = \frac{\left(\omega p_{FHt}^{\frac{\epsilon}{1+\epsilon}} + (1-\omega) p_{HHt}^{\frac{\epsilon}{1+\epsilon}}\right)^{\frac{1+\epsilon}{\epsilon}}}{\left(\omega p_{HHt}^{\frac{\epsilon}{1+\epsilon}} + (1-\omega) p_{FHt}^{\frac{\epsilon}{1+\epsilon}}\right)^{\frac{1+\epsilon}{\epsilon}}}.$$

3.8 Adjusting for housing services

The real estate market in my model is simplistic in the sense that there is no sector for the production of housing nor commercial structures; land parcels are divided between investors and workers. Moreover, rental and mortgage markets do not play a role. However, data on Personal Consumption Expenditures and Gross Domestic Product compiled in the National Income and Product Accounts

[13] This definition of the exchange rate is specific to the final tradable good sector. A more general definition would be a composite of the prices of these goods and the prices of a non-tradable component that would be real estate.

comprises values for housing services. Therefore, in order for my statistics to be compared to data, I follow Davis and Heathcote (2005)'s approach and assume that a household could well rent out some parts of their own real estate. In fact, it would be indifferent to doing so if the lower marginal utility caused by a smaller share of housing is counterbalanced by greater consumption, so that the price is equal to ξ_{it}.

$$\xi_{it} = \frac{U_{h^W it}(c^W_{it}, l_{it}, h^W_{it})}{U_{cit}(c^W_{it}, l_{it}, h^W_{it})} \tag{31}$$

The adjustment takes place both for PCE and GDP such that:

$$\begin{aligned} PCE_{it} &= c^P_{it} + c^W_{it} + \xi_{it} h^W_{it}, \\ GDP_{it} &= Y_{it} + \xi_{it} h^W_{it}. \end{aligned}$$

In the data, PCE_{it} includes the value of tenant-occupied housing and the imputed rental value of owner-occupied housing. A potential caveat to this approach is that changes in prices the way they are measured by equation (31) result from long-run adjustment in consumption and land, so that it abstracts from short-run changes in the relative price of housing services with respect to the final goods.

4 Calibration

4.1 Technology and financial shocks

Since the data analyzed is at a business cycle frequency, the first step is to de-trend it to retrieve the shocks. I follow the approach of Jermann and Quadrini (2012) in log-linearizing the shocks and work with deviations rather than levels, since that can matter greatly for the financial shocks. I remove a linear trend from the logarithm of all series for which the deviation from the steady state is required. All variables and their construction are described in Appendix B.

Since the model has a two-good structure, final-good output can be rewritten as:

$$Y_{it} = \frac{A_{it} h^{P\nu}_{it-1} k^{\mu}_{it-1} n^{1-\nu-\mu}_{it}}{\left(\omega + (1-\omega) TOT_t^{\frac{\epsilon}{1+\epsilon}}\right)^{\frac{1+\epsilon}{\epsilon}}}, \tag{32}$$

so that the technology shock or Solow residual involves terms of trade and has the following form:[14]

$$\widehat{A_{it}} = \left(\omega + (1-\omega)(1+\widehat{TOT_{it}}(\frac{\epsilon}{1+\epsilon}))\right)^{\frac{1+\epsilon}{\epsilon}}(1+\widehat{Y_{it}}) - 1 - \nu\widehat{h_{it-1}^{P}} - \mu\widehat{k_{it-1}} - (1-\nu-\mu)\widehat{n_{it}} \quad (33)$$

where $\widehat{TOT_{it}}$, $\widehat{Y_{it}}$, $\widehat{h_{it}^{P}}$, $\widehat{k_{it}}$ and $\widehat{n_{it}}$ are log-deviations from a linear trend of their respective variables. For example, $\widehat{Y_{it}} = \log(Y_{it}) - \widehat{\beta}_0 - \widehat{\beta}_1 t$ where $\widehat{\beta}_0$ and $\widehat{\beta}_1$ are estimated from an OLS regression.[15]

As for the financial shocks, I assume that the borrowing constraint (8) always binds,[16] so that in the steady state it is described by:

$$\bar{\lambda}\left(\iota_k\bar{k} + \bar{q}\bar{h}^{P}\right) = \bar{e} + \bar{Y}.$$

The log-linearization of this constraint results in:

$$\widehat{\lambda_{it}} \approx \alpha_k\widehat{k_{it}} + \alpha_h\left(E_t\widehat{q_{it+1}} + \widehat{h_{it}^{P}}\right) + \alpha_e\widehat{e_{it}} + \alpha_y\widehat{y_{it}}. \quad (34)$$

where $\alpha_k = \dfrac{-\iota_k\bar{k}}{\iota_k\bar{k} + \bar{q}\bar{h}^{P}}$, $\alpha_{h^P} = \dfrac{-\bar{q}\bar{h}}{\iota_k\bar{k} + \bar{q}\bar{h}^{P}}$, $\alpha_Y = \dfrac{\bar{Y}}{\bar{Y}+\bar{e}}$ and $\alpha_e = \dfrac{\bar{e}}{\bar{Y}+\bar{e}}$. For the construction of the financial shocks in equation (34), the data is available for all variables with the exception of the expected value of next period's land price $E_t\widehat{q_{it+1}}$. I assume that agents base their expectations on contemporaneous land prices, so that: $E_t\widehat{q_{it+1}} = \rho_q\widehat{q_{it}}$. I estimate $\widehat{q_{it}} = \rho_q\widehat{q_{it-1}} + \epsilon_{it}$ by OLS and use the estimated value for the persistence parameter $\widetilde{\rho}_q = 0.645$ to generate a series for $E_t\widehat{q_{it+1}} = \widetilde{\rho}_q\widehat{q_{it}}$. When I estimate the model, I make sure that this level of persistence is consistent with the data generated by the model.

In Table 1, I report the results of the maximum likelihood estimation of equation (23) from which shocks are derived from equations (33)-(34). In order to be consistent with the rest of the literature, symmetry is imposed to the shock process matrix for business cycle statistics. The shocks' processes are also specified so that they are no contemporaneous effects from the other shocks. Compared to BKK's estimated technology process for the United States and Europe, the persistence and spill-overs are somewhat smaller and the correlation of innovations is also lower. An interesting observation is that financial shocks are more persistent than technology shocks.

[14]Since $Y_{it} = \dfrac{p_{iit}}{P_{it}}y_{it}$, I substitute the denominator by equation (29) and divide both the numerator and denominator by p_{iit}, so that the terms of trade appear in equation (32).

[15]Note that variations in terms of trade only contribute to a tiny fraction of the estimated Solow residual.

[16]Note that this assumption remains to be verified. I refer the reader to Appendix C of Iacoviello (2005) who shows, from a partial equilibrium model, that the constraint is always binding if the gap between the discount and the interest rate is not too small and if risk aversion is not too big.

Table 1: Parametrization of shock processes

Symmetric shock processes				
Technology shocks	(1)	$\widehat{\Gamma} = \begin{bmatrix} 0.868 & 0.022 & 0 & 0 \\ 0.022 & 0.868 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$	$\widehat{\sigma_A} = 0.0055$	$\widehat{\rho_{A_H,A_F}} = 0.31$
Financial shocks	(2)	$\widehat{\Gamma} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0.942 & 0.038 \\ 0 & 0 & 0.038 & 0.942 \end{bmatrix}$	$\widehat{\sigma_\lambda} = 0.0054$	$\widehat{\rho_{\lambda_H,\lambda_F}} = 0.31$
Both shocks	(3)	$\widehat{\Gamma} = \begin{bmatrix} 0.781 & 0.077 & -0.086 & 0.062 \\ 0.077 & 0.781 & 0.062 & -0.086 \\ -0.091 & 0.113 & 0.914 & 0.074 \\ 0.113 & -0.091 & 0.074 & 0.914 \end{bmatrix}$	$\widehat{\sigma_A} = 0.0053$ $\widehat{\sigma_\lambda} = 0.0053$	
			$\widehat{\rho} = \begin{bmatrix} 1.00 & & & \\ 0.317 & 1.00 & & \\ 0.678 & 0.341 & 1.00 & \\ 0.341 & 0.678 & 0.374 & 1.00 \end{bmatrix}$	

I perform a joint test for symmetry of the shocks processes parameters. For shock process (1), H_0: $\widehat{\gamma_{1,1}} = \widehat{\gamma_{2,2}}$, $\widehat{\gamma_{1,2}} = \widehat{\gamma_{2,1}}$ and $\widehat{\sigma_{A_H}} = \widehat{\sigma_{A_F}}$. For (1), I cannot reject the null hypothesis at 5% from a Lagrange multiplier test such that $\chi^2(3) = 5.9$. For shock process (2), H_0: $\widehat{\gamma_{3,3}} = \widehat{\gamma_{4,4}}$, $\widehat{\gamma_{3,4}} = \widehat{\gamma_{4,3}}$ and $\widehat{\sigma_{\lambda_H}} = \widehat{\sigma_{\lambda_F}}$. For (2), I reject the null hypothesis with a p-value lower than 0.001, such that $\chi^2(3) = 39.76$. For (3) I reject the null hypothesis with a p-value lower than 0.001, such that $\chi^2(12) = 56.6$. The symmetry joint tests for (3) have H_0: $\widehat{\gamma_{1,1}} = \widehat{\gamma_{2,2}}$, $\widehat{\gamma_{3,3}} = \widehat{\gamma_{4,4}}$, $\widehat{\gamma_{1,2}} = \widehat{\gamma_{2,1}}$, $\widehat{\gamma_{1,3}} = \widehat{\gamma_{2,4}}$, $\widehat{\gamma_{1,4}} = \widehat{\gamma_{2,3}}$, $\widehat{\gamma_{3,1}} = \widehat{\gamma_{4,2}}$, $\widehat{\gamma_{3,2}} = \widehat{\gamma_{4,1}}$, $\widehat{\gamma_{3,4}} = \widehat{\gamma_{4,3}}$, $\widehat{\sigma_{A_H}} = \widehat{\sigma_{A_F}}$, $\widehat{\sigma_{\lambda_H}} = \widehat{\sigma_{\lambda_F}}$, $\widehat{\rho_{1,3}} = \widehat{\rho_{2,4}}$ and $\widehat{\rho_{1,4}} = \widehat{\rho_{2,3}}$.

Table 2: Parametrization of preferences and technology

Symbol	Value	Definition
ϖ	0.5	share of investors in the economy
Preferences		
ς_W	0.066	workers discount factor
γ	0.97	investors discount factor
η	1.58	parameter controlling the labor wage elasticity
j	0.07	h utility weight
ζ	2.99	n disutility weight
Technology		
ν	0.009	h share
$1-\nu-\mu$	0.64	n share
δ	0.025	k depreciation
ω	0.85	weight on domestic good
σ=1/(1+ϵ)	0.85	elasticity of substitution between traded goods

4.2 Preferences and technology parameters

In Table 2, I report the parametrization of preferences and technology. I assume that they are the same in the two countries and that steady-state targets match US data. I also assume that countries are the same size so that the United Kingdom represents an aggregate of European countries. The fraction of investors in each economy is set to half, following Campbell and Mankiw (1990)'s findings that half of households face borrowing constraints.[17] The calibration of the housing parameters are based on Iacoviello (2005), except that I consider the value of both commercial and residential land rather than on the value of real estate of these sectors. I use Davis (2009)'s database to measure the value of real estate attributed to land and structures on average between 1988 and 2007. Hence, by using land measures, double accounting of capital is avoided when measures of land are used. I set ν so that commercial land corresponds to an average of 8.7% of annual output (real estate corresponds to 62% of annual output).

As for the form of the household's utility function, the housing services interact with the GHH component in a logarithmic function and that is consistent with the findings of Davis and Ortalo-Magné (2011), so that expenditure shares on housing are constant. The parameter that controls utility from housing services is j and is set so that residential land corresponds to 41% of annual output (real estate corresponds to 140% of annual output). As for the parameters that control labor, τ is set so that working hours correspond to 30% of total time. For the parameter that controls the elasticity of labor, η, I set it equal to 1.58, so that it corresponds to an inter-temporal

[17] This assumption is standard in two-country models for which a fraction are borrowing-constrained, see *e.g.* Devereux and Yetman (2010) and Iacoviello and Minetti (2006).

elasticity of labor of 1.7 that is the value used by Greenwood, Hercowitz, and Huffman (1988). However, the Frisch elasticity of labor depends on steady state values and is as follows

$$\eta^n = \frac{1}{\bar{n}\left((\eta-1)\bar{n}^{-1} + \frac{\zeta\bar{n}^{\eta-1}}{(\bar{c}^W - \frac{\zeta}{\eta}\bar{n}^\eta)(\overline{h^W}^j)} + (\bar{c}^W - \frac{\zeta}{\eta}\bar{n}^\eta)(\overline{h^W}^j)\right)}. \quad (35)$$

In my model the Frisch elasticity of labor supply is equal to 0.31. The discount factor for workers is standard in the literature and ς_W is set so that β is equal to 0.99 in the steady state, corresponding to an annual real interest of 4%. The discount factor for investors γ is set to 0.97 so that there is an interest premium of two percentage points, following the calibration of Bernanke, Gertler, and Gilchrist (1999). Since I construct the shocks from quarterly data, I assume a depreciation rate δ of 2.5% corresponding to an annual depreciation rate of 10%. For the elasticity of the different input factors in the Cobb-Douglas production function, the share of labor is 0.64 as is standard in the literature.

International parameters are set in accordance with Heathcote and Perri (2002), since ω is greater than 0.5 there is some home bias. In the sensitivity analysis, I test the model with different values for that parameter. The elasticity of substitution between Home and Foreign goods seems to be quite disputed in the literature. In fact, the range of values is quite large depending, amongst other things, on whether the model has non-traded goods, a distribution sector and price stickiness.[18] For the benchmark calibration I use the value of 0.85, which seems to be an intermediate value and is the one reported in Bodenstein (2011). The parameter that controls for home bias ω is set to 0.85, so that imports correspond to 15% of output, a value that also corresponds to the average for the United States from 1988 to 2007.

4.3 Simulated Method of Moments

All parameters described in sub-section (4.2) are fixed throughout the estimation of the model, whereas the last category of parameters are estimated by simulated method of moments. In order to isolate the additional effects that borrowing constraints bring, I also estimate a representative-agent version of the model that consists of the baseline model stripped out of borrowing constraints. The vector ϱ comprises four structural parameters for the baseline and only the last two for the representative-agent version: $\varrho = (\bar{\lambda}, \iota_k, \phi_k, \phi_h)$.

These parameters are picked in order to minimize a weighted sum of the squared-distance between empirical standard deviations and standard deviations generated by the model of four

[18] See Bodenstein (2011) for a discussion on the different values this parameter has taken in the literature.

Table 3: Estimated parameters

Symbol	Value (1)	Value (2)	Definition
Credit			
$\bar{\lambda}$	-	0.25	enforcement parameter
ι_k	-	0.6	fraction of capital collateralized
Adjustment Costs			
ϕ_k	0.01	0.12	capital adjustment cost
ϕ_h	0	0.08	real estate adjustment cost

Column 1 corresponds to the representative agent model and column 2 to the baseline model with borrowing constraints with capital and real estate as collateral.

variables: output, *labor wedge*, investment and the value of real estate used in production. I choose these first two moments in order to match the magnitude of financial shocks, since $\bar{\lambda}$ and ι_k are also parameters that enter the construction of these shocks. Moreover, the *labor wedge* created by financial shocks is picked because it is shown that it can help resolve some open economy puzzles. Finally, the parameters ϕ_k and ϕ_h are picked so that jointly with other standard deviations, the volatility of investment and the value of real estate generated by the baseline model correspond to the estimated values of the data. The estimate of ϱ solves

$$\arg\min_{\varrho} \left(\Lambda(\varrho) - \tilde{\Lambda}\right)' W \left(\Lambda(\varrho) - \tilde{\Lambda}\right). \tag{36}$$

The matrix W is a 4×4 weighting matrix and is chosen so that it matches the inverse of the asymptotic variance of the moments:

$$W = \Omega^{-1} = \left(\frac{2}{80-1}\right)^{-1} \begin{pmatrix} 0.0109^2 & 0 & 0 & 0 \\ 0 & 0.0104^2 & 0 & 0 \\ 0 & 0 & 0.0394^2 & 0 \\ 0 & 0 & 0 & 0.0422^2 \end{pmatrix}^{-1}$$

Since there are no interaction terms in the estimation of this variance matrix, it is diagonal. The estimates of ϱ are summarized in Table 3. Moments of the baseline model are much more precisely estimated for the baseline model than for the representative-agent model. The estimate of $\bar{\lambda}$ corresponds to a low leverage scenario, but is close to the estimate, 0.1965, of a similar parameter by Jermann and Quadrini (2012). From the estimate of ι_k, 15% of capital is collateralized in the steady state. Moreover, land corresponds to 8.2% of all collateralized assets. From the fraction of land in commercial real estate that leads to 50.7% of the value of the collateral would be commercial real estate and the 36.6% remaining would be capital in machinery and equipment. A value that is not so far away from the average of 58% of real estate in total tangible assets as reported by Liu, Wang, and Zha (2011).

The standard practice in the international real business cycle literature is to pick the capital adjustment cost in order to match the relative standard deviation of investment over GDP. Parameters in this paper however are estimated so that targeted moments are jointly matched. As will be shown in the sensitivity analysis section, the parameter that controls for the transaction costs ϕ_h is crucial to explain the level of international risk sharing and the *Backus-Smith* puzzle. Resulting from this parametrization, in the steady state of the baseline model, consumption of workers is 62.8% of output, consumption of investors corresponds to 21% and investment to 16.2%.

5 Results of the business cycle estimation

5.1 Impulse responses

In this section, I examine the responses of key variables to 1 % temporary Home technology and financial shocks to the Home economy that are reported in Figures 4-5. It should be noted that the size of the various effects described below hinge on the parametrization.[19]

5.1.1 Technology shocks

In order to have a better understanding of the borrowing mechanism, I start by presenting the effects in a closed-economy environment. As a result of a Home positive temporary shock, output grows: directly from the Solow residual and indirectly because the marginal product of its inputs are increased. Since the firm must pay its factors of production and dividends to its shareholders before receiving its revenues, it contracts a greater *intra-period loan*. From equation (8), liabilities on the right hand side cannot exceed the value of real estate and capital that can be repossessed on the left hand side. For the production of intermediate goods, firms substitute real estate for capital. Moreover, from a positive income effect, workers will want to acquire more real estate. Hence, a fraction of real estate switches from the commercial to the residential sector. As a result and for the parametrization described in the previous section, the value of the collateralized assets is not sufficiently important for the *inter-period debt* to increase and that leads firms to get a lower interest rate on their *inter-period loans*.

[19] All simulations have been performed with DYNARE 4.1.1.

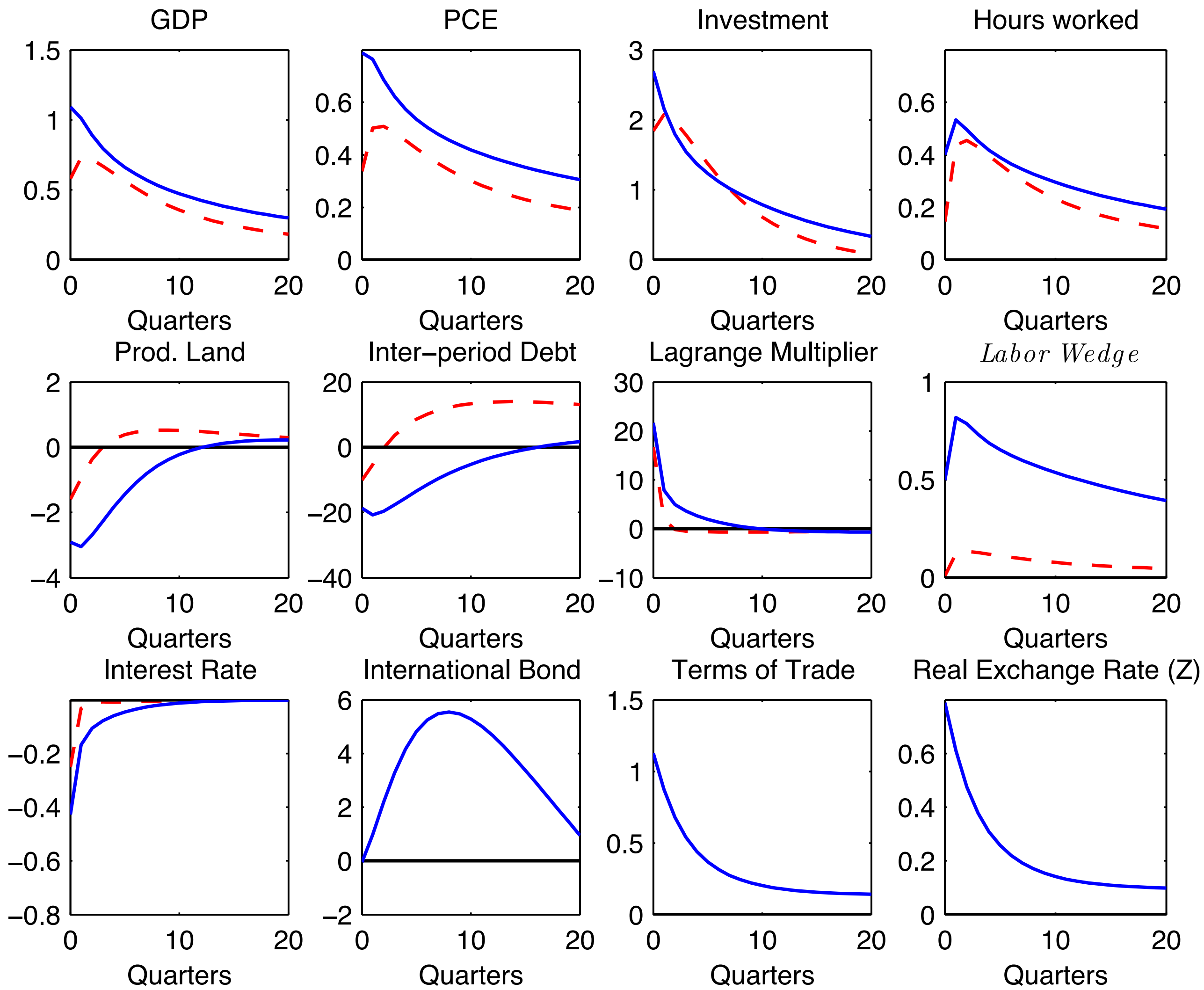

Figure 4: Impulse responses to a 1% temporary Home technology shock: Home (*solid blue* line) Foreign (*dashed red* line) generated from the baseline model. Responses are all measured in percentage deviations from their steady state, except for the international bond that is scaled to match the deviation of the *inter-period debt*.

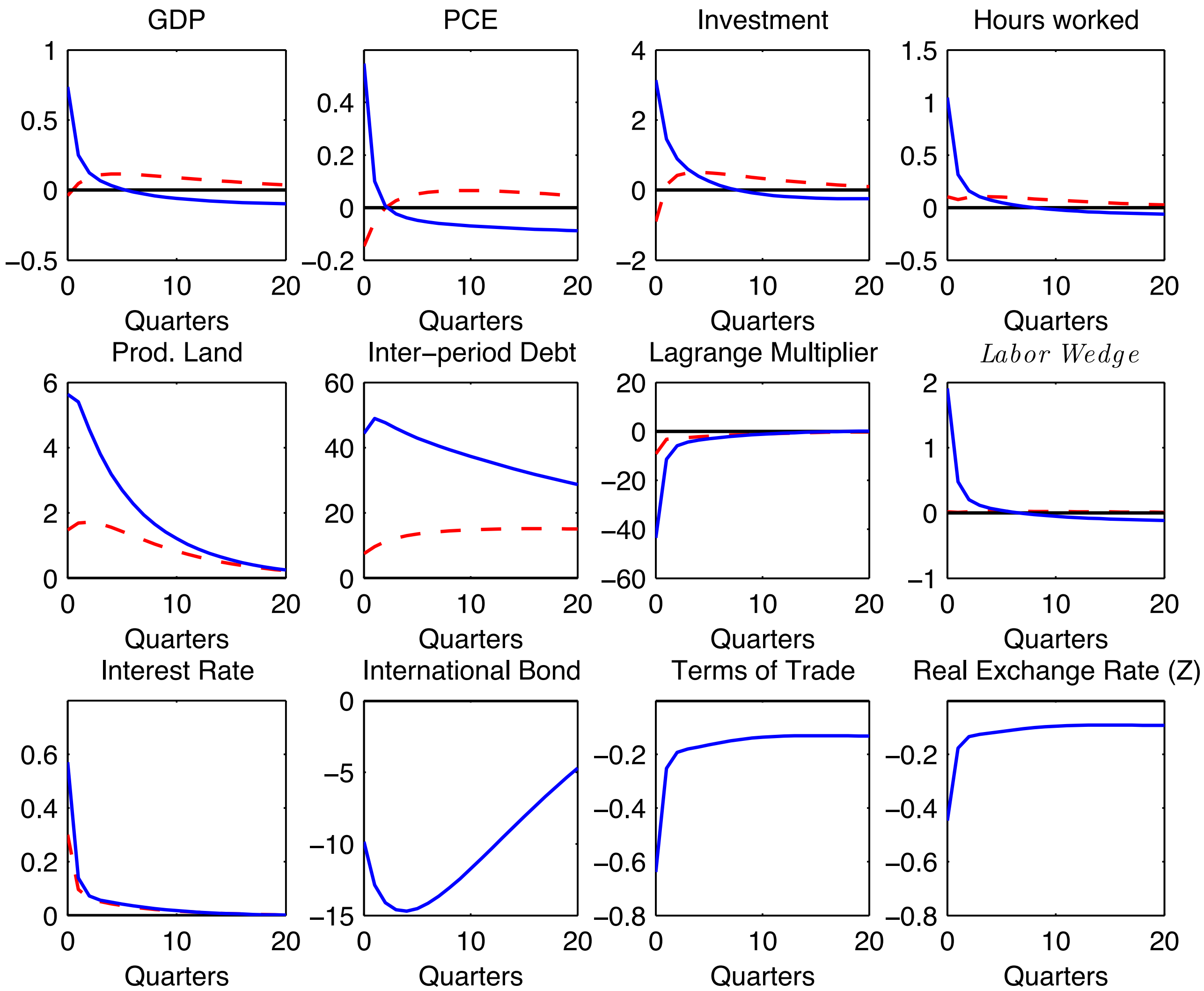

Figure 5: Impulse responses to a 1% temporary Home financial shock: Home (*solid blue* line) Foreign (*dashed red* line) generated from the baseline model. Responses are all measured in percentage deviations from their steady state, except for the international bond that is scaled to match the deviation of the *inter-period debt*.

How do these effects matter in an open-economy? The answer is through uncovered interest rate parity. Movements in the real exchange rate are not large enough to reverse the fall in the Foreign interest rate below its steady state value. Yet the Foreign interest rate is higher than the Home one, so that Home workers lend to Foreign workers. This result is in stark contrast with BKK whose model predicts that Home workers borrow from Foreign workers, since the marginal product of capital is equal to the interest rate. Borrowing constraints for which capital plays a role as collateral break the link between the marginal product of capital and the interest rate. On the production side, the Home economy exports more of good a, so that its price decreases in the Foreign economy implying favorable terms of trade for the Foreign economy, so that they produce more of good b.[20] Therefore, interest rate dynamics and terms of trade effects both contribute to the positive correlation of output. Another feature of real estate that plays a role is its non-tradability, as home workers cannot purchase it from the Foreign country, it is reduced from the home firms' holdings and that has an effect on their borrowing constraint.

In an incomplete asset market environment, separable preferences would imply that expected growth in real exchange rates and in relative consumptions are perfectly correlated. However, non-separable preferences between consumption and leisure break this perfect correlation, since movements in hours worked affect marginal utilities. In order to isolate the role played by non-separable preferences, I substitute for marginal utilities in equation (19):

$$\frac{E_t\left(\Delta\left(c^W_{Ht+1}-\frac{\zeta}{\eta}n^{\eta}_{Ht+1}\right)\right)}{E_t\left(\Delta\left(c^W_{Ft+1}-\frac{\zeta}{\eta}n^{\eta}_{Ft+1}\right)\right)}=\frac{\beta_{Ht}}{\beta_{Ft}}E_t\Delta Z_{t+1}. \tag{37}$$

I go a step further and substitute ζn^{η}_{Ht} and ζn^{η}_{Ft} from firms' labor demand conditions (11) and workers' labor supply (19) in equation (37), so that:

$$\frac{E_t\left(\Delta\left(c^W_{Ht+1}-\frac{(1-\nu-\mu)}{\eta}Y_{Ht+1}(1-\vartheta_{Ht+1})\right)\right)}{E_t\left(\Delta\left(c^W_{Ft+1}-\frac{(1-\nu-\mu)}{\eta}Y_{Ft+1}(1-\vartheta_{Ft+1})\right)\right)}=\frac{\beta_{Ht}}{\beta_{Ft}}E_t\Delta Z_{t+1}. \tag{38}$$

Since firms face working capital requirements, wages are not equal to the marginal product of labor. Hence, the *labor wedge* (the difference between the marginal rate of substitution between consumption and leisure and the marginal product of labor) also plays a role in driving the correlation between expected growth in the real exchange rate and in relative consumptions. Non-separable preferences combined with the effects of a more relaxed or binding borrowing constraints,

[20] Results for which countries do not specialize in the production of a good are presented in Appendix C.

summarized by Lagrange multipliers ϑ_H and ϑ_F, are important in explaining the *Backus-Smith* puzzle. In the absence of international prices, *i.e.* the one-good version of the baseline model, borrowing constraints affect cross-country correlations in consumption, as can be seen in Table 6. As it will be shown in the next sub-section, these effects are more important in the case of financial shocks. Technology shocks contribute to elevate business cycle synchronization of output more than explaining the lack of international risk sharing.

5.1.2 Financial shocks

In an environment in which firms face working capital requirements, financial shocks directly affect the *labor wedge* to a much greater extent than technology shocks. From the impulse response to a temporary Home positive shock presented in Figure 5, financial shocks alone are not able to generate the positive international co-movements observed in the data. However, some inconsistencies between BKK's model and data are reconciled.

The effects of the shock on output are larger in the Home country, but it is nevertheless propagated internationally. Since the borrowing constraint is relaxed, Home firms increase their levels of *intra-period loan* and *inter-period debt*. In order for workers to lend more they are compensated by a greater lending rate. The positive effects on output take place through many channels: in particular through the growth in labor demand made possible by a relaxed borrowing constraint. Since Home firms borrow more, they accumulate more capital and purchase land from Home workers. Even though Home firms cannot directly borrow from Foreign workers, they do it through the international bond that Home workers trade with Foreign workers. Hence, the mechanism underlying borrowing constraints creates an amplification effect on output of the Home country.

Through the uncovered interest rate parity condition, the interest rate in the Foreign country also increases, but movements in the real exchange rate dampen its rise. Foreign firms cut back on their investment levels and substitute capital for land to productive uses. This substitution effectively increases the value of their collateral, so that their borrowing constraint is relaxed. Similar effects as in the Home economy result from a relaxed borrowing constraint, so that Foreign labor demand increases and, since labor is an important factor of production, the growth rate of Foreign output rises. Due to the important growth in Foreign workers' lending, their consumption in the period in which the shock arises and in the following periods is smaller. This results in a greater cross-country correlation in output than in consumption, which is consistent with the data. As it can be appreciated in equation (38), financial shocks significantly affect Lagrange multipliers ϑ_{Ht} and ϑ_{Ft}. Non-separable preferences allow for expected growth in relative consumptions to be negatively correlated with expected growth in real exchange rate, which is also consistent with the data. Thus, the *quantity anomaly* and the *Backus-Smith* puzzle can be partly explained by financial shocks to borrowing capacity.

5.2 Quantitative analysis

5.2.1 Baseline model

Table 4 reports the moments generated by a model for which the embedded shock processes are calibrated according to Table 1. In columns 2 and 3, I examine the results of the baseline model for which both capital and real estate are collateralized. Column 4 corresponds to the baseline model stripped of the real estate sector. Since there are no borrowing constraints in the representative agent model, financial shocks are ruled out and therefore, statistics generated by that model appear in the first column. Finally, in column 5, since there are no borrowing constraints in the representative-agent model, financial shocks are ruled out, so that only technology shocks are examined.

The impact of endogenous borrowing constraints and working capital requirements can be assessed in the column 2 as there is greater business cycle synchronization. The outcome of these borrowing constraints is the introduction of wedges between wages and the marginal product of labor and the interest rate and the marginal product of capital. In fact, a positive technology shock translates into a greater interest rate in a representative-agent framework, but as was shown in the previous section this is not the case when firms face borrowing constraints. The low level of investment volatility however contributes mainly to the important level of cross-country correlation in investment.[21]

When financial shocks are added, the gap between wages and the marginal product of labor becomes narrower, so that firms increase their labor demand as it can be seen in the column 3: volatilities of hours worked and of the *labor wedge* are much greater. The effects of these shocks on the level of international risk sharing are similar to the ones described in the previous section and operate through a mechanism that involves non-separable preferences. Hence, the results of the baseline model's estimation that combines the two shocks and their estimated volatilities are documented in column 4. That column shows that the model matches data much better than the representative-agent model with regards to the levels of international correlations. The gap between the cross-country correlations in output and in consumption is somewhat larger than what it is in the data.[22] The correlation between expected growth in real exchange rates and in relative consumptions remains negative.

[21] Note that statistics in column 2 are generated from the baseline model for which parameters estimated by SMM correspond to an estimation that involves both shocks.

[22] However, it is not that far away from the average gap of industrialized country pairings.

Table 4: Business cycle statistics

Model:		Baseline		*without real estate*	Rep.-agent
Shocks:		Tech.	Both	Both	Tech.
	Data				
Volatility					
% Standard deviations					
GDP	**1.09**	0.86	1.16	1.97	0.99
Standard deviations relative to GDP					
Investment	**3.62**	2.37	3.3	3.77	3.24
Hours worked	**0.95**	0.53	0.84	1.33	0.72
Prod. real estate ($q_t h_t^P$)	**3.67**	1.75	3.8	-	0.87
Domestic Co-movement					
Net Exports/GDP	**-0.41**	-0.36	-0.41	-0.65	-0.52
International Correlations					
GDP_{US}, GDP_{UK}	**0.69**	0.67	0.58	0.09	0.38
PCE_{US}, PCE_{UK}	**0.61**	0.64	0.29	-.2	0.32
X_{US}, X_{UK}	**0.34**	0.56	0.36	-0.48	-0.19
N_{US}, N_{UK}	**0.62**	0.69	0.46	0.28	0.38
Backus-Smith puzzle					
$\Delta \frac{PCE_{US}}{PCE_{UK}}, \Delta Z$	**-0.32**	-0.17	-0.47	-0.88	-0.21

Statistics in the first column for the *volatility* and *domestic co-movement* sections are calculated from US time series described in Appendix B from 1988Q1 to 2007Q4. The *international correlations* are calculated from US and UK time series. Statistics in the second and third columns are generated from the estimation of the baseline model with collateral constraints and real estate. Statistics in the fourth column correspond to the baseline model with both shocks from which real estate is removed. Statistics of the fifth column correspond to the baseline model fed with shocks estimated in section 4. Statistics in the last column are generated from the estimation of the representative-agent model. All series have been logged (except net exports) and Hodrick-Prescott filtered with a smoothing parameter of 1,600.

The value added by including real estate in the model can be assessed by comparing the results generated by the baseline model to a similar model that does not include any real estate assets. The results of that model are reported in column 4 of Table 4. In this case, the firm's borrowing simply consists of $e_{it}^P + Y_{it} \leq \lambda_{it}\iota_k k_{it}$. Both the non-tradable feature of real estate and its substitutability with capital are important for generating a positive cross-country correlation in investment. In comparison, a positive financial shock in the baseline model would lead to a reallocation from the residential to the commercial sector, so that the value of the collateral would increase and less capital would need to flow internationally. Hence, the substitution of land for capital accumulation helps to increase synchronization. As a result, the cross-country correlation in investment is negative for the model without real estate and that also leads other international correlations to be lower.

Finally, in column 5, the resulting cross-country correlations in output and in consumption show that there is a gap between the two correlations that is consistent with the data. Non-separable preferences and the substitutability of real estate and capital play a role to lower the international co-movement in consumption. However, the international correlations generated by the representative-agent model are much lower than those in the data.

5.2.2 Sensitivity analysis

I perform a sensitivity analysis of within-country and international business cycle statistics to changes in key parameters. Table 5 presents the moments from different specifications and compares them to those for the baseline model (column 1) and for the data (column 9). In columns 2 and 3, I examine the sensitivity of the elasticity of substitution between Home and Foreign goods ϵ. As mentioned earlier in the paper, there is no consensus in the literature on the exact value this parameter should take. A first observation that is not shown in Table 5 is that lower values of this elasticity magnify the volatility of international prices, *i.e.* real exchange rates and terms of trade. This result is similar to the findings of Heathcote and Perri (2002) for an incomplete asset markets structure. Moreover, lower values of the elasticity affect the correlation between net exports and output, so that greater complementarity positively affects imports in similar fashion to Raffo (2008) for a two-country model with GHH preferences.

As for the correlation between the expected growth in the real exchange rate and in relative consumptions, *i.e.* the *Backus-Smith* puzzle, greater elasticity values lead to lower correlations, since technology shock responses lead to greater discrepancies in Home and Foreign consumption as the elasticity increases. Hence, it appears that the negative sign of that correlation is robust to higher values of trade elasticities; this is not the case for high values in the model of Corsetti, Dedola, and Leduc (2008) for their baseline persistence parameter of technology shocks to tradable goods. Their results hinge on large wealth effects generated by high terms of trade and real exchange

Table 5: Sensitivity analysis statistics

Model:	Baseline	$\sigma = 0.5$	$\sigma = 2.5$	$\phi_k = 0$	$\phi_h = 0$	$\bar{\lambda} = 0.75$	$\iota_k = 1$	shock processes (1) & (2)	**Data**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Volatility									
% Standard deviations									
GDP	1.16	1.15	1.18	1.17	1.05	1.74	1.48	1.02	**1.09**
Standard deviations relative to GDP									
Investment	3.3	3.33	3.26	4.47	3.44	2.12	3.16	3.02	**3.62**
Hours worked	0.84	0.85	0.83	0.81	0.7	1.23	1.04	0.86	**0.95**
Prod. real estate ($q_t h_t^P$)	3.8	3.86	3.65	3.27	5.69	1.71	5.06	5.56	**3.67**
Domestic Co-movement									
Net Exports/GDP	-0.44	-0.44	-0.16	-0.46	-0.34	-0.46	-0.49	-0.41	**-0.41**
International Correlations									
GDP_{US}, GDP_{UK}	0.58	0.6	0.52	0.51	0.68	0.55	0.47	0.51	**0.69**
PCE_{US}, PCE_{UK}	0.29	0.28	0.31	0.31	0.48	0.47	0.13	0.38	**0.61**
X_{US}, X_{UK}	0.36	0.35	0.34	0.1	0.51	0.02	0.18	0.05	**0.34**
N_{US}, N_{UK}	0.46	0.45	0.45	0.46	0.64	0.57	0.38	0.38	**0.62**
Backus-Smith puzzle									
$\Delta \frac{PCE_{US}}{PCE_{UK}}, \Delta Z$	-0.47	-0.45	-0.43	-0.79	0.58	-0.82	-0.79	-0.92	**-0.32**

Statistics in the column 1 are generated from the estimation of the baseline model with both technology and financial shocks. Statistics of columns 2-8 are generated from variations of the baseline model for some key parameters. Columns 2 and 3 correspond to lower and higher elasticities of substitution between Home and Foreign good, column 4 to the model without capital adjustment costs, column 5 to the model without real estate adjustment costs, column 6 to a greater enforcement parameter, column 7 to the same level of redeployment for both assets, and column 8 to shock processes that have no spill-overs between technology and financial shocks and uncorrelated technology and financial innovations. Statistics of the last column for the *volatility* and *domestic co-movement* sections are calculated from US time series described in Appendix B from 1988Q1 to 2007Q4. The *international correlations* are calculated from US and UK time series. All series have been logged (except net exports) and Hodrick-Prescott filtered with a smoothing parameter of $\lambda = 1,600$.

rate volatilities. Alternatively, the mechanism that drives the results of this paper stresses the non-separability between consumption and leisure.

In column 4, results for a specification for which there are no capital adjustment costs are shown. First, the volatility of investment increases and the cross-country correlation in investment falls and reaches negative levels. Firms simply import less investment goods from abroad. Additionally, the cross-country correlation in consumption increases and the cross-country correlation in output decreases so that the gap between the two correlations switches sign. Following a positive Home financial shock, Foreign workers lend more internationally and less to Foreign firms the lower is the capital adjustment cost parameter. Deeper financial integration with the Home economy of Foreign workers leads to greater cross-country correlation in consumption. The value of the capital adjustment cost also affects international risk sharing. A greater value effectively leads to more capital and consequently to more utility smoothing for a few periods following a technology shock. Real exchange rate and relative consumptions growth are positively correlated for these periods, so that more smoothing implies a lower value of the correlation.

In column 5, I shut down the parameter that controls real estate adjustment costs ϕ_h. The most notable difference in the results from all other specifications is that the sign of the correlation between the expected growth in real exchange rates and in relative consumptions that is reversed. In Figure 6, I show the sensitivity of the *Backus-Smith* puzzle to parameter ϕ_h. Following a positive financial shock, firms purchase real estate from workers, but as ϕ_h increases it is more costly to reallocate land. Hence, they substitute real estate for labor in the period in which the shock occurs. In the following periods, since firms have not accumulated as much collateral assets, the borrowing constraint is not relaxed as much, so that the *labor wedge* is not as important and hours worked drop from their first-period level. The movements in labor are key to explain international risk sharing through the fluctuations of marginal utility of consumption. From a variance decomposition, financial shocks contribute to 4.92% of the variance in real exchange rate growth in the case for which there are no adjustment costs $\phi_h = 0$, whereas they contribute to 54.02% for the baseline calibration of the model $\phi_h = 0.08$.

In column 6, the business cycle statistics are shown for a greater value of the enforcement parameter $\bar{\lambda} = 0.75$, corresponding to a loan-to-value of the inter-period debt over the collateralized assets of 0.68 in the steady-state. This value is a middle-ground between loan-to-values of Iacoviello (2005)'s entrepreneurs and impatient households, and the enforcement parameter in Jermann and Quadrini (2012) ($\bar{\lambda} = 0.1965$). A greater enforcement parameter leads to a greater contribution of financial shocks to the volatilities of many variables. The resulting international correlations and international risk sharing correlation are thus closer to a model without technology shocks. Similar results are obtained for a calibration of an identical level of redeployment for both assets: capital

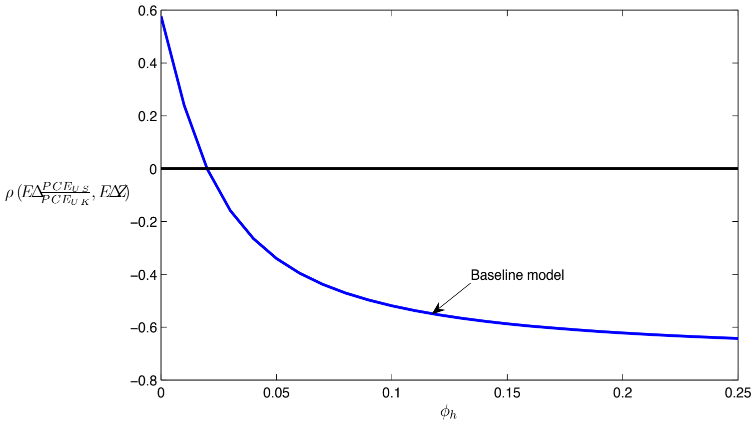

Figure 6: The correlation between the expected growth in real exchange rates and in relative consumptions for different calibrated values of the real estate adjustment cost ϕ_h.

and real estate $\iota_k = 1$ as it is assessed in column 7. Finally, column 8 presents a sensitivity analysis to the characterization of the shock processes as I do not allow for spill-overs nor correlation in the innovations across technology and financial shocks. An important finding is that the *Backus-Smith* puzzle correlation is particularly affected by variations in the characterization, but the sign of the correlation remains negative as in the data.

6 Conclusion and extensions

In this paper, I build a two-country, two-good model with endogenous borrowing constraints and real estate in order to have a better understanding of many open-economy puzzles and the following stylized facts: (i) the high level of business cycle synchronization, (ii) the gap between cross-country correlations in output and in consumption: the *quantity anomaly* and (iii) the international risk sharing implications for international prices: the *Backus-Smith* puzzle. It appears that the combination of real estate, working capital requirements and terms of trade dynamics contribute, in the presence of technology shocks, to a greater (i) business cycle synchronization. A *labor wedge* emerges from the introduction of endogenous borrowing constraints and working capital requirements. I have shown that financial shocks have a sizable impact on this wedge, so that through non-separable preferences, international risk sharing is affected and contributes to explain (ii) and (iii).

Moreover, this work has implications for macro-prudential policies in an international environment. Policy-makers could have effects on financial shocks by regulating loan-to-values for instance. One finding of this paper is that more volatile financial shocks lead to less international risk-sharing.

Hence, the implementation of counter-cyclical policies that would curb the size of the shocks could be welfare-improving. Further work should be pursued for such normative analysis.

While I have adopted an agnostic approach in assuming that financial shocks are exogenous, in contrast, Perri and Quadrini (2011) put forward the idea that self-fulfilling expectations might play an important role in the shocks' propagation, in particular, when financial markets are internationally integrated. Hence, it may not be clear in my framework why negative shocks have affected simultaneously the United States and the United Kingdom during the Great Recession. Are more correlated financial shocks driven by the phenomenon of financial globalization? In that regard, the same framework of analysis with a different calibration to match data of other countries could be interesting to examine.

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Appendix

A Steady-state solution of the model

$$
\begin{aligned}
\frac{qh^P}{Y} &= \frac{\frac{\gamma^2\nu}{\beta}}{1-\gamma-(1-\frac{\gamma}{\beta})\bar{\lambda}} \\
\frac{k}{Y} &= \frac{\frac{\gamma^2\mu}{\beta}}{1-\gamma(1-\delta)-(1-\frac{\gamma}{\beta})\bar{\lambda}\iota_k} \\
\frac{e}{Y} &= \alpha\left(\bar{\lambda}\left(\frac{qh^P}{Y}+\iota_k\frac{k}{Y}\right)-1\right) \\
\frac{c^W}{Y} &= (1-\beta)\left(\frac{Re}{Y}\right)+(1-\nu-\mu)(\gamma-\beta) \\
\frac{c^P}{Y} &= (\nu+\mu)(\gamma-\beta)+1-(\gamma-\beta)-\delta\frac{k}{Y}+(1-R)\left(\frac{e}{Y}\right) \\
Y &= h^{P^\nu}k^\mu l^{1-\nu-\mu} \\
nx &= Y-(c^P+c^W)-\delta k
\end{aligned}
$$

Since all variables are in real terms, finding prices p_{HHt}, p_{HFt}, p_{FFt}, p_{FHt} is done by nonlinear methods with four equations two from the production approach and two from the expenditure approach to output.

B Data sources and construction of variables

B.1 Data used for Figures 1-3

Real GDP and real private consumption are constructed by the author from data made available by the OECD that spans for different time periods for these countries:

- Australia (1961Q1-2007Q4)
- Austria (1961Q1-2007Q4)
- Belgium (1980Q1-2007Q4)
- Canada (1961Q1-2007Q4)
- Denmark (1977Q1-2007Q4)
- Finland (1961Q1-2007Q4)
- France (1961Q1-2007Q4)
- Germany (1961Q1-2007Q4)
- Ireland (1961Q1-2007Q4)
- Italy (1961Q1-2007Q4)
- Japan (1961Q1-2007Q4)
- Korea (1970Q1-2007Q4)
- Mexico (1980Q1-2007Q4)
- Netherlands (1977Q1-2007Q4)
- New Zealand (1982Q2-2007Q4)
- Norway (1961Q1-2007Q4)
- Portugal (1988Q1-2007Q4)
- Spain (1961Q1-2007Q4)
- Sweden (1961Q1-2007Q4)
- Switzerland (1980Q1-2007Q4)
- Turkey (1987Q1-2007Q4)
- United Kingdom (1961Q1-2007Q4)
- United States (1961Q1-2007Q4)

B.2 United States

Variable name: CPI
Source: BLS
Definition: U.S. City Average (Quarter Average, Seasonally Adjusted)

Variable name: GDP deflator
Source: BEA, NIPA, Table 1.1.9
Definition: Index 2005=100 (Seasonally Adjusted)

Variable name: Price Index for Business Value Added
Source: BEA, NIPA, Table 1.3.4
Definition: Index 2005=100 (Seasonally Adjusted)

Variable name: Net New Borrowing
Source: Federal Reserve Board, Table F.101
Definition: Net increase in credit markets instruments of non-financial business (Quarter Average, Seasonally Adjusted)
Deflator used: Price Index for Business Value Added

Variable name: Land Price Index (Q_{US})

Source: Constructed by Liu et al. (2011)[23]
Definition: Liquidity-adjusted price index for residential land (Quarterly)
Deflator used: Consumption deflator

Variable name: Business Value Added (Y_{US})
Source: NIPA 1.3.5
Deflator: Index for business value added (NIPA 1.3.4) (seasonally adjusted)

Variables names: Real Consumption (C_{US})
Real Net Exports of Goods and Services (NX_{US})
Source: BEA, NIPA, Table 1.1.6
Definition: Billions of chained (2005) dollars (Seasonally adjusted)

Variable name: Nominal Market Value, Price and Quantity Index of Land
Source: Davis' (2009) database
Definition: 2 different categories: households and non-profits and corporate non-financial (Quarterly)

Variables names: Total Employment
Hours worked per worker
The product of these two variables is equal to N_{US}
Source: Ohanian and Raffo (2012)

Variables names: Consumption of Fixed Capital in Non-Financial Corporate Business
Consumption of Fixed Capital in Non-Financial Non-Corporate Business
Source: Federal Reserve Statistical Release, Flow of Funds, Table F.8
Definition: Millions of US Dollars (Quarterly)
Deflator used: Business Value Added

Variable name: Terms of trade (TOT_{US})
Source: OECD
Definition: Ratio of Implicit Price Deflator Indices for Imports and Exports of Goods and Services

B.3 United Kingdom

Variable name: CPI
Source: IFS (International Financial Statistics)
Definition: All items (seasonally adjusted with X12-ARIMA)

Variable name: GDP deflator
Source: ONS, YBGB
Definition: GDP (Expenditure) at market prices deflator (Seasonally Adjusted)

[23] I refer the reader to Appendix A of their paper for a thorough description of that variable.

Variable name: Domestic Loans (e_{UK})
Source: Bank of England, LPQVQSG
Definition: Quarterly amounts outstanding of monetary financial institutions' sterling net lending to private non-financial corporations (Seasonally Adjusted)
Deflator used: CPI

Variable name: Residential property prices, all dwellings (Q_{UK})
Source: Halifax Building Society, Press Release[24]
Definition: Index 1983=100 (seasonally adjusted with X12-ARIMA and liquidity-adjusted for time-on-market uncertainty following the methods of Quan and Quigley (1991).)
Deflator used: GDP deflator

Variable name: Consumption (C_{UK})
Source: OECD, Quarterly National Accounts
Definition: Chained-volume estimates (2005 in pounds) (seasonally adjusted)

Variables names: Gross value added at basic prices (seasonally adjusted) (Y_{UK})
Gross Fixed Capital Formation: Total GFCF (seasonally adjusted)
Total capital consumption (seasonally adjusted)
Source: ONS (CGCE, NPQT, CIHA)
Definition: Millions of pounds

Variables names: Gross Fixed Capital Formation non-residential and residential construction (seasonally adjusted)
Source: OECD
Definition: Millions of pounds

Variables names: Tangible Assets: Residential Buildings & Commercial, Industrial and Other Buildings
Source: ONS(CGLK,CGMU)
Definition: Millions of pounds

Variables names: Total Employment
Hours worked per worker
The product of those two variables is equal to N_{UK}
Source: Ohanian and Raffo (2012)

[24] I am thankful to the BIS for providing me this series.

Variable name: Terms of trade (TOT_{UK})
Source: OECD
Definition: Ratio of Implicit Price Deflator Indices for Imports and Exports of Goods and Services

B.4 Construction of variables

H^P_{US} is constructed from quantity indices so that the productive land index corresponds to the quantity index for the corporate non-financial over the sum of the two sectors:

$$H^P_{US} = \frac{\text{Corporate Non-Financial}}{\text{Households and Non-Profits + Corporate Non-Financial}}$$

Similarly to H^P_{US}, H^P_{UK} also corresponds to the ratio of land of the corporate non-financial over total land. I construct land series for each sector by following Davis (2009), so that the value of land is equal to the value of tangible assets minus the capital stock' value. In order to have quarterly values, capital stocks are constructed recursively as follows:

$$K^{NR;R}_{UKt+1} = 0.9961 K^{NR;R}_{UKt} + GFCF^{NR;R}$$

where the quarterly depreciation rate corresponds to 0.39%, a value consistent with the one found by Davis and Heathcote (2005) for residential structures. The initial quarter for the residential (non-residential) capital stock is 1955Q4 (1964Q4) and the corresponding value is 9,100 (9,300) and the corresponding series are *Net Capital Stock: Dwellings: Households* (CIWV) and *Net Capital Stock: Other buildings and works: PNFCs* (CIXB). As for tangible assets, since the frequency of series is yearly, I interpolate linearly for each quarter.

K_{US} is constructed recursively in the same way as described in the appendix of Jermann and Quadrini (2011). I pick the initial value of K_{US} for the first quarter of 1952 such that the capital-output ratio does not exhibit any trend over the period 1952-2010. *Depreciation* corresponds to the sum of *Non-Financial Corporate and Non-Corporate Business Consumption of Fixed Capital* and *Investment* to *Capital Expenditures in Non-Financial Business.*

$$K_{USt+1} = K_{USt} - Depreciation + Investment$$

For the United Kingdom, the recursion is similar to the one described for the United States and in this case the period is a bit shorter: 1955-2010. *Investment* corresponds to *Total Gross Fixed Capital Formation* and *Depreciation* to *Total Capital Consumption.*

e_{US} is also constructed recursively in the same way as described in the appendix of Jermann and Quadrini (2012). The initial value for the (nominal) stock of debt is set to 94.12, which is the value reported in the balance sheet data from the Flow of Funds in 1952I for the nonfarm non-financial business (Table B.102, line 22).

$$e_{USt+1} = e_{USt} + NetNewBorrowing$$

The terms of trade series (TOT) corresponds to the ratio of the implicit price deflator for imports to the implicit price deflator for exports (NIPA 1.1.9).

C Results of the one-good model

Table 6: Business cycle statistics (one-good)

Model:	Baseline		*without real estate*	
Shocks:	Technology	Both	Both	**Data**
Volatility				
% Standard deviations				
GDP	0.58	1.01	1.72	**1.09**
Standard deviations relative to GDP				
Investment	3.24	4.07	5.37	**3.62**
Hours worked	0.38	0.83	1.4	**0.95**
Prod. real estate ($q_t h_t^P$)	1.93	5.05	-	**3.87**
Domestic Co-movement				
Net Exports/GDP	0.59	0.01	-0.3	**-0.41**
International Correlations				
GDP, GDP^*	0.04	0.27	0.44	**0.69**
PCE, PCE^*	0.29	0.09	-0.12	**0.61**
X, X^*	0.54	-0.40	-0.66	**0.34**
N, N^*	0.08	0.18	0.53	**0.62**

Statistics in the first and second columns are generated from the estimation of the baseline model with collateral constraints and real estate. Statistics of the third column correspond to the baseline model with both shocks from which real estate is removed. Statistics of the last column for the *volatility* and *domestic co-movement* sections are calculated from US time series described in the appendix from 1988Q1 to 2007Q4. The *international correlations* are calculated from US and UK time series. All series have been logged (except net exports) and Hodrick-Prescott filtered with a smoothing parameter of 1,600.