National and International Business Cycles: 
The Role of Financial Frictions and Shocks

by

Jean-François Rouillard

A thesis submitted to the
Department of Economics
in conformity with the requirements for
the degree of Doctor of Philosophy

Queen’s University
Kingston, Ontario, Canada
April 2013

Copyright © Jean-François Rouillard, 2013
Abstract

This dissertation investigates the effects of frictions that emerge from financial markets on business-cycle fluctuations. The purpose of Chapter 1 is to situate my work in the literature and to stress its contributions. In Chapter 2, I reassess the role of financial frictions in amplifying the impacts of productivity shocks using a framework in which a fraction of firms are borrowing-constrained and land is a collateral asset. A first finding is that amplification effects are much lower when land is supplied elastically. However, financial shocks that affect the maximum allowable ratio of loans to collateral have greater effects on output. Another result pertains to the role of the elasticity of substitution between land and capital in responses to financial shocks: lower values generate greater output responses.

While Chapter 2’s environment is set up to be in a closed-economy, the last two chapters involve two-country settings. Chapter 3 still intersects with Chapter 2 on some dimensions, in particular, land dynamics and financial frictions that feature borrowing-constrained firms. The borrowing mechanism brings about a distortion in labour markets that interacts with a class of preferences that are non-separable between consumption and leisure. Technology shocks contribute to explain international co-movements, whereas financial shocks allow the model to replicate the lack of international risk sharing that is characterized by the quantity anomaly and the
In Chapter 4, I apply Chari, Kehoe, and McGrattan’s (2007) business cycle accounting method to a two-country, two-good real business cycle model. Using their approach, I measure the same closed-economy time-varying wedges and I introduce an international wedge that accounts for discrepancies between the growth in real exchange rates and in the stochastic discount factors ratio. In fact, the effects of financial frictions embedded in Chapter 3’s framework can be retrieved from a combination of labour and investment wedges. The volatility of the international wedge corresponds to a metric of bilateral risk sharing. An important finding is that, from a non-separable preferences specification of the baseline model, the investment wedge partly accounts for the Backus-Smith puzzle. This suggests that distortions in national capital markets are important to consider for international risk sharing.
Acknowledgments

I am greatly indebted to several people for the realization of this thesis. I would like to thank primarily my advisor, Huw Lloyd-Ellis, for his excellent guidance, support and receptiveness to my ideas. He taught me the simmering process of research and has instilled in me the passion to pursue a career in academia. I am also grateful to all other Macroeconomics professors at Queen’s University for their comments and feedback on my work and seminar presentations, a special thanks to Marco Cozzi, Allen C. Head, Thorsten V. Koeppl, Beverly Lapham, Gregor W. Smith and Amy Hongfei Sun.

I wish to thank conference participants at the Midwest Macroeconomics Meetings, Journées du CIRPÉE, Theories and Methods in Macroeconomics Conference, Canadian Economics Association Conference, CIREQ Ph.D. Students’ Conference, Congrès annuel de la société canadienne de science économique, and Eastern Economics Conference, seminar participants at Queen’s University, Université du Québec à Montréal, Université de Sherbrooke, and Université Laval, and discussants of my work at conferences: Kyriacos Lambrias and Tatsuma Wada. For Chapter 3 of this thesis, I also thank Zheng Liu for providing me with data on liquidity-adjusted land prices for the United States, and the Bank for International Settlements for series on housing prices for the United Kingdom. I acknowledge financial support from the
FQRSC (Fonds québécois de recherche sur la société et la culture).

This thesis has also benefited from the ongoing feedback from my colleagues during my Ph.D. journey. I thank, in particular, Mike Cloutier, Jean-Denis Garon, Babak Mahmoudi, Nicolas Martineau, and Louis Perrault for their support and for sharpening my critical thinking skills. Many thanks also go to my dulcinée, Caren, who has always been a great source of inspiration and whose generous encouragements have generated an amplification of my own research productivity shocks.

Finalement, je voudrais aussi remercier profondément mes parents qui m’ont offert un soutien indéfectible et desquels j’ai hérité d’une curiosité intellectuelle précieuse.
Table of Contents

Abstract i

Acknowledgments iii

Table of Contents v

List of Tables vii

List of Figures ix

Chapter 1:
   General Introduction ........................................ 1

Chapter 2:
   Land Dynamics and Financial Shocks ...................... 13
   2.1 Introduction ............................................. 13
   2.2 Commercial land stylized facts .......................... 18
   2.3 The model ............................................... 19
   2.4 Calibration ............................................... 29
   2.5 Results .................................................. 34
   2.6 Conclusion and extensions .............................. 47
Chapter 3:

International Risk Sharing and Land Dynamics . . . . . . . . . . . . . . 49
  3.1 Introduction . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 49
  3.2 International risk sharing stylized facts . . . . . . . . . . . . . . . . 55
  3.3 The business-cycle model . . . . . . . . . . . . . . . . . . . . . . . . 59
  3.4 Calibration . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 74
  3.5 Results of the business cycle estimation . . . . . . . . . . . . . . . . 82
  3.6 Conclusion and extensions . . . . . . . . . . . . . . . . . . . . . . . 97

Chapter 4:

Wedges and International Risk Sharing . . . . . . . . . . . . . . . . . . . . 99
  4.1 Introduction . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 99
  4.2 The diagnostic framework . . . . . . . . . . . . . . . . . . . . . . . . 105
  4.3 Calibration . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 117
  4.4 Results . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 123
  4.5 Conclusion and extensions . . . . . . . . . . . . . . . . . . . . . . . . 132

Chapter 5:

Summary and Conclusions . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 135

Appendix A:

International Risk Sharing and Land Dynamics . . . . . . . . . . . . . . . . 153
  A.1 Steady-state solution of the model . . . . . . . . . . . . . . . . . . . . 153
  A.2 Data sources and construction of variables . . . . . . . . . . . . . . . . 154
  A.3 Results of the one-good model . . . . . . . . . . . . . . . . . . . . . . 160
# List of Tables

2.1 Parametrization ................................. 30
2.2 Amplification effects of the baseline model in response to a 1% temporary financial shock with different specifications of preferences and elasticities of substitution between land and capital for output for which the enforcement parameter ($\bar{\xi} = 0.7$) ................................. 45
3.1 Parametrization of shock processes ..................... 76
3.2 Parametrization of preferences and technology ................ 77
3.3 Estimated parameters ................................. 81
3.4 Business cycle statistics ................................. 90
3.5 Sensitivity analysis statistics ................................. 93
4.1 Parametrization ................................. 120
4.2 Estimated parameters of the stochastic processes for wedges ........ 122
4.3 Variance decomposition of the *international wedge* .................. 127
4.4 Variance decomposition of the separable preferences model (M4) ................ 129
4.5 Standard deviations of the national and *international wedges* for the non-separable preferences model (M4) ................................. 130
4.6 Variance decomposition of the non-separable preferences model (M4) 131
4.7 The correlation between real exchange rates and relative consumptions 132
A.1 Business cycle statistics (one-good) ........................................ 160
List of Figures

2.1 Amplification effects of the baseline model in response to 1% temporary productivity and financial shocks ............................................. 35
2.2 Amplification effects of the baseline model for which land is supplied elastically in response to a 1% temporary productivity shock ........... 39
2.3 Amplification effects of the model for which land is the only input \((\psi = 1)\) in response to 1% temporary productivity and financial shocks 42
2.4 Amplification effects of the baseline model in response to a 1% temporary financial shock with partially non-separable preferences and GHH preferences for the consumption-leisure choice .................................. 45
3.1 Cross-country correlations in output and difference between cross-country correlations in output and consumption for twenty-three OECD countries 56
3.2 Percentage of differences between cross-country correlations in output and consumption that are statistically significant at 10% level ........... 57
3.3 Cross-country correlation in output and the difference between cross-country correlations in output and consumption for the United States and the United Kingdom ............................................................... 58
3.4 Impulse responses to a 1% temporary Home technology shock ............. 83
3.5 Impulse responses to a 1% temporary Home financial shock ............... 84
3.6 The correlation between the expected growth in real exchange rates and in relative consumptions for different calibrated values of the real estate adjustment cost

4.1 U.S.-Canada exchange rate

4.2 Measure of international risk sharing

4.3 Measure of international risk sharing for separable preferences

4.4 Measure of international risk sharing for non-separable preferences
Chapter 1

General Introduction

According to the celebrated Modigliani-Miller theorem, the capital structure of firms is irrelevant. According to this theorem, any tightening of credit standards by banks should lead firms to substitute their financing from external to internal sources, so that investment decisions would remain unaffected. Consequently, real economic activity should be totally disconnected from movements in financial flows. Recent developments suggest otherwise, as a financial crisis preceded the Great Recession. Setting aside extreme events, the study of financial markets is also relevant for business-cycle fluctuations. For the time-period 1984:Q1 to 2010:Q2, Jermann and Quadrini (2012) estimate correlations between equity payouts, debt repurchases and output, and reject the hypothesis that the behavior of the two financial variables is acyclical. In the macro-finance literature, there are two main ways in which financial markets are linked to real economic activity: amplification of real shocks to the economy and the impact of shocks to financial markets themselves.\(^1\) The first channel considers that financial frictions amplify exogenous disturbances such as productivity and monetary

\(^1\)See Quadrini (2011) for an exhaustive categorization of the related literature into these two channels.
shocks, while the second channel pertains to shocks that emanate from the financial sector.

The contribution of this dissertation consists of assessing the role of both channels for business cycles at national and international levels along numerous dimensions. In Chapter 2, I investigate the importance of land collateralization for firms’ productive activities in an environment that considers many features of the commercial real estate market. In Chapter 3, I examine the effects of land reallocation between residential and commercial sectors coupled with frictions in national financial markets, and financial shocks in order to account for synchronization of economic activity across industrialized countries and the degree of international risk sharing. Since financial frictions and shocks produce wedges, in Chapter 4, I proceed to an international business cycle accounting exercise to identify which national wedges best explain the lack of international risk sharing. From the estimation of the international wedge, I also put forward a measure of international risk sharing.

Prior to the Great Recession, the macro-finance literature typically stressed the role of amplification mechanisms related to financial frictions. The “financial accelerator” introduced by Bernanke and Gertler (1989) is one of the earliest attempts to embed financial frictions into a general equilibrium model. Its mechanism is based on costly state verification by lenders that do not have free access to information regarding borrowers’ actions. Hence, there is a premium associated with external financing and the endogenous variations in this premium amplify output fluctuations following productivity or monetary policy shocks. Carlstrom and Fuerst (1997) embed this particular type of information asymmetry into a canonical real business cycle model, while Bernanke, Gertler, and Gilchrist (1999) add a dynamic New Keynesian flavor.
to the costly state verification device.

The endogenous borrowing mechanism embedded in the models of this dissertation pertains to a different category of agency problems: limited enforcement. Djankov, Hart, McLiesh, and Shleifer (2008) document how institutional differences in legal systems across countries affect debt enforcement procedures. The approach that I favor is to introduce heterogenous economic agents who discount the future at different rates, so that borrowers are impatient and lenders are patient. Liquidation costs related to asset redeployment also induce lenders to accept contracts for which loans are a fraction of the value of borrowers’ assets. The design of the enforcement problem in my analysis does not follow the literature on optimal dynamic contracts to which Kehoe and Levine (1993) and Cooley, Marimon, and Quadrini (2004) belong. Instead the models that I develop are based on Kiyotaki and Moore’s (1997) type of collateral constraint. In their framework, a positive productivity shock leads to a rise in the value of a collateralized asset available in fixed supply, such as land, thereby allowing the borrowing constraint to be relaxed. Therefore, more assets are allocated to borrowers that have a higher marginal productivity and output movements are amplified.

Related to the literature on endogenous borrowing constraints is the role of working capital. In addition to inter-period debt, working capital requirements imply that borrowing firms also contract intra-period loans that do not incur any interest in order to pay their factors of production before revenues accrue to them. This introduces a distortion between the marginal product of labour and the wage. Working capital requirements have been used extensively in the monetary economics literature, but have also been embedded in non-monetary models, see Neumeyer and Perri (2005).
The approaches put forward by Mendoza and Quadrini (2010), Jermann and Quadrini (2012) and Perri and Quadrini (2011) aim at reconciling working capital with other financial frictions.

The last work of Jermann and Quadrini (2012) and Perri and Quadrini (2011) also place greater stress on the other channel that has emerged during the developments of the 2007-2009 financial crisis: credit or financial shocks. The type of financial shocks that are examined in Chapters 2 and 3 are similar to those considered by these two studies. These shocks alter the fraction of the collateralized asset that can be repossessed by lenders. Many factors such as waves of optimism and pessimism, regulations and financial innovations are contributors to these shocks emanating from the financial sector. For Jermann and Quadrini (2009) the nature of these shocks is very broad: “something changing the ability of borrowers to raise funds”. In this dissertation, I do not explore the causes of movements in financial shocks or “financial market freezes”, see e.g. Acharya, Gale, and Yorulmazer (2011) and Chiu and Koepl (2011) for micro-founded approaches to sudden financial market disruptions.

Credit shocks are also at the heart of many explanations of the financial crisis. Khan and Thomas’s (2011) framework features heterogeneous agents and partial investment irreversibility, while Kiyotaki and Moore (2012) examine liquidity properties of financial assets and introduce a shock to the fraction of equity holding an agent can resell. In Gertler and Karadi (2011) and Mendoza and Quadrini (2010), financial shocks arise in the financial intermediaries sector. Del Negro, Eggertsson, Ferrero, and Kiyotaki (2011) construct a framework that features liquidity frictions and shocks in order to evaluate the effects of public intervention in asset markets at the nominal interest rate zero lower bound.
Even though borrowing constraints and financial shocks are similar to Jermann and Quadrini’s (2012) work, in this dissertation I place a greater emphasis on the role of commercial real estate and its interactions with capital rather than labour demand fluctuations in both national and international business cycles. Following Davis and Heathcote (2007), real estate can be decomposed into land and structures components, so that commercial land and capital have different properties. As highlighted by Shleifer and Vishny (1992) in their analysis of Williamson’s (1988) concept of asset redeployment, commercial land has a higher liquidation value than capital since it has more alternative uses.

An important feature of land that I examine is its role as collateral for firms’ borrowing. Hence, my perspective on the role of land contrasts with Davis and Heathcote’s (2005) multi-sector growth model and its use as collateral only for households that is present in Campbell and Hercowitz (2005) and Monacelli (2009). The collateral constraints embedded in models of this dissertation resemble those considered by Iacoviello (2005) and Liu, Wang, and Zha (2011). In the former, collateral effects from demand shocks are examined in a monetary framework, whereas the objective of the latter work is to account for the dynamics of land prices and business investment.

Chapter 2 contributes to the debate on the quantitative effects of the mechanism proposed by Kiyotaki and Moore (1997) to enhance productivity shocks. Córdoba and Ripoll (2004) and Kocherlakota (2000) present a very skeptical view of the amplification channel, but yet they still find small effects. My results are much starker as they point to lower amplification effects than for a representative-agent framework following a productivity shock. In fact, from an extensive calibration exercise, Córdoba and Ripoll (2004) argue that only the right combination of parameters can lead
to a sizable endogenous amplification and that implies making implausible assumptions. Using a Cobb-Douglas production function that aggregates both capital and land inputs, Kocherlakota (2000) also notes the sensitivity of amplification to factor shares. In contrast to Córdoba and Ripoll (2004), Mendicino (2011) shows that a lower degree of enforcement (but still sufficiently high) leads to greater amplification effects since the productivity gap between borrowers and lenders is larger. I find, however, that these effects vanish once an elastic land supply is assumed. In fact, as will be shown in Chapter 2, the stock of non-farm land varies across business cycles due to zoning regulations for example.

An additional finding of Chapter 2 is that financial shocks lead to considerable reallocation of land from lenders to borrowers and generate more endogenous fluctuations in output than productivity shocks. Augmenting the benchmark model with reproducible capital, I also find that the elasticity of substitution between land and capital can greatly affect the size of output responses to financial shocks. Hence, for a reasonable choice of parameters, if the standard assumption of a unitary elasticity of substitution is cut by half, I find an additional amplification of over 50%. In comparison, labour market dynamics that are central to Jermann and Quadrini’s (2012) results do not seem to affect output fluctuations as much.

In Chapter 3, I explore the roles played by land dynamics and financial shocks in helping us to understand several key issues related to international business cycles. As reported by Obstfeld and Rogoff (2000), “puzzles” in the field of international finance and macroeconomics abound. However, in contrast to the role of trading costs proposed by Obstfeld and Rogoff (2000), my approach to understanding these long-standing “puzzles” features national financial frictions, land and non-separable
preferences.\footnote{Backus, Kehoe, and Kydland (1992) and Backus, Kehoe, and Kydland (1995) show that trade costs alone cannot explain the low level of cross-country correlations in a complete-markets free-trade Walrasian framework.} The industrialized countries’ “puzzles” or “anomalies” that this dissertation tackles are listed below.

First, the workhorse international real business cycle model developed in Backus, Kehoe, and Kydland (1992) (hereafter BKK) features complete financial markets and predicts perfect risk sharing, so that growth rates of consumption are perfectly correlated across countries. In the same framework, productivity shocks lead to a negative cross-country correlation in output, as investment flows to the country hit by a positive shock. In the data, however, cross-country correlations in output are greater than in consumption. BKK call this discrepancy between the results of their model and the data the \textit{quantity anomaly}. 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 \textit{international co-movement} puzzle. Finally, in a two-good model, Backus and Smith (1993) show that complete financial markets imply perfect correlation between real exchange rates and relative consumptions, yet they estimate that this correlation is negative in the data. This is the \textit{Backus-Smith} puzzle.

There have been many attempts at solving these puzzles in the international real business cycle literature. Some approaches, such as Kollmann (1996) and Baxter and Crucini (1995), rely on the incompleteness of asset markets. Baxter and Crucini (1995) show that if the only asset that is traded across countries is a non-contingent
bond, highly persistent or not internationally transmittable technology shocks can explain the *quantity anomaly*. Heathcote and Perri (2002) show that incompleteness of asset markets may not be sufficient and suggest that international *co-*movements and terms of trade volatility generated by a two-good, two-country model featuring financial autarky are more consistent with the data. The asset market structure of the model introduced in Chapter 3 is incomplete. However, that feature is not the one that drives down the cross-country correlation in consumption. Following the closed-economy literature on optimal dynamic contracts, Keohoe and Perri (2002) and Bai and Zhang (2012) 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. Financial frictions in my model take place within countries rather than at the international level.

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.

In fact, non-separable preferences in consumption and leisure, introduced in the international business cycle literature by Devereux, Gregory, and Smith (1992) 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. They use non-separable preferences derived by Greenwood, Hercowitz, and Huffman (1988) (hereafter, GHH) in a two-country model and show that the evidence on low cross-country correlation in consumption can be reconciled with this category of preferences. Johri, Letendre, and Luo (2011) also show that a model that features GHH preferences and organizational capital can generate positive international co-movements.

However, the findings of panel regressions that are performed by Lewis (1996) and Bai and Zhang (2012) suggest that movements in leisure only explain a tiny fraction of the movements in tradable consumption. This finding leads them to conclude that non-separability between consumption and leisure cannot account for low cross-country correlations in consumption. However, in their estimations leisure is proxied by employment-based measures that display a much smaller variability than consumption and they do not take non-linearities into consideration in their regressions. The use of GHH preferences is widespread in the open economy literature, see e.g. Mendoza (1991) and Correia, Neves, and Rebelo (1995).

More closely related to my work in Chapter 3 is the literature examining the effects of financial frictions in a two-country environment. Faia (2007), Dedola and
Lombardo (2009), and Ueda (2012) make use of Bernanke, Gertler, and Gilchrist’s (1999) financial accelerator to emphasize the importance of international portfolio and banking globalization. Other studies that embed Kiyotaki and Moore’s (1997) type of collateral constraint are Devereux and Yetman (2010), Paasche (2001), and Iacoviello and Minetti (2006).

In Chapters 2 and 3, the presence of borrowing-constrained firms entail that factors of production are not paid at their marginal values. Following Chari, Kehoe, and McGrattan’s (2007) (hereafter, CKM) accounting approach, I will refer to these distortions or discrepancies with a standard real business cycle model as “wedges”. Financial markets are not modelled explicitly in the framework discussed in Chapter 4, but variations in wedges that I construct could result from financial frictions and shocks. CKM identify four wedges: the efficiency wedge that is similar to a TFP shock, the labour wedge that can be interpreted as a tax on labour supply, the inter-temporal investment wedge, and the government consumption wedge that corresponds to government expenditures. I apply the same method to a two-country, two-good model, so that an additional wedge that I call the international wedge arises between the expected growth in real exchange rates and SDFs. I consider the volatility of that wedge to be a metric for international risk sharing. I assume that these deviations are due to international asset market frictions, although as shown by Fitzgerald (2012), trade costs could also contribute significantly to these deviations.

One important contribution of Chapter 4 is to reconcile two strands of the literature: international real business cycle and international risk sharing measures. Viani (2011) emphasizes the importance of taking into account international prices for constructing bilateral risk sharing metrics. In contrast to my framework, however,
she only considers endowment shocks. Devereux and Hnatkovska (2011) also use the same measure for country and regions within country pairings and find a significant border effect. In fact, the taste shocks introduced in Stockman and Tesar (1995) affect the inter-temporal Euler equation and thus would contribute to movements in that wedge. The insurance role of international prices was first discussed in the literature by Cole and Obstfeld (1991) and has recently been analyzed by Viani (2011). She shows theoretically, based on a social planner problem, that larger deviations from SDFs lead to greater welfare losses, so that measures put forward for example by Brandt, Cochrane, and Santa-Clara (2006) and Flood, Marion, and Matsumoto (2012) are flawed.

I calibrate the model to match U.S. and Canadian data and under the assumption of constant population growth, log-linearization implies that countries size do not affect results. Since the characterization of SDFs is different for separable and non-separable preferences and, consequently, the measured international wedges diverge too, I investigate whether movements in leisure can explain the degree of international risk sharing. In order to achieve this goal, I estimate volatilities of the international wedge for separable and non-separable preferences. I find that for some sub-periods, measures of international risk sharing derived from separable preferences suggest a fall in the degree of risk sharing, whereas non-separable preferences suggest that is stable. During the so-called Great Moderation period from 1984:Q1 to 2007:Q4, however, fluctuations in the nominal exchange rate account for most variations.

I also examine the role of national wedges in explaining the Backus-Smith puzzle. In Chapter 3, an important finding is that a framework featuring national financial frictions and non-separable preferences can replicate the negative correlation between
the growth in real exchange rate and relative consumptions. In Chapter 4, the investment wedge embedded in the international business cycle accounting framework is the national wedge that contributes the most to bring down this cross-correlation.

The remainder of this dissertation is organized as follows. In Chapter 2, I revisit Kiyotaki and Moore’s (1997) amplification mechanism and I examine the quantitative effects of financial shocks on asset reallocation and output for calibrated values of parameters that match characteristics of commercial real estate. In Chapter 3, I assess the roles of land dynamics and financial frictions to explain international finance and macroeconomics “puzzles”. In Chapter 4, I present an approach to measure the level of international risk sharing that can be reconciled with the international real business cycle literature. In Chapter 5, I conclude and suggest extensions for future research.
Chapter 2

Land Dynamics and Financial Shocks

2.1 Introduction

From credit crunch to downturn in economic activity, the Great Recession has indisputably shed light on the linkages between financial markets and business cycle fluctuations. The recent episode of coincident business and credit cycles is, however, far from being unique. Based on a sample that covering a large number of advanced and emerging economies over a long period of time (1960:Q1-2007:Q4), Claessens, Kose, and Terrones (2011) have documented the cyclical behavior of credit and asset prices during the booms and busts phases of cycles. They also find that house price busts tend to be associated with prolonged recessions. These findings suggest that the framework of analysis should depart from a complete markets environment and should lead researchers to investigate which mechanisms are important for the transmission of financial flows to the real economy.

\footnote{From US micro-data, Covas and Den Haan (2011) find that the two financing means of firms: debt and equity are cyclical. Moreover, Reinhart and Rogoff (2009), in their historical survey of crisis periods, highlight the role that financial variables have played.}
In a synthesis of recent developments in the macro-finance literature, Quadrini (2011) classifies propagation channels into two broad categories: amplification and financial shocks as described in Chapter 1. Financial frictions can play a role in amplifying and propagating shocks that do not emanate from the financial sector, whereas financial shocks can also have direct effects on real economic activity. The scope of this chapter is essentially to compare the effectiveness of these two channels in a framework in which land and real estate dynamics play a prominent role.

Housing markets also have received much attention during the recent financial crisis that has shadowed the importance of land as a collateral asset for firms’ investment decisions. The 1990’s Japanese land market collapse is often used as an example to study the importance of commercial real estate in business cycles. Gan (2007) finds evidence of a significant collateral channel, so that a 10% decrease in land value led to a drop in the investment rate of 0.8%. That should not be surprising considering that the Bank of Japan reports that 70% of loans are backed by land. For the U.S. booming commercial real estate market (1993-2007), Chaney, Sraer, and Thesmar’s (2012) findings point to the fact that U.S. corporate firms increase their investment by $0.06 for every additional $1 increase in the value of their collateral. Contrary to Japan, it is not possible to obtain a ratio of loans to the value of land for the U.S. corporate sector. However, Berger and Udell (1990) find that collateral is pledged for over 70% of commercial and industrial loans. Since tangible assets are assets that can be more easily repossessed by banks and since commercial real estate corresponds to 58% of tangible assets, this suggest that investigating land dynamics is fundamental.

\[^2\text{This ratio is compiled by Liu, Wang, and Zha (2011) from Flow-of-Funds tables made available by the Federal Reserve Board.}\]
In this chapter, I adapt the framework of Kiyotaki and Moore (1997) in order to match more closely key characteristics of the real estate market. I relax the assumption of inelastic land supply and introduce land developers who react to changes in land prices. I present empirical evidence in the next section that points to elastic land supply even at business cycle frequencies. In the theoretical exercise that I pursue, I find that allowing for elastic land supply partially shuts down the price channel that is central to the amplification mechanism. Therefore, in this environment there does not seem to be any value-added to use a model that encompasses borrowing-constrained agents. In contrast, financial shocks lead to smoother responses of land prices or in some cases cause land prices to drop, so that the lending rate does not appreciate as much. Hence, more borrowing occurs due to an increase in the quantity of land owned by borrowers rather than a price appreciation of this asset.

Another important finding pertains to the role of the complementarity of capital and land in the production function. From commercial Japanese real estate data, Sakuragawa and Sakuragawa (2011) estimate an elasticity of substitution that ranges from 0.31-0.37, a value that is well below the value of unity that is commonly assumed. In the theoretical model, lowering the elasticity of substitution results in responses of the borrowers’ capital that are more coordinated with those of borrowers’ land. From a parametrization that will be discussed below, the amplification of output for a production function with an elasticity of substitution of 0.5 is over 50% larger than for a Cobb-Douglas production function.

This chapter contributes to the debate on both the quantitative effects of financial frictions following productivity shocks (see, *e.g.* Kocherlakota 2000; Córdoba and
Ripoll 2004; Mendicino 2011) and the importance of financial shocks themselves. In a similar fashion to Jermann and Quadrini (2012) and Perri and Quadrini (2011), I introduce the idea of working capital as an additional financial friction. It is important to note that my results are robust to different borrowing constraint characterizations, but this particular one has the advantage of being derived from a micro-founded debt renegotiation problem. Since factors of production need to be paid before revenues are recouped, firms contract both inter-period and interest-free intra-period loans and use productive assets as collateral. Embedding this characterization, I compare the explanatory power of land dynamics to the main source of business cycles according to Jermann and Quadrini (2012): labour demand fluctuations.

In the macro real estate literature, most studies have focused on residential real estate and commercial real estate seems to have been left aside. There are some exceptions though. Iacoviello (2005) proposes a hybrid model in which land is in fixed supply and allocated between entrepreneurs, patient and impatient households, so that only patient households are unconstrained by their land holdings. The collateral channel brings about important amplification effects on aggregate demand in response to housing price shocks. In contrast to previous work, Liu, Wang, and Zha (2011) analyze exclusively the role of collateralized commercial real estate in a model that features capital and land aggregated through a Cobb-Douglas production function. In order to match land and output dynamics, they consider different types of shock. In

---

3 Many advances have been realized on the ground of identification. From a borrowing constraint that is always binding, Jermann and Quadrini (2012) retrieve a financial shock analogously to the Solow residual from a production function. The shock identified by Benk, Gillman, and Kejak (2005) involves policy regulatory changes in the banking sector. From a structural FAVAR model, Gilchrist, Yankov, and Zakrajsek (2009) find that shocks originating from the corporate bond market are important contributors to downturns in economic activity. The importance of contractions in credit supply is reassessed with the construction of a credit spread index in Gilchrist and Zakrajsek (2011).
their variance decomposition, around 90% of land prices fluctuations are explained by a housing preference shock at different horizons. For shorter horizons, the contribution of that shock to fluctuations in investment, output and hours worked exceeds that of all other types of shocks. A collateral shock similar to the financial shock embedded in my model has more modest effects since only 6% to 12% of output fluctuations are explained by this shock. As it is the case in my framework, I suspect that the assumption of a lower elasticity of substitution would boost the importance of the collateral channel in their model.

This chapter is particularly close to the work of Sakuragawa and Sakuragawa (2011) in many ways. From their estimation of elasticities of substitution between land and capital in production for the Japanese economy, they construct a model based on Iacoviello (2005) in which all entrepreneurs face a borrowing constraint. They find that a lower elasticity of substitution coupled with investment adjustment costs leads to greater amplification of TFP shocks. In contrast to my model, reallocation of land occurs between residential and commercial sectors so that households’ land holdings shrink considerably. In a framework that features elastic land supply and reallocation of land across firms, I find that productivity shocks have negligible effects.

The remainder of this chapter is organized as follows. In section 2, I present some stylized facts on land dynamics. Section 3 lays out the baseline model in which the production side of the economy is collateralized. In section 4, I calibrate the model along the lines of Mendicino’s (2011) study in order to have a better understanding of the role of elastic land supply. In section 5, results of the baseline model’s estimation are analyzed and a sensitivity analysis with regards to factor shares is performed. In section 6, I conclude and propose some extensions.
2.2 Commercial land stylized facts

2.2.1 Elasticity of land supply

Use of land changes throughout time as farmland can be substituted by urban land for residential or commercial uses. Around the years of the U.S. housing boom, Shiller (2007) argued that

“there is reason to expect that as existing urban land becomes very expensive to structures, there will be efforts to substitute away from that land [...]”

This implies that zoning is endogenous (see McMillen and McDonald, 1991 for implications of endogenous zoning on urban land value functions). A demand shock that puts upward pressure on land prices may lead local authorities to change zoning from farmland to urban, since the city or municipality would benefit from higher property tax revenues. Glaeser, Gyourko, and Saks (2005) find evidence that rights to build and other regulatory constraints significantly affect housing prices. Glaeser and Gyourko (2008) also argue that the rapid population growth experienced by cities in Sun Belt states during the recent housing boom is due to quick changes in zoning of farmland to urban land. Moreover, cities across the country compete to attract firms to relocate or start up their productive activities. Cheaper developable land for which zoning has recently been changed can be a good selling point. This extensive margin can be important for land supply fluctuations at business cycle frequency.
2.2.2 Elasticity of substitution between land and capital

Most theoretical work uses a Cobb-Douglas production function to aggregate land and capital thereby assuming a unitary elasticity of substitution. However, there is some empirical evidence that points out to the existence of greater levels of complementarity. From Japanese data on non-financial corporations, the estimates of Sakuragawa and Sakuragawa (2011) suggest an elasticity of 1/3. For the United States residential sector, Albouy and Ehrlich (2012) obtain a point estimate of 0.49 for metropolitan areas, although they cannot reject unity. To my knowledge, no work has focused on estimating this elasticity for the U.S. commercial real estate sector. However, given the evidence for Japan and the U.S. residential sector, I believe that it is reasonable to check the sensitivity of the responses to shocks for values lower than one.

2.3 The model

The model is based on Kiyotaki and Moore (1997) in which firms face endogenous borrowing constraints. I assume an additional factor of production and collateral asset to land that is capital. Moreover, there are two types of agents with different discount factors, so that firms are either owned by patient or impatient agents.

All firms are atomistic and the only difference between them is the way their investors discount the future: they can either be patient ($i = 1$) or impatient ($i = 2$). Hence, discount factors are ordered in the following way: $1 > \beta_1 > \beta_2$, so that firms owned by patient investors have a higher discount factor than those owned
by impatient investors. In equilibrium, patient investors are lenders and impatient investors are borrowers. The parameter $\omega \in (0, 1)$ corresponds to the fraction of patient investors. It should be noted that the version of the model described below is the most general one and the interpretation of special cases is discussed in the results section.

### 2.3.1 Firms

Output is given by

\[
 f(z_t, k_{it-1}, l_{it-1}, n_{it}) = \begin{cases} 
  z_t \left( \psi l_{it-1} + (1 - \psi)k_{it-1} \right)^{\frac{1}{1 + \phi}} n_{it}^{1-\alpha} & \phi \neq 0 \\
  z_t \left( \psi_k l_{it-1} \right)^\alpha n_{it}^{1-\alpha} & \phi = 0 
\end{cases}
\]  

(2.1)

where $z_t$ denotes an exogenous productivity shock common to both types of investors, $l_{it-1}$ denotes land, $k_{it-1}$ denotes capital and $n_{it}$ is total labour hours. Note that I assume a constant-elasticity of substitution (CES) production function for which $\frac{1}{1 + \phi}$ corresponds to the elasticity of substitution between land and capital and $\psi$ represents land’s weight relative to capital in the production function. I also assume decreasing returns to scale for the aggregation of capital and land, so that $0 < \alpha < 1$. In the case of a Cobb-Douglas production function, \textit{i.e.} $\phi = 0$, $\psi \alpha$ corresponds to the elasticity of output with respect to land and $(1 - \psi)\alpha$ the elasticity of output with respect to capital.

Firms accumulate capital according to the following equation:

\[
 k_{it} = (1 - \delta)k_{it-1} + x_{it}
\]  

(2.2)
where \( x_{it} \) corresponds to investment and \( \delta \) to the depreciation rate. Land is purchased from land developers.

At the end of each period, firms recover revenues from the sales of their production that can be used by both firms and investors as consumption or investment goods. Their budget constraint is as follows:

\[
d_{it} + w_{it} n_{it} + x_{it} + q_t (l_{it} - l_{it-1}) + b_{it-1} = f(z_t, k_{it-1}, l_{it-1}) + \frac{b_{it}}{R_t}. \tag{2.3}
\]

Firms pay out dividends \( d_{it} \) and the wage bill \( w_{it} n_{it} \) to households, invest \( x_{it} \), buy or sell land at price \( q_t \) and incur new debt at interest rate \( R_t \) so that their net new borrowing corresponds to \( \frac{b_{it}}{R_t} - b_{it-1} \). However, these expenses are assumed to be incurred earlier in the period, before revenues accrue to the firms. Since firms need working capital, they contract an interest-free intra-period loan:

\[
\ell_{it} = d_{it} + w_{it} n_{it} + x_{it} + q_t (l_{it} - l_{it-1}) + b_{it-1} - \frac{b_{it}}{R_t} \tag{2.4}
\]

from investors that do not own or work for the firm, so that \( \ell_{it} = f(z_t, k_{it-1}, l_{it-1}, n_{it}) \). In equilibrium, firms that are owned by impatient investors will borrow from the ones that are owned by patient investors. Since debt is not perfectly enforced, firms that borrow may decide not to honor their contract at the end of the period. In that event, a stochastic fraction \( \xi_t \) of their collateralized assets would be seized and liquidated in the next period. Variation in this fraction corresponds to the financial shocks.

I also assume that lending firms must go through a liquidation process and cannot directly use the repossessed assets to produce. The value of liquidated assets would
be $\xi_t(q_{t+1}l_{it} + \vartheta k_{it})$ where $\vartheta$ controls capital degree’s of liquidity relative to that of real estate. I refer the reader to Perri and Quadrini’s (2011) appendix that shows that a Pareto-optimal allocation can be reached in the event of no default so that firms have the following borrowing constraint:

$$b_{it} + f(z_{it}, l_{it-1}, k_{it-1}) \leq \xi_t (E_t(q_{t+1}l_{it}) + \vartheta k_{it}) .$$

(2.5)

On the left-hand side of equation (2.5), overall borrowing that corresponds to the sum of inter-period debt and intra-period loans cannot exceed a fraction of land and capital expected values. Since firms face working capital requirements, an increase in current production tightens their inter-period borrowing. Lending and borrowing firms are both rational and have the same information and expected price of next period’s land at the end of the period when borrowing firms can default. I assume that borrowing firms have all the bargaining power. I formulate the optimization problem recursively as follows:

$$V(s; n_i, k_i, l_i, b_i) = \max_{d_i, n_i, k_i', l_i', b_i'} \{d_i + E_i m_i' V(s'; n_i', k_i', l_i', b_i')\}$$

(2.6)

subject to:

$$b_i + w_i n_i + d_i + x_i + q(l_i' - l_i) = f(z, k_i, l_i, n_i) + \frac{b_i'}{R},$$

$$\xi(E_i q' l_i' + \vartheta k_i') \geq \frac{b_i'}{R} + f(z, k_i, l_i, n_i),$$

$$k_i' = (1 - \delta) k_i + x_i.$$

The value of the firm $V(s; n_i, k_i, l_i, b_i)$ is characterized by the aggregate state variable $s$, labour $n_i$, capital $k_i$, land $l_i$ and inter-period debt $b_i$. In any given period, it is
CHAPTER 2. LAND DYNAMICS AND FINANCIAL SHOCKS

defined as the sum of its current dividends and the expected continuation value that is discounted at stochastic factor $m_i$. The investors’ optimization problem determines the value of this factor. Firms face budget, borrowing and capital accumulation constraints with corresponding Lagrange multipliers $\theta_i$, $\lambda_i$ and $Q_i$. In order to simplify the equations, I substitute the first order condition for $d_i$, $\theta_i = 1$ into the remaining ones for $b'_i$, $n_i$, $x_i$, $k'_i$, $l'_i$ and obtain:

\begin{align*}
1 & = REm'_i + \lambda_i, \quad (2.7) \\
w_i & = f_{n_i}(1 - \lambda_i), \quad (2.8) \\
Q_i & = 1, \quad (2.9) \\
Q_i & = Em'_i (f_{k'_i} + Q'_i (1 - \delta)) + \lambda_i \theta_i \xi - \lambda_i f_{k'_i}, \quad (2.10) \\
q & = Em'_i (f_{l'_i} + q') + \lambda_i \xi Eq' - \lambda_i f_{l'_i}, \quad (2.11) \\
\lambda_i & \geq 0, \quad (2.12) \\
0 & = (b'_i + f(z, k_i, l_i) - \xi (Eq'l_i + \partial k_i)) \lambda_i. \quad (2.13)
\end{align*}

The last two equations (2.12-2.13) are Kuhn-Tucker conditions. In the case of firms owned by patient investors, the borrowing constraint is never binding so that $\lambda_1$ is equal to zero. I assume that the distance between the discount factors $\beta_1$ and $\beta_2$ is large enough and shocks sufficiently small to ensure that the borrowing constraint of firms owned by impatient investors is always binding ($\lambda_2 > 0$).\(^4\) That implies from equation (2.7) that their discount rate is always greater than the interest rate.

\(^4\)The estimation of the model by the parameterized expectations approach allows me to confirm that the assumption of a binding constraint is reasonable for the calibrated values of the parameters that I describe in the next section.
Financial frictions add a distortion to the optimization problem of the borrowing firms. From equation (2.8), the working capital constraint implies that the marginal labour productivity of borrowing firms does not equal the wage. Hence, this ensures the presence of a “labour wedge” between the marginal rate of substitution of consumption and leisure and marginal product of labour, a distortion that would not arise in a complete markets environment. The Lagrange multiplier for capital holdings $Q_i$ corresponds to Tobin’s q and is constant here since there are no capital adjustment costs. The lenders’ problem is similar to that of unconstrained agents so that combining equations (2.7), (2.10) and (2.11) leads the interest rate to be function of expected marginal productivity of land and capital:

\[
\begin{align*}
R &= (1 - \delta) + Ef_{k_i} \\
R &= \frac{E(f_{l_i}' + q')}{q}
\end{align*}
\]

where $Ef_{k_i}$ and $Ef_{l_i}'$ correspond to the expected marginal productivity of capital and land. These conditions show tradeoffs that the lending firms have to make. First, by lending at rate $R$, they are giving up additional output in the next period that would be provided by one unit of capital. Second, they also sacrifice the marginal product of land in terms of land prices and they would also expect to be able to sell land at a higher price. Since there are interactions with the borrowing constraint multiplier created by financial frictions, borrowers’ conditions are more complicated.
2.3.2 Households

The owners of the firms receive dividends $d_{it}$ every period and maximize the utility function:

$$E_{i0} \sum_{t=0}^{\infty} \beta_{it} u(c_{it}, n_{it}).$$

(2.16)

where

$$u(c_{it}, n_{it}) = \begin{cases} (c_{it}(1 - n_{it})^{\chi_i})^{1-\sigma} - 1 & \sigma \neq 1, \\ \frac{1}{1-\sigma} \log(c_{it}) + \chi_i \log(1 - n_{it}) & \sigma = 1. \end{cases}$$

(2.17)

I assume that the class of preferences is CRRA, so that $\sigma$ corresponds to the inverse of the inter-temporal elasticity of substitution. A unitary elasticity of substitution corresponds to separable preferences, but for all other values preferences are non-separable. Hence, I refer to the utility function (2.17) as representing partially non-separable preferences. Moreover, $\chi_i$ corresponds to the weight allocated to leisure.

The investors face the following budget constraint: $s_{it}(d_{it} + p_{it}) + w_in_{it} = c_{it} + p_{it}s_{it+1}$, where $s_{it}$ corresponds to equity shares and $p_{it}$ to the market price of those shares. Investors optimize with respect to their levels of shares, consumption and hours worked. The combination of the two first order conditions leads to

$$p_{it}c_{it}^{-\sigma} = \beta_{it} E_{it} (c_{it+1}^{-\sigma}(d_{it+1} + p_{it+1})), \quad (2.18)$$

so that, by forward substitution, the market price of shares is equal to the discounted
sum of expected dividends: \( p_{it} = E_{it} \sum_{j=1}^{\infty} \left( \beta_i \left( \frac{c_{it+j}}{c_{it}} \right)^{-\sigma} \right) \). Since the price of the shares coincide with the value of the firm, the stochastic discount factor is \( m_{it+j} = \beta_i E_{it+j} \left( \frac{c_{it+j}}{c_{it}} \right)^{-\sigma} \).

The last two first order conditions give the intra-temporal condition between leisure and consumption, the marginal rate of substitution, as follows:

\[
- \frac{u_{it}'}{u_{ct}'} = w_{it} \tag{2.19}
\]

### 2.3.3 Land developers

I depart from Córdoba and Ripoll (2004) and Mendicino’s (2011) models in relaxing the assumption that total land supply for use in production is fixed. Hence, since land supply is not completely inelastic, I assume there exists a different category of firms, called developers, that clears land or buys it from the agricultural sector and sells it to producers at price \( q_t \). This market is competitive, so that, in equilibrium, a zero-profit condition applies. I assume myopic land developers that optimize with respect to total commercial land supply \( \bar{l}_t \) and developments in land holdings \( \bar{x}_l \), so that their maximization problem is as follows:

\[
\max \Pi_t = q_t \left( \bar{l}_t - \bar{l}_{t-1} \right) - \bar{x}_l \tag{2.20}
\]

subject to:

\[
\bar{l}_t = \bar{l}_{t-1} + \bar{x}_l \bar{r}_{t-1}^\zeta \tag{2.20}
\]
CHAPTER 2. LAND DYNAMICS AND FINANCIAL SHOCKS

The constraint describes the accumulation process for land. If \( \zeta = 0 \), land accumulates in a similar fashion to capital with no depreciation. At the other extreme, if \( \zeta \to \infty \), land supply is fixed. From the land developers’ problem, the implied inverse land supply function is given by:

\[
q_t = \frac{\zeta}{t-1} 
\]

(2.21)

where \( \zeta \) corresponds to the inverse of land supply elasticity, so that it controls how much land prices react to developments in land supply.

2.3.4 Shocks

Shocks are stochastic, so that \( \Gamma \) corresponds to a \( 2 \times 2 \) persistence matrix, and \( A_t \) consists of a matrix of productivity and financial shocks as described by the following equation:

\[
A_t = \Gamma A_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, \Sigma)
\]

(2.22)

where \( A_t = [z_t, m_t]' \) and \( \varepsilon_t = [\varepsilon_{zt}, \varepsilon_{\xi t}]' \) that is the innovations matrix. Elements off the diagonal of matrix \( \Gamma \) are defined as spill-overs. The variance-covariance matrix is given by \( E_t(\varepsilon_t \varepsilon_t') = \Sigma \).
CHAPTER 2. LAND DYNAMICS AND FINANCIAL SHOCKS

2.3.5 Market Clearing

The land market clears since land developers sell all new parcels of commercial land to firms, as summarized by the following equation:

\[ \omega l_{1t} + (1 - \omega)l_{2t} = \bar{l}_t. \]  \hfill (2.23)

Moreover, the bond market clearing condition is:

\[ \omega b_{1t} + (1 - \omega)b_{2t} = 0. \]  \hfill (2.24)

Since firms and investors have the same effective discount factor, all dividends are consumed:

\[ d_{it} = c_{it} \quad \text{for } i = 1, 2. \]  \hfill (2.25)

The resource constraint for the economy as a whole completes the market clearing conditions, so that:

\[ Y_t = \omega f_{1t} + (1 - \omega) f_{2t} = \omega(c_{1t} + x_{1t}) + (1 - \omega)(c_{2t} + x_{2t}) + q_t(\bar{l}_t - \bar{l}_{t-1}). \]  \hfill (2.26)

where \( Y_t \) corresponds to total output for the economy.
2.3.6 Equilibrium

The state of the economy is summarized by $s_t$ for the definition of the equilibrium and consists of four aggregate variables: the shocks $A_t$ summarized by (2.22), aggregate land $L_{t-1}$ and aggregate capital $K_{t-1}$ and aggregate borrowing $B_{t-1}$.

Definition 1. An equilibrium is defined as a set of functions for

(i) firms’ policies $d_{it}(s_t), n_{it}(s_t), b_{it}(s_t), k_{it}(s_t), l_{it}(s_t)$;
(ii) investors’ policies $c_{it}(s_t), s_{it}(s_t), n_{it}(s_t)$
(iii) real estate developers’ policies $l_t(s_t), x_t(s_t)$;
(iv) land prices $q_t$ and the lending rate $R_t$;
(v) law of motion of the aggregate state $s_{t+1} = \Psi(s_t)$.

Such that:

(i) firms’ policies satisfy conditions (2.7-2.13);
(ii) investors’ policies satisfy conditions (2.18-2.19);
(iii) land developers’ policies satisfy conditions (2.21);
(iv) interest rates and prices clear the bond and land markets (2.23-4.14);
(v) the resource constraint (2.26) is satisfied.

2.4 Calibration

All parameters’ values are reported in Table 2.1 and are chosen in order to match U.S. quarterly data. Some of them are determined outside the model, whereas others are chosen to match steady-state ratios.

The fraction of investors that are borrowing-constrained is set to 0.5, a level that is consistent with Campbell and Mankiw’s (1990) estimates of households that face
Table 2.1: Parametrization

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.5</td>
<td>fraction of lenders</td>
</tr>
<tr>
<td>Preferences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma$</td>
<td>2</td>
<td>inverse of the inter-temporal elasticity of sub.</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.99</td>
<td>patient investor discount factor</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.97</td>
<td>impatient investor discount factor</td>
</tr>
<tr>
<td>$\lambda_1$</td>
<td>1.86</td>
<td>hours worked of the patient investor ($n_1 = 0.3$)</td>
</tr>
<tr>
<td>$\lambda_2$</td>
<td>1.81</td>
<td>hours worked of the impatient investor ($n_2 = 0.3$)</td>
</tr>
<tr>
<td>Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.36</td>
<td>elasticity of output with respect to inputs</td>
</tr>
<tr>
<td>$\delta_k$</td>
<td>0.025</td>
<td>$k$ depreciation rate</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.126</td>
<td>share of land in production</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>1</td>
<td>inverse land supply elasticity</td>
</tr>
<tr>
<td>$\varsigma = 1/(1+\phi)$</td>
<td>$1.42$</td>
<td>elasticity of sub. between land and capital</td>
</tr>
<tr>
<td>Credit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.7</td>
<td>enforcement parameter in s.s.</td>
</tr>
<tr>
<td>$\vartheta$</td>
<td>0.528</td>
<td>fraction of capital collateralized relative to land in s.s.</td>
</tr>
</tbody>
</table>
credit constraints. The value of $\sigma$, the inverse of the inter-temporal elasticity of substitution, is set to 2 which is standard in the business cycle literature. The patient investors’ discount factor $\beta_1$ is chosen to imply a 4% annual risk-free interest rate. The elasticity of output with respect to capital and land $\alpha$ is standard and fixed at 0.36. The capital depreciation rate $\delta$ is 2.5% on a quarterly basis so that it corresponds to 10% annually.

The enforcement parameter is set to 0.7 in line with Sakuragawa and Sakuragawa (2011) who refer to banking practices in Japan. This value is also at midpoint of the loan-to-value parameters estimated by Iacoviello’s (2005) that are 0.89 for entrepreneurs and 0.55 for impatient households. As for the parameter that controls the inverse commercial land supply elasticity $\zeta$, to my knowledge no estimation has been performed for the United States’ commercial land sector. However, Saiz (2010) estimates local housing supply elasticity and, from his sample of metropolitan statistical areas, finds a mean value of 1.17 and a median value of 0.9. I use an intermediate value, so that $\zeta = 1$. However, I consider the sensitivity of my results to alternative values for this parameter.

The remaining parameters are set to match steady-state targets. Since impatient investors face a shadow price of borrowing, I follow Bernanke, Gertler, and Gilchrist (1999) and set the impatient investor discount factor $\beta_2$ so that the interest premium $(\frac{\lambda_2}{\beta_2})$ is two percent. The parameter that controls leisure’s weight in the utility function for (im)patient investors $\chi_1(\chi_2)$ corresponds to a value for which 30% of the investor’s time is spent at work.

One key parameter for which the United States commercial land literature is silent
is the one that controls the elasticity of substitution between land and capital $\zeta$. For Japanese data, Sakuragawa and Sakuragawa (2011) obtain estimates that range from 0.33 to 0.39. For the U.S. housing market, Albouy and Ehrlich (2012) find an elasticity of land and other input factors of 0.48, but they cannot reject the null hypothesis of a Cobb-Douglas production function ($\zeta=1$). I examine the sensitivity of the results to different values of $\zeta$ ranging from $1/3$ to 1.

The parameter that controls the share of land in the production function, $\psi$, is set to match the ratio of commercial land over capital of non-financial businesses $\frac{q_l}{k_1 + k_2}$. I make use of Davis’s (2009) decomposition of the market value of non-financial real estate into market values of structures and land in order to retrieve a ratio of one over the other for a time period that spans from 1952Q1 to 2007Q4. The land-capital ratio is adjusted in two ways. First, since the price index of capital in structures has increased more than the CPI and, in my model, capital and consumption take the same price, the denominator is deflated. Second, I use Gomme and Rupert’s (2007) estimates of the weight of capital in structures in total non-residential capital. The ratio’s average from these two adjustments corresponds to 0.19 for the time-period that I study. I calibrate $\psi$ to match it in the steady-state.\footnote{Since the market value of land is retrieved as a residual, Davis (2009) makes the implicit assumption that the real estate production function is Cobb-Douglas. Hence, for the parameters that are calibrated in steady-state, I assume a unitary elasticity of substitution ($\zeta = 1$).}

Moreover, I assume that capital cannot be liquidated as easily as commercial land, so that $\vartheta < 1$. I refer to Williamson’s (1988) concept of assets’ redeployment. In the event of a default to repay their debt, the firm that repossesses the assets can use commercial land for different uses, whereas capital can be industry-specific or
firm-specific. The steady-state target that $\psi$ is chosen to match is the ratio of inter-period debt over output for non-financial businesses. I use financial data from the Flow of Funds Account of the Federal Reserve Board for non-financial corporate and non-corporate credit market instruments (Table B.102, line 22 and Table B.103, line 25) and for non-financial businesses income before taxes (Table F.101, line 1) from 1952Q1 to 2007Q4 and find a ratio of 3.65.

For calibrated values of the persistence and volatility of shocks, since I present impulse responses only I do not proceed to any estimation. I follow a common practice in the real business cycle literature for productivity shocks and assume that they follow a $AR(1)$ process for which persistence parameters are 0.95. Thus far, there is no interaction between both types of shocks. Hence, elements off the diagonal matrices $\Gamma$ and $\Sigma$ are equal to zero. Note that the Solow residual typically estimated does not correspond to the exogenous productivity shock considered here, since capital and land reallocation lead to endogenous total factor productivity disturbances. Total factor productivity is instead computed as follows:

$$TFP_t = \frac{f(z_t, k_{1t-1}, l_{1t-1}, n_{1t}) + f(z_t, k_{2t-1}, l_{2t-1}, n_{2t})}{f(1, k_{1t-1} + k_{2t-1}, l_{1t-1} + l_{2t-1}, n_{1t} + n_{2t})}$$

where the numerator corresponds to total production of the borrowing and lending firms and the denominator to the measure of production of a representative firm that aggregates all inputs with productivity shock $z_t = 1$ at the steady state. Since in this framework a fraction of firms are borrowing-constrained, the reallocation of inputs to firms that have the greatest marginal productivity leads to an endogenous increase in TFP that is not captured by movements in the technology shock $z_t$. 
2.5 Results

Since I augment Kiyotaki and Moore’s (1997) work along several dimensions, I present the baseline model first and compare the second-period responses of productivity shocks and financial shocks for different specifications for which labour supply is inelastic. I present my results this way in order to disentangle the effects of land and labour market dynamics. Second, I show the contribution of land dynamics to output amplification in a framework for which land is the sole factor of production and collateral asset. Finally, I assess the role of labour dynamics for output fluctuations, and I consider two types of preferences: (i) partially non-separable, and (ii) non-separable GHH. In a similar fashion to Mendicino (2011), my results are displayed in order to isolate the sensitivity of results to different levels of the enforcement parameter.

2.5.1 Model with labour inelastically supplied

Baseline model with land and capital

I examine two key features of land separately: (i) the level of land supply elasticity, and (ii) the value of the elasticity of substitution between land and capital. Figure 2.1 presents the amplification effects of productivity shocks and financial shocks and also compares two versions of the model: one for which commercial land is supplied inelastically and another one for which the total quantity of commercial land varies as a result of land developers’ decisions. In order to assess the importance of the elasticity...
Figure 2.1: Amplification effects of the baseline model in response to 1% temporary shocks to productivity for which the solid line corresponds to an inelastic land supply and the dashed line to an elastic land supply, and 1% temporary financial shocks for which the dash-dotted line corresponds to an inelastic land supply and the dotted cyan line to an elastic land supply. Responses are all measured in percentage deviations from their steady state, except for the response of output to a productivity shock that singles out the exogenous amplification, so that results that are depicted correspond to $\frac{Y_2 - 0.01 T(1.1) - Y}{Y} \cdot 100$. 
of commercial land supply, I assume a unitary elasticity of substitution between land and capital \((\varsigma = 1)\). I investigate the second-period responses of output, land price, and borrowers’ land and capital holdings as seen in Figure 2.1. Contemporaneous effects are not as interesting, since inputs take one period to enter the production function. Figure 2.2 presents the sensitivity of responses to values of the elasticity of substitution between land and capital \(\varsigma\) that range between 1/3 and 1.

First, I analyze the amplification effects of a productivity shock. For output impulse responses, I only consider the \textit{endogenous amplification effects}, so that I remove the direct effects on output caused by the exogenous technology shock. Hence, for a 1\% technology shock and a persistence parameter that corresponds to 0.95, I subtract 0.95\% from the original output impulse responses. It is important to note that a similar representative-agent model that shares all characteristics with the baseline model besides the heterogeneity in discount factors also generates endogenous amplification effects that takes place from capital and land (if it is elastic) accumulation. Reallocation of assets from lending firms to borrowing-constrained firms leads to additional amplification effects, since the productivity gap between the two types of firms effectively shrinks.

For lower levels of the enforcement parameter \((\bar{\xi} < 0.7)\) and an inelastic land supply, land is reallocated from borrowing to lending firms in the opposite direction than expected. Following a positive shock, lenders also cut down their inter-temporal lending. Since capital depreciates over time, land that they purchase initially will be sold later in order to cover capital expenses. For greater levels of the enforcement parameter \((\bar{\xi} > 0.7)\), the flows of land are reversed for reasons that will be made clearer in the model for which land is the only asset. The enforcement parameter’s
threshold ($\bar{\xi} = 0.7$) also corresponds to the level for which output impulse responses are greater than the representative-agent model ones (0.025). Hence, reallocation of assets to borrowing-constrained firms is key for amplification.

For the elastic land supply version of the baseline model, land accrues to borrowers, but output impulse responses are much smaller than for the inelastic land supply case. Smaller growth in capital holdings explains the difference between output responses of the two models. Borrowing firms accumulate land in order to sell it back to land developers in the future. However, the proceeds of land sales are not redistributed from lenders to borrowers or vice-versa, as land developers collect these. Therefore, resources that could be allocated for capital holdings are curtailed by land developers. Smaller amplification is nevertheless compensated by greater persistence of output. As in Córdoba and Ripoll (2004), the addition of reproducible capital does not contribute to enhance output responses significantly whether land supply is elastic or inelastic. Hence, these results lead one to question the effects that financial frictions have in generating substantial levels of amplification. As for the small adjustment of land prices compared to the inelastic land supply version, log-linearization of the land supply equation (2.21) allows us to relate it directly to variations in total land holdings: $\tilde{q}_t = \zeta \tilde{l}_{t-1}$ where $\tilde{q}_t$ and $\tilde{l}_{t-1}$ correspond to percentage deviations from steady state for these two variables. The accumulation of aggregate land is a slow process similar to capital accumulation that explains the slow increase in land prices.

The analysis of financial shocks is simplified, since for most enforcement parameter values, the total stock of land appears to be constant for the elastic land supply case. More reallocation of capital and land than in the case of technology shocks leads to greater output amplification. The aggregate capital stock also remains equal to
its pre-shock level. Borrowing increases both due to the relaxation of the borrowing constraint and through an increase in the quantity of inputs that play the role of collateral. Hence, the land price channel does not account for greater responses in borrowing and in output. The decomposition of the effects that explain a magnification of output with greater levels of the enforcement parameter will follow the lines of Mendicino (2011) in the next sub-section.

In an elastic land supply environment, responses of output to financial shocks for lower values of the elasticity of substitution between capital and land are plotted in Figure 2.2. Lower levels of this elasticity imply more complementarity between factors of production so that the two inputs accrue to borrowers in the same proportions and that results in a more efficient distribution of these factors of production. Greater levels of the enforcement parameter also lead to more borrowing and to much larger output responses. Following the shock, lenders disinvest massively in land and capital, so that both assets are sold to borrowers in order for lenders to lend more initially. The price of land is affected less by the fall in their demand for land. As the shock decays, they slowly re-accumulate land and capital. The gains in output responses that result from a lower value of the elasticity of substitution are substantial. Reducing it from $\varsigma = 1$ to $\varsigma = 0.5$ results in a 51\% greater second-period output response. For $\varsigma = 1/3$ it reaches amplification levels that are 78\% greater, when the steady-state value of the enforcement parameter is 0.7.
Figure 2.2: Amplification effects of the baseline model for which land is supplied elastically in response to a 1% temporary productivity shock for different values of the elasticity of substitution between land and capital. The solid line corresponds to a unitary elasticity $\varsigma = 1$, the dashed line to $\varsigma = 1/2$ and the dotted line to $\varsigma = 1/3$. Responses are all measured in percentage deviations from their steady state.
Baseline model with land only \((\psi = 1)\)^6

The version of the baseline for which land is the only asset is the one that has received the most attention in the literature. Córdoba and Ripoll (2004) show that output amplification following a productivity shock can be decomposed into four components: a productivity gap between borrowers and lenders, the collateral share in output, the output share and the redistribution of land. Analytically, the elasticity of output with respect to both types of shocks \((\epsilon_{Yj})\) is as follows:

\[
\epsilon_{YA} = \epsilon_{Yl} \epsilon_{lA} = (f_{l2} - f_{l1}) \frac{l_2}{Y} \epsilon_{lA} \text{ where } A = \{z, \xi\}
\]

This elasticity is equal to the product of two elasticities: the elasticity of output with respect to borrowers’ land \(\epsilon_{Yl2}\) and the elasticity of borrowers’ land with respect to the shock \(\epsilon_{l2A}\). The former elasticity can be replaced by the product of the productivity gap and the ratio of borrowers’ land to total output \(Y\).

Mendicino (2011) stresses the importance of the elasticity of borrowers’ land with respect to the productivity shock and shows that it is inversely related to a downpayment variable that she constructs. When purchasing a unit of land, borrowers can increase their level of debt since their collateral is greater. Hence, the downpayment is just the difference between the price of land and the value of land that is collateralized, so that \(dp = q - \frac{\xi E q'}{R}\). Even though the enforcement constraint differs from the one embedded in Mendicino’s (2011) work, the hump-shape of second-period impulse responses across different values of the enforcement parameter remains as can be seen

---

^6In order to economize space, I do not present results for the baseline model with capital only \((\psi = 0)\). They are available from the author.
The price channel is critical in the amplification of a productivity shock, since both lenders and borrowers want to take advantage of greater marginal productivity levels. Greater aggregate demand for land and inelastic supply contribute significantly to pushing up the price of land. Hence, a greater expected value of the collateral asset leads to more borrowing and a greater share of land allocated to borrowers. The relaxation of the borrowing constraint stimulates borrowing and land reallocation ensues. For a shock of similar size, there is greater output amplification in the event of financial shocks compared to productivity shocks. It also appears that the presence of land developers curtails the effectiveness of the price channel in the short-term for the propagation of productivity shocks, as can be seen in Figure 2.3. Since there is a direct mapping between land prices and the quantity of land, an increase in land demand from borrowing firms results into a greater land price. In order to purchase additional land, this category of firms need to borrow more. However, lending firms only lend if they can sell some of their land at a high price which is not possible because the presence of land developers leads to a greater supply of land. Since land redistribution is minimal, output responses are much smaller than the ones generated by a model that features inelastic land supply. On the other hand, land accumulation gives rise to more persistence of shocks.

As for the effects of financial shocks on output, they are greater in the model with land developers, especially for high enforcement values. This result arises despite decreasing total land supply and land price that are proportional in equilibrium since $\zeta = 1$. In this case, an interest rate channel takes over the price channel that is effective only for productivity shocks. From equation (2.15), it appears that most
Figure 2.3: Amplification effects of the model for which land is the only input ($\psi = 1$) in response to a 1% temporary shock to productivity for which the solid line corresponds to an inelastic land supply and the dashed line to an elastic land supply, and to a 1% temporary financial shock for which the dash-dotted line corresponds to an inelastic land supply and the dotted line to an elastic land supply. Responses are all measured in percentage deviations from their steady state, except for the response of output to a productivity shock that singles out the exogenous amplification, so that results that are depicted correspond to $\frac{Y_2 - 0.01 \Gamma(1,1) - Y}{Y} \cdot 100$. 
changes of the interest rate can be attributed to an expected price growth. In the case of inelastic land supply there is an important land price hike following a credit shock and lenders set a higher interest rate, since they are giving up the opportunity to sell land at a higher price in the next period. Hence, facing greater borrowing costs, borrowers do not borrow as much. The presence of land developers however ensures smoother price shifts and, for some greater values of the enforcement parameter, lower land prices. In periods following the shock, aggregate land drops, but in future periods there is a slow accumulation that takes place. An interest rate that almost does not budge allows more borrowing which leads to more reallocation and an amplification of the output response. Since returns on debt are lower, lenders maintain their consumption by selling land and that explains the lower total quantity of land in the bottom-right panel of Figure 2.3. The lower levels of amplification, for enforcement parameters that approach one, results from the smaller productivity gap between the two types of agents.

2.5.2 Baseline model with elastic labour supply

In this section, I focus on the role of labour markets in accounting for the responses of output to financial shocks exclusively. Jermann and Quadrini (2012) emphasize that the labour wedge (the discrepancy between the marginal rate of substitution between consumption and leisure and the marginal product of labour) is strongly affected by financial shocks, so that labour demand fluctuations are the main contributors to the business cycle. I reexamine whether their results still hold in the presence of a second
factor of production and collateral asset, that is land. Since hours worked can be adjusted contemporaneously, the response of output to shocks is also contemporaneous. However, since there is a one-period lag for land and capital, most effects take place in the period following the shock, so it is more interesting to examine these. With partially non-separable preferences, hours worked increase for borrowers but decrease for lenders following a positive financial shock. Table 2.2 presents the effects of financial shocks on output for various specifications of preferences assuming an enforcement parameter $\bar{\xi} = 0.7$. Labour fluctuations also affect the marginal product of capital and land, but the total effects are small: elastic labour supply contributes only to an increase in the response of output of respectively 20, 15 and 13% for elasticities of substitution of $\zeta = 1, 1/2$ and $1/3$.

As for the sensitivity of results to the elasticity of substitution, augmenting the model with elastic labour supply does not alter the order of importance of responses: a smaller value of $\zeta$ implies a greater response. There appear to be greater income effects, however, for higher values of the enforcement parameter as illustrated in the left panel of Figure 2.4. The importance of real estate can also be assessed by comparing the lower line which corresponds to the model with elastic labour supply but without land. It appears that the contribution of real estate is sizable as it contributes to an additional 53% to the response of output for a Cobb-Douglas production function. Moreover, the response of output increases by an additional 45 and 68% when the elasticity of substitution is cut down to $\zeta = 1/2$ and $1/3$, respectively. Hence, both the inclusion of land in production and the level of complementarity with capital play key roles in driving business cycles.
Figure 2.4: Amplification effects of the baseline model in response to a 1% temporary financial shock with partially non-separable preferences and GHH preferences for the consumption-leisure choice. The solid line corresponds to an elasticity of substitution between land and capital of $\zeta = 1$, the dashed line to $\zeta = 1/2$ and the dash-dotted line to $\zeta = 1/3$. The dotted line corresponds to model with capital as the only asset. Responses are all measured in percentage deviations from their steady state.

<table>
<thead>
<tr>
<th>Preferences</th>
<th>Elasticity of substitution ($\zeta$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inelastic labour supply</td>
<td>1.00                  0.50                  0.33</td>
</tr>
<tr>
<td>Partially non-separable</td>
<td>1.00                  0.50                  0.33</td>
</tr>
<tr>
<td>GHH</td>
<td>1.00                  0.50                  0.33</td>
</tr>
</tbody>
</table>

Table 2.2: Amplification effects of the baseline model in response to a 1% temporary financial shock with different specifications of preferences and elasticities of substitution between land and capital for output for which the enforcement parameter ($\bar{\xi} = 0.7$). Responses are all measured in percentage deviations from their steady state and multiplied by 100.
Non-separable preferences

I also examine the sensitivity of results to allow non-separable preferences. Specifically, I use Greenwood, Hercowitz, and Huffman’s (1988) reduced-form utility function that is derived from an optimization problem with home production:

\[ u(c_{it}, n_{it}) = \frac{1}{1-\sigma} (c_{it} - B_i \chi n_{it})^{1-\sigma}. \]

Results are presented in the right panel of Figure 2.4 for a calibration of \( \chi \) that corresponds to the labour wage elasticity \((\chi - 1)^{-1}\) of 1.7, the value that is considered by GHH. The other parameters \( B_1 \) and \( B_2 \) are calibrated so that in steady-state investors allocate 30\% of their time to work. Since the income effect is dampened, levels of output amplification are enhanced when compared to partially non-separable preferences. Hours worked have a multiplicative effect on output, particularly for high values of the enforcement parameter. My results suggest that the contribution of hours worked to output is sensitive to the specification of the utility function as in this case they contribute to a magnification of output responses by 75, 64 and 62 \% for elasticities of substitution of \( \varsigma = 1, 1/2 \) and \( 1/3 \), respectively, as seen in Table 2.2. As for the importance of real estate, the addition of that asset increases the response of output by 52\%. Finally, lower elasticities of substitution (\( \varsigma = 1/2 \) and \( 1/3 \)) also result in larger output responses as they add factors of 42\% and 64\%, to the Cobb-Douglas production function, assuming a steady-state enforcement parameter of \( \bar{\xi} = 0.7 \).
2.6 Conclusion and extensions

In conclusion, new findings on the role of commercial land in business cycle fluctuations emerge in a framework of endogenous borrowing constraints. First, when land developers can affect commercial land supply, it appears that the price channel emphasized by Kiyotaki and Moore (1997) is no longer effective for the amplification of technology shocks. Second, for sufficiently high enforcement levels, financial shocks generate sizable output responses that are ensured by smooth variations of the interest rate. These responses are also enhanced when we allow for a greater level of complementarity between land and capital. Third, the contribution of labour fluctuations to business cycles is sensitive to the specification of the utility function. Jermann and Quadrini (2012) find that labour demand is a major contributor to business cycle fluctuations. In contrast under similar assumptions regarding preferences and borrowing constraints, my model points to a greater importance of land dynamics and its interactions with capital.

These findings also suggest new directions for the estimation of structural models that focus on financial frictions and land dynamics. In light of my results, it appears that the introduction of financial shocks in the estimation proposed by Iacoviello and Neri (2010) may overshadow the contributions of other shocks. Liu, Wang, and Zha (2011) consider a variance decomposition that include financial shocks in a similar fashion to the ones study in this work. One identification strategy to find the value of the elasticity of substitution between land and capital would be to conduct their Bayesian estimation by setting a prior distribution for this parameter.
Although helpful in identifying an additional source of business cycle fluctuations, the effects of a financial shock bring about a negative correlation between output and land prices that is contrary to stylized facts. This result is due to the ability of firms to sell land to land developers. Future research should focus on this aspect in order to identify mechanisms that would allow land prices to increase following a positive financial shock. Interactions with the residential sector may modify the behavior of this price.
Chapter 3

International Risk Sharing and Land Dynamics

3.1 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 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. Another one is the *international co-movement puzzle*: their model cannot generate positive cross-country correlations in investment and in hours worked that are present in the data. 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.\footnote{The reader should note that throughout this chapter, 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.} Reallocation of land from the productive to the residential sector plays a key role for the mechanism examined in this chapter.

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.

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 labour wedge corresponding to the difference between the marginal rate of substitution between consumption and leisure (MRS) and the marginal product of labour (MPN). Jermann and Quadrini (2012) show that this mechanism helps to generate more volatility in labour demand thereby accounting for a great share of output fluctuations. In this chapter, financial frictions and non-separable preferences result in a labour wedge that is central to replicating the lack of international risk sharing.\(^2\)

Consider the impact of a temporary positive financial shock to the Home country’s borrowing capacity. Since firms have working capital requirements, the labour 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 labour demand schedule shifts up in both countries. Since labour’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, labour 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

\(^2\)Since this labour wedge arises because firms that do not pay wages to the value of their marginal product, it differs from Karabarbounis (2011) who emphasizes the consumption of non-market goods and its effects on the MRS. In order to account for business cycle synchronization, Karabarbounis (2011) sets the correlation of market technology shocks to a sizable level: 0.45, whereas my model relies on endogenous propagation effects to generate synchronization.
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 labour 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.

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 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.

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’s (1994) 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). Another one has been to introduce non-separable preferences between consumption and leisure, see e.g. Devereux, Gregory, and Smith (1992).

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.

The rest of this chapter 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 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.

**3.2 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.\(^3\) I follow the method presented by Ambler, Cardia, and Zimmermann (2004) and proceed to a GMM estimation. In order to

---

\(^3\)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 A.2 for a detailed description of the data.
be consistent with previous studies, all series are logged and de-trended using the Hodrick-Prescott filter.

In panel A of Figure 3.1, 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 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 3.2 presents the percentage of differences between these correlations
that are statistically significant at 10% level. 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

---

4In order to test the significance of differences, correlations undergo a Fisher-z transformation that is the following: \( \rho^* = 0.5 \log \frac{1 + \rho}{1 - \rho} \). The variance of these correlations is then approximated by \( \sigma^2_{\rho^*} = \frac{1}{(N - 3)} \).
CHAPTER 3. INTERNATIONAL RISK SHARING AND LAND DYNAMICS

Figure 3.3: 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.

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 3.3. 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 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.5 As for the evidence of the Backus-Smith puzzle, Corsetti, Dedola, and

5See 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.
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.

3.3 The business-cycle model

The baseline model presented in this chapter augments the incomplete financial markets version of Backus, Kehoe, and Kydland (1994) and the bond economy of Heathcote and Perri’s (2002) 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 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 \( \pi \in (0, 1) \) of households are investors and the remaining \( 1 - \pi \) 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 labour 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 labour 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.

### 3.3.1 Firms

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

\[
y_{it} = A_{it} h_{it-1}^{1-\nu} L_{it}^{\mu} k_{it}^{1-\nu-\mu}
\]  

(3.1)
where factor shares for productive real estate $h_{it-1}^P$ and capital $k_{it-1}$ correspond respectively to $\nu$ and $\mu$. Since the production function exhibits constant return to scale, the share of labour $n_{it}$ 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:

$$G(a_{Ht}, b_{Ht}) = \left[\omega^{\epsilon+1}a_{Ht}^{-\epsilon} + (1 - \omega)^{\epsilon+1}b_{Ht}^{-\epsilon}\right]^{-\frac{1}{\epsilon}}, \quad (3.2)$$

$$G(a_{Ft}, b_{Ft}) = \left[(1 - \omega)^{\epsilon+1}a_{Ft}^{1-\epsilon} + \omega^{\epsilon+1}b_{Ft}^{1-\epsilon}\right]^{-\frac{1}{1-\epsilon}} \quad (3.3)$$

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

$$a_{Ht} + a_{Ft} = y_{Ht}, \quad (3.4)$$

$$b_{Ht} + b_{Ft} = y_{Ft}. \quad (3.5)$$

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.\(^6\)

\(^6\)In the rest of this section, I use firms to implicitly refer to intermediate good firms.
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 $\Psi_{h_{it}}(h_{it}^P, q_{it}, h_{it-1}^P)$ 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:

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

where $\phi_h$ is a parameter chosen to control the level of that cost.\(^7\)

The choice of labour 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:

$$p_{iit} y_{it} + e_{it}^P = d_{it} + x_{it} + q_{it} (h_{it}^P - h_{it-1}^P) + \Psi_{h_{it}} + R_{it-1} e_{it-1}^P + w_{it} n_{it}. \quad (3.6)$$

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 $\Psi_{h_{it}}$ are all made before the revenues are realized, the firm contracts an \textit{intra-period loan} $l_{it}$:

$$l_{it} = R_{it-1} e_{it-1}^P - e_{it}^P + d_{it} + x_{it} + q_{it} (h_{it}^P - h_{it-1}^P) + \Psi_{h_{it}} + w_{it} n_{it}. \quad (3.7)$$

\(^7\)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.
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 $\lambda_{it}$ 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.\footnote{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.} Hence, the recovery value if a default occurs is $\lambda_{it} E_{it}(t_k k_{it} + q_{it+1} h^P_{it})$. Since the total liabilities of the firm are $l_{it} + e_{it}$, in order to prevent any defaults the borrowing constraint is as follows:\footnote{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.}

$$\lambda_{it} E_{it}(t_k k_{it} + q_{it+1} h^P_{it}) \geq l_{it} + e^P_{it}. \quad (3.8)$$

Equation (3.8) can also be expressed as:

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

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 $\bar{V}_{it}(s_{it+1}; k_{it+1}, h^P_{it+1}, e^P_{it+1})$, 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:

$$
V_{it}(s_{it+1}; k_{it+1}, h_{it+1}^P, e_{it+1}^P) = E_{it} \sum_{j=1}^{\infty} m_{it+j}d_{it+j}
$$

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

$$
k_{it} = (1 - \delta)k_{it-1} + \left( \frac{g_1}{1 - \phi_k} \right) \left( \frac{x_{it}}{k_{it-1}} \right)^{1-\phi_k} + g_2 k_{it-1} \tag{3.9}
$$

where $1/\phi_k$ corresponds to the elasticity of investment with respect to Tobin’s $q$ and $\delta$ 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.

**Recursive Formulation of the Firms’ Problem**

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

$$
V(s_i; k_i, x_i, h_i^P, e_i^P) = \max_{d_i, n_i, k_i, h_i^{P'}, e_i^{P'}} \left\{ d_i + E m_i' V(s_i'; k_i', h_i'^{P'}, e_i'^{P'}) \right\} \tag{3.10}
$$

subject to:

$$
q_i h_i^P + Y_i + e_i^{P'} - w_i n_i = d_i + x_i + q_i h_i'^{P'} + \Psi h_i^P + R_i e_i^P,
$$
$$
\lambda_i E(q_i h_i'^{P'} + \epsilon_k k_i') \geq e_i'^{P'} + Y_i,
$$
\[ k'_i = (1 - \delta)k_i + \left( \left( \frac{g_1}{1 - \phi_k} \right) \left( \frac{x_i}{k_i} \right)^{1 - \phi_k} + g_2 \right) k_i. \]

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 \( \vartheta_i \) and \( Q_i \) correspond respectively to Lagrange multipliers on the borrowing constraint and on the capital accumulation equation.

\[ Y_{ni} = \frac{w_i}{1 - \vartheta_i}, \quad (3.11) \]
\[ 1 = Em'_i(R'_i + \vartheta_i), \quad (3.12) \]
\[ q_i + \Psi'_{h_i^P} = Em'_i \left( q'_i + Y_{h_i^P}(1 - \vartheta'_i) + \lambda_i \vartheta_i q'_i + \Psi'_{h_i^P} \right), \quad (3.13) \]
\[ Q_i = g_1 \left( \frac{k_i}{x_i} \right)^{\phi_k}, \quad (3.14) \]
\[ Q_i = \lambda_i x_k \vartheta_i + Em'_i \left( Y_{k_i}(1 - \vartheta'_i) + Q'_i \left[ 1 - \delta + g_2 + g_1 \left( \frac{\phi_k}{1 - \phi_k} \right) \left( \frac{k_i}{k_i} \right)^{1 - \phi_k} \right] \right). \quad (3.15) \]

Equation (3.11) corresponds to the derivative with respect to labour. In a representative agent model without a borrowing constraint, wages would correspond to the marginal product of labour. Working capital requirements create a labour wedge between the marginal rate of substitution between consumption and leisure and the marginal product of labour. A relaxed borrowing constraint leads to lower levels of the Lagrange multiplier \( \vartheta_i \) that directly affect the labour demand schedule. Equation (3.12) refers to a standard Euler equation for a borrowing-constrained model. The Lagrange multiplier \( \vartheta_i \) also affects the inter-temporal substitution of consumption as
CHAPTER 3. INTERNATIONAL RISK SHARING AND LAND DYNAMICS

the marginal utility of consumption decreases while the borrowing constraint is relaxed. Equations (3.13-3.15) show real estate and capital dynamics and highlight the importance of capital and land as collateral.

3.3.2 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:

$$s_{it}(d_{it} + p_{it}^s) = c_{it}^p + p_{it}^s s_{it+1}$$

(3.16)

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:

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

(3.17)

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: $m_{it+1} = \gamma E_t u_c(d_{it+1})/u_c(d_{it})$. 
3.3.3 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 \( i = \{H, F\} \).

\[
E_0 \sum_{t=0}^{\infty} \beta_i^t U(c_{it}^W, h_{it}^W, n_{it})
\]

where

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

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’s (1991) approach and render the discount factor endogenous\(^{10}\) as follows

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

At the beginning of each period, workers have a housing stock \( h_{it}^W \) and bond

\(^{10}\)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.
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 $Z_tR_{t-1}f_{Ht-1}$. 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:

$$R_{Ht-1}e_{Ht-1}^W + Z_tR_{t-1}f_{Ht-1} + w_{Ht}n_{Ht} = c_{Ht}^W + q_{Ht}Δh_{Ht} + Ψ_{h_{Ht}}^W + e_{Ht}^W + Z_tf_{Ht}. \quad (3.19)$$

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

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

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.

**Workers’ First Order Conditions**

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

$$\frac{U_{Ht}^W}{E_t(U_{Ht+1}^W)} = \frac{β_{Ht} U_{Ft}^W}{β_{Ft} E_t(U_{Ft+1}^W)} E_t(Z_{t+1}) Z_t, \quad (3.20)$$

$$E_t \left( \frac{Z_t}{Z_{t+1}} R_{Ht} \right) = R_{Ft} = R_t, \quad (3.21)$$
\[
\zeta_{it}^{w-1} = w_{it}, \tag{3.22}
\]
\[
U_{cw_{it}}\left(q_{it}U_{h_{it}}^{W} + \Psi_{h_{it}}^{W}\right) = \beta_{it}E_t\left(U_{cw_{it+1}}\right)\left(q_{it+1}U_{h_{it+1}}^{W} + \Psi_{h_{it+1}}^{W}\right). \tag{3.23}
\]

The combination of first order conditions with respect to consumption and to the international bond for both Home and Foreign workers leads to equation (3.20). 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 \(\beta_{Ht}\) and \(\beta_{Ft}\) 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 (3.21), it results from the combination of first order conditions for the international and inter-period bonds. Equation (3.22) refers to labour supply. In contrast with logarithmic preferences, consumption does not show up with GHH preferences, so that income effects are dampened. Finally, the fourth condition (3.23) 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.

### 3.3.4 Shocks

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

\[
\Omega_t = \Gamma\Omega_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \Sigma) \tag{3.24}
\]
where $\Omega_t = [A_{Ht}, A_{Ft}, \lambda_{Ht}, \lambda_{Ft}]'$ and $\varepsilon_t = [\varepsilon_{A_{Ht}}, \varepsilon_{A_{Ft}}, \varepsilon_{\lambda_{Ht}}, \varepsilon_{\lambda_{Ft}}]'$. Elements off the diagonal in matrix $\Gamma$ are defined as spill-overs. The variance-covariance matrix is given by: $E(\varepsilon_t \varepsilon_t') = \Sigma$.

### 3.3.5 Market Clearing

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

$$e^P_{it} + e^W_{it} + x_{it} = G(a_{it}, b_{it}) \text{ where } i = \{H, F\}. \quad (3.25)$$

$$ (1 - \varpi)e^P_{it} + \varpi e^W_{it} = 0 \quad (3.26)$$

The international bonds market clearing condition is:

$$Z_t f_{Ht} + f_{Ft} = 0, \quad (3.27)$$

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

$$h^P_{it} + h^W_{it} = 1. \quad (3.28)$$
3.3.6 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 $c^W_i(s), n_i(s), h^W_i(s), f_i(s), e^W_i(s)$;
(ii) investors’ policies $c^P_i(s)$
(iii) firms’ policies $d(s; k, h^P, e_i), l(s; k, h^P, e_i), k(s; k, h^P, e_i), h^P(s; k, h^P, e^P_i)$ and $e^P_i(s; k, h^P, e^P_i)$;
(iv) firms’ value $V(s; k, h^P, e^P_i)$;
(v) aggregate prices for each country $w(s), R(s), R_i(s), p_{ii}(s), p_{ij}(s), P_i(s), q(s)$
and $m(s, s')$;
(vi) law of motion for the aggregate state $s' = \Psi(s)$.

Such that:

(i) workers’ policies satisfy conditions (3.20-3.23);
(ii) investors’ policies satisfy conditions 3.17;
(iii) firms’ policies are optimal and $V(s; k, h^P, e^P_i)$ satisfies the Bellman’s equation (3.10);
(iv) the wage, interest rates and prices clear the labour, bond markets, housing markets ($h^P + h^W = 1$), goods markets (3.4) and (3.5), and $m(s, s') = \gamma U_{c^P}/U_{c^P}$;
(v) the resource constraint (3.25) 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 $\lambda_i$.

3.3.7 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, \( p_{Ht} \) corresponds to the price of good \( a \) in the Home country with \( i = \{ H, F \} \)

\[
p_{Ht} = \frac{\partial G(a_{it}, b_{it})}{\partial a_{it}}, \quad p_{Ft} = \frac{\partial G(a_{it}, b_{it})}{\partial b_{it}}.
\]  

(3.29)

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

\[
P_{Ht} = \left( \omega p_{HHt} + (1 - \omega)p_{FFt} \right)^{1+\epsilon}
\]  

(3.30)

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:

\[
TOT_t = \frac{p_{FHt}}{p_{HT}} = \frac{1 - \omega}{\omega} \left( \frac{a_{Ht}}{b_{Ht}} \right)^{1+\epsilon}
\]  

(3.31)

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\(^{11}\)

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

\(^{11}\)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.
3.3.8 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 comprises values for housing services. Therefore, in order for my statistics to be compared to data, I follow Davis and Heathcote’s (2005) 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 $\xi_{it}$.

\[
\xi_{it} = \frac{U_{hW_{it}}(c_{it}^W, l_{it}, h_{it}^W)}{U_{cit}(c_{it}^W, l_{it}, h_{it}^W)}
\]  

(3.32)

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

\[
PCE_{it} = c_{it}^P + c_{it}^W + \xi_{it} h_{it}^W,
\]

\[
GDP_{it} = Y_{it} + \xi_{it} h_{it}^W.
\]

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 (3.32) 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.

3.4 Calibration

3.4.1 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 A.2.

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

\[
Y_{it} = \frac{A_{it}h_{it-1}^{\nu}k_{it-1}^{\mu}n_{it}^{1-\nu-\mu}}{(\omega + (1 - \omega)TOT_{it})^{\frac{\epsilon}{1+\epsilon}}},
\]

(3.33)

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

\[
\hat{A}_{it} = \left(\omega + (1 - \omega)(1 + TOT_{it}(\frac{\epsilon}{1+\epsilon}))\right)^{\frac{1+\epsilon}{\epsilon}}(1 + \bar{Y}_{it}) - 1 - \nu\hat{h}_{it-1}^{\nu} - \mu\hat{k}_{it-1}^{\mu} - (1 - \nu - \mu)\hat{n}_{it}.
\]

(3.34)

\[\text{12Since } Y_{it} = \frac{p_{it}}{P_{it}}y_{it}, \text{ I substitute the denominator by equation (3.30) and divide both the numerator and denominator by } p_{it}, \text{ so that the terms of trade appear in equation (3.33).}\]
where $\hat{TOT}_{it}$, $\hat{Y}_{it}$, $\hat{hP}_{it}$, $\hat{k}_{it}$ and $\hat{m}_{it}$ are log-deviations from a linear trend of their respective variables. For example, $\hat{Y}_{it} = \log(Y_{it}) - \hat{\beta}_0 - \hat{\beta}_1 t$ where $\hat{\beta}_0$ and $\hat{\beta}_1$ are estimated from an OLS regression.\(^{13}\)

As for the financial shocks, I assume that the borrowing constraint (3.8) always binds,\(^{14}\) so that in the steady state it is described by:

$$\bar{\lambda}(\bar{t_k}\bar{k} + \bar{q}\bar{hP}) = \bar{\epsilon} + \bar{Y}.$$  

The log-linearization of this constraint results in:

$$\hat{\lambda}_{it} \approx \alpha_k \hat{k}_{it} + \alpha_h \left(E_t \hat{q}_{it+1} + \hat{hP}_{it}\right) + \alpha_e \hat{\epsilon}_{it} + \alpha_Y \hat{y}_{it}. \quad (3.35)$$

where $\alpha_k = \frac{-t_k}{t_k \bar{k} + \bar{q}\bar{hP}}$, $\alpha_h = \frac{-\bar{q}}{t_k \bar{k} + \bar{q}\bar{hP}}$, $\alpha_Y = \frac{\bar{Y}}{\bar{Y} + \bar{\epsilon}}$ and $\alpha_e = \frac{\bar{\epsilon}}{\bar{Y} + \bar{\epsilon}}$. For the construction of the financial shocks in equation (3.35), the data is available for all variables with the exception of the expected value of next period’s land price $E_t \hat{q}_{it+1}$.

I assume that agents base their expectations on contemporaneous land prices, so that: $E_t \hat{q}_{it+1} = \rho_q \hat{q}_{it}$. I estimate $\hat{q}_{it} = \rho_q \hat{q}_{it-1} + \epsilon_{it}$ by OLS and use the estimated value for the persistence parameter $\hat{\rho}_q = 0.645$ to generate a series for $E_t \hat{q}_{it+1} = \hat{\rho}_q \hat{q}_{it}$. When I estimate the model, I make sure that this level of persistence is consistent with the data generated by the model.

In Table 3.1, I report the results of the maximum likelihood estimation of equation

\(^{13}\)Note that variations in terms of trade only contribute to a tiny fraction of the estimated Solow residual.

\(^{14}\)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 3.1: Parametrization of shock processes

<table>
<thead>
<tr>
<th>Type of Shock Processes</th>
<th>Shock Process</th>
<th>( \hat{\Gamma} )</th>
<th>( \hat{\sigma}_\lambda )</th>
<th>( \hat{\rho}_\lambda )</th>
</tr>
</thead>
</table>
| Symmetric Technology shocks | (1) | \[
\begin{bmatrix}
0.868 & 0.022 & 0 & 0 \\
0.022 & 0.868 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
\end{bmatrix}
\] | 0.0055 | 0.31 |
| Financial shocks | (2) | \[
\begin{bmatrix}
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0.942 & 0.038 & 0.942 \\
0 & 0.058 & 0.038 & 0.942 \\
\end{bmatrix}
\] | 0.0054 | 0.31 |
| Both shocks | (3) | \[
\begin{bmatrix}
0.781 & 0.077 & -0.086 & 0.062 \\
0.077 & 0.781 & 0.062 & -0.086 \\
-0.091 & 0.113 & 0.914 & 0.074 \\
0.113 & -0.091 & 0.074 & 0.914 \\
\end{bmatrix}
\] | 0.0053 | \[
\hat{\rho} = \begin{bmatrix}
1.00 \\
0.317 & 1.00 \\
0.678 & 0.341 & 1.00 \\
0.341 & 0.678 & 0.374 & 1.00 \\
\end{bmatrix}
\] |

I perform a joint test for symmetry of the shocks processes parameters. For shock process (1), \( H_0: \gamma_{1,1} = \gamma_{2,2}, \gamma_{1,2} = \gamma_{2,1} \) and \( \sigma_{\lambda H} = \sigma_{\lambda F} \). For (1), I cannot reject the null hypothesis at 5% from a Lagrange multiplier test such that \( \chi^2(3) = 0.8 \). For shock process (2), \( H_0: \gamma_{3,3} = \gamma_{4,4}, \gamma_{3,4} = \gamma_{4,3} \) and \( \sigma_{\lambda H} = \sigma_{\lambda F} \). For (2), I reject the null hypothesis with a p-value lower than 0.001, such that \( \chi^2(3) = 302.52 \). For (3) I reject the null hypothesis with a p-value lower than 0.001, such that \( \chi^2(12) = 201.8 \). The symmetry joint tests for (3) have \( H_0: \gamma_{1,1} = \gamma_{2,2}, \gamma_{3,3} = \gamma_{4,4}, \gamma_{1,2} = \gamma_{2,1}, \gamma_{1,3} = \gamma_{2,4}, \gamma_{1,4} = \gamma_{2,3}, \gamma_{3,1} = \gamma_{4,2}, \gamma_{3,2} = \gamma_{4,1}, \gamma_{3,4} = \gamma_{4,3} \), \( \sigma_{\lambda H} = \sigma_{\lambda F}, \sigma_{\lambda H} = \sigma_{\lambda F}, \rho_{1,3} = \rho_{2,4} \) and \( \rho_{1,4} = \rho_{2,3} \).
(3.24) from which shocks are derived from equations (3.34)-(3.35). 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.

### 3.4.2 Preferences and technology parameters

In Table 4.1, 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’s (1990) findings that half of households face borrowing constraints.\textsuperscript{15} 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’s (2009) 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 $\nu$ 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 labour, $\tau$ is set so that working hours correspond to 30\% of total time. For the parameter that controls the elasticity of labour, $\eta$, I set it equal to 1.58, so that it corresponds to an inter-temporal elasticity of labour of 1.7 that is the value used by Greenwood, Hercowitz, and Huffman (1988). However, the Frisch elasticity of labour depends on steady state

\textsuperscript{15}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).
values and is as follows

\[
\eta^n = \frac{1}{\bar{n} \left( (\eta - 1)\bar{n}^{-1} + \frac{\bar{\eta}^{\eta - 1}}{\bar{c}^W - \bar{\eta}\bar{n}^\gamma} + (\bar{c}^W - \bar{\eta}\bar{n}^\gamma) (h^W) \right)}.
\]

(3.36)

In my model the Frisch elasticity of labour supply is equal to 0.31. The discount factor for workers is standard in the literature and \(\varsigma_W\) is set so that \(\beta\) is equal to 0.99 in the steady state, corresponding to an annual real interest of 4\%. The discount factor for investors \(\gamma\) 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 \(\delta\) 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 labour is 0.64 as is standard in the literature.

International parameters are set in accordance with Heathcote and Perri (2002), since \(\omega\) 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.\(^{16}\) 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 \(\omega\) is set to 0.85, so that imports correspond to 15\% of output, a value that

\(^{16}\)See Bodenstein (2011) for a discussion on the different values this parameter has taken in the literature.
also corresponds to the average for the United States from 1988 to 2007.

### 3.4.3 Simulated Method of Moments

All parameters described in sub-section (3.4.2) 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 $\varrho$ 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 variables: output, labour 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 $\iota_k$ are also parameters that enter the construction of these shocks. Moreover, the labour wedge created by financial shocks is picked because it is shown that it can help resolve some open economy puzzles. Finally, the parameters $\phi_k$ and $\phi_h$ 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 $\varrho$ solves

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

(3.37)
Table 3.3: Estimated parameters

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value (1)</th>
<th>Value (2)</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\lambda$</td>
<td>-0.25</td>
<td>-0.1965</td>
<td>enforcement parameter</td>
</tr>
<tr>
<td>$\eta_k$</td>
<td>-0.6</td>
<td>0.15</td>
<td>fraction of capital collateralized</td>
</tr>
<tr>
<td>Adjustment Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\phi_k$</td>
<td>0.01</td>
<td>0.12</td>
<td>capital adjustment cost</td>
</tr>
<tr>
<td>$\phi_h$</td>
<td>0</td>
<td>0.08</td>
<td>real estate adjustment cost</td>
</tr>
</tbody>
</table>

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.

The matrix $W$ is a $4 \times 4$ 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 $\varrho$ are summarized in Table 3.3. Moments of the baseline model are much more precisely estimated for the baseline model than for the representative-agent model. The estimate of $\lambda$ 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 $\eta_k$, 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 chapter 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 $\phi_h$ 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%.

3.5 Results of the business cycle estimation

3.5.1 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 3.4-3.5. It should be noted that the size of the various effects described below hinge on the parametrization.$^{17}$

---

$^{17}$All simulations have been performed with DYNARE 4.1.1.
Figure 3.4: Impulse responses to a 1% temporary Home technology shock: Home (solid line) Foreign (dashed 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 3.5: Impulse responses to a 1% temporary Home financial shock: Home (solid line) Foreign (dashed 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.
CHAPTER 3. INTERNATIONAL RISK SHARING AND LAND DYNAMICS

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 (3.8), 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*.

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 \(b\).

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 (3.20):

\[
E_t \left( \Delta \left( c^{W}_{Ht+1} - \frac{\zeta \eta}{\eta} n^{\eta}_{Ht+1} \right) \right) = \frac{\beta_{Ht}}{\beta_{Ft}} E_t \Delta Z_{t+1}. \tag{3.38}
\]

\[
E_t \left( \Delta \left( c^{W}_{Ft+1} - \frac{\zeta \eta}{\eta} n^{\eta}_{Ft+1} \right) \right) = \frac{\beta_{Ht}}{\beta_{Ft}} E_t \Delta Z_{t+1}. \tag{3.39}
\]

I go a step further and substitute \(\zeta n^{\eta}_{Ht}\) and \(\zeta n^{\eta}_{Ft}\) from firms’ labour demand conditions (3.11) and workers’ labour supply (3.20) in equation (3.38), so that:

\[
E_t \left( \Delta \left( c^{W}_{Ht+1} - \frac{(1 - \nu - \mu)}{\eta} Y_{Ht+1}(1 - \vartheta_{Ht+1}) \right) \right) = \frac{\beta_{Ht}}{\beta_{Ft}} E_t \Delta Z_{t+1}. \tag{3.39}
\]

\(^{18}\)Results for which countries do not specialize in the production of a good are presented in Appendix A.3.
Since firms face working capital requirements, wages are not equal to the marginal product of labour. Hence, the labour wedge (the difference between the marginal rate of substitution between consumption and leisure and the marginal product of labour) 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, summarized by Lagrange multipliers $\vartheta_H$ and $\vartheta_F$, 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 A.1. 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.

**Financial shocks**

In an environment in which firms face working capital requirements, financial shocks directly affect the labour wedge to a much greater extent than technology shocks. From the impulse response to a temporary Home positive shock presented in Figure 3.5, 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 labour 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 labour demand increases and, since labour 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 (3.39), financial shocks significantly affect Lagrange multipliers $\vartheta_{Ht}$ and $\vartheta_{Ft}$. 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
3.5.2 Quantitative analysis

Baseline model

Table 3.4 reports the moments generated by a model for which the embedded shock processes are calibrated according to Table 4.2. 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 labour 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
### Table 3.4: Business cycle statistics

<table>
<thead>
<tr>
<th>Model: Baseline</th>
<th>without real estate</th>
<th>Rep.-agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shocks: Data</td>
<td>Tech. Both</td>
<td>Both Tech.</td>
</tr>
<tr>
<td>% Standard deviations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP</td>
<td>1.09</td>
<td>0.86</td>
</tr>
<tr>
<td>Standard deviations relative to GDP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>3.62</td>
<td>2.37</td>
</tr>
<tr>
<td>Hours worked</td>
<td>0.95</td>
<td>0.53</td>
</tr>
<tr>
<td>Prod. real estate ( (q_t h_t^P) )</td>
<td>3.67</td>
<td>1.75</td>
</tr>
<tr>
<td>Domestic Co-movement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Exports/GDP</td>
<td>-0.41</td>
<td>-0.36</td>
</tr>
<tr>
<td>International Correlations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( GDP_{US}, GDP_{UK} )</td>
<td>0.69</td>
<td>0.67</td>
</tr>
<tr>
<td>( PCE_{US}, PCE_{UK} )</td>
<td>0.61</td>
<td>0.64</td>
</tr>
<tr>
<td>( X_{US}, X_{UK} )</td>
<td>0.34</td>
<td>0.56</td>
</tr>
<tr>
<td>( N_{US}, N_{UK} )</td>
<td>0.62</td>
<td>0.69</td>
</tr>
<tr>
<td>Backus-Smith puzzle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( E(\Delta PCE_{US}/PCE_{UK}), E(\Delta Z) )</td>
<td>-0.32</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

Statistics in the first column for the **volatility** and **domestic co-movement** sections are calculated from US time series described in Appendix A.2 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 3.4. 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.
When financial shocks are added, the gap between wages and the marginal product of labour becomes narrower, so that firms increase their labour demand as it can be seen in the column 3: volatilities of hours worked and of the labour 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.\(^{20}\) The correlation between expected growth in real exchange rates and in relative consumptions remains negative.

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 3.4. In this case, the firm’s borrowing simply consists of \(e^{p}_{it} + Y_{it} \leq \lambda_{it}k_{it}\). 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

\(^{19}\)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.

\(^{20}\)However, it is not that far away from the average gap of industrialized country pairings.
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.

Sensitivity analysis

I perform a sensitivity analysis of within-country and international business cycle statistics to changes in key parameters. Table 3.5 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 $\epsilon$. As mentioned earlier in the chapter, there is no consensus in the literature on the exact value this parameter should take. A first observation that is not shown in Table 3.5 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
Table 3.5: Sensitivity analysis statistics

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

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 A.2 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 \( \lambda = 1,600 \).
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 rate volatilities. Alternatively, the mechanism that drives the results of this chapter 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 $\phi_h$. 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 3.6, I show the sensitivity of the Backus-Smith puzzle to parameter $\phi_h$. Following a positive financial shock, firms purchase real estate from workers, but as $\phi_h$ increases it is more costly to reallocate land. Hence, they substitute real estate for labour 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 labour wedge is not as important and hours worked drop from their first-period level. The movements in labour 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’s (2005) 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
Figure 3.6: The correlation between the expected growth in real exchange rates and in relative consumptions for different calibrated values of the real estate adjustment cost $\phi_h$.

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 and real estate $\tau_k = 1$ 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.
3.6 Conclusion and extensions

In this chapter, 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 \textit{quantity anomaly} and (iii) the international risk sharing implications for international prices: the \textit{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 \textit{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).

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.
Chapter 4

Wedges and International Risk Sharing

4.1 Introduction

The ratio of the sum of foreign assets and liabilities over GDP for industrial countries has grown exponentially in the past decades. In 2007, it has reached levels that were over 6.5 times greater than in 1970.\textsuperscript{1} Greater financial integration certainly brings about more opportunities for countries to share risk, but have these opportunities been seized? There are welfare implications to better international risk sharing. Among a set of 20 OECD countries, Van Wincoop’s (1994) findings point out that the lack of international risk sharing implies as much as 1.8% to 5.6% permanent cutbacks in consumption.

\textsuperscript{1}The ratio is compiled by the author from data made available by Lane and Milesi-Ferretti (2007) for Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.
One objective of this chapter is to incorporate the measure of bilateral risk sharing introduced by Viani (2011) into a business cycle accounting exercise à la Chari, Kehoe, and McGrattan (2007). They identify four distortions from a standard closed-economy real business cycle model that they call “wedges”. In addition to efficiency, labour, investment and government consumption wedges, the international wedge examined in this chapter corresponds to Viani’s (2011) measure of the gap between countries’ stochastic discount factors (SDFs). This wedge can be the result of time-varying frictions in the international financial markets such as borrowing constraints or international portfolio adjustment costs.

Since fluctuations of international prices are important to account for international risk sharing, the baseline model that I use is the two-country, two-good model of Backus, Kehoe, and Kydland (1994) with the addition of wedges in a complete asset market environment. Hence, in similar fashion to CKM, four wedges per country are identified by feeding the model with data on investment, consumption, government expenditures and total hours worked and finally, the international wedge with data on the real exchange rate. Larger deviations of the growth in the ratio of marginal utilities growth to that of the real exchange rate imply that the degree of international risk sharing is lower. The metric that I consider is the volatility of this wedge computed for different time windows.

I compare this volatility measure for separable and non-separable preferences in leisure and in consumption and observe that it leads to very different conclusions as to whether bilateral risk sharing has improved or not. Over the period from 1961 to
1987 for the pairing of Canada and the United States, assuming separable preferences implies a decline in the level of bilateral risk sharing whereas assuming non-separable preferences implies the reverse. For the recent time period, from 2003:Q1 to 2007:Q4, an interesting finding is that the sharp appreciation of the Canadian dollar vis-à-vis the US dollar causes bilateral risk sharing to decrease quite dramatically, so that leads to important welfare losses.

A second objective of this chapter is to investigate if wedges besides the international wedge can help to explain the Backus-Smith puzzle. If separability of preferences is assumed, the ratio of marginal utilities is proportional to relative consumptions. However, in the data these two ratios are negatively correlated. This puzzle is intimately related to international risk sharing as Corsetti, Dedola, and Leduc (2008) show that this negative correlation results in a lower degree of insurance across countries. In fact, if movements in the real exchange rate match those of the ratio of SDFs that implies perfect bilateral risk sharing. One main finding is that the introduction of an investment wedge plays a role in lowering the correlation between the real exchange rate and the ratio of consumptions. Investment wedges resemble time-varying taxes in the prototype model, that are a reduced-form of frictions that affect capital markets. Investment-specific technology and financial shocks can also contribute to this category of wedge. This result also contrasts with CKM’s findings for a closed-economy: they estimate that most fluctuations in output during the Great Depression and the 1982 recession were driven by downturns of the efficiency and labour wedges whereas investment wedges are found to be negligible for these episodes.

Since the frequency of the data I use for the accounting exercise is at business cycle levels, so is the frequency of the risk sharing index that I construct, i.e. between
8 and 32 quarters. The main objective of early work on international risk sharing revolves around testing hypotheses that countries’ participation in international financial markets have allowed them to insure their consumption against idiosyncratic shocks. For example, in order to account for low cross-country correlation in consumption, Lewis (1996) tests the significance of both non-separabilities in tradable and non-tradable goods and imperfect financial markets. When the two hypotheses are tested separately they are rejected, however when they are tested jointly they cannot be rejected.

The indices proposed by Brandt, Cochrane, and Santa-Clara (2006) and Flood, Marion, and Matsumoto (2012) do not allow for any movements in international prices that can provide additional insurance to idiosyncratic shocks (see Cole and Obstfeld, 1991). Viani (2011) demonstrates how these indices are flawed by simulating a two-good, two-country model with different asset market structures. For some values of the elasticity of substitution between the Home and the Foreign good, these indices predict that there is more risk sharing under financial autarky than under complete asset markets. Hence, she proposes an alternative bilateral index that is the volatility of the difference between real exchange rate growth and the SDFs ratio that I call the international wedge. This wedge is a product of many factors that affect international financial frictions. Viani (2011) also shows theoretically from a social planner’s problem that larger deviations from SDFs imply greater welfare losses. In her baseline model, there is no investment nor labour, so that output fluctuations emanate solely from endowment shocks. I adapt her method to a two-good international real business cycle framework with wedges that correspond to the ones that CKM derive.
The addition of labour to Viani’s (2011) model allows us to examine the differences in indices that the assumption of separable and non-separable preferences imply, since marginal utilities diverge. The literature is not conclusive on the role of non-separabilities between consumption and leisure in explaining the lack of international risk sharing. The findings of regressions that are performed by Lewis (1996) and Bai and Zhang (2012) suggest otherwise as movements in leisure can only explain a tiny fraction of the movements in tradable consumption. However, in their estimations leisure is proxied by employment-based measures that display a much smaller variability than consumption and they do not take non-linearities into consideration in their regressions.\footnote{From data that ranges from 1985 to 1992, Lewis (1996) uses the unemployment rate that has a variability that corresponds to only one sixth of consumption’s.} The data for labour that I use is the newly constructed series of total hours provided by Ohanian and Raffo (2012). This data implies a variability of leisure that is on average 20\% greater than that of consumption’s for OECD countries from 1985:Q1 to 2007:Q4.

In a complete asset market environment and in the absence of the international wedge, separable preferences and similar discount factors imply that the real exchange rate, defined as the product of the nominal exchange rate, \( e_n^t \), and the Foreign price index, \( p_t^* \), over the Home price index \( p_t \) is proportional to the ratio of Home consumption \( c_t \) over Foreign consumption \( c_t^* \), i.e. \( e_n^t p_t^* p_t \propto c_t / c_t^* \). Backus and Smith (1993) point out that these theoretical results are inconsistent with the data, since most real exchange rates are negatively correlated with consumption ratios. This negative correlation also suggests that international prices do not play any insurance role as the outcome is pushed farther away from the social optimum. Corsetti, Dedola, and Viani (2012) reassess the Backus-Smith puzzle from a spectral decomposition and show that
is more prevalent at business cycle and frequencies lower than two years. The role of non-tradable goods to account for that puzzle has been examined extensively in the literature and some studies have had some success, notably Corsetti, Dedola, and Leduc (2008) and Benigno and Thoenissen (2008).

I investigate whether a different type of non-separability, the one between consumption and leisure can account for the puzzle. Following Devereux, Gregory, and Smith (1992), Raffo (2010) uses GHH non-separable preferences and finds that investment-specific technology shocks can help to explain the Backus-Smith puzzle. The model introduced in Chapter 3 also shows that credit shocks to the fraction that firms can borrow against the value of their collateralized assets substantially affect international risk sharing. Karabarbounis (2011) introduces a non-separable utility function in market-produced and in home-produced consumption goods in his two-sector framework. From his estimation of technology shocks for both sectors, his model is able to match various international moments and the negative correlation between real exchange rates and the ratio of consumptions. Bengui, Mendoza, and Quadrini (2012) develop a framework to identify the size of a portfolio adjustment cost parameter that minimizes the distance between tradable consumption in the data and the same series that is generated by their model. From pairings of emerging markets and advanced countries with their own aggregate of the rest of the world, they identify a parameter that is, for many countries, so high that it corresponds to financial autarky. In fact, if that parameter were to be time-varying it would resemble the international wedge that I construct.

Finally, this chapter is closely related to Otsu (2009) that performs an international business cycle accounting exercise for Japan and the United States. Contrary
CHAPTER 4. WEDGES AND INTERNATIONAL RISK SHARING

to my work, the focus of his work pertains to the identification of wedges that affect the synchronization of output across these two countries. Two international wedges are added to CKM’s prototype model: the international price wedge and the international trade wedge. The former wedge resembles the international wedge introduced in my framework, however, since there is only one good in his baseline model, real exchange rate movements are captured by this wedge. Therefore, its variability is not a good indicator of the degree of international risk sharing.

The rest of this chapter is organized as follows. In section 2, I present the diagnostic framework that simply adds some international layers to CKM. In section 3, I discuss data issues and estimate the process that drives the wedges. In section 4, I analyze the trend of the index that I construct under various specifications and I evaluate which types of wedges contribute the most to account for the Backus-Smith puzzle. Section 5 concludes and considers potential extensions to the baseline model.

4.2 The diagnostic framework

The prototype model is based on Backus, Kehoe, and Kydland (1994) in a complete asset market environment. In order to simplify the notation, I describe the problems from the perspective of the Home economy. There are four stochastic variables per country: the efficiency wedge $z(s')$, the labour wedges $1 - \tau^s_l(s')$ and $1 - \tau^n_l(s')$ for separable and non-separable preferences, the investment wedge $1/(1 + \tau_x(s'))$ and the government consumption wedge $G(s')$. I estimate the international wedge as a growth rate differential between international bond taxes of each country: $\tau_{iw}(s') =$
\[ \Delta(\tau_f(s^t) - \tau_f^*(s^t)) \]. In each country, there are firms that specialize in the production of intermediate goods for which capital and labour are inputs. Since they are imperfect substitutes, these goods are combined by final good producers to form expenditure goods that can be used for consumption (households and governments) and investment. The households, intermediate and final good producers and government’s problems and stochastic processes of the wedges follows.\(^4\)

4.2.1 Households

The history of wedges that have been realized in the past periods is summarized by \( s^t = (s_0, ..., s_t) \) where \( s_0 \) is given and \( s_t \) corresponds to the wedges in period \( t \). The probability of a state to occur is \( \pi(s_t) \). Households optimize their period utility and their expected utility value discounted by factor \( \beta_t \) by picking their consumption \( c_t \) and hours worked \( l_t \) levels, as follows:

\[
E_0 \sum_{t=0}^{\infty} \sum_{s^t} \pi(s_t) \beta_t u(c(s^t), l(s^t)) N_t,
\]

and

\[
\text{iu}(c(s^t), l(s^t)) = \begin{cases} 
\frac{c(s^t)^{1-\sigma}}{1-\sigma} - \frac{\psi_s \eta_s}{1 + \eta_s} l(s^t)^{1+\eta_s}, & \text{if separable, and} \\
\frac{1}{1-\sigma} \left( c(s^t) - \frac{\psi_n \eta_n}{1 + \eta_n} l(s^t)^{1+\eta_n} \right)^{1-\sigma} & \text{if non-separable.}
\end{cases}
\] (4.1)

where \( \sigma \) corresponds to the inverse of the intertemporal elasticity of substitution, \( \psi_s \) and \( \psi_n \) are measures of the disutility of working, \( \eta_s \) corresponds to the labour Frisch

\(^4\)Lowercase letters denote per capita levels of variables.
elasticity, and $\eta_n$ is a parameter that controls the labour wage elasticity. The size of
the Home country is denoted by its population level $N_t$ that grows at rate $1 + \gamma_n$. i

Households face the following budget constraint (where $j = \{s, n\}$):

$$
\begin{align*}
& p(s^t) \left[ c(s^t) + (1 + \tau_x(s^t)) x(s^t) \right] \\
+ & p_H(s^t) \sum_{s^{t+1} \mid s^t} q(s^{t+1} | s^t) f_s(s^{t+1}) (1 + \gamma_n) \leq p(s^t) \left[ (1 - \pi_f(s^t)) w(s^t) l(s^t) + r^k(s^t) \frac{k_{s^t-1}}{1 + \gamma_n} \right] \\
+ & p_H(s^t) \left( 1 + \tau_f(s^t) \right) f(s^t) + p(s^t) tr(s^t),
\end{align*}
$$

(4.2)

and the law of motion for capital corresponds to:

$$
k(s^t) = (1 - \delta) \frac{k(s^t-1)}{1 + \gamma_n} + x(s^t)
$$

(4.3)

where $p(s^t)$ corresponds to the price of the Home final good, $p_H(s^t)$ is the price of
the Home intermediate good, $q(s^{t+1} | s^t)$ is the price of state-contingent claims, $x(s^t)$
is investment, $k(s^t)$ is capital, $\delta$ is the depreciation rate, $f(s^t)$ is the amount of the
international bond, $w(s^t)$ is wages, $r(s^t)$ is the lending rate of that bond, $r^k(s^t)$ is
the rental rate of capital and $tr(s^t)$ is lump-sum transfers from the government. Note
that for Foreign households their holdings of the Foreign bond is also priced in terms
of the Home intermediate good.
4.2.2 Firms

Since real exchange rate movements are important to assess the level of international risk sharing, my model features two goods and two types of firms: final and intermediate good producers.

Final good producers

Home final good producers purchase intermediate good $A(s^t)$ which is produced by Home and intermediate good $B(s^t)$ which is produced by Foreign and sold at the price of $p_F(s^t)$ per unit in the Home economy. They maximize profits:

$$
\max_{Y(s^t), A(s^t), B(s^t)} p(s^t) Y(s^t) - p(s^t) A(s^t) - p_F(s^t) B(s^t)
$$

subject to the Armington aggregator or production function:

$$
Y(s^t) = [\omega^{\epsilon+1} A(s^t)^{-\epsilon} + (1 - \omega)^{\epsilon+1} B(s^t)^{-\epsilon}]^{-\frac{1}{\epsilon}}
$$

(4.4)

where $\omega \in (0, 1)$ corresponds to home bias in production and $\epsilon$ controls the elasticity of substitution between Home and Foreign intermediate goods.
Intermediate goods producers

Home intermediate goods producers hire Home households and rent capital to produce and sell their production to Home and Foreign good producers.

\[
\max_{L(s^t), K(s^t)} p_H(s^t)[A(s^t) + A^*(s^t)] - p(s^t) \left[ w(s^t)L(s^t) + r^k(s^t) \frac{K(s^t-1)}{1 + \gamma_n} \right]
\]

(4.5)

subject to production function:

\[
A(s^t) + A^*(s^t) = e^{Z(s^t)} \left( \frac{K(s^t-1)}{(1 + \gamma_n)} \right)^\theta (1 + \gamma_z)^t L(s^t)^{(1-\theta)}.
\]

(4.6)

Aggregate total factor productivity has two components: a stochastic stationary shock \( e^{Z(s^t)} \) and a non-stochastic labour-augmenting trend that grows at rate \( \gamma_z \).

4.2.3 Government

The government collects lump-sum taxes and uses those revenues for its own spending \( G(s^t) \) and redistributes the remainder to households as lump-sum transfers \( p(s^t)N_t tr(s^t) \), so that its budget is balanced as follows:

\[
p(s^t)[G(s^t) + N_t tr(s^t)] = p(s^t)N_t [\tau_1(s^t)w(s^t)l(s^t) + \tau_x(s^t)x(s^t)] + p_H(s^t)N_t \tau f(s^t)f(s^t).
\]

(4.7)
4.2.4 Stochastic processes

Wedges, summarized by vector $\tilde{s}_t = (\tilde{Z}_t, \tilde{Z}^*_t, \tilde{\tau}_{lt}, \tilde{\tau}^*_{lt}, \tilde{\tau}_{xt}, \tilde{\tau}^*_{xt}, \tilde{G}_t, \tilde{G}^*_t)$, are linearly detrended and expressed as deviations from their steady state levels. I assume that they follow a VAR(1) process:

$$\tilde{s}_{t+1} = P\tilde{s}_t + \epsilon_{t+1},$$

where $P$ corresponds to the persistence matrix and $\epsilon_t = (\epsilon_{z_t}, \epsilon_{z^*_t}, \epsilon_{\tau_{lt}}, \epsilon_{\tau^*_{lt}}, \epsilon_{\tau_{xt}}, \epsilon_{\tau^*_{xt}}, \epsilon_{G_t}, \epsilon_{G^*_t})$ to the vector of innovations assumed follow a joint normal distribution with mean zero and covariance matrix $V = QQ'$ where $Q$ is a lower triangular matrix. This decomposition of the covariance matrix ensures that estimates of $V$ are positive semi-definite.

4.2.5 Market clearing

In order for markets to clear, the production of final goods is equal to domestic absorption, so that:

$$N_t c(s^t) + N_t x(s^t) + G(s^t) = Y(s^t),$$

whereas for intermediate goods, Home intermediate firms produce good $A$ and Foreign intermediate firms produce good $B$:

$$GDP(s^t) = \tilde{p}_H(s^t) (A(s^t) + A^*(s^t)),$$
\[ GDP^*(s^t) = \tilde{p}_F^*(s^t)(B(s^t) + B^*(s^t)). \]

(4.11)

where \( \tilde{p}_H(s^t) = \frac{p_H(s^t)}{p(s^t)} \) and \( \tilde{p}_F(s^t) = \frac{p_F^*(s^t)}{p^*(s^t)} \), so that final goods are *numéaires* in their respective countries. Moreover the aggregate amount of capital and consumption consists in the product of the representative agent’s consumption and the population size of each country:

\[ N_t k(s^t) = K(s^t), \]

(4.12)

\[ N_t c(s^t) = C(s^t). \]

(4.13)

Finally, the international bond’s market clearing condition is as follows:

\[ N_t f(s^t) = p^*(s^t). \]

(4.14)

4.2.6 Equilibrium

The state variables are the vector of wedges \( \tilde{s} \), the aggregate capital stocks in each country \( K, K^* \) and the international bond holdings \( F \).

**Definition 1.** A recursive competitive equilibrium is defined as a set of functions for

(i) Home households’ policies \( c(\tilde{s}, K, K^*, F) \), \( x(\tilde{s}, K, K^*, F) \), \( l(\tilde{s}, K, K^*, F) \), \( f'(\tilde{s}, K, K^*, F) \) and Foreign households’ policies \( c^*(\tilde{s}, K, K^*, F) \), \( x^*(\tilde{s}, K, K^*, F) \), \( l^*(\tilde{s}, K, K^*, F) \), \( f'^*(\tilde{s}, K, K^*, F) \);

(ii) Home intermediate good firms’ policies \( L(\tilde{s}; K, K^*, F) \), \( k(\tilde{s}; K, K^*, F) \) and Foreign intermediate good firms’ policies \( L^*(\tilde{s}; K, K^*, F) \), \( k^*(\tilde{s}; K, K^*, F) \);

(iii) Home final good firms’ policies \( Y(A, A^*, B, B^*) \) and Foreign final good firms’ policies \( Y^*(A, A^*, B, B^*) \);

(iv) law of motion for the aggregate state $\bar{s}' = \Psi(\bar{s})$.

Such that:

(i) households’ allocations are optimal considering the problem that they are facing;
(ii) intermediate and final good firms’ are price-takers and their allocations are optimal considering the problem that they are facing;
(iii) the wages, interest rates and prices clear the labour, bond markets (4.14), goods markets (4.10) and (4.11), and the capital and consumption aggregation conditions are satisfied (4.12) and (4.13);
(iv) the resource constraint (4.9) is satisfied;
(v) the law of motion in each country $\Psi(\bar{s})$ is consistent with individual decisions and the stochastic processes for all states as defined by (4.8).

Prices and real exchange rate

I assume that the law of one price holds, so that the price of intermediate goods is the same in both countries: $p_H(s^t) = p_H^*(s^t)$ and $p_F(s^t) = p_F^*(s^t)$. From the production of final goods, price indices are aggregates of Home and Foreign country intermediate goods prices:

$$p(s^t) = \left(\omega p_H(s^t)^{1+\epsilon} + (1 - \omega)p_F(s^t)^{1+\epsilon}\right)^{\frac{1}{1+\epsilon}},$$

$$p^*(s^t) = \left(\omega p_F(s^t)^{1+\epsilon} + (1 - \omega)p_H(s^t)^{1+\epsilon}\right)^{\frac{1}{1+\epsilon}},$$

so that home bias contributes to price differentials. The real exchange rate is defined as the ratio of these two final good prices: $e(s^t) = \frac{p^*(s^t)}{p(s^t)}$. 


**CHAPTER 4. WEDGES AND INTERNATIONAL RISK SHARING**

4.2.7 Optimization conditions

Households’ optimization conditions

In order to find a stationary solution to the optimization problem, I remove a non-stochastic trend \((1 + \gamma_z)^t\) from total factor productivity.\(^5\) Hence, variables that are affected by this transformation have a “hat” as superscript. For example, consumption is transformed as follows: \(\hat{c}(s^t) = c(s^t)/(1 + \gamma_z)^t\). Moreover, the household budget constraint (4.2) is normalized in order to be in terms of the final goods price. Households’ first order conditions are as follows (where \(j = \{s, n\}\)):

\[
\begin{align*}
    u'(\hat{c}(s^t)) &= \lambda(s^t), \quad \text{(4.15)} \\
    -\frac{u'(l(s^t))}{u'(\hat{c}(s^t))} &= \hat{w}(s^t)(1 - \tau_j^l(s^t)), \quad \text{(4.16)} \\
    \lambda(s^t) &= \frac{\beta(1 + \gamma_z)^{1-\sigma}}{(1 + \tau_x(s^t))} E_t \left( \lambda(s^{t+1}) \left( (1 + \tau_x(s^{t+1}))(1 - \delta) + r^k(s^{t+1}) \right) \right), \quad \text{(4.17)} \\
    \kappa &= e(s^t) \frac{N_t \lambda(s^t)}{N_t^* \lambda^*(s^t)} \left( \frac{1 + \tau_j(s^t)}{1 + \tau_j^*(s^t)} \right) \quad \text{(4.18)}
\end{align*}
\]

In the first order condition (4.15), marginal utility of consumption is equal to the Lagrange multiplier \(\lambda_t\). The combination of this condition with the first order condition with respect to labour leads to equation (4.15) for which the labour wedge between wages and the marginal rate of substitution between consumption and leisure arises. Equation (4.17) is the Euler equation derived with respect to capital, so that the investment wedge also has an intertemporal dimension. Since asset markets are complete, the product of the real exchange rate and a constant \(\kappa\) that corresponds

---

\(^5\)See CKM’s appendix for a detailed description of the modifications to the optimization problem.
to relative wealth is equal to the product of the ratio of the size of the countries, the ratio of marginal utilities and the ratio of international bond taxes.

Firms’ optimization conditions

Since all taxes affect the households’ budget constraint, they do not show up in the firms’ problem. Hence, intermediate good producers pay real wages and a rental rate for capital that correspond to their respective marginal products:

\[
\hat{w}_t = \hat{p}_H(s^t)(1 - \theta)e^{Z(s^t)}\left(\frac{\hat{K}(s^t-1)}{1 + \gamma_n}\right)^\theta L(s^t)^{-\theta}
\]  \hspace{1cm} (4.19)

and

\[
r^k(s^t) = \hat{p}_H(s^t)\theta e^{Z(s^t)}\left(\frac{\hat{K}(s^t-1)}{1 + \gamma_n}\right)^{(\theta-1)} L(s^t)^{(1-\theta)}.
\]  \hspace{1cm} (4.20)

As for final good producers, they purchase quantities of goods \(A_H(s^t)\) and \(B_H(s^t)\) that depend on their relative prices, so that:

\[
\hat{A}_H(s^t) = \omega(\hat{p}_H(s^t))^{-\frac{1}{\hat{d}_H}} \hat{Y}(s^t)
\]  \hspace{1cm} (4.21)

and

\[
\hat{B}_H(s^t) = (1 - \omega)\left(\hat{p}_F(s^t)e(s^t)\right)^{-\frac{1}{\hat{d}_H}} \hat{Y}(s^t).
\]  \hspace{1cm} (4.22)
4.2.8 Procedure to estimate wedges

In this section, I show how my approach to estimate wedges differs from CKM. In order to evaluate the contribution of each wedge, four versions are estimated, each sequentially adding another wedge: (i) only efficiency wedges, (ii) labour wedges and (i), (iii) government consumption wedges and (ii), and (iv) all four wedges. For all these matrices $P$ and $Q$ of equation (4.8) are estimated by maximum likelihood.

Efficiency wedges are closely related to total factor productivity shocks, but are not exactly the same since I estimate a two-good model. From log-linearization of equations (4.10) and (4.11), I retrieve the sum of the local intermediate goods price that is generated by the model $\tilde{p}_H (\bar{s}_t; K(s^t), K^*(s^t), F(s^t))$ and the productivity shock:

$$
\begin{pmatrix}
\tilde{p}_H (\bar{s}_t; K(s^t), K^*(s^t), F(s^t)) + \tilde{Z}(s^t) \\
\tilde{p}_F(s^t) (\bar{s}_t; K(s^t), K^*(s^t), F(s^t)) + \tilde{Z}^*(s^t)
\end{pmatrix}
$$

(4.23)

with $\tilde{K}_{t+1} = (1 - \delta)\tilde{K}_t + \tilde{X}_t^d$ and $K_0 = 0$. In order to estimate the efficiency wedge, I use data on three variables per country so that $\tilde{GDP}_t, \tilde{GDP}_t^*, \tilde{X}_t^d, \tilde{X}_t^*, \tilde{L}_t^d$ and $\tilde{L}_t^*$ correspond to deviations in percentage from a linear trend of the data for all those variables. The sum of the two variables on the left hand side of equation (4.23) generated by the model should be the same to the residual identified in the data.
From decision rules, I can find estimates of $\tilde{Z}(s^t)$ and $\tilde{Z}^*(s^t)$ that do not depend on any expected values.

For *labor wedges* $\tilde{\tau}_l^j(s^t)$ and $\tilde{\tau}_l^{*j}(s^t)$ where $j = \{s, n\}$, these are deviations from the steady state that will be calibrated in the next section. In order to construct these wedges, I use data on consumption $\tilde{C}_d$ and $\tilde{C}_d^*$, hours worked $\tilde{L}_d$ and $\tilde{L}_d^*$, and output $\tilde{GDP}_d$ and $\tilde{GDP}_d^*$. In a similar fashion to *efficiency wedges*, I log-linearize equation (4.16) for separable preferences for Home and Foreign economies:

$$
\begin{pmatrix}
\tilde{\tau}_l^s(s^t) \\
\tilde{\tau}_l^{*s}(s^t)
\end{pmatrix}
= 
\begin{pmatrix}
\sigma \tilde{C}_d + \left(1 + \frac{\eta_s}{\eta_n}\right) \tilde{L}_d - \tilde{GDP}_d^d \\
\sigma \tilde{C}_d^* + \left(1 + \frac{\eta_s}{\eta_n}\right) \tilde{L}_d^* - \tilde{GDP}_d^{*d}
\end{pmatrix}.
$$

(4.24)

In order to compare the level of bilateral risk sharing for separable and non-separable preferences, the decision rule implied by the right hand side of (4.24) would still hold for non-separable preferences. However, since the first order condition implied by equation (4.16) differs from the specification of preferences, *labor wedges* $\tilde{\tau}_l^n(s^t)$ and $\tilde{\tau}_l^{*n}(s^t)$ correspond to:

$$
\begin{pmatrix}
\tilde{\tau}_l^n(s^t) \\
\tilde{\tau}_l^{*n}(s^t)
\end{pmatrix}
= 
\begin{pmatrix}
\tilde{\tau}_l^s(s^t) + \left(\frac{1}{\eta_m} - \frac{1}{\eta_s}\right) \tilde{L}(\tilde{s}_t; K(s^t), K^*(s^t), F(s^t)) - \sigma \tilde{C}(\tilde{s}_t; K(s^t), K^*(s^t), F(s^t)) \\
\tilde{\tau}_l^{*s}(s^t) + \left(\frac{1}{\eta_m} - \frac{1}{\eta_s}\right) \tilde{L}^*(\tilde{s}_t; K(s^t), K^*(s^t), F(s^t)) - \sigma \tilde{C}^*(\tilde{s}_t; K(s^t), K^*(s^t), F(s^t))
\end{pmatrix}.
$$

(4.25)
Government consumption wedges correspond to deviations of government spending in the data, so that:

\[
\begin{pmatrix}
\tilde{G}(s^t) \\
\tilde{G}^*(s^t)
\end{pmatrix} = \begin{pmatrix}
\tilde{G}^d_t \\
\tilde{G}^{*d}_t
\end{pmatrix}
\] (4.26)

In order to estimate investment wedges, I also impose that \(\tilde{X}(s^t) = \tilde{X}^d_t\) and \(\tilde{X}^*(s^t) = \tilde{X}^{*d}_t\) in addition to conditions implied by all three preceding wedges. Since the expected value of \(\tilde{\tau}_x(s^t)\) and \(\tilde{\tau}_x^*(s^t)\) enter a first order condition, equation (4.17), investment wedges are sensitive to the values of the persistence matrix \(P\).

Finally, from equation (4.18), I estimate the international wedge that corresponds to:

\[
\tilde{\tau}_{iw}(s^t) = \Delta \tilde{\tau}^d_t + \gamma^*_n - \gamma_n + \Delta \left( \tilde{\lambda}(\tilde{s}_t; K(s^t), K^*(s^t), F(s^t)) - \tilde{\lambda}^*(\tilde{s}_t; K(s^t), K^*(s^t), F(s^t)) \right).
\] (4.27)

4.3 Calibration

4.3.1 Data

The model is calibrated to match U.S. and Canadian data between 1961:Q1 and 2007:Q4, so that I exclude the period of the Great Recession. Real GDP, consumption and investment series are retrieved from the OECD Economic Outlook, whereas total hours worked series come from indices constructed by Ohanian and Raffo (2012).
Since the intensive margin is important in explaining variations in total hours worked, this measure is preferred to an employment-based series. From 1961:Q1 to 1984:Q4, the variability of total hours is 16% and 18% greater than employment for, respectively, Canada and the United States and 28% and 27% greater from 1985:Q1 to 2007:Q4.

The real exchange rate is the product of the nominal exchange rate and the ratio of consumption price indices where the former is retrieved from the International Financial Statistics of the IMF (period average) and implicit price deflators for consumption from the OECD. In the left panel of Figure 4.1, the levels of the real and nominal exchange rates are plotted. The ratio of price indices is 1 in the base year, 2002. For a short time period, the Canadian dollar was pegged to the U.S. dollar at the rate 0.925 (1962-1970), whereas it has been floating for the rest of the sample. In the right panel of Figure 4.1, the standard deviations of the RER and NER series logged and HP-filtered ($\lambda = 1600$) are displayed for windows that span forty quarters. Since the end of the 1990s, the volatility of exchange rates at business cycle frequency has increased dramatically, due to the sharp appreciation of the Canadian dollar. In fact, the NER accounts for most of the variability of the RER. Similar to Chari, Kehoe, and McGrattan (2002), I compute the cross-correlation between the two series and obtain a level of 0.963 that is comparable to CKM’s estimates for many industrialized country pairings.
Figure 4.1: Panel A: U.S.-Canada real exchange rate (solid blue line) and U.S.-Canada nominal exchange rate (red dashed line) for which 2002 is the base year of price indices (2002=1) for 1961:Q1-2007:Q4. Panel B: Last quarter of a 40-quarter window of standard deviations in percentage of the RER and NER that are logged and HP-filtered with $\lambda = 1600$. 


Table 4.1: Parametrization

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma$</td>
<td>1</td>
<td>Inverse of the inter-temporal elasticity of substitution</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>households discount factor in s.s.</td>
</tr>
<tr>
<td>$\eta_s$</td>
<td>1</td>
<td>Frisch elasticity of labour supply</td>
</tr>
<tr>
<td>$\eta_n$</td>
<td>1.7</td>
<td>labour wage elasticity</td>
</tr>
<tr>
<td>$\psi_s$</td>
<td>7.93</td>
<td>$n$ disutility weight</td>
</tr>
<tr>
<td>$\psi_n$</td>
<td>3.22</td>
<td>$n$ disutility weight</td>
</tr>
<tr>
<td>Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.36</td>
<td>capital share</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.014</td>
<td>$k$ depreciation</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.85</td>
<td>weight on domestic good</td>
</tr>
<tr>
<td>$\sigma_{tg} = 1/(1 + \epsilon)$</td>
<td>0.85</td>
<td>elasticity of substitution between traded goods</td>
</tr>
<tr>
<td>Wedges in s.s.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{\tau}_l$</td>
<td>0.4</td>
<td>labour wedge</td>
</tr>
<tr>
<td>$\bar{\tau}_x$</td>
<td>0</td>
<td>investment wedge</td>
</tr>
<tr>
<td>$\bar{G}$</td>
<td>0.207</td>
<td>government consumption wedge</td>
</tr>
</tbody>
</table>

4.3.2 Parametrization

Following the rest of the international real business cycle literature, parameter values are symmetric and based on the United States that is the Home economy, and Canada is the Foreign economy. All parameter values that are displayed in Table 4.1 match quarterly data.

I assume that the population has grown at constant rate in both countries, so that the relative size of countries will not affect the log-linearized estimation. The inter-temporal elasticity of substitution is set to 1. I set $\varsigma$ so that, in steady state, the household’s discount factor $\beta$ takes the value of 0.99 that corresponds to a 4%
annual interest rate. For separable preferences, the Frisch elasticity of labour supply \( \eta_s \) corresponds to 1, a value that is in between macroeconomic and microeconomic estimates and that is used by Shimer (2009) to construct a labour wedge measure. For non-separable preferences, the labour wage elasticity \( \eta_n \) is 1.7 corresponding to the estimates of Greenwood, Hercowitz, and Huffman (1988). Parameters \( \psi_s \) and \( \psi_n \) are set to values that ensure that households work 30% of their time in steady state.

For the production function, I choose the capital share \( \theta = 0.36 \), so that the remaining corresponds to the fraction of labour income in total income. The depreciation rate of capital \( \delta \) corresponds to an annualized depreciation of 5.7%. Similar to Heathcote and Perri (2002), the home bias on domestic goods \( \omega \) is set so that imports correspond to 15% of GDP. As for the elasticity of substitution between traded goods \( \sigma_{tg} \), I pick an intermediate value for macroeconomic models that is put forward by Bodenstein (2011). I set the steady state labour wedge to the value estimated by Prescott (2004) for the United States between 1970-74 and 1993-96. The steady state investment wedge and government consumption wedge are set respectively to zero and 16.5% of GDP corresponding to the U.S. average for the time period covered.

4.3.3 Maximum likelihood estimation

I estimate the stochastic processes of equation (4.8) by maximum likelihood from wedges retrieved from the procedure described by equations (4.23 – 4.26). Moreover, the only inter-temporal wedges: investment wedges are retrieved from the estimation of the model so that the investment series generated by the model is the same as in the data. Table 4.2 presents the estimation of the persistence matrices \( P \) and
Table 4.2: Estimated parameters of the stochastic processes for wedges

<table>
<thead>
<tr>
<th></th>
<th>( \hat{P} )</th>
<th>( \hat{V} )</th>
</tr>
</thead>
</table>
| **Separable**       | \[
\begin{bmatrix}
0.966 & 0 & -0.006 & 0.02 & -0.021 & 0.048 & 0.036 & -0.3 \\
0.011 & 0.954 & -0.012 & 0.022 & 0.027 & -0.006 & 0.024 & 0.57 \\
-0.01 & -0.028 & 0.992 & 0.022 & 0.104 & -0.068 & -0.009 & 0.028 \\
0.074 & -0.036 & 0.04 & 0.992 & 0.029 & 0.036 & -0.033 & 0.117 \\
-0.044 & 0.017 & -0.011 & 0.014 & 0.953 & 0.052 & 0.039 & -0.106 \\
-0.059 & -0.015 & -0.043 & 0.031 & 0.018 & 0.961 & 0.05 & 0.443 \\
0.023 & -0.009 & 0 & -0.007 & -0.01 & 0.973 & -0.041 \\
-0.005 & 0.002 & -0.001 & 0 & 0.003 & -0.004 & 0.012 & 0.86 \\
\end{bmatrix}
\]  |
| **Non-separable**   | \[
\begin{bmatrix}
0.652 & 0.092 & 0.756 \\
-0.02 & -0.058 & 1.669 \\
-0.088 & 0.175 & 0.356 & 1.942 \\
-0.003 & 0.034 & -0.057 & 0.065 & 0.233 \\
0.006 & 0.004 & -0.039 & -0.05 & 0.004 & 0.045 \\
0.0002 & -0.008 & -0.057 & -0.0001 & 0.0001 & 0.002 & 0.2216 \\
-0.01 & 0.025 & 0.036 & -0.01 & -0.01 & 0.001 & 0.013 & 0.044 \\
\end{bmatrix}
\]  |

**Note**: \( \hat{P} \) and \( \hat{V} \) are estimated parameters for the stochastic processes corresponding to separable and non-separable preferences, respectively. The values are given in a matrix format with each element representing the estimated parameter value. The asterisk (*) indicates significant values.
the variance matrices $V$ for both category of models, assuming separable and non-separable preferences. All wedges are very persistent but not all elements outside the diagonal of matrix $\hat{P}$ are significant. For separable preferences, the efficiency and labour wedges show the highest variances, whereas the variances of the investment and government consumption wedges are much smaller. In contrast, the variability of the investment wedges is very important in the non-separable preferences version of the model. Since labour wedges do not capture the same gap between variables in the data with non-separable preferences, their variances are smaller.

### 4.4 Results

#### 4.4.1 Measure of international risk sharing

Figure 4.2 presents the standard deviation of the logged and H-P filtered ($\lambda = 1,600$) international wedge $\tilde{\tau}_{int}$ for 40-quarter rolling windows that corresponds to the measure of international risk sharing proposed by Viani (2011). She demonstrates that this measure is preferred to others because it takes into consideration the insurance role played by international prices. Comparing one window to another, a greater value of the variance of the international wedge implies a lower bilateral risk sharing. Contrary to the maximum likelihood estimation methods that I use, Viani (2011) estimates the parameters that control the inverse of the intertemporal elasticity of substitution and both countries’ discount factors by non-linear GMM. She obtains an estimation of the gap between SDFs.
Figure 4.2: The measure of international risk sharing that is the standard deviation of the international wedge $\tilde{\tau}_{iw}$ is measured from equation (4.27) for which variables are logged and H-P filtered with $\lambda = 1,600$ (1970:Q4-2007:Q4).
Another way to approach the international wedge is by decomposing its elements, so that the measure of bilateral risk sharing is simply the model’s fit to explain the variance of the real exchange rate. Table 4.3 presents the variance decomposition assuming that the discount factors are the same for both countries. The variance of the growth of real exchange rate in the data is $\sigma_{\Delta \tilde{e}_d}^2$, whereas the variance generated by the model is $\sigma_{\Delta \tilde{\lambda}(\tilde{s})}^2 = \sigma_{\Delta (\tilde{\lambda}(\tilde{s}) - \tilde{\lambda}^*(\tilde{s}))}^2$. For both specifications of preferences, the covariance between the data and the model’s estimate $\sigma_{\Delta \tilde{e}_d, \Delta (\tilde{\lambda}(\tilde{s}) - \tilde{\lambda}^*(\tilde{s}))}$ is very small.

From 1961:Q1 to 1983:Q4, variations are evenly attributed to variances of both factors in the case of separable preferences, whereas for non-separable preferences it is the real exchange generated by the model that contributes most to the variance of the international wedge. For the period spanning the so-called Great Moderation, i.e. from 1984:Q1 to 2007:Q4, the real exchange rate, specifically the nominal exchange rate as seen in Figure 4.1, contributes to most of the variance in the international wedge. As the exchange-rate disconnect puzzle coined by Obstfeld and Rogoff (2000) would suggest, the volatility of the exchange rate may not be related to any changes in macroeconomic aggregate variables. The large decrease in international risk sharing from 2003:Q1 to 2007:Q4 can also be attributed to the increasing volatility of the nominal exchange rate. During this time period, the Canadian dollar has sharply appreciated by 53% vis-à-vis the US dollar. The estimates of Beine, Bos, and Coulombe (2012) point to a significant positive relationship between increases in world commodity prices and long-run appreciation of the Canadian dollar.

Since the covariance between the growth of the real exchange rate in the data and the one generated by the model is tiny compared to other variances that means that the difference between the level of risk sharing for non-separable and separable
preferences can be attributed to the difference in the variances of the SDF ratio. This result is related to the findings of Backus, Kehoe, and Kydland (1994) and Heathcote and Perri (2002) that international real business cycle models generate much less volatility for the terms of trade and the real exchange rate than in the data. In order to identify factors that can account for the fluctuations in the international wedge, Devereux and Hnatkovska (2011) compare the level of risk sharing for within and across country pairings. Pooling all the measures of international risk sharing, they find that a border effect accounts for 53% of the international wedge and that the explanatory power of this effect drops to 35% when fluctuations in the nominal exchange rate are set apart. These results suggest that the exchange rate regime is an important contributor to the level of risk sharing.

Most previous analyses focus on separable preferences, whereas I find that for some time-periods non-separable preferences lead to different conclusions about the level of risk sharing that prevails. From Figure 4.2, it appears that the level of bilateral risk sharing is lower for non-separable preferences than for separable preferences, since the non-separable SDF ratio also embeds leisure decisions. One notable difference between the behavior of the risk sharing measure is for the period covered by windows from 1982:Q1 to 2003:Q4 the measure is stable on average for non-separable preferences, while measured by separable preferences risk sharing has worsened. However, from 2004:Q1 to 2007:Q4, measures for both separable and non-separable preferences show a dramatic increase of the index that emphasizes the disconnection of the exchange rate from macroeconomic aggregate variables more so than a worsening measure of international risk sharing.
Table 4.3: Variance decomposition of the international wedge

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Separable preferences</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma^2_{\Delta \tilde{e}d}$</td>
<td>77.14</td>
<td>47.02</td>
<td>92.98</td>
</tr>
<tr>
<td>$\sigma^2_{\Delta(\tilde{\lambda}(\tilde{s})-\tilde{\lambda}^*(\tilde{s}))}$</td>
<td>23.25</td>
<td>46.39</td>
<td>11.01</td>
</tr>
<tr>
<td>$-2 \cdot \sigma_{\Delta z d, \Delta(\tilde{\lambda}(\tilde{s})-\tilde{\lambda}^*(\tilde{s}))}$</td>
<td>-0.39</td>
<td>6.59</td>
<td>-3.99</td>
</tr>
<tr>
<td><strong>Non-separable preferences</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma^2_{\Delta \tilde{e}d}$</td>
<td>62.37</td>
<td>31.31</td>
<td>84.77</td>
</tr>
<tr>
<td>$\sigma^2_{\Delta(\tilde{\lambda}(\tilde{s})-\tilde{\lambda}^*(\tilde{s}))}$</td>
<td>37.65</td>
<td>66.39</td>
<td>16.87</td>
</tr>
<tr>
<td>$-2 \cdot \sigma_{\Delta z d, \Delta(\tilde{\lambda}(\tilde{s})-\tilde{\lambda}^*(\tilde{s}))}$</td>
<td>-0.02</td>
<td>2.3</td>
<td>-1.64</td>
</tr>
</tbody>
</table>

Separable preferences

In this sub-section, I compare the different measures of international risk sharing that are obtained by allowing for the presence of some wedges. For model (M1), only efficiency wedges are embedded, for model (M2), I add labour wedges to model (M1), for model (M3), I add government consumption wedges to model (M2), and, finally, model (M4) corresponds to the separable preferences model as seen in Figure 4.2. The measures of international risk sharing delivered by the models listed above are displayed for different time periods in Figure 4.3. Since most fluctuations of these measures are attributed to real exchange rate variations in the second half of the sample, all models predict a similar behavior of risk sharing. However, in the first half of the sample, investment wedges contribute to lower levels of risk sharing. From equations (4.17) and (4.18), the absence of investment wedges imply that all expected lending rate of capital differentials $E_t(r^k(s^{t+1}))$ are accounted by the growth of real
Figure 4.3: The measure of international risk sharing for separable preferences where (i) \((M1)\) corresponds to the model with only efficiency wedges, (ii) \((M2)\) to \((M1)\) and labour wedges, (iii) \((M3)\) to \((M2)\) and government consumption wedges, (iv) \((M4)\) to all wedges.

exchange rates. The introduction of investment wedges weakens that condition and affect inter-temporal Euler equations.

Table 4.4 presents the variance decomposition of several variables for the estimation of model \((M4)\) that comprises all wedges. Country-specific labour wedges contribute the most to all domestic variables. Moreover, labour wedges are the wedges that generate the most volatility in the real exchange rate. Since the growth of this variable is equal to the ratio of SDFs that is not surprising. Apart from fluctuations in hours worked, efficiency wedges contribute significantly to the variance of all variables, whereas investment wedges mainly contribute to fluctuations in investment levels.
Table 4.4: Variance decomposition of the separable preferences model (M4)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Y</th>
<th>Y*</th>
<th>C</th>
<th>C*</th>
<th>X</th>
<th>X*</th>
<th>L</th>
<th>L*</th>
<th>e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z(s')</td>
<td>20.09</td>
<td>2.36</td>
<td>15.57</td>
<td>1.78</td>
<td>26.77</td>
<td>0.71</td>
<td>0.15</td>
<td>0.67</td>
<td>9.14</td>
</tr>
<tr>
<td>Z*(s')</td>
<td>6.23</td>
<td>22.2</td>
<td>0.28</td>
<td>20.17</td>
<td>2.75</td>
<td>13.94</td>
<td>1.01</td>
<td>0.74</td>
<td>12.6</td>
</tr>
<tr>
<td>τ_l(s')</td>
<td>49.08</td>
<td>8.24</td>
<td>68.8</td>
<td>5.22</td>
<td>27.39</td>
<td>1.26</td>
<td>87.54</td>
<td>0.95</td>
<td>27.36</td>
</tr>
<tr>
<td>τ*_l(s')</td>
<td>15.08</td>
<td>59.2</td>
<td>0.82</td>
<td>64.86</td>
<td>4.27</td>
<td>32.03</td>
<td>2.85</td>
<td>92.45</td>
<td>39.29</td>
</tr>
<tr>
<td>G(s')</td>
<td>0.96</td>
<td>0.17</td>
<td>1.09</td>
<td>0.19</td>
<td>1.35</td>
<td>0.44</td>
<td>0.49</td>
<td>0.01</td>
<td>0.45</td>
</tr>
<tr>
<td>G*(s')</td>
<td>0.07</td>
<td>0.04</td>
<td>0.08</td>
<td>0.36</td>
<td>0.33</td>
<td>0.82</td>
<td>0.04</td>
<td>0.11</td>
<td>0.28</td>
</tr>
<tr>
<td>τ_x(s')</td>
<td>7.68</td>
<td>4.95</td>
<td>8.99</td>
<td>1.4</td>
<td>25.69</td>
<td>19.25</td>
<td>6.87</td>
<td>3.33</td>
<td>8.2</td>
</tr>
<tr>
<td>τ*_x(s')</td>
<td>0.8</td>
<td>2.84</td>
<td>4.37</td>
<td>6.03</td>
<td>11.45</td>
<td>31.56</td>
<td>1.05</td>
<td>1.74</td>
<td>2.68</td>
</tr>
</tbody>
</table>

Non-separable preferences

As in Figure 4.3, I plot the measures of international risk sharing for the same model specifications in Figure 4.4 but for GHH preferences. For the first half of the sample, the addition of investment wedges to model M3 affects the level of risk sharing downwards, as with separable preferences. Variance decomposition, results are shown in Table 4.6. The contribution of labour wedges to explain key variables is also crucial, but it appears that the contribution of efficiency wedges is augmented for output, consumption, investment and hours worked. Moreover, it is this category of wedges that contributes the most to fluctuations in the real exchange rate. Table 4.5 presents the volatility of wedges, so that the importance of the deviations in the international wedge can be compared to the national wedges. For both sub-periods its volatility is greater than that of the efficiency and government consumption wedges and smaller than that of the labour wedges. The maximum likelihood estimates also point to a large discrepancy between the standard deviations of the U.S. and Canadian investment wedges.
Chapter 4. Wedges and International Risk Sharing

Figure 4.4: The measure of international risk sharing for non-separable preferences where (i) M1 corresponds to the model with only efficiency wedges, (ii) M2 to M1 and labour wedges, (iii) M3 to M2 and government consumption wedges, (iv) M4 to all wedges.

Table 4.5: Standard deviations of the national and international wedges for the non-separable preferences model (M4)

<table>
<thead>
<tr>
<th>Wedges</th>
<th>Standard deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z(s^t)</td>
<td>1.04</td>
</tr>
<tr>
<td>Z*(s^t)</td>
<td>0.87</td>
</tr>
<tr>
<td>τ_l(s^t)</td>
<td>2.97</td>
</tr>
<tr>
<td>τ_l*(s^t)</td>
<td>3.28</td>
</tr>
<tr>
<td>G(s^t)</td>
<td>1.27</td>
</tr>
<tr>
<td>G*(s^t)</td>
<td>0.27</td>
</tr>
<tr>
<td>τ_x(s^t)</td>
<td>0.64</td>
</tr>
<tr>
<td>τ_x*(s^t)</td>
<td>3.19</td>
</tr>
<tr>
<td>τ_{lw}(s^t)</td>
<td>2.14</td>
</tr>
</tbody>
</table>
Table 4.6: Variance decomposition of the non-separable preferences model (M4)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Y</th>
<th>Y*</th>
<th>C</th>
<th>C*</th>
<th>X</th>
<th>X*</th>
<th>L</th>
<th>L*</th>
<th>e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wedges</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z(s^t)</td>
<td>20.09</td>
<td>2.36</td>
<td>15.57</td>
<td>1.78</td>
<td>26.77</td>
<td>0.71</td>
<td>0.15</td>
<td>0.67</td>
<td>9.14</td>
</tr>
<tr>
<td>Z*(s^t)</td>
<td>6.23</td>
<td>22.2</td>
<td>0.28</td>
<td>20.17</td>
<td>2.75</td>
<td>13.94</td>
<td>1.01</td>
<td>0.74</td>
<td>12.6</td>
</tr>
<tr>
<td>τ_l(s^t)</td>
<td>49.08</td>
<td>8.24</td>
<td>68.8</td>
<td>5.22</td>
<td>27.39</td>
<td>1.26</td>
<td>87.54</td>
<td>0.95</td>
<td>27.36</td>
</tr>
<tr>
<td>τ_l*(s^t)</td>
<td>15.08</td>
<td>59.2</td>
<td>0.82</td>
<td>64.86</td>
<td>4.27</td>
<td>32.03</td>
<td>2.85</td>
<td>92.45</td>
<td>39.29</td>
</tr>
<tr>
<td>G(s^t)</td>
<td>0.96</td>
<td>0.17</td>
<td>1.09</td>
<td>0.19</td>
<td>1.35</td>
<td>0.44</td>
<td>0.49</td>
<td>0.01</td>
<td>0.45</td>
</tr>
<tr>
<td>G*(s^t)</td>
<td>0.07</td>
<td>0.04</td>
<td>0.08</td>
<td>0.36</td>
<td>0.33</td>
<td>0.82</td>
<td>0.04</td>
<td>0.11</td>
<td>0.28</td>
</tr>
<tr>
<td>τ_x(s^t)</td>
<td>7.68</td>
<td>4.95</td>
<td>8.99</td>
<td>1.4</td>
<td>25.69</td>
<td>19.25</td>
<td>6.87</td>
<td>3.33</td>
<td>8.2</td>
</tr>
<tr>
<td>τ_x*(s^t)</td>
<td>0.8</td>
<td>2.84</td>
<td>4.37</td>
<td>6.03</td>
<td>11.45</td>
<td>31.56</td>
<td>1.05</td>
<td>1.74</td>
<td>2.68</td>
</tr>
</tbody>
</table>

4.4.2 Backus-Smith puzzle

For non-separable preferences, the link between the growth in real exchange rate $\Delta e_t$ and in the consumption ratio $c_{US}^t/c_{CAN}^t$ is broken. In Table 4.7, I report the cross-correlation of these two variables HP-filtered $\lambda = 1,600$ for the full sample and split samples. Since a standard two-country model with separable preferences would predict a perfect correlation, there is an inconsistency with the estimated negative correlation in the data that is known as the Backus-Smith puzzle. This correlation is above the median of correlations of OECD countries pairings with the United States (-0.18) reported by Corsetti, Dedola, and Viani (2012) for 1971:Q1 to 2009:Q2. Although the correlation is still positive, the addition of investment wedges lowers the cross-correlation, so that the estimate of the correlation for the baseline model is 0.55.

Models that allow for national capital market frictions are promising for explaining the Backus-Smith puzzle. One approach is the combination of investment-specific shocks and non-separable preferences are examined by Raffo (2010) and Mandelman,
Table 4.7: The correlation between real exchange rates and relative consumptions $\rho(e_t, c_t^{US}/c_t^{CAN})$

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(M1) Efficiency wedges</td>
<td>-0.06</td>
<td>-0.14</td>
<td>-0.02</td>
</tr>
<tr>
<td>(M2) M1 and labour wedges</td>
<td>0.91</td>
<td>0.88</td>
<td>0.95</td>
</tr>
<tr>
<td>(M3) M2 and government consumption wedges</td>
<td>0.68</td>
<td>0.7</td>
<td>0.87</td>
</tr>
<tr>
<td>(M4) M3 and investment wedges</td>
<td>0.86</td>
<td>0.87</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>0.55</td>
<td>0.58</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Rabanal, Rubio-Ramírez, and Vilán (2011). Otherwise, the introduction of financial market frictions and financial shocks as proposed in Chapter 3 can also account for this negative correlation.

### 4.5 Conclusion and extensions

To conclude, I have shown that CKM’s business cycle accounting method which identifies time-varying wedges can also be extended to two-country models. In fact, the introduction of an international wedge between the growth of real exchange rate and the ratio of SDFs allows the international real business cycle literature to be reconciled with international risk sharing metrics. Different specifications of the utility function and the presence of some wedges lead to various risk sharing paths throughout time. For Canadian and U.S. data from 1984:Q1 to 2007:Q4, real exchange rate fluctuations prevail for the behavior of bilateral risk sharing measures and its volatility has increased significantly during that time period, especially from 2003:Q1 to 2007:Q4.
To answer the question that was posed in the introduction of the chapter, opportunities to share risk brought forward by a heightened level of financial integration do not appear to have been seized for Canada and the U.S., if international prices movements are taken into consideration. These findings are conflicting with those of Flood, Marion, and Matsumoto (2012) who find that financial globalization has improved international risk sharing. However, their measure does not take into account movements in international prices. As in CKM, efficiency and labour wedges explain output fluctuations more than the investment wedge. Even though, with non-separable preferences, the Backus-Smith puzzle persists in the presence of investment wedges, it appears that this inter-temporal wedge plays a role to lower the cross-correlation between real exchange rate growth and the growth in relative consumptions. Hence, national capital market frictions can be important to account for this anomaly.

There are many possible extensions to this work. I believe that it would be interesting to examine the evolution of risk sharing for more country pairings, rest-of-the-world aggregates, especially countries that have commodity currencies such as Australia and New Zealand. Quantifying the welfare losses generated by the recent sharp appreciation of the Canadian dollar vis-à-vis the US dollar is definitely work for future research. Terms of trade shocks could also be identified and introduced to the baseline model, as commodity prices have had sizable effects on the Canadian dollar for some periods of time. Finally, in order to strengthen the links between real business cycle research and financial markets, CKM’s framework could be extended to embed a wedge to the firms’ borrowing in a similar fashion to Jermann and Quadrini’s (2012) financial shocks.
Chapter 5

Summary and Conclusions

This thesis undertook to examine the role of financial frictions and shocks to drive national and international business cycles. Financial markets structure has not been examined in depth as financial intermediaries are not featured in the models that were studied. Nevertheless, since a fraction of firms were borrowing-constrained that allowed us to deviate from a perfect financial markets analysis. The main contribution of this thesis pertained to the importance of commercial real estate as a collateralized asset in dynamic general equilibrium models. Moreover, I showed that financial frictions and working capital requirements can be mapped in a model that embeds time-varying wedges.

In Chapter 2, my findings pointed out to a greater importance of commercial real estate than labour market dynamics for business cycle fluctuations. I reexamined the amplification mechanism of Kiyotaki and Moore (1997) and found that the endogenous propagation of productivity shocks is muted if land is elastically supplied. However, exogenous disturbances to the maximum allowable ratio of loans to collateral, financial shocks, led to a considerable reallocation of the asset from patient to
impatient agents. I showed that this type of shock is an important source of business cycle fluctuations. Augmenting the benchmark model with reproducible capital, I also found that the elasticity of substitution between land and capital can greatly affect the size of output responses to financial shocks. Hence, for a reasonable choice of parameters, if the standard assumption of a unitary elasticity of substitution is cut by half, I found an additional amplification of over 50%.

In Chapter 3, I introduced national endogenous borrowing constraints and frictionless international financial markets to a two-good, two-country model to account for business cycle synchronization and international finance and macroeconomics “puzzles” that are related to international risk sharing. When preferences are non-separable between consumption and leisure, the borrowing mechanism brought about an internal labour wedge that interacts with the efficient international allocation for a class of preferences that are non-separable between consumption and leisure. This labour wedge also appeared to be fundamental to explain the Backus-Smith puzzle or consumption—real exchange rate anomaly. I identified that technology shocks contributed to explain international co-movements, whereas country-specific financial shocks to borrowing capacity allowed the model to replicate the lack of international risk sharing. When the model was augmented with an additional sector, real estate, international co-movements were matched more closely.

In Chapter 4, I applied CKM’s business cycle accounting method to a two-good, two-country real business cycle model calibrated to match Canadian and U.S. data. In a similar fashion, efficiency, labour, investment, and government consumption wedges were retrieved for both countries. From the goods market structure an additional wedge between the growth rate of real exchange rate and stochastic discount factors
ratio arose that I called the \textit{international wedge}. The volatility of that wedge over time was considered as an indicator of the degree of bilateral risk sharing. First, I found that this metric was sensitive to the specification of preferences whether there were some separability between leisure and consumption. Another finding that emerged from the estimation of the non-separable preferences version of the model was that the \textit{investment wedge} contributed to lower the correlation between the real exchange rate and the ratio of consumptions, so that it is more consistent with the data.

This thesis provided a better understanding of some important sources of business cycle fluctuations at national and international levels from a positive perspective. The highlighted findings suggest some implications for economic policy that have not been discussed so far. The macro-prudential literature considers the instruments central banks and governments dispose of in order to mitigate business cycle fluctuations. Modifying regulations related to loan-to-values for the real estate sector would affect the behavior of financial shocks, so that it can lead to smaller business cycle fluctuations and also affect international risk sharing. Hence, the implementation of counter-cyclical policies that would curb the size of shocks could be welfare-improving. Further work should be pursued for such normative analysis. Canadian policy-makers should also devote attention to exchange rate volatility as it has particularly undermined bilateral U.S-Canada risk sharing in the last twenty years as shown in Chapter 4.

I discuss below additional extensions specific to frameworks of each chapter. In Chapter 2, elasticity of land supply is inherent to the presence of land developers. This formulation is a reduced-form of developments on the supply side of land markets. In order to have a better understanding land supply micro-foundations, further research
on changes of zoning regulations is required. Search theory in land markets is also an interesting avenue of research.

In Chapter 3, the level of output synchronization is ensured by a fall in the interest rate following a positive temporary technology shock. As an extension to that chapter, a structural vector autoregressive (SVAR) model could be estimated to verify if that relationship holds in the data. The sensitivity of results in that chapter could also be tested by assuming similar characteristics of real estate to the ones that are presented in Chapter 2. Moreover, the importance of non-separability between consumption and leisure for international risk sharing, that is rejected by Lewis (1996), could be revisited by performing tests that use leisure from the new database on hours worked constructed by Ohanian and Raffo (2012) for many industrialized countries. Finally, in Chapter 4, in similar fashion to the approach of Fitzgerald (2012), the international wedge could categorize frictions that arise from asset markets and trade costs.
Bibliography


Journal of Monetary Economics, 25, 21–42.


in a quantitative business cycle framework,” in Handbook of Macroeconomics, 

Economics, 84, 160–177.

risk sharing is better than you think, or exchange rates are too smooth,” Journal 
of Monetary Economics, 53, 671–698.


CAMPBELL, J. Y. AND N. G. MANKIW (1990): “Permanent Income, Current Income, 

CARLSTROM, C. T. AND T. S. FUERST (1997): “Agency Costs, Net Worth, and 
Business Fluctuations: A Computable General Equilibrium Analysis,” American 

Real Estate Shocks Affect Corporate Investment,” The American Economic Review, 
102.6, 2381–2409.


BIBLIOGRAPHY


Appendix A

International Risk Sharing and Land Dynamics

A.1 Steady-state solution of the model

\[ \frac{q_h P}{Y} = \frac{\gamma^2 \nu}{1 - \gamma - (1 - \frac{2}{\beta}) \lambda} \]

\[ \frac{k}{Y} = \frac{\gamma^2 \mu}{1 - \gamma(1 - \delta) - (1 - \frac{2}{\beta}) \lambda t_k} \]

\[ \frac{e}{Y} = \alpha \left( \frac{\lambda}{Y} \left( \frac{q_h P}{Y} + t_k \frac{k}{Y} \right) - 1 \right) \]

\[ \frac{c^W}{Y} = (1 - \beta) \left( \frac{Re}{Y} \right) + (1 - \nu - \mu) (\gamma - \beta) \]

\[ \frac{c^P}{Y} = (\nu + \mu) (\gamma - \beta) + 1 - (\gamma - \beta) - \delta \frac{k}{Y} + (1 - R) \left( \frac{e}{Y} \right) \]

\[ Y = R^P k^\mu (1 - \nu - \mu) \]

\[ n_x = Y - (c^P + c^W) - \delta k \]
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.

A.2 Data sources and construction of variables

A.2.1 Data used for Figures 3.1-3.3

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)

A.2.2 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)
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)

\(^{1}\)I refer the reader to Appendix A of their paper for a thorough description of that variable.
APPENDIX A. INTERNATIONAL RISK SHARING AND LAND DYNAMICS

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 those 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

A.2.3 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)

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\(^2\)
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

\(^2\)I am thankful to the BIS for providing me this series.
APPENDIX A. INTERNATIONAL RISK SHARING AND LAND DYNAMICS

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

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

A.2.4 Construction of variables

$H_{US}^{P}$ 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:

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

Similarly to $H_{US}^{P}$, $H_{UK}^{P}$ 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:

$$K_{UKt+1}^{NR:R} = 0.9961 K_{UKt}^{NR:R} + GFCF^{NR:R}$$

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.

$$K_{US,t+1} = K_{US,t} - \text{Depreciation} + \text{Investment}$$
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).


A.3 Results of the one-good model

Table A.1: Business cycle statistics (one-good)

<table>
<thead>
<tr>
<th>Model:</th>
<th>Baseline</th>
<th>without real estate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shocks:</td>
<td>Technology</td>
<td>Both</td>
</tr>
<tr>
<td>Volatility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Standard deviations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP</td>
<td>0.58</td>
<td>1.01</td>
</tr>
<tr>
<td>Standard deviations relative to GDP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>3.24</td>
<td>4.07</td>
</tr>
<tr>
<td>Hours worked</td>
<td>0.38</td>
<td>0.83</td>
</tr>
<tr>
<td>Prod. real estate ($q_t h_t P_t$)</td>
<td>1.93</td>
<td>5.05</td>
</tr>
<tr>
<td>Domestic Co-movement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Exports/GDP</td>
<td>0.59</td>
<td>0.01</td>
</tr>
<tr>
<td>International Correlations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP, GDP*</td>
<td>0.04</td>
<td>0.27</td>
</tr>
<tr>
<td>PCE, PCE*</td>
<td>0.29</td>
<td>0.09</td>
</tr>
<tr>
<td>X, X*</td>
<td>0.54</td>
<td>-0.40</td>
</tr>
<tr>
<td>N, N*</td>
<td>0.08</td>
<td>0.18</td>
</tr>
</tbody>
</table>

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.