THREE ESSAYS IN MACROECONOMICS

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By

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Abstract

This thesis contains three chapters on topics in macroeconomics. Chapter 1 explains why unemployment is more persistent than average hours worked following a financial crisis. Chapter 2 assesses the performance of different monetary policy rules in stabilizing macroeconomic fluctuations in response to adverse financial shocks. Chapter 3 studies the links between U.S. monetary policy uncertainty and the default incentives of emerging nations' governments.

In Chapter 1, I study why average hours worked in the U.S. recovers much faster than the unemployment rate following a financial crisis. Using an identified vector autoregression (VAR) framework with nine quarterly U.S. time series from 1984 to 2014, I find that an adverse financial shock leads to a fall in economic activity with a persistent increase in the unemployment rate but a transitory decrease in average hours worked. I then embed labor market frictions and financial frictions into a New Keynesian model to explain this stylized fact. The model introduces a relatively new financial shock - the default cost shock, which has been explored a little in the literature. I estimate the model using Bayesian methods with ten quarterly US time series and a similar number of shocks. In the estimated model, the default cost shock plays an important role in explaining macroeconomic fluctuations even in the presence of other important shocks. In particular, this shock can account for the economic downturn of a financial crisis better than the other relevant shocks because (i) productivity shocks cannot explain the movements in average hours

worked, inflation, and the policy rate; (ii) capital quality shocks cannot explain the movements in average hours worked; and (iii) marginal efficiency of investment shocks cannot explain the movements in the price of capital and entrepreneurs' net worth.

In Chapter 2, I evaluate the performance of different monetary policy rules following a financial crisis. The recent Great Recession has raised a number of questions regarding the strategy of monetary policy in many countries, especially the United States. From its beginning until its nadir in 2009, the U.S. unemployment rate rose from 4.7 percent to 10 percent. Motivated by these facts, this chapter constructs a monetary DSGE model with explicit labor market and credit market frictions to study how these two frictions interact with each other in order to generate fluctuations in both financial and real variables following an adverse financial shock. It also assesses the performance of different monetary policy rules with an objective to meet the central bank's mandate as specified in the Federal Reserve Act - "maximum employment, stable prices, and moderate long-term interest rate." The model introduces two financial shocks - the bankruptcy cost shock and the bank intermediation cost shock, which directly originate in the credit market. Unlike many shocks used in the literature, these shocks can endogenously explain the movements in the external finance premium, the leverage ratio, net worth, credit quantity, and the price of capital. I calibrate the model economy to the U.S. data and find that the policy rule that responds to financial variables such as credit spread or asset prices in addition to output and inflation fluctuations is more efficient than the conventional Taylor rule to combat a financial crisis.

In Chapter 3, coauthored with Alok Johri and Cesar Sosa-Padilla, we study the effects of uncertainty about the U.S. interest rate on emerging market economies (EMEs). As the United States emerged from the Great Recession, there was considerable uncertainty around the future direction of U.S. monetary policy

exemplified by the chatter and speculation around tapering of quantitative easing by the U.S. Fed in the financial press. The increased uncertainty around the timing and speed of the tapering coincided with a sharp spike in the sovereign bond yields of several emerging economies. This study explores the impact of an increase in interest rate uncertainty on the borrowing costs of a small open economy in an otherwise standard model of sovereign default, where the spread between the yield on the debt of the small open economy and the yield on the risk-free world interest rate is endogenous. We calibrate the economy to Argentina and find that when we introduce time-varying volatility in the world interest rate (i.e. uncertainty shocks) the model predicts a mean sovereign spread that is 115% larger and 126% more volatile. The model also predicts that countries default more than twice as frequently. Moreover, the equilibrium debt-to-income ratio is 19% lower (showing that countries engage into precautionary behavior). The welfare gains from eliminating uncertainty about the world interest rate amount up to a 1.8% permanent increase in consumption. The model also does fairly well to match the other business cycle moments observed in the data. Overall, our findings provide quantitative support for the widespread concerns regarding the uncertainty about when and how the Fed will unwind its quantitative easing.

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Contents

List of Figures

List of Tables

Declaration of Academic Achievement

Chapter 3 is co-authored with Professor Alok Johri and Professor Cesar Sosa-Padilla. I am the sole author of Chapter 1 and Chapter 2. I participated in all stages of the research.

Introduction

The financial crisis that commenced in 2007 and its aftermath consequences created the largest economic downturn in the United States since the Great Depression of the 1930s. From its beginning until its nadir in 2009, the official unemployment rate rose from 4.7 percent to 10 percent. At the same time, the labor market had been exceptionally sluggish after the crisis and it recovered quite differently along the intensive margin than the extensive margin. For instance, at the beginning of the recovery, there was a growth in hours worked per week rather than a growth in employment. This suggests that businesses first restored hours or overtime before they started hiring additional workers.

This recession also raised a number of questions regarding the strategy of monetary policy. For instance, the U.S. Federal Reserve (Fed) reduced its operating target for the federal funds rate aggressively in late 2007 and beginning 2008 even though there was no sign of economic downturn through movements in GDP and inflation in late 2007. According to Curdia and Woodford (2010), this large reduction exceeded what was required according to the standard Taylor rule. After the financial panic of September 2008, several central banks of the industrial world expanded their balance sheets aggressively. This was also known as the era of quantitative easing (QE). In the fourth quarter of 2008, following the collapse of Lehman Brothers, the U.S. Fed expanded their balance sheets by buying distressed exposures from failing financial institutions. After the economic recovery started in late 2009, the Fed focused more on labor market recoveries and began to accumulate U.S. Treasury securities, extended their maturities and purchased mortgage-backed securities under QE-2 and QE-3. As a consequence, in January 2012, the Fed announced an explicit long-run inflation target but also made clear its intention to keep a balanced method between reducing deviations of both inflation and employment from target. However, the most unusual and unexpected event happened once Fed chair commenced his "taper talk" in May 2013 - when and how the Fed might taper its asset purchases. This announcement immediately triggered the financial market. The Treasury bond yield rose as did market volatility. The S&P 500 Index went to a new record high over the next second half of 2013. A sharp market adjustment also followed in emerging market economies (EMEs), including a reversal in capital flows, and a spike in government bond yields. EMEs perceived this "tapering talk" as a sign of earlier than anticipated tightening of U.S. monetary policy and reacted in response. On average, sovereign spreads across EMEs rose by 1%, currencies depreciated by 3%, and equities fell by 7%. The announcement made by the U.S. Fed also gave a strong signal to the rest of the world that the U.S. economy was strong enough to grow on its own without any emergency assistance.

My thesis was inspired by the events that happened during the recent financial crisis. My first and second chapters share a focus on the linkage between financial and labor market frictions in propagating shocks from the financial sector to the labor market, an under-studied area in business cycle research. In the first chapter, I show that labor market inputs in the U.S. move differently in the intensive and extensive margins following a financial crisis. Using vector autoregression (VAR) methodologies with nine quarterly U.S. time series from 1984 to 2014, I find that an adverse financial shock leads to a fall in economic activity with a persistent increase in the unemployment rate but a transitory fall in average hours worked. Motivated by these facts, I modify a standard New Keynesian model on the basic structure of Christiano, Eichenbaum and Evan (2005) by incorporating labor market search frictions, as in Mortensen and Pissarides (1994) and financial frictions, as in Bernanke et al. (1999; hereafter BGG) and Gunn and Johri (2013).[1] After developing the theoretical model, I proceed in the spirit of Smets and Wouters (2007) by including a large number of shocks and by using Bayesian methods for the model estimation. In my estimation, I use ten quarterly U.S. time series and a similar number shocks for the periods 1984 to 2014.

My model has two important features. First, it allows for variations in the labor inputs in both the intensive and extensive margins. Thus, unlike many studies in the labor-search literature, where bargaining takes place over wages only, in my model bargaining takes place along two dimensions: wages and hours worked. Second, the model introduces a relatively new financial shock – the default cost shock, which directly originates in the credit market. This cost is imposed on the model through a financial contract between financial intermediaries and entrepreneurs. Following BGG (1999), I assume that lenders must incur a default cost to observe and retrieve borrowers' realized returns when borrowers default. Hence, asymmetric information between borrowers and lenders creates a financial wedge between the risk-free rate and the rate of return of capital, also known as the external finance premium, to compensate lenders for default risks. In BGG (1999) and other related literature, the default cost parameter is assumed to be constant. However, in my model this cost varies over time and thus creates a time-varying wedge between the external finance premium and the entrepreneur's leverage ratio. As a result, the contract menu offered to entrepreneurs' changes over time, and this can endogenously explain the movements in the external finance premium,

[1] Monacelli et al. (2011), Christiano, Trabandt and Walentin (2011), Chugh (2013), Petrosky-Nadeau (2014), and Mumtaz and Zanetti (2016) used a similar framework to explain the role of financial frictions on unemployment fluctuations.

the leverage ratio, net worth, credit quantity, and the price of capital, without having to assume exogenous movements in these variables.

Three main results of this chapter can be summarized as follows. First, I estimate a set of structural parameters that characterize the dynamics of the U.S. labor market. In particular, I identify a relatively low Frisch elasticity of labor supply, which is consistent with microeconomic studies and reflects the fact that employment is more volatile along the extensive margin than the intensive one. This also suggests that the model does not rely on unrealistic adjustments to the intensive labor margin to match the data. Second, I find that the default cost shock plays an important role in explaining macroeconomic fluctuations even in the presence of other important shocks. In particular, the smoothed shock series of the default cost shows that this shock largely accounts for the economic downturn of the 2007-2009 crisis. Third and most importantly, my model is able to capture the VAR evidence, in particular, it can explain why average hours worked recovers much faster than the unemployment rate during the recovery phase of a financial crisis. In contrast, productivity shocks, capital quality shocks and MEI shocks, which are considered to be important drivers of the U.S. business cycle in many studies, fail to explain some important stylized facts of a financial crisis.

In Chapter 2, I study the performance of different Taylor-type interest rate rules in stabilizing macroeconomic fluctuations following a financial crisis. This chapter is motivated by the fact that central banks of many countries, especially the United States, faced a number of obstacles to conduct monetary policy during the recent financial crisis. One particularly important feature of that crisis was that a sharp increase in the credit spread[2] was followed by a highly persistent increase in the unemployment rate (see Figure 2.1). Moreover, there is a large

[2]Credit spread or external finance premium is measured by the difference between Moody's seasoned BAA corporate bond yield and the 3 month T-bill rate.

number of papers that find financial and labor market frictions as key elements in replicating important stylized facts in the U.S. data. There are also many recent studies that argue that frictions and shocks in the financial sector are major sources of macroeconomic fluctuations, such as Wasmer and Weil (2004), Christensen and Dib (2008), De Graeve (2008), Nolan and Thoenissen (2009), Christiano et al. (2011), Jermann and Quadrini (2012), Gunn and Johri (2011, 2013), Jorda et al. (2013), Christiano et al. (2014), and Kaihatsu and Kurozumi (2014), among others. Motivated by these facts, this chapter constructs a monetary dynamic stochastic general equilibrium (DSGE) model, as in Chapter 1, to study how these two frictions interact with each other in order to generate aggregate fluctuations. It also proposes two monetary policy rules that not only respond to output and inflation fluctuations but also react to financial variables such as credit spread or asset prices. To meet the policy objectives, I set coefficients on financial variables in the policy rules such that the central bank aims to minimize some quadratic loss function, where losses are caused by inflation, output, and unemployment being away from their respective targets.

The structure of the model in Chapter 2 differs from Chapter 1 in two ways. First, I have introduced a new financial shock, called bank intermediation cost shocks, in addition to default cost shocks as in Chapter 1. Second, labor supply can vary only along the extensive margin, unlike Chapter 1 where this can vary along both the intensive and extensive margins. Similar to default cost shocks, the bank intermediation cost shock also creates a time varying negative wedge between the external finance premium and the leverage ratio, thus this shock can endogenously explain the movements in the external finance premium, the leverage ratio, net worth, credit quantity, and the price of capital. I calibrate the model economy to the U.S. data and show that both shocks can capture the business cycle features of a financial crisis. I also show that augmented Taylor type interest rate rules featuring financial variables effectively improve the outcome of monetary policy relative to standard Taylor-type policy rules following a financial crisis. My findings also support a number of recent studies that recommend that policy rules should react to financial variables because this helps to ensure macroeconomic stability and increase social welfare.

My third chapter coauthored with Alok Johri and Cesar Sosa-Padilla is motivated by the fact that when the United States emerged from the Great Recession, there was considerable uncertainty around the future direction of U.S. monetary policy, and this uncertainty increased even further once Fed Chairman Bernanke commenced his "taper talk" in May 2013. This chapter contributes to the sovereign defaults literature by studying the links between U.S. monetary policy uncertainty and the default incentives of emerging market economies. In particular, it analyses the effects of uncertainty about the U.S. interest rate on the borrowing costs of a small open economy in an otherwise standard model of sovereign default, where the spread is endogenous. We make two contributions. First, we develop a general equilibrium model of sovereign debt with endogenous default and endogenous country spread wherein investors face a stochastic world interest rate rather than a constant one, which provides a more accurate representation of the market conditions.[3] Our framework is able to quantify the impact of such shocks and inform the policy discussion about the effects of uncertain unwinding of the Fed's quantitative easing. Second, this paper provides a mechanism by which changes in world interest rate uncertainty could affect the sovereign default risk, a country's borrowing decisions, and the sovereign bond spread even when the level of the interest rate itself is fixed.

We calibrate the economy to Argentina and find that when we introduce time-

[3] We follow the approach of Fernandez-Villaverde et al. (2011) to model the stochastic behavior of the world interest rate.

varying volatility in the world interest rate (i.e. uncertainty shocks) the model predicts a mean sovereign spread that is 115% larger and 126% more volatile. The model also predicts that countries default more than twice as frequently. Moreover, the equilibrium debt-to-income ratio is 19% lower (showing that countries engage into precautionary behavior). The welfare gains from eliminating uncertainty about the world interest rate amount up to a 1.8% permanent increase in consumption. The model also does fairly well to match the other business cycle moments observed in the data. Overall, our findings provide quantitative support for the widespread concerns regarding the uncertainty about when and how the Fed will unwind its quantitative easing.

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Chapter 1

Financial Crises and Labor Market Recoveries: A Bayesian Evaluation

1.1 Introduction

In recent years, there has been considerable interest in understanding the interaction between financial markets and labor markets to explain aggregate fluctuations. While many papers[1] study the role of credit market frictions in propagating nonfinancial market shocks (such as productivity and monetary policy shocks) to the labor market, few studies explain the dynamics of labor markets following an adverse financial shock. However, the financial turmoil that began with the subprime mortgage crisis in 2007 showed that disturbances that originated in the U.S. financial market had large spillover effects in the U.S. labor market. One particularly important feature of that crisis was that a sharp increase in the credit

[1] For instance, Acemoglu (2001), Wasmer and Weil (2004), Chugh (2013), Petrosly-Nadeau (2014), and others.

spread[2] was followed by a highly persistent increase in the unemployment rate (see Figure 1.1). Average hours worked dropped on impact but this variable returned to its pre-crisis level much faster than the unemployment rate (see Figure 1.2).

The aforementioned facts are also supported by the VAR evidence, which is described in Section 1.3. In the VAR analysis, I isolate the response to financial shocks and find that an increase in the excess bond premium[3] dampens economic activity through a large decline in investment, employment and output. Although both labor inputs are adversely affected, the impact on average hours worked is less severe and this variable recovers much quicker than the unemployment rate (see Figure 1.3). The main objective of this paper is to explain these salient features of the data. To my knowledge, there is no model that explains why unemployment is more persistent than average hours worked during the recovery phase of a financial crisis.

A canonical New Keynesian model with only financial frictions cannot explain these phenomena. In this model, workers are never unemployed, and only hours per worker vary over the business cycle. Moreover, a survey conducted by Nickell (1997) shows that the labor markets of major industrialized countries are characterized by frictions. Motivated by these facts, I modify a standard New Keynesian model on the basic structure of Christiano, Eichenbaum and Evan (2005) by incorporating labor market search frictions, as in Mortensen and Pissarides (1994) and financial frictions, as in Bernanke et al. (1999; hereafter BGG) and Gunn and Johri (2013).[4] After developing the theoretical model, I proceed in the spirit of Smets

[2]Credit spread or external finance premium is measured by the difference between Moody's seasoned BAA corporate bond yield and the 3 month T-bill rate following Nolan and Thoenissen (2009).

[3]A measurement that reflects the effective risk-bearing capacity of the financial sector, proposed in Gilchrist and Zakrajsek (2012). It has been widely applied in the literature to assess the economic effects of financial shocks.

[4]Monacelli et al. (2011), Christiano, Trabandt and Walentin (2011), Chugh (2013), Petrosky-Nadeau (2014), Mumtaz and Zanetti (2016) have also used a similar framework to explain the role of financial frictions on unemployment fluctuations. But none of these papers explains why

and Wouters (2007) by including a large number of shocks [5] and by using Bayesian methods for the model estimation. In my estimation, I use U.S. time series for ten macroeconomic measures: real GDP per capita, real investment per capita, real consumption per capita, the external finance premium, the federal funds rate, inflation, the real wage, average hours worked, the unemployment rate, and the vacancy rate for the time periods 1984:Q1 to 2014:Q4.[6]

Three key results of the paper can be summarized as follows. First, I estimate a set of structural parameters that characterize the dynamics of the U.S. labor market. In particular, I identify a relatively low Frisch elasticity of labor supply, which is consistent with microeconomic studies and reflects the fact that employment is more volatile along the extensive margin than the intensive margin.[7] This also suggests that the model does not rely on unrealistic adjustments to the intensive margin of labor supply to match the data. The model also does a decent job in matching the key moments observed in the data. Second, I find that the financial shock accounts for a significant portion of business cycle fluctuations over the sample period, even in the presence of other important demand and supply shocks used in the literature. The financial shock has substantial explanatory power in explaining the fluctuations in unemployment growth, vacancy growth and other key macro variables, such as output growth, investment growth, the federal funds rate, and the external finance premium at business cycle frequencies. In particular, the smoothed shock series shows that the financial shock largely accounts for the

labor inputs behave differently at the intensive and extensive margins following a financial crisis.

[5] I consider ten shocks in the model: total factor productivity (TFP), labor supply, capital quality, marginal efficiency of investment (MEI), bankruptcy cost, monetary policy, government expenditure, cost-push, wage markup, and matching efficiency.

[6] I choose 1984 as the first year for my analysis, since Jermann and Quadrini (2012) argue that 1984 corresponds to a break in the volatility in many business cycle variables and the structural change in U.S. financial markets was more stable after 1984, compared to previous periods.

[7] Most microeconomic studies estimates this elasticity to be small, between 0 and 0.50, whereas macro studies tend to work with elasticities that are much higher than microeconomic estimates, typically unity and above.

economic downturns of the 2007-2009 crisis. Third and most importantly, the model is able to capture the VAR evidence of the data, that is, it can explain why average hours worked recovers much faster than the unemployment rate following an adverse financial shock.

My model has two main features. First, it allows for variations in the labor inputs in both the extensive and intensive margins. A search-and-matching friction accounts for fluctuations in the extensive margin, and bargaining between workers and firms accounts for variations in both the intensive margin and wages. In contrast, most of the models in the labor-search literature consider variations in the labor supply only along the extensive margin. Second, the model considers a relatively new financial shock - the default cost (or the bankruptcy cost) shock, which has been studied very little in the literature. This cost is imposed on the model through a financial contract between financial intermediaries and entrepreneurs. Following BGG (1999), I assume that lenders must incur a default cost to observe and retrieve borrowers' realized returns when borrowers default. Hence, asymmetric information between borrowers and lenders creates a financial wedge between the risk-free rate and the rate of return of capital, also known as the external finance premium, to compensate lenders for default risks. In my model, this cost varies over time and thus creates a time-varying wedge between the external finance premium and the entrepreneur's leverage ratio, whereas this negative relationship is fixed in BGG(1999). As a result, the contract menu offered to entrepreneurs changes over time, and this can endogenously explain the movements in the external finance premium, the leverage ratio, net worth, credit quantity, and the price of capital, without having to assume exogenous movements in these variables.

Shocks to the default cost, which are also known as credit shocks, are modeled as innovations that affect the bankruptcy cost parameter. These shocks originate in the financial sector and are motivated by the sharp increases in credit spread that was observed during the post-2008 financial crisis. This default cost shows the evolution of financial stress over time. Some existing studies also document the impact of the default cost on the economy. For instance, Carlstrom and Fuerst (1997) document that this cost reflects auditing, accounting, legal expenditures associated with liquidation, and losses associated with business interruption. Levin et al. (2004), on the other hand, first document evidence about the time variation in the marginal bankruptcy cost parameter by estimating a partial framework of the BGG model with a panel of 900 nonfinancial firms in the U.S. for the periods 1997:Q1 to 2003:Q3. They find a significant time variation in the marginal bankruptcy cost and conclude that a model implied external finance premium is mainly driven by fluctuations of this parameter. Most recently, Gunn and Johri (2013) define the bankruptcy cost as a stochastic process, and interpret shocks to this process as a stochastic variation in financial innovation. They show that a change in expectations about these parameters can explain the boom-bust cycle episodes that were observed in the U.S. economy before and after the recent financial crisis. Following these studies, I add the bankruptcy cost shock to my model.

My model has a novel mechanism. An adverse financial shock has a negative impact on labor market performance. An increase in the bankruptcy cost parameter increases the negative wedge between the risk premium and the entrepreneur's leverage ratio. For a given leverage ratio, entrepreneurs now face a higher external finance premium over a risk-free rate to borrow funds from financial intermediaries. As the external borrowing cost to finance new capital purchases increases, the demand for capital declines, and this reduces the price of capital and entrepreneurs' net worth. Entrepreneurs, in turn, reduce their capital accumulation and this decreases the flow of capital from entrepreneurs to intermediate firms. Since intermediate firms use constant returns to scale (CRS) technology to produce goods using both capital and labor as inputs, a lower supply of capital goods also reduces the demand for labor inputs. This leads firms to post fewer job vacancies and reduce average labor hours. This action reduces the labor market tightness and the probability of a worker finding a job, thereby leading to an increase in the unemployment rate and a fall in wages.

During the recovery phase, when the external finance premium begins to fall, the demand for capital begins to rise, thereby drives up the price of capital. As a consequence, entrepreneurs' net worth increases and this leads them to accumulate more capital. Accordingly, firms increase their production by renting capital from entrepreneurs and by adjusting labor inputs at both margins. Since hiring is costly, firms find it cheaper to assign extra hours to existing workers rather than incurring the search and job posting costs associated with hiring new workers. Analogously, both existing and new workers want to work additional hours as the marginal utility of consumption is relatively higher right after a crisis. Thus, firms and workers bargain over wages and hours of work in such a way that each worker chooses to work additional hours over their normal workweek. As a result, average hours worked returns to the pre-crisis level much faster than the unemployment rate.

After the Great Recession of 2007-2009, many studies focused on the role of investment channels in explaining the US business cycle facts. In line with this idea, I add to my model the marginal efficiency of investment (MEI) shock in the spirit of Justiniano, Primiceri, and Tambalotti (2010)(hereafter, JPT(2010)), and the capital quality shock in the spirit of Gertler and Karadi(2011) (hereafter, GK(2011)). The MEI shock represents exogenous disturbances to the process by which investment goods are transformed into productive capital to be used for production. An increase in the external finance premium increases the cost of investment relative to the potential yield, and thus an efficiency of the investment process is closely linked to the efficiency of the financial system. The MEI shock is a way to capture such inefficiencies in the investment process. The capital quality shock, on the other hand, captures the exogenous disturbances to the quality of productive capital and is found to be important in many studies to account for the cyclical variations in the aggregate macroeconomic variables.

The variance decomposition of my Bayesian estimation shows that the MEI shock explains well the fluctuations in investment growth, inflation and the federal funds rate. In contrast, capital quality shocks are primarily responsible for capturing fluctuations in consumption growth and output growth. These shocks also explain quite well the long-run fluctuations in real wages, inflation, the federal funds rate, and hours worked. However, these shocks fail to explain the macroeconomic fluctuations of a financial crisis. Using impulse responses analysis, I show that the default cost shock has much larger predictive power in the short run than the other relevant shocks do because (i) the MEI shock cannot explain the movements in the price of capital and entrepreneurs' net worth, and ii) capital quality shocks cannot explain the movements in average hours worked. Analogously, a negative productivity shock cannot capture the movements in average hours worked, inflation and the federal funds rate as they are observed in the data.

The rest of the paper is organized as follows. Section 1.2 outlines the related literature. Section 1.3 presents the empirical evidence that motivates the paper. Sector 1.4 develops the model. Section 1.5 presents the empirical evaluation. Section 1.6 reports and discusses results. Section 1.7 concludes.

1.2 Related Literature

Many recent studies show that shocks that originate in the financial sector are important factors in explaining the observed dynamics of real and financial variables over the business cycle. Seminal work by BGG (1999) shows that asymmetric information in credit markets generates a negative relationship between firms' net worth and the cost of external finance, two variables that interact with each other to amplify the magnitude and persistence of macroeconomic fluctuations. This paper also complements a large number of studies that show the importance of financial frictions in explaining aggregate fluctuations. Christiano, Motto and Rostagno (2007) use Bayesian techniques to estimate a model that incorporate net wealth shocks, along with many other types of shocks. Their variance decomposition generally suggests a significant role for net wealth shocks. Similarly, Wasmer and Weil (2004), Christensen and Dib (2008), De Graeve (2008), Nolan and Thoenissen (2009), Christiano et al. (2011), Jermann and Quadrini (2012), Gunn and Johri (2011, 2013), Jorda et al. (2013), and Kaihatsu and Kurozumi (2014) show that the financial sector acts as a source of macroeconomic fluctuations. However, all of these papers show that financial frictions improve a model's empirical performance in the context of a frictionless labor market.

On the other hand, many studies show that labor market frictions are a key element in replicating important stylized facts in the US data. In these models, adjustments in the labor market are not frictionless and it is costly to hire workers due to labor market search and matching frictions. This paper is related to many strands of literature. The influential work of Merz (1995) and Andolfatto (1996) embed labor search friction in business cycle models. Papers such as those by Cooley and Quadrini (1999), den Haan, Ramey, and Watson (2000), Krause and Lubik (2007), Gertler, Sala, and Trigari (2008), Trigari (2009), Gertler and Trigari

(2009), Leduc and Liu (2016), among others, incorporate search-and-matching in many different macroeconomic models. But most of these papers consider that productivity shocks, monetary policy shocks, and uncertainty shocks are the main drivers of economic fluctuations.

This paper combines the approaches of these two strands of literature and focuses its attention on examining how shocks that originated in a financial sector affect labor market inputs at both intensive and extensive margins. This paper is related to Christiano, Tribant and Walentin (2011, hereafter CTW), who introduce the BGG-type financial frictions and the Montensen-Pissarides search model into an otherwise standard DSGE model. They estimate the model using Swedish data and show that financial shocks and frictions have important impacts on unemployment fluctuations. However, they do not explain why average hours worked behave differently than the unemployment rate following a crisis. This paper is also related to Altug and Kabaca (2014), who develop a small open economy to examine the role of the extensive and intensive margins of labor input to explain the nature of labor market fluctuations in emerging market economies. They incorporate financial friction in the form of a working capital constraint and consider only the interest rate and productivity shocks in their model.

Chugh (2013) and Petrosky-Nadeau (2014) also consider labor and financial market frictions and show how these two frictions work closely to reduce the amplification and persistence of changes in labor market variables in response to productivity shocks. They develop models in the framework of a real business cycle, whereas my model includes nominal price rigidities so that I can also examine how the inflation rate and the federal funds rate react to an adverse financial shock. In a similar study, Monacelli et al. (2011) find the importance of financial markets for unemployment fluctuations in a model with matching frictions where firms and consumers borrow under limited enforcement. However, their main goal is to examine how financial frictions affect unemployment fluctuations. In addition to this, they look at the movements in only three other variables: output, wages and debt. In this paper, I consider the reactions of a broad set of macroeconomic variables including the movements in the labor inputs in both the extensive and intensive margins.

1.3 Empirical Evidence

In this section, I use a VAR methodology to estimate the dynamic response of different variables to an identified exogenous financial shock, using nine quarterly U.S. time series from 1984 to 2014. The variables included in the analysis are measures of output, investment, the unemployment rate, the vacancy rate, average hours worked, the nominal interest rate, inflation, the external finance premium (or credit spread), and the excess bond premium.

The series for the excess bond premium is taken from Gilchrist and Zakrajsek (2012), and averaged over the quarter. The series for the nominal interest rate is the federal funds rate, annualized and averaged over the quarter. The series for the external finance premium is measured by the difference between Moody's seasoned BAA corporate bond yield and the 3 month T-bill rate, annualized and averaged over the quarter.[8] The series for output and investment are the log-difference of the quarterly real GDP and real investment, respectively. The series for inflation is the log-difference of the GDP deflator between two consecutive quarters. The series for unemployment is the civilian unemployment rate. The series for the vacancy rate is the Help Wanted Index. The series for average labor hours is the log-difference of the nonfarm business sector: average weekly hours. The constructions and sources

[8]Following Nolan and Thoenissen (2009), the spread between BAA corporate bond yield and the 3 month T-bill rate comes closest to the model's definition of the external finance premium, $\frac{R^k_{t+1}}{R_{t+1}}$.

of the data are described in the appendices. Also included are two lagged values for all the variables in the VAR, according to the Hannah Quinn criterion (HQC).

The model can be represented by

$$Y_t = B_0 + B_1 Y_{t-1} + B_2 Y_{t-2} + ... + B_s Y_{t-s} + u_t; t = 1, 2, ...T \qquad (1.1)$$

where Y_t is an 9×1 vector of variables at date t, B_i is an 9×9 coefficient matrix for each lag of the variable vector with B_0 being the constant term, u_t is the vector of one step ahead prediction error.

I identify financial shocks by imposing short run restrictions, computed with a Cholesky decomposition of the reduced form residuals' covariance matrix. I assume that shocks to the excess bond premium affect economic activity and inflation with a lag, but the external finance premium (or credit spread) and federal funds rate can react contemporaneously to such an adverse financial shock. This identification scheme is similar to that of Gilchrist and Zakrajsek (2012).

Figure 1.3 presents the Cholesky orthogonalised impulse response functions of the endogenous variables to a one percentage point increase in the excess bond premium. The VAR generated impulse responses can be summarized as follows:

- An adverse financial shock leads to a persistent increase in the unemployment rate but a relatively small decrease in average hours worked. The increase in unemployment remains significant at the 95-percent level for about fifteen quarters. The peak increase is about 4 percentage points and this occurs about seven quarters after the impact period. The largest fall in average hours worked is about 0.50 percentage points. This occurs at the third quarter and it returns to the initial level much faster than the unemployment rate.

- Vacancies, Output, and investment fall, with the peak effect occurring for vacancies after about six quarters, for investment after about three quarters; and and for output after about two quarters. The external finance premium increases by 1 percentage point and this occurs after about six quarters from the impact period.

- A persistent decline in the federal funds rate is also observed. The fall in the federal funds rate remains significant at the 95-percent level for about ten quarters.

- The inflation rate falls, with the largest drop of about 0.20 percentage points; this occurs about four quarters after the period of the shock.

I document the VAR impulse responses as the key relationships in the data. In the following sections, I develop a theoretical model to capture these facts.

1.4 The Model

The model is characterized by three main blocks: financial frictions in the financial market, nominal rigidities in price setting, and search and matching frictions in the labor market. There are eight types of agents in the model: households, entrepreneurs, capital producers, intermediate goods producers, retailers, financial intermediaries, a government, and a monetary authority.

The goods market is composed of four types of producers: intermediate firms, capital producers, entrepreneurs, and retailers. At the beginning of each period, intermediate firms hire new workers by posting vacancies in the labor market, which is costly. These firms produce intermediate goods in competitive markets, using labor and capital as their inputs. They sell their output to retailers who are monopolistically competitive. Retailers sell the final goods to the households and capital producers, and set nominal prices in a staggered fashion ‘a la Calvo (1983).

Entrepreneurs accumulate physical capital and rent it to intermediate firms. They purchase new capital from capital producers and finance this purchase by borrowing from financial intermediaries and using their net worth. The presence of asymmetric information between entrepreneurs and financial intermediaries creates a financial wedge between borrowing and lending rates. That is, financial intermediaries charge a premium over the risk-free rate to compensate for default risks. Capital producers build new capital by combining old capital purchased from entrepreneurs and investment goods purchased from retailers; they then sell this capital to entrepreneurs.

Government spending is financed by issuing government nominal bonds to households and through lump-sum taxes. The monetary policy follows a modified Taylor (1993) rule as in Clarida et al. (1998). The nominal interest rate depends on its lagged values, and it adjusts in response to output growth and deviations of inflation from its steady-state value.

In the following, I discuss in detail the behavior of each of these agents and the structure of the goods, labor and financial markets.

1.4.1 Households

The economy is populated by a continuum of infinitely-lived identical households. Each household consists of a continuum of family members of measure one. Every household member is either employed or looking for work. Those who are employed receive wage income, $w_t h_t$, and those who are unemployed search for jobs but also receive government benefits, b, during their unemployment spells. Total household income is shared equally among all members. I follow Merz (1995) and Andolfatto (1996) in assuming that there is perfect risk-sharing among members of a household, thereby yielding the same consumption level for everyone.

The problem of the representative household is to maximize an expected utility function of the following form

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \chi_t \int_0^1 n_{jt} \frac{h_{jt}^{1+\phi}}{1+\phi} dj \right] \tag{1.2}$$

where β is the discount factor, C_t is consumption, $\sigma \geq 0$ is the coefficient of relative risk aversion, and the parameter ϕ is the inverse of the Frisch labor supply elasticity. The variable n_{jt} denotes the number of household members who are employed and h_{jt} denotes the corresponding average hours per worker. The labor market will be considered in more detail later on. χ_t is an exogenous stochastic AR(1) process, where $0 < \rho_\chi < 1$ measures the persistence of the shock and $\epsilon_{\chi,t} \sim i.i.d.N(0, \sigma_\chi)$, which I refer to as a labor supply shock.

The household chooses to consume, C_t, purchase new nominal government bonds, B_t and deposit real funds, D_t at the financial intermediary so as to maximize the utility function in (1.2) subject to a sequence of flow budget constraints as follows:

$$C_t + D_t + \frac{B_t}{P_t} = R_{t-1} D_{t-1} + R_{t-1}^n \frac{B_{t-1}}{P_t} + \int_0^1 w_{jt} h_{jt} n_{jt} dj + b(1-n_t) + +\Pi_t - T_t \tag{1.3}$$

where P_t denotes the price level which will be defined later, w_t denotes the real hourly wage, R_t^n denotes the risk free nominal interest rate[9], R_t denotes the real interest rate the financial intermediary pays on households' deposits, and b denotes unemployment benefits. The household also pays a lump-sum tax, T_t, to the government, and receives an aggregate dividend, Π_t, as a lump-sum income from the ownership of all firms. There is no explicit household labor supply choice because labor market inputs, employment and the optimal hours are determined at the firm level during negotiations.

[9]The link between nominal and real interest rates gives the Fisher relation. See Gertler and Karadi (2011).

The first-order conditions with respect to C_t , B_t, and D_t are:

$$C_t^{-\sigma} = \lambda_t \tag{1.4}$$

$$\frac{1}{R_t^n} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} \tag{1.5}$$

$$\frac{1}{R_t} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \tag{1.6}$$

where λ_t is the lagrangian multiplier, which represents the marginal utility of consumption, and $\pi_t \equiv \frac{P_t}{P_{t-1}}$ denotes the gross inflation rate.

1.4.2 Firms and Labor Market

There is a continuum of intermediate firms measured on the unit interval. Each firm j produces output $y_t(j)$ using capital $K_t(j)$, labor $n_t(j)$ and $h_t(j)$ hours per worker. Let A_t denotes total factor productivity and ξ_t denotes the quality of capital, so that, $\xi_t K_t$ is the effective quantity of capital. The production function is given by the following:

$$y_t(j) = A_t(h_t(j)n_t(j))^{\alpha}(\xi_t K_t(j))^{1-\alpha} \tag{1.7}$$

where A_t captures shocks to total factor productivity. It follows a stochastic AR(1) process, where $0 < \rho_a < 1$ measures the persistence of the shock and $\epsilon_{a,t} \sim i.i.d.N(0, \sigma_a)$. The shock, ξ_t is meant to capture the exogenous variations in the value of the effective unit of capital. The price of capital is determined endogenously as I will explain later. ξ_t also follows a stochastic AR(1) process, where $0 < \rho_\xi < 1$ measures the persistence of the capital quality shock and $\epsilon_{\xi,t} \sim i.i.d.N(0, \sigma_\xi)$.

I assume that capital is perfectly mobile across firms and that there is a competitive rental market for capital. But, firms meet workers on a matching market and hire them from the unemployment pool through a costly process. Workers' wages and hours of work are determined through a decentralized bargaining process. Firms post vacancies and unemployed workers search for jobs. Vacancies are matched with job-searching workers at a rate that depends on the number of searches on each side of the market.[10] I assume that the matching function takes the Cobb-Douglas form so that the flow, M_t, of successful matches is formed within period t as follows

$$M_t(u, v) = m_t u_t^{\alpha_m} v_t^{1-\alpha_m} \tag{1.8}$$

where $u_t = \int_0^1 u_{jt} dj$ is the number of unemployed workers and $v_t = \int_0^1 v_{jt} dj$ is the total number of vacancies posted by all firms, $0 < \alpha_m < 1$ is the match elasticity of the unemployed worker and m_t captures the shocks to the efficiency of the matching process. This follows a stochastic AR(1) process, where $0 < \rho_m < 1$ measures the persistence of the shock and $\epsilon_{m,t} \sim i.i.d.N(0, \sigma_m)$. Defining labor market tightness as $\tau_t \equiv \frac{v_t}{u_t}$, the probability that any open vacancy is matched with a searching worker is given by

$$p^v(\tau_t) = \frac{M_t}{v_t} = m_t \tau_t^{-\alpha_m} \tag{1.9}$$

This implies that firms with vacancies can hire workers more easily when the labor marker tightness is relatively low, that is, when the number of searching workers is higher than the number of job postings. Similarly, the probability that any worker

[10] Another way to think about the labor recruitment process is to introduce employment agencies that post vacancies and perform wage bargaining, and intermediate firms receive labor services from these agencies in a competitive market. See CTW (2011) for more details. However, it is more natural to consider that intermediate firms do their own employee searches.

who is looking for a job is matched with an open vacancy is given by

$$p^u(\tau_t) = \frac{M_t}{u_t} = m_t \tau_t^{1-\alpha_m} \tag{1.10}$$

Analogously, this implies that job-searching workers find employment more easily when the labor marker tightness is relatively high, that is, when the number of job postings is higher than the number of job-seekers.

Now, let us define the employment dynamics. I follow the literature by assuming that matches are destroyed at a constant rate ρ_s. For instance, Hall (2005) and Shimer (2007) argue that movements in the separation rate play a minor role in explaining movements in unemployment. To illustrate this, consider that firm j begins t with $n_{t-1}(j)$ workers, and a fraction $(1 - \rho_s)n_{t-1}(j)$ of them survives to the next period. At the same time, M_t new matches are formed and newly hired workers immediately become productive. Hence, employment evolves according to the following dynamic equation:

$$n_t(j) = (1 - \rho_s)n_{t-1}(j) + p^v(\tau_t)v_t(j) \tag{1.11}$$

Firm's Optimization Problem

The firm's problem is to choose its number of employees, $n_t(j)$, its number of vacancies, $v_t(j)$, and its capital stock $K_t(j)$ so as to maximize the present value of future discounted profits; it takes the wage schedules and the capital rental rate as given. A bargaining process determines the wages and average hours worked, which will be discussed shortly. Defining the competitive price for intermediate goods as mc_t and the vacancy posting cost per hire as k, the firm j's problem can then be written as follows:

$$\max E_t \sum_{s=0}^{\infty} \beta^s \frac{\lambda_{t+s}}{\lambda_t} \left\{ mc_{t+s}(j) y_{t+s}(j) - w_{t+s}(j) h_{t+s}(j) n_{t+s}(j) - k v_{t+s}(j) - r_{t+s} k_{t+s}(j) \right\} \tag{1.12}$$

subject to the production function (equation 1.7), and the law of motion for employment (equation 1.11).

Let's define $V_t^f(j)$, the lagrange multiplier on employment, as the marginal value of additional worker. Since, in equilibrium, all firms will choose the same allocation, I can assume symmetry and drop index j hereafter. The first-order conditions with respect to K_t, v_t and n_t are given by the following:

$$r_t = \alpha \frac{y_t}{K_t} mc_t \tag{1.13}$$

$$V_t^f = \frac{\kappa}{p_t^v} \tag{1.14}$$

$$V_t^f = \alpha \frac{y_t}{n_t} mc_t - w_t h_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[(1 - \rho_s) V_{t+1}^f \right] \tag{1.15}$$

Equations (1.14) and (1.15) equate the marginal cost of hiring a new worker to the value of hiring an additional worker. Equation (1.15) shows that the current period marginal value of employment equals to the marginal revenue product of employment net of wage payments, plus the expected value of the worker in the next period, if the job survives.

Worker's Problem

To derive the wage schedule, I also need to consider the marginal values of a match for workers. If a worker is employed, then he receives a wage income less the disutility of working. In period t+1, the match is separated with probability ρ_s but the separated worker can get a new match with probability p_{t+1}^u. Thus with probability $\rho_s(1-p^u_{t+1})$ the separated worker remains in the unemployment pool. Otherwise, with probability $1-\rho_s(1-p^u_{t+1})$ the worker continues in the match in t+1. Therefore, the value of being employed is given by:

$$V^n_t = w_t h_t - \frac{\chi_t \frac{h_t^{1+\phi}}{1+\phi}}{\lambda_t} + \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[[1-\rho_s(1-p^u_{t+1})]V^n_{t+1} + \rho_s(1-p^u_{t+1})V^u_{t+1} \right] \right\} \quad (1.16)$$

where V^u_t denotes the value of an unemployed worker.

An unemployed worker receives real unemployment benefit, b, and is expected to move into employment with probability, p^u_{t+1}. Therefore, the value of being unemployed is given by:

$$V^u_t = b + \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[p^u_{t+1} V^n_{t+1} + (1-p^u_{t+1}) V^u_{t+1} \right] \right\} \quad (1.17)$$

The difference between equations (1.16) and (1.17) determines the worker's surplus.

Bargaining

In equilibrium, a job match strictly yields higher returns for both firms and workers, rather than otherwise. This is because the hiring process is costly for firms and when workers go through an unemployment spell they receive a small fraction of the income they would otherwise be earning. Hence, when both parties form a match through bargaining they take into account the expected costs of an unmatched outcome. I assume that workers and firms bargain period-by-period at the individual level, over their joint matching surplus, according to the Nash Bargaining solution. This is a very common assumption in dynamic general equilibrium search models.[11] However, unlike many studies in the labor-search

[11] We can also think of a match specific wage that depends on the idiosyncratic productivity of the job. A high skilled worker will receive higher wages than a low skilled worker will. See Krause and Lubik (2007) for details. Since the main focus of this paper is to evaluate the aggregate effects on labor market inputs, I simplify the bargaining process, assuming that all matched

literature, where bargaining takes place over wages only, in this paper bargaining takes place along two dimensions: the real wage and hours per worker. The Nash bargaining problem can be written as

$$\max_{w_t,h_t} \left[V_t^n - V_t^u\right]^{\eta}\left[V_t^f\right]^{1-\eta} \tag{1.18}$$

The parameter, $\eta \in (0,1)$, reflects the worker's bargaining power. The wage that is chosen by the match satisfies the optimal sharing rule between the firm and the worker:

$$V_t^n - V_t^u = (\frac{\eta}{1-\eta})V_t^f \tag{1.19}$$

In equilibrium, I assume that the real wage equals the Nash bargaining wage. Using equations (1.14) to (1.19) and setting $w_t = w_t^N$, I obtain the equilibrium Nash bargaining wage bill per worker as follows:

$$w_t^N h_t = (1-\eta)\left[\frac{\kappa_h \frac{h_t^{1+\phi}}{1+\phi}}{\lambda_t} + b\right] + \eta\left[\alpha\frac{y_t}{n_t}mc_t + \beta\kappa(1-\rho_s)E_t\Big(\frac{\lambda_{t+1}}{\lambda_t}\Big)\tau_{t+1}\right] \tag{1.20}$$

Equation (1.20) shows that the total wage payment to the worker is a weighted average between the worker's marginal revenue product plus the expected savings in terms of future hiring costs if the match continues in t+1, and the unemployment benefits plus the marginal disutility of labor at the level of hours worked, h_t.

The average hours determined by the match satisfies the following optimality condition:

$$\eta V_t^f\left[\chi_t\frac{u_h}{\lambda_t} - w_t\right] = (1-\eta)(V_t^n - V_t^u)\left[(mc_t)y_h - w_t\right] \tag{1.21}$$

Using equation (1.19), it can be simplified to

$$\chi_t\frac{u_h}{\lambda_t} = (mc_t)y_h \tag{1.22}$$

workers will get the same wage and work the same number of hours.

where $u_h \equiv \frac{\partial u}{\partial h}$ and $y_h \equiv \frac{\partial y}{\partial h}$, with h representing the labor hours. This equalizes the marginal product of labor to the marginal rate of substitution between leisure and consumption. In other words, hours will be set at the level where the marginal disutility of working one additional hour in terms of consumption goods is equal to the marginal product of labor. The same optimality condition holds in a competitive labor market, but the hours in this bargaining process are chosen independently of the wage, unlike the competitive labor market equilibrium.

1.4.3 Wage Rigidity

Shimer (2005) and Hall (2005) have demonstrated that the real wage derived from period-by-period Nash bargaining between firms and workers is too volatile relative to the data. Hall (2005) further points out that real wage rigidity is important to deliver empirically plausible volatilities in unemployment and vacancies. Therefore, in order to allow the model to capture wage rigidity, I follow Leduc and Liu (2016) and adopt the following wage rule:

$$w_t = w_{t-1}^{\alpha_w} {w_t^N}^{1-\alpha_w} \epsilon_t^w \tag{1.23}$$

where $\alpha_w \in (0, 1)$ represents the degree of real wage rigidity and the variable ϵ_t^w represents a wage markup shock. This follows a stochastic AR(1) process, where $0 < \rho_w < 1$ measures the persistence of the shock and $\eta_t^w \sim i.i.d.N(0, \sigma_w)$.

1.4.4 Entrepreneurs and Financial Intermediaries

The entrepreneurial sector closely follows the framework of BGG (1999) and Gunn and Johri (2013). There is a continuum of risk neutral entrepreneurs who accumulate physical capital. At the beginning of period t, the entrepreneurs rent their capital $K_t(i)$ to the intermediate goods-producers at rental rate r_t. At the end of period t, the entrepreneurs sell all of their accumulated capital to the capital producers at price, Q_{t+1} and then repurchase new capital, $K_{t+1}(i)$ at price Q_t. The entrepreneurs finance this purchase using their net worth, X_{t+1}, and obtaining external financing from a financial intermediary, $B_{t+1}(i)$, such that it satisfies

$$Q_t K_{t+1}(i) = X_{t+1}(i) + B_{t+1}(i) \tag{1.24}$$

This ensures that the entrepreneur has to go to the capital market to borrow funds prior to purchasing the capital. I also assume that each entrepreneur has a finite planning horizon, which ensures that he will never accumulate enough net worth to fully finance the new capital acquisition. The probability that an entrepreneur will survive until the next period is η^e; newly born entrepreneurs replace the existing ones, thus the expected lifetime horizon is $\frac{1}{1-\eta^e}$.

The gross return to holding capital from t to t+1 is given by

$$R^k_{t+1} = \frac{r_{t+1} + (1-\delta)Q_{t+1}\xi_{t+1}}{Q_t} \tag{1.25}$$

where $(1-\delta)Q_{t+1}\xi_{t+1}$ is the return from selling the undepreciated capital stock to the capital producers. Notice that the capital quality shock can drive the return to capital, and the current price of capital, Q_t, depends on beliefs about the expected future path of ξ_{t+i}.

Following BGG (1999), I assume the existence of an agency problem between the entrepreneurs and the intermediaries, which makes the external financing more expensive than the internal funds. At the beginning of period, t+1, the entrepreneur is hit by an idiosyncratic shock such that one unit of capital from the end of time t is transformed into ω_{t+1} units of capital in time t+1, where ω^i_{t+1}, for all i, is i.i.d. across firms and time with c.d.f. $F(\omega)$ and is normalized such that $E[\omega] = 1$. The entrepreneur freely observes the realization of ω_{t+1}; however, financial intermediary incurs a monitoring cost, μ, to observe this realization. This cost can be interpreted as a bankruptcy cost that captures financial rigidity. In many existing studies, this cost is assumed to be constant. But, following Levin et al. (2004) and Johri and Gunn (2013), I assume that μ_t is time varying and it follows a stochastic process, such that an exogenous change in the level of this parameter will affect the business cycle properties of the model.

Given that the entrepreneur is risk neutral, he is willing to bear all of the aggregate risks on his loans. Thus, the entrepreneur offers a debt contract that ensures the financial intermediary receives an expected return that is equal to the opportunity cost of the funds. The financial intermediary can diversify idiosyncratic risks by holding a perfectly diversified portfolio, thus it offers households a risk-free rate on deposits. The debt contract is, thus, characterized by the loan amount, B_{t+1}, contractual rate of gross interest rate, R^l_{t+1}, and a reservation value of the idiosyncratic shock $\overline{\omega}_{t+1}(i)$ such that

$$R^l_{t+1}(i)B_{t+1}(i) \equiv \overline{\omega}_{t+1}(i)R^k_{t+1}Q_tK_{t+1}(i) \tag{1.26}$$

If the idiosyncratic shock exceeds the reservation value, such that $\omega_{t+1}(i) \geq \bar{\omega}_{t+1}(i)$, the financial intermediary will be repaid the full loan amount $R^l_{t+1}(i)B_{t+1}(i)$, and if the idiosyncratic realization falls below the cuttoff, $\omega_{t+1}(i) < \bar{\omega}_{t+1}(i)$, then the entrepreneur will default, and the financial intermediary steps in and seizes the entrepreneur's assets net of monitoring costs, $(1-\mu_t)\omega_{t+1}(i)R^k_{t+1}(i)Q_tK_{t+1}(i)$.

Given this set up, the expected gross return on the loan to the financial intermediary can be written as

$$\left[[1-F(\bar{\omega}_{t+1})]\bar{\omega}_{t+1}(i) + (1-\mu_{t+1})\int_0^{\bar{\omega}(i)} \omega_{t+1}(i)dF(\omega)\right] R^k_{t+1}(i)Q_tK_{t+1}(i) \tag{1.27}$$

Defining

$$\Gamma(\bar{\omega}_{t+1}) = [1 - F(\bar{\omega}_{t+1})]\bar{\omega}_{t+1}(i) + \int_0^{\bar{\omega}(i)} \omega_{t+1}(i) dF(\omega), \tag{1.28}$$

and

$$G(\bar{\omega}_t) = \int_0^{\bar{\omega}} \omega dF(\omega) \tag{1.29}$$

I can re-write the financial intermediary's expected return on the loan contract as follows:

$$\left[\Gamma(\bar{\omega}_{t+1}) - \mu_{t+1} G(\bar{\omega}_{t+1})\right] R^k_{t+1} Q_t K_{t+1}(i) \tag{1.30}$$

The terms of the debt contract are chosen to maximize entrepreneur's expected profits conditional on the lender's expected return for each aggregate state of the world, being equal to the opportunity costs of the funds, denoted as $R^d_{t+1} B_{t+1}(i)$. That is, the participation constraint is given by the zero profit condition for the financial intermediary. Accordingly, the loan contract must satisfy the following:

$$\left[\Gamma(\bar{\omega}_{t+1}) - \mu_{t+1} G(\bar{\omega}_{t+1})\right] R^k_{t+1} Q_t K_{t+1}(i) = R^d_{t+1} \left(Q_t K_{t+1}(i) - X_{t+1}(i)\right) \tag{1.31}$$

Defining the leverage ratio as, $\kappa_{t+1}(i) = \frac{Q_t K_{t+1}(i)}{X_{t+1}(i)}$, I can rearrange equation (1.31) as follows

$$\frac{R^k_{t+1}}{R^d_{t+1}} = \frac{1}{\left[\Gamma(\bar{\omega}_{t+1}) - \mu_{t+1} G(\bar{\omega}_{t+1})\right]} \left(1 - \frac{1}{\kappa_{t+1}(i)}\right) \tag{1.32}$$

Equation (1.32) implies that financial intermediaries charge a premium over the risk-free rate, also known as the external finance premium, $\frac{R^k_{t+1}}{R^d_{t+1}}$, to provide funds to entrepreneurs wishing to undertake a risky project. It affects the demand for capital by making a linkage between the entrepreneur's leverage ratio and the cost of the external finance. The above equation also states that the risk premium can be affected by two channels: (i) through the elasticity of the external finance premium with respect to the leverage ratio, $\frac{1}{\Gamma(\bar{\omega}_{t+1})-\mu_{t+1}G(\bar{\omega}_{t+1})}$, and (ii) through changes to the leverage ratio.

One can also notice that shocks to the default cost introduce a time varying wedge between the external finance premium and the leverage ratio. As a result, the contract menu offered to entrepreneurs changes over time and it can endogenously explain the movements in the external finance premium, the leverage ratio, net worth, credit quantity, and the price of capital without having to assume exogenous movements in these variables.

The marginal bankruptcy cost or default cost, μ_t, which is assumed to be time-varying, can affect the external finance premium through changes to the elasticity of the external finance premium with respect to the leverage ratio. Following Gunn and Johri (2013), I assume that μ_t evolves according to the stationary AR(1) process, where $0 < \rho_\mu < 1$ measures the persistence of the shock and $\epsilon_{\mu,t} \sim i.i.d.N(0, \sigma_\mu)$.

Given the state-contingent debt form of the optimal contract, the entrepreneur's expected return can be expressed as follows:

$$\int_{\bar{\omega}_{t+1}}^{\infty} \omega_{t+1}(i) R^k_{t+1}(i) Q_t K_{t+1}(i) dF(\omega_{t+1}) - R^l_{t+1}(i) B_{t+1}(i). \tag{1.33}$$

Using the above definitions, I can simplify equation (1.33) such that the entrepreneur's objective is to choose $K_{t+1}(i)$ and $\bar{\omega}_{t+1}(i)$ for a given level of net-worth $X_{t+1}(i)$ to maximize

$$\left[1 - \Gamma(\bar{\omega}_{t+1}(i))\right] R^k_{t+1} Q_t K_{t+1}(i). \tag{1.34}$$

subject to the set of state-contingent constraints equation (1.32) implies.

1.4.5 Capital Producers

Capital producers are competitive. At the end of the period t, they buy the depreciated capital from the entrepreneurs and combine a fraction of the final goods purchased from the retailers as investment goods, I_t, to produce new capital goods, K_{t+1}, which they sell at price Q_t. The capital accumulation is given by

$$K_{t+1} = (1-\delta)\xi_t K_t + \gamma_t \Phi(\frac{I_t}{K_t})K_t \tag{1.35}$$

where $\Phi(.)$ is increasing and concave, and satisfies $\Phi(I/K) = I/K$ and $\Phi'(I/K) = 1$, where I/K is the net investment to capital ratio. γ_t represents the MEI shock, which captures the exogenous disturbance to the process by which investment goods are turned into the capital that is to be used in production. This follows an AR(1) stochastic process as follows:

$$log\gamma_t = \rho_\gamma log\gamma_{t-1} + \epsilon_{\gamma,t} \tag{1.36}$$

where $\epsilon_{\gamma,t} \sim i.i.d.N(0, \sigma_\gamma)$. The optimal condition for capital producers is as follows:

$$Q_t = \left[\Phi'(\frac{I_t}{K_t})\right]^{-1} \tag{1.37}$$

1.4.6 Retailers

There is a continuum of monopolistically competitive retailers of measure 1. Retailers buy intermediate goods from intermediate producers and produce a good of variety i. Let $Y_t(i)$ be the retail good sold by retailer i to households and let $P_t(i)$ be its nominal price. The final good, Y_t, is the composite of the individual retail goods,

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\theta_t - 1}{\theta_t}} di\right]^{\frac{\theta_t}{\theta_t - 1}} \tag{1.38}$$

where θ_t is the time-varying elasticity of demand for each intermediate good. This acts as a cost-push shock and follows a stochastic AR(1) process, where $0 < \rho_\theta < 1$ measures the persistence of the shock and $\epsilon_{\theta,t} \sim i.i.d.N(0, \sigma_\theta)$.

The demand that each retailer faces is as follows:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta_t} Y_t \tag{1.39}$$

where the price index is given by

$$P_t = \left[\int_0^1 P_t(i)^{1-\theta_t} di\right]^{\frac{1}{1-\theta_t}} \tag{1.40}$$

Following Calvo (1983), I assume that each period, each retail firm sets prices such that a fraction, $(1 - \zeta)$, of retail firms sets a new price, whereas the remaining fraction, ζ, of firms keeps the price unchanged. Therefore, firm i sets a new price, $P_t(i)$, at time t and maximizes its profit as follows:

$$E_0 \sum_{j=0}^{\infty} (\beta\zeta)^j \frac{\lambda_{t+j}}{\lambda_t} \left\{ \left(\frac{P_t(i)}{P_t}\right)^{-\theta_t} Y_{t+j} \left[\frac{P_t(i)}{P_{t+j}} - mc_{t+j}\right] \right\} \tag{1.41}$$

The first-order condition is

$$P_t^*(i) = \frac{\theta_t}{\theta_t - 1} \frac{E_t \sum_{j=0}^{\infty} (\beta\zeta)^j \left[\lambda_{t+j} mc_{t+j} y_{t+j}(j) p_{t+j}^{\theta_t}\right]}{E_t \sum_{j=0}^{\infty} (\beta\zeta)^j \left[\lambda_{t+j} y_{t+j}(j) p_{t+j}^{\theta_t - 1}\right]} \tag{1.42}$$

where the retailer chooses price, $P_t^*(i)$. The aggregate price index follows

$$P_t = \left[\zeta P_{t-1}^{1-\theta_t} + (1 - \zeta) P_t^{*1-\theta_t}\right]^{\frac{1}{1-\theta_t}} \tag{1.43}$$

These equations lead to the following New Keynesian Phillips curve:

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1-\beta\zeta)(1-\zeta)}{\zeta}(\hat{mc}_t + \hat{\theta}_t) \tag{1.44}$$

where mc_t is the real marginal cost, and the variables with hats are log deviations from the steady-state values.

1.4.7 Government Policy

Households buy nominal government bonds, B_t, and pay real lump-sum taxes, T_t, to the government. With this income, the government finances real exogenous spending, G_t, and the amount of real unemployment benefits, $b(1-n_t)$, for the unemployed members of households. Hence the government budget constraint at time t follows:

$$G_t + b(1-n_t) + \frac{B_{t-1}R^n_{t-1}}{P_t} = T_t + \frac{B_t}{P_t} \tag{1.45}$$

where G_t equals to

$$G_t = (1 - \frac{1}{g_t})Y_t \tag{1.46}$$

where g_t represents the government spending shock. This follows a stochastic AR(1) process, where $0 < \rho_g < 1$ measures the persistence of the shock and $\epsilon_{g,t} \sim i.i.d.N(0, \sigma_g)$.

The monetary authority adjusts the nominal interest rate, R^n_t, in response to movements in output growth and deviations of inflation from its steady-state. This evolves according to the following:

$$log(\frac{R^n_t}{R^n}) = \rho log(\frac{R^n_{t-1}}{R^n}) + (1-\rho)\Big(\phi_\pi log(\frac{\pi_t}{\pi}) + \phi_y log(\frac{Y_t}{Y_{t-1}})\Big) + \epsilon^r_t \tag{1.47}$$

where R^n and π are the steady-state values of R^n_t and π_t. ϕ_π and ϕ_y are the response coefficients to inflation and output. ρ_r is the smoothing parameter of the interest rate. The monetary policy shock ϵ_t^r follows a first order autoregressive process, where $0 < \rho_r < 1$ measures the persistence of the shock and $\eta_t^r \sim i.i.d.N(0, \sigma_r)$.

1.4.8 Equilibrium

Equilibrium is defined by a contingent sequence of decision rules that satisfy the following conditions: (i) the allocations solve all eight agents' problems; (ii) all markets clear; and (iii) the resource constraint holds. Good market clearing implies that the final good is the sum of consumption, investment, government expenditures, the labor hiring cost and the aggregate cost of monitoring associated with bankruptcies. Therefore, the aggregate resource can be defined as follows:

$$Y_t = C_t + I_t + G_t + kV_t + \mu_t \int_0^{\bar{\omega_t}} \omega dF(\omega) R_t^k Q_{t-1} K_t \tag{1.48}$$

1.5 Empirical Evaluation

The model is estimated using Bayesian methods. First, I log-linearized the model around the deterministic steady-state. I then solve the model and apply the Kalman filter to evaluate the likelihood function of the observable variables. Next, I estimate the posterior modes by maximizing the log posterior function, which combines the prior information on the parameters with the likelihood of the data. I then use the Metropolis-Hastings algorithm to generate the posterior distribution. The total number of draws is 100,000, and the first 20% draws are discarded. Figure 1.4 shows the multivariate convergence statistic of the Markov chain Monte Carlo (MCMC) simulation. The red and blue lines represent specific within and between chain measures. The top panel represents the interval statistic and is constructed around the parameter mean. The middle panel represents the m2 statistics and is formed on the variance. The third panel represents the m3 statistic and is based on third moments. As shown in the figure, the simulation converges when the two lines are getting closer and overlap each other.[12]

The model is estimated over the period 1984:Q1 to 2014:Q4, using ten shocks and ten data series, as follows: the log difference of real GDP, the log difference of real investment, the log difference of real consumption, the log difference of the unemployment rate, the log difference of the vacancy rate, the external finance premium measured as the difference between Moody's BAA corporate bond yields and the 3-month T-bill rate, the nominal interest rate as measured by the federal funds rate, the inflation rate as measured by the log difference of the GDP deflator, the log of real wages and the log of average hours worked. The series of nominal interest rate, inflation, real wages, and average hours worked are detrended using Hodrick-Prescott filter with smoothing parameter 1600. The data are demeaned and the output, investment, and consumption series are expressed in per capita terms prior to estimation.

The ten shocks in my model are total factor productivity (TFP) shocks (A_t), default cost shocks (μ_t), labor supply shocks (χ_t), capital quality shocks (ξ_t), marginal efficiency of investment (MEI) shocks (γ_t), cost-push shocks (θ_t), wage mark up shocks (ϵ_t^w), worker-firm matching shocks (m_t), government expenditure shocks (g_t), and monetary policy shocks (ϵ_t^r).

1.5.1 Calibrated Values

I calibrate some parameters to match the steady-state values in the model with similar quantities found in the data. I also set the parameters based on those in existing studies. The preference and production parameters are standard in the business cycle model. I set $\beta = 0.99$, which implies that a steady-state real interest

[12]The MCMC univariate convergence diagnostic test results are available upon request.

rate is 4% per year. I set the share of labor in production, α, to 0.67, which is a value commonly used in the literature. I set the depreciation rate of physical capital, δ, to 0.025, to produce a 10% annual depreciation rate. The steady-state value of the elasticity of substitution between intermediate goods, θ, is set to 11, so that the steady-state price markup, $\frac{\theta}{\theta-1}$, is 10%, on average. The steady-state government spending - output ratio, $\frac{G}{Y}$, is set to 0.20.

The steady-state unemployment rate is set at 0.064, which is consistent with the average unemployment rate in the data. I follow Hall and Milgrom (2008) to set the unemployment benefits, b, to 0.25, which implies that the unemployment benefit is, on average, about 25% of the wage income. I set the vacancy filling rate, p^v, to 0.70, as in den Haan, Ramey and Watson (2000) and Krause and Lubik (2007).

I follow BGG (1999) to set the parameters associated with the financial contract and the entrepreneur. I set the entrepreneur's quarterly survival rate to 0.973, the variance of the log-normally distributed productivity variable, $log\overline{w}$, to 0.174, and the steady-state bankruptcy cost to 0.136, to target the steady-state values of the external finance premium of 200 basis points annually, the leverage ratio of 0.50 and entrepreneur's default rate of 0.076 quarterly.

I estimate the remaining parameters as follows: the capital adjustment cost parameter, $\eta_{\frac{i}{k}}$; the worker's wage bargaining power, η; the elasticity of matches to unemployment, α_m; the per unit vacancy posting cost, κ; the job separation rate, ρ_s; the Calvo price parameter, ς; the inverse of the Frish elasticity of labor supply, ϕ; and the Taylor rule parameters, ϕ_π, ϕ_y, and ρ. I also estimate the first order autocorrelations of all the exogenous shocks and their respective standard deviations.

1.5.2 Priors

Tables 1.2 and 1.3 report the prior and the posterior distributions of all these variables.[13] I set the priors based on the existing literature. I set the prior for the job separation rate, ρ_s to 0.10, which is consistent with the average monthly job separation rate of about 3.5% computed by Shimer(2005). I set the prior for the elasticity of matches to unemployment, α_m, to 0.40, which is obtained by Blanchard and Diamond (1989). I set the prior for the workers' bargaining power parameter, η, to 0.50, which is standard in the literature. I set the prior for the per unit vacancy posting cost, κ, to 0.05, as in Merz (1995).

I set the probability that a firm does not change its price within a given period, ς, equal to 0.65, with a standard error of 0.05. The inverse of the Frish elasticity of labor supply, ϕ is assumed to be 2, with standard error of 0.75. I set the prior for the investment adjustment cost, $\eta_{\frac{i}{k}}$, to 0.10, with a standard error of 0.02, as there is no firm evidence about the exact value of this parameter. However, it is reasonable to assume that the adjustment cost should fall within the range of between 0 and 0.50.

The prior mean of the interest rate smoothing parameter, ρ, is set to 0.50. I use the beta distribution for the parameters that take sensible values between zero and one, the gamma distribution for the coefficients that are restricted to being positive, and the normal distribution for the two parameters: the investment adjustment cost and the output coefficient in the Taylor rule. The priors on the shock processes are harmonized as much as possible following Smets and Wouters (2007). The standard deviation of the shocks are assumed to follow an inverted gamma distribution, with a mean of 1% and two degrees of freedom. The persistence of the shock processes is beta distributed with a mean of 0.50 and a

[13]Figures with the prior and posterior distributions of all the parameters are available upon request.

standard deviation of 0.20.

1.6 Estimation Results

1.6.1 Posterior Estimates

Tables 1.2 and 1.3 present the mode, the mean and the 5 and 95 percentiles of the posterior distribution of the structural and shock processes. The means of all of the conventional parameters are estimated to be close to the priors and are consistent with existing studies. The capital adjustment cost parameter is estimated to be around 0.21, which is very close to the value (0.25) that BGG (1999) considered. The posterior mean of the relative risk aversion is equal to 0.94, which is very close to its prior mean and is consistent with other studies. The posterior mean of the inverse of the Frisch elasticity of labor supply is equal to 4.34 (or a labor supply elasticity $\approx$ 0.23), which is substantially higher than its prior and is in line with microeconomic estimates as surveyed by Card (1994). This high estimate reflects the fact that employment is more volatile along the extensive margin than the intensive margin.

The posterior mean of the elasticity of the matching function is 0.29, which is lower than its prior mean. This indicates that the model allows a lower elasticity of job matching with respect to unemployed workers than for the number of vacancies. The posterior mean of the job separation rate is 0.13, which is in line with those used in the literature, which range from 0.07 (Merz, 1995) to 0.15 (Andolfatto, 1996). The posterior mean of the workers' bargaining power is 0.26, thereby indicating that firms have much higher bargaining power over wages and hours worked than workers do.

The posterior means of the price and real wage rigidity parameters are 0.88 and

0.79, respectively. This shows that high degrees of price and wage rigidity exist in the model. The parameters of the Taylor rule are estimated fairly well. The mean response of the interest rate to inflation, ρ_π, is estimated to be around 1.74, and the reaction coefficient to output growth, ρ_y, is estimated to be around 0.20. This suggests that the monetary policy responds more strongly to fluctuations in inflation than to output growth, which is in line with the estimates of Smets and Wouters (2007). There is a moderate degree of interest rate smoothing. The mean coefficient on the lagged interest rate is estimated to be 0.49, which suggests that the monetary authorities prefer to smooth interest rate fluctuations.

Turning to the persistence of the exogenous disturbances, the estimates for the autoregressive coefficients are reasonable. The government expenditure, MEI, TFP, and matching efficiency are the most persistent shocks. The default cost, cost-push, and labor supply shocks are estimated to be moderately persistent, while capital quality, monetary policy, and wage mark-up shocks appear to be less persistent. The mean of the standard error of the TFP, monetary policy, government expenditure, MEI, and wage markup shocks are relatively low, suggesting that these shocks are less volatile compared to other shocks in the model.

Overall, for most parameters I obtain reasonable and tight estimates. More importantly, the data seems to be very informative on the behavioral parameters and stochastic processes for the exogenous disturbances.

Figure 1.6 plots the smoothed estimates of the default cost shock that is computed by using the Kalman smoothing algorithms from the state-space representation of the estimated model. One can observe that the recent Great Recession coincided with a rise in default cost shocks. It is also evident that this shock appears largely responsible for pulling investment growth down in business-cycle troughs during the 2007-2009 financial crisis.

1.6.2 Variance Decomposition

To analyze the importance of the different shocks, I measure the contribution of each shock to the forecast error variance of the observable variables. Table 1.4 reports the variance decomposition at three horizons: one quarter, one year, and five years, based on the mode of the model's posterior distribution reported in Section 1.6.1.

The results show that the default cost, monetary policy, cost-push, labor supply, and wage markup shocks are the major driving forces that explain the fluctuations in the data. The default cost shock, in particular, appears to be important to accounting for the movements in investment growth, output growth, unemployment growth, vacancy growth, and the external finance premium. In each case, the share in the variance attributed to the default shock is found to be in one of the four major shocks. For the investment growth and external finance premium, the default cost shock contributes by far the most to the variance in any time horizons. The default cost shock's contributions to the variance of the external finance premium and investment growth are roughly 70% and 30%, respectively. For unemployment growth and vacancy growth, the default cost shock appears to be an equally significant driving force as wage markup shocks are. This can explain about 11% of the fluctuations in these variables; whereas the MEI and capital quality shocks appear to be less important to capturing fluctuations in unemployment growth and vacancy growth. For output growth, the default cost shock seems to be as equally important as TFP, capital quality, and labor supply shocks. The default cost shock's contributions to the variance in output growth is about 12%, while TFP, capital quality, and labor supply can explain about 10%, 14%, and 12%, respectively. For the federal funds rate, the default cost shock significantly contributes to its short-run fluctuations in a range of between

10% and 31%, within a year. This explains why the monetary authorities should respond directly to financial shocks while at the same time stabilizing inflation.

The default cost shock plays a subsidiary role to explain fluctuations in consumption growth, hours worked, inflation, and real wages. Capital quality, government expenditure, TFP, labor supply, and monetary policy shocks appear to be the key drivers of the variance in consumption growth. Labor supply and wage mark-up shocks emerge as the most important contributors to movements in average hours worked and real wages. The variance decomposition also reveals that monetary policy, labor supply, and cost-push shocks explain a large portion of the movements in output growth, the federal funds rate, unemployment growth, and vacancy growth. For inflation, though the cost push and labor supply shocks explain a significant portion of the movements here; the MEI, TFP, and wage mark-up shocks also emerge as important driving forces for that variable.

In summary, the variance decomposition suggests that shocks to the default cost significantly contribute to the variances of the key macro and labor market variables, even in the presence of other important demand and supply shocks.

1.6.3 Key Moments

In this section, I compare the correlations and standard deviations of the key variables, that are generated by the model, against the data. Tables 1.5 and 1.6 report the theoretical contemporaneous correlations generated by the model and their data counterparts. Overall, the model does a decent job in matching the moments observed in the data. For instance, the model closely matches the well-known correlation between unemployment and vacancies, also known as the Beveridge curve (-0.86 in the model versus -0.90 in the data). The model matches the fact that unemployment and spread are countercyclical whereas vacancies and investment are procyclical. The model also captures the strong negative correlation between unemployment and investment and the positive correlation between vacancies and investment. Further, it appears to capture the positive correlation between unemployment and spread, and the negative correlation between investment and spread, and also between vacancies and spread.

Table 1.7 shows the relative standard deviations of the key labor market variables with respect to output. The model captures the fact that both unemployment and vacancies are highly volatile and real wages are relatively rigid. It also captures the fact that the labor supply is more volatile along the extensive margin than the intensive one.

1.6.4 Why Unemployment is More Persistent than Averages Hours Worked

In this section, I conduct a short-run analysis to examine how the model responds to default cost shocks and other relevant shocks, such as TFP, MEI, and capital quality, which are found in many studies to be important drivers of U.S. business cycles. In each case, I set an adverse shock such that it generates a recession. Figures 1.7 to 1.10 show the economy's impulse response functions to these shocks. Impulse responses are computed as the expected future path of the endogenous variables, conditional on a shock in period 1 to the exogenous variables. I have computed the IRFs for 11 key variables: the external finance premium, investment, output, entrepreneur's net worth, capital price, real wages, average hours worked, unemployment, vacancies, inflation, and the policy rate.

Default Cost Shocks

Figure 1.7 illustrates the model's response when the marginal bankruptcy cost (or default cost) increases by one standard deviation in the first period. This shock generates an immediate fall in economic activity with the largest impact occurring in the first period, and then a persistent increase towards the steady-state.

The fall in real activity is accompanied by a fall in the price of capital and net worth. A higher risk premium combined with a lower net worth decrease entrepreneurs' demand for new capital. This has two effects. First, a lower demand for capital reflects a decrease in investment by capital producers. Second, intermediate firms do not receive enough capital goods as inputs for production. As a result, the demand for labor inputs also falls. Firms decrease vacancy postings and reduce average hours worked of each matched worker. This action decreases the labor market tightness and the probability of a worker finding a job, thereby leading to an increase in the unemployment rate and a drop in real wages. As some members are laid off, this decreases household income and increases the marginal utility of consumption. Accordingly, the demand for intermediate goods falls, thereby deceasing the price of intermediate goods. Since prices are set based on expected future marginal costs, inflation also falls. Finally, the monetary authority responds to the fall in economic activity by reducing the policy rate.

During the recovery phase, when the spread begins to fall, the demand for capital begins to rise, which in turn drives up the price of capital. As a consequence, entrepreneurs' net worth increases and this leads them to accumulate more capital. Accordingly, firms increase their production by renting capital from entrepreneurs and by adjusting labor inputs at both the intensive and extensive margins. However, the speed of the adjustments of these two labor inputs differ. Since hiring is costly, firms find it cheaper to offer existing workers work more hours over incurring the search and vacancy posting costs associated with hiring a new worker. At the same time, both old and new workers agree to work additional hours as the marginal utility of consumption is relatively higher right after the crisis. As a result, firms and workers bargain over wages and hours in a way such that each matched worker works extra hours and firms slowly begin to hire new workers. This explains why average hours per worker returns to its pre-crisis level much faster than the unemployment rate during the recovery phase of a financial crisis.

Overall, the default cost shock generates similar impulse responses as those observed empirically. While the response of output, investment and unemployment are large and highly persistent, average hours worked falls transitorily and returns to its pre-crisis level much faster. These results are consistent with the VAR evidence.

Productivity Shocks

Following the seminal work of Kydland and Prescott (1982), the conventional view on the sources of the business cycle has mainly focused on the productivity shocks (TFP). So, I examine how the model responds to an adverse productivity shock.

Figure 1.8 shows the impulse responses to a one standard deviation negative productivity shock. As shown in the figure, this shock cannot explain the movements in average hours worked, inflation and the policy rate as observed in the data. A lower TFP decreases the return to capital, which in turn drops the price of capital and, thus, decreases entrepreneurs' net worth. Output and investment also drop and firms post fewer vacancies, thereby leading to an increase in the unemployment rate. However, as the wealth effect from the lower marginal product of labor outweighs the substitution effect, average hours worked increases through Nash negotiations between firms and workers. This response is opposite to what has been observed in the data. Thus, a negative productively shock cannot capture the business cycle facts that we observed following a financial crisis.

Marginal Efficiency of Investment Shocks

The MEI shock affects the process by which investment goods are transformed into productive capital and is found to be an important driver of business cycle fluctuations. For instance, JPT (2010) shows that US business cycles are primarily driven by MEI shocks, as opposed to the shocks that affect the transformation of consumption into investment goods (IST shocks). Other studies have found the MEI shock to be highly correlated with interest rate spread and that this accounts for most of the fall in output and hours in 2007 and 2008.

Figure 1.9 shows the impulse responses to a one standard deviation negative MEI shock. As shown in the figure, this shock immediately creates recessions but cannot capture the movements in the price of capital and entrepreneurs' net worth. Output, investment, average hours worked, employment, inflation and the interest rate all decline. But the model's prediction about the external finance premium is counterfactual because entrepreneurs' net worth and the price of capital are not falling at the same time. Instead, a negative MEI shock increases the price of capital and thus leads to a sharp increase in entrepreneurs' net worth, which both go against the facts of a financial crisis. Carlstrom et al. (2014) document a similar discrepancy in a model with BGG type financial frictions in response to a MEI shock.

Capital Quality Shocks

Capital quality shocks directly affect the firm's production function, capital accumulation equation and the return of capital. These shocks are modeled as exogenous disturbances that affect the quality of capital and are highly correlated with the credit spread.

Figure 1.10 shows the impulse responses to a one standard deviation negative capital quality shock. As shown in the figure, this shock can create a recession as observed in the data, but it cannot explain the movements in average hours worked. An exogenous negative disturbance to the quality of productive capital increases the rental cost of capital and reduces its price. The external finance premium increases and entrepreneurs's net worth falls on impact. As a consequence, the entrepreneur's leverage ratio rises and this drives up the external finance premium even further. Accordingly, investment, output, employment, inflation and the interest rate decline severely and the economy makes a slow recovery. Similar to a negative productivity shock, however, this shock leads to an increase in average hours worked. A fall in the effective unit of capital reduces the marginal product of labor as the latter is a function of the former. As explained earlier, the wealth effect from the lower marginal product of labor outweighs the substitution effect and thus average hours worked increases in the period of the shock, which is not supported by the data.

1.6.5 Robustness Issues

In this section, I check the robustness of the estimation results with respect to three frictions (i) habit formation in consumption, (ii) nominal price stickiness, and (iii) the investment adjustment cost, $\psi_{i/k}$.

First, I introduce consumption habit formation in the household utility function as follows:

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - \psi C_{t-1})^{1-\sigma} - 1}{1-\sigma} - \chi_t \int_0^1 n_{jt} \frac{h_{jt}^{1+\phi}}{1+\phi} dj \right] \tag{1.49}$$

where ψ reflects the degree of habit formation.

I then re-estimate the model, using this one additional parameter. Second, I estimate the baseline model by reducing each of other frictions (price and investment), one at a time. I conduct an experiment to examine how the estimation results change when I consider a value that is lower than the baseline estimates for these two frictions. Table 1.8 presents the estimates of the mode of the structural parameters, the autoregressive parameters of the exogenous shock processes and the log data density under different scenarios.

The posterior mode of the consumption habit is equal to 0.18, which is lower than its prior mean of 0.50 (with a standard deviation of 0.10), therefore ruling out the consumption habit as an important source for generating persistence in the model. Also, adding the consumption habit increases the log data density by only 6 and decreases households' risk aversion from 0.94 to 0.87. The changes in the other structural parameters fall within in the range of between 0 and 5%. Table 1.9 reports the historical variance decomposition of the baseline model and the model with consumption habit. The results show that adding consumption habit does not change the role of the default cost shock in explaining macroeconomic fluctuations in the data. Also, a model with consumption habit produces similar impulse responses to a default cost shock, as shown in Figure 1.11.

A lower nominal price stickiness reduces the log data density by 13, from 4,353 to 4,340. The three major impacts of this friction are on the labor supply elasticity, households' risk aversion, and the monetary policy rule. A lower degree of price stickiness leads to a decrease in the inverse labor supply elasticity from 4.34 to 2.47 and a drop in households' risk aversion from 0.94 to 0.82. The interest rate rule becomes less smoothing and reacts more to fluctuations in inflation than to output growth. The other structural parameters are less affected.

A lower investment adjustment cost reduces the log data density by 50, from 4,353 to 4,303. The main impacts of this adjustment cost are as follows: (i) households' risk aversion falls from 0.94 to 0.78, (ii) the inverse labor supply elasticity falls from 4.34 to 2.99, and (iii) the real wage rigidity drops from 0.79 to 0.62. The interest rate rule also becomes more responsive to the fluctuations in inflation and output growth, due to a fall in the investment adjustment cost.

Overall, the above analysis illustrates that the baseline estimation results are robust with the addition of the consumption habit, changes in nominal price stickiness, and investment adjustment cost, one at a time.

1.7 Conclusion

The recent financial crisis revealed that turmoil in the financial system can generate a large fall in real and financial wealth. This leads firms to restructure both their financial and labor market positions by cutting external borrowing and reducing labor forces. This study shows that while both labor inputs - average hours worked and unemployment, are adversely affected during a financial crisis, the impact on the former is less severe and less persistent than on the latter.

The paper makes both empirical and theoretical contributions. Using VAR methodologies, I study the macroeconomic effects of an adverse financial shock for the US economy, and then develop as well as estimate a monetary dynamic stochastic general equilibrium (DSGE) model using Bayesian techniques to uncover the stylized facts. The model has two important features. First, labor inputs can vary in both the intensive and extensive margins. Second, the model introduces a relatively new financial shock - the default cost (or the bankruptcy cost) shock, that directly originates in the financial sector. This shock creates a time-varying wedge between the external finance premium and the entrepreneur's leverage ratio and thus can endogenously explain the movements in the external finance premium, the leverage ratio, net worth, credit quantity, and the price of capital.

I estimate a set of structural parameters that characterize the dynamics of the US labor market. In particular, I identify a relatively low Frisch elasticity of labor supply, which is consistent with microeconomic studies. This suggests that the model does not rely on unrealistic adjustments to the intensive labor margin, as do most macro models, to match the data. The model also does a decent job in matching the key moments observed in the data. I find that the default cost shock plays an important role in explaining macroeconomic fluctuations even in the presence of other important shocks. The smoothed default cost shock series also confirm that the default cost shock largely accounts for the economic downturn of the 2007-2009 crisis. Using impulse responses analysis, I show that the default cost shock can account for the key business cycle facts of a financial crisis. In particular, this shock can explain why average hours worked recovers much faster than the unemployment rate following a financial crisis. In contrast, TFP shocks, capital quality shocks and MEI shocks, which in many studies are considered to be important drivers of the US business cycle, fail to explain some important stylized facts of a financial crisis.

Some avenues for future research are: (i) first, the current model assumes that wages are determined by period-by-period Nash bargaining and that the wage rigidity is exogenously defined in the model. I could possibly introduce staggered multi-period wage contracting, as in Gertler and Trigari (2009), to endogenize the wage rigidity; (ii) second, I use aggregate data for hours and unemployment so as to establish the different movements in these variables. It would be worthwhile to consider different sectoral compositions, and use micro level data to examine how distinctly two labor inputs react across different sectors during a crisis. I leave these important extensions for future research.

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Appendix

VAR and Bayesian Data Construction

The following quarterly time series data for the U.S. economy were used in the VAR and Bayesian estimation:

1. Nominal GDP: Gross domestic product, billions of dollars, seasonally adjusted at annual rates. Source: U.S. Bureau of Economic Analysis (BEA, http://www.bea.gov) National Income and Product Accounts Tables (Table 1.1.5).

2. Nominal Investment: sum of gross private domestic fixed nonresidential investment in structures, equipment and software. Source: BEA, National Income and Product Accounts Tables (Tables 1.1.5 and 5.3.5).

3. Nominal Consumption: sum of personal consumption expenditures, durable goods and services, billions of dollars, seasonally adjusted at annual rates. Source: BEA, National Income and Product Accounts Tables (Table 1.1.5).

4. Real GDP: Gross domestic product, billions of chained (2009) dollars, seasonally adjusted at annual rates. Source: BEA, National Income and Product Accounts Tables (Table 1.1.6).

5. Nominal Wage: Nonfarm Business Sector: Compensation Per Hour (COMPNFB). Source: U.S. Bureau of Labor Statistics, retrieved from Federal Reserve Bank of St. Louis (FRED, http://www.stlouisfed.org/).

6. Unemployment: Civilian Unemployment Rate (UNRATE). Source: U.S. Bureau of Labor Statistics, retrieved from FRED.

7. Vacancy: Help-Wanted Index (HWI). Source: "Building a composite Help-Wanted Index" (Barnichon, 2010).

8. Excess Bond Premium (EBP). Source: Gilchrist and Zakrajsek (2012).

9. Hours Worked: Nonfarm Business Sector: Average Weekly Hours (PRS85006023). Source: U.S. Bureau of Labor Statistics, retrieved from FRED.

10. Moody's Seasoned Baa Corporate Bond Yield (BAA). Source: Moody's, retrieved from FRED.

11. T-Bill Rate: 3-Month Treasury Bill, Secondary Market Rate. Source: Board of Governors of the Federal Reserve System (US), retrieved from FRED.

12. Nominal Interest Rate: Effective Federal Funds Rate (FEDFUNDS). Source: Board of Governors of the Federal Reserve System (US), retrieved from FRED

13. Population: Working Age Population: Aged 15-64: All Persons for the United States (LFWA64TTUSM647S), Seasonally Adjusted. Source: Organization for Economic Co-operation and Development, retrieved from FRED.

14. GDP Deflator: constructed as (14) = (1) / (4).

15. Real Investment: constructed as (15) = (2) / (14).

16. Real Consumption: constructed as (16) = (3) / (14).

17. External Finance Premium (or Credit Spread): constructed as (17) = (10) - (11).

Table 1.1: Calibrated Values

Parameter	Description	value
β	Discount factor	0.99
α	Labor share	0.67
δ	Capital depreciation rate	0.025
θ	Elasticity of substitution between intermediate goods	11
$\frac{G}{Y}$	Steady-state government spending-output ratio	0.20
u_{ss}	Steady-state unemployment rate	0.064
b	Unemployment benefits	0.25
p^v	Vacancy filling rate	0.70
η^e	Survival rate of entrepreneurs	0.973
$log\overline{w}$	Variance of the log-normally distributed productivity variable	0.174
μ_{ss}	Steady-state bankruptcy cost	0.136

Table 1.2: Prior and Posterior Distribution of Structural Parameters

Parameters	***Prior distribution***			***Posterior distribution***			
	Distr.	Mean	St. Dev	Mode	Mean	5%	95%
σ	Gamma	1.0	0.10	0.94	0.94	0.84	1.04
ϕ	Normal	2.0	0.75	4.34	4.35	3.62	5.07
$\eta_{\frac{i}{k}}$	Normal	0.10	0.02	0.21	0.21	0.19	0.23
ζ	Beta	0.65	0.05	0.88	0.88	0.86	0.90
α_w	Beta	0.75	0.05	0.79	0.79	0.74	0.84
α_m	Beta	0.40	0.05	0.29	0.29	0.25	0.34
η	Beta	0.50	0.05	0.25	0.26	0.21	0.29
k	Gamma	0.05	0.02	0.046	0.049	0.034	0.065
ρ_s	Beta	0.10	0.02	0.13	0.13	0.09	0.17
ρ	Beta	0.50	0.10	0.49	0.49	0.42	0.57
ϕ_π	Gamma	1.50	0.10	1.72	1.74	1.62	1.87
ϕ_y	Normal	0.20	0.05	0.19	0.20	0.12	0.28

Table 1.3: Prior and Posterior Distribution of Shock Processes

Parameters	***Prior distribution***			***Posterior distribution***			
	Distr.	Mean	St. Dev	Mode	Mean	5%	95%
ρ_μ	Beta	0.50	0.20	0.74	0.74	0.70	0.78
ρ_a	Beta	0.50	0.20	0.83	0.82	0.78	0.85
ρ_γ	Beta	0.50	0.20	0.98	0.97	0.95	0.99
ρ_ξ	Beta	0.50	0.20	0.17	0.18	0.13	0.23
ρ_l	Beta	0.50	0.20	0.73	0.73	0.69	0.77
ρ_m	Beta	0.50	0.20	0.92	0.92	0.87	0.96
ρ_g	Beta	0.50	0.20	0.97	0.97	0.96	0.98
ρ_θ	Beta	0.50	0.20	0.72	0.71	0.65	0.77
ρ_w	Beta	0.50	0.20	0.09	0.12	0.02	0.20
ρ_r	Beta	0.50	0.20	0.20	0.17	0.08	0.26
σ_μ	Invgamma	0.01	2	0.343	0.346	0.298	0.393
σ_a	Invgamma	0.01	2	0.008	0.008	0.007	0.009
σ_γ	Invgamma	0.01	2	0.009	0.009	0.007	0.012
σ_ξ	Invgamma	0.01	2	0.014	0.014	0.012	0.016
σ_l	Invgamma	0.01	2	0.019	0.019	0.016	0.022
σ_m	Invgamma	0.01	2	0.016	0.016	0.014	0.018
σ_g	Invgamma	0.01	2	0.005	0.005	0.004	0.005
σ_θ	Invgamma	0.01	2	0.022	0.023	0.016	0.029
σ_w	Invgamma	0.01	2	0.009	0.0085	0.0075	0.0095
σ_r	Invgamma	0.01	2	0.002	0.002	0.001	0.002

Note: σ_a = TFP, σ_γ = MEI, σ_ξ = capital quality, σ_μ = default cost, σ_r = monetary policy, σ_l = labor supply, σ_g = government expenditure, σ_θ = cost push, σ_m = matching efficiency, and σ_w = wage markup shocks.

Table 1.4: Forecast Error Variance Decomposition at Different Horizons

	σ_a	σ_γ	σ_ξ	σ_μ	σ_r	σ_l	σ_g	σ_θ	σ_m	σ_w
One quarter										
Consumption Growth	11	1	35	**0**	9	12	21	6	0	5
Investment Growth	6	18	0	**31**	12	5	0	24	0	3
Output Growth	10	3	14	**12**	18	13	1	24	0	6
Unemployment Growth	0	2	1	**11**	18	32	0	24	0	12
Vacancy Growth	0	2	1	**11**	18	31	0	24	0	12
Real Wage	0	0	1	**0**	0	0	0	1	0	98
Finance Premium	4	0	3	**66**	0	10	0	13	0	4
Inflation	14	6	6	**2**	2	33	1	26	0	10
Federal Funds Rate	0	21	4	**31**	37	3	4	0	0	0
Hours Worked	1	0	4	**0**	1	73	3	0	0	17
One year										
Consumption Growth	11	1	34	**0**	11	12	20	6	0	5
Investment Growth	6	16	2	**31**	14	5	0	23	0	3
Output Growth	9	3	14	**12**	20	12	1	23	0	6
Unemployment Growth	1	2	2	**11**	21	30	0	23	0	11
Vacancy Growth	1	2	1	**11**	23	29	0	22	0	10
Real Wage	0	0	4	**1**	1	0	0	5	0	87
Finance Premium	3	0	4	**72**	3	6	0	9	0	3
Inflation	15	11	8	**2**	1	29	2	21	0	10
Federal Funds Rate	8	19	2	**10**	22	19	3	11	0	6
Hours Worked	2	0	6	**0**	1	66	4	0	0	20
Five years										
Consumption Growth	11	2	33	**0**	11	12	19	6	0	5
Investment Growth	6	16	2	**31**	13	5	0	23	0	3
Output Growth	10	3	14	**12**	20	12	1	24	0	6
Unemployment Growth	1	2	2	**10**	20	30	0	23	0	11
Vacancy Growth	1	2	1	**11**	23	29	0	22	0	10
Real Wage	2	9	32	**2**	1	1	0	7	0	45
Finance Premium	3	0	4	**72**	3	7	0	9	0	3
Inflation	14	21	11	**2**	1	23	5	15	0	8
Federal Funds Rate	11	28	9	**5**	11	16	6	9	0	6
Hours Worked	3	1	11	**0**	1	56	11	0	0	19

Note: σ_a = TFP, σ_γ = MEI, σ_ξ = capital quality, σ_μ = default cost, σ_r = monetary policy, σ_l = labor supply, σ_g = government expenditure, σ_θ = cost push, σ_m = matching efficiency, and σ_w = wage markup shocks.

Table 1.5: Contemporaneous Correlation of the Key Variables in the Data

Data	Spread	Investment	Output	Unemployment	Vacancies
Spread	1.00				
Investment	-0.60	1.00			
Output	-0.66	0.82	1.00		
Unemployment	0.67	-0.90	-0.84	1.00	
Vacancies	-0.71	0.81	0.87	-0.90	1.00

Table 1.6: Contemporaneous Theoretical Correlation of the Key Variables in the Model

Model	Spread	Investment	Output	Unemployment	Vacancies
Spread	1.00				
Investment	-0.76	1.00			
Output	-0.54	0.85	1.00		
Unemployment	0.68	-0.95	-0.91	1.00	
Vacancies	-0.84	0.84	0.71	-0.86	1.00

Table 1.7: Relative Standard Deviation of the Key Variables

	Output	Unemployment	Vacancies	Hours Worked	Real Wage
Data	1.00	10.09	10.86	0.39	0.57
Model	1.00	11.85	8.59	0.17	0.49

Table 1.8: Model Sensitivity

Parameters	Baseline	Habits	$\zeta = \mathbf{0.65}$	$\eta_{\frac{i}{k}} = \mathbf{0.10}$
Mode of the structural parameters				
σ	0.94	0.87	0.82	0.78
ϕ	4.34	4.47	2.47	2.99
$\eta_{\frac{i}{k}}$	0.21	0.21	0.18	**0.10**
ζ	0.88	0.89	**0.65**	0.82
α_w	0.79	0.80	0.78	0.62
α_m	0.29	0.29	0.30	0.31
η	0.25	0.26	0.25	0.47
k	0.05	0.05	0.04	0.10
ρ_s	0.13	0.13	0.13	0.14
ρ	0.49	0.48	0.41	0.41
ϕ_π	1.72	1.75	1.90	2.04
ϕ_y	0.19	0.17	0.17	0.40
ψ	0.00	**0.18**	0.00	0.00
Mode of the autoregressive parameters of the shock processes				
ρ_μ	0.74	0.74	0.73	0.68
ρ_a	0.83	0.83	0.82	0.87
ρ_γ	0.98	0.98	0.97	0.70
ρ_ξ	0.17	0.19	0.17	0.11
ρ_l	0.73	0.73	0.80	0.92
ρ_m	0.92	0.92	0.92	0.93
ρ_g	0.97	0.97	0.96	0.96
ρ_θ	0.72	0.73	0.85	0.63
ρ_w	0.09	0.09	0.09	0.49
ρ_r	0.20	0.23	0.17	0.05
Log data density	**4,353**	**4,358**	**4,303**	**4,340**

Table 1.9: Forecast Error Variance Decomposition at the Infinite Horizon

	σ_a	σ_γ	σ_ξ	σ_μ	σ_r	σ_l	σ_g	σ_θ	σ_m	σ_w
Baseline Model										
Consumption Growth	11	2	33	**0**	11	12	19	6	0	5
Investment Growth	6	16	2	**31**	13	5	0	23	0	3
Output Growth	10	3	14	**12**	20	12	1	24	0	6
Unemployment Growth	1	2	2	**10**	20	30	0	23	0	11
Vacancy Growth	1	2	1	**11**	23	29	0	22	0	10
Real Wage	1	45	32	**1**	0	1	0	3	0	17
Finance Premium	3	2	6	**69**	3	6	0	8	0	3
Inflation	12	23	13	**2**	1	21	7	14	0	7
Federal Funds Rate	9	30	12	**4**	10	13	8	7	0	5
Hours Worked	2	16	11	**0**	0	43	13	0	0	14
Model with Consumption Habit										
Consumption Growth	10	2	36	**0**	9	11	19	7	0	5
Investment Growth	6	17	1	**31**	13	5	0	24	0	3
Output Growth	9	3	16	**12**	18	11	1	24	0	6
Unemployment Growth	1	2	2	**11**	19	28	1	24	0	11
Vacancy Growth	1	3	1	**12**	22	27	1	23	0	10
Real Wage	1	46	33	**1**	0	0	0	3	0	15
Finance Premium	3	2	7	**70**	3	5	0	8	0	2
Inflation	12	22	15	**2**	1	20	6	15	0	8
Federal Funds Rate	9	29	14	**4**	10	13	7	8	0	6
Hours Worked	2	13	10	**0**	0	43	16	0	0	15

Note: σ_a = TFP, σ_γ = MEI, σ_ξ = capital quality, σ_μ = default cost, σ_r = monetary policy, σ_l = labor supply, σ_g = government expenditure, σ_θ = cost push, σ_m = matching efficiency, and σ_w = wage markup shocks.

Figure 1.1: Detrended unemployment rate and credit spread for the United States. Shaded areas indicate NBER recessions.

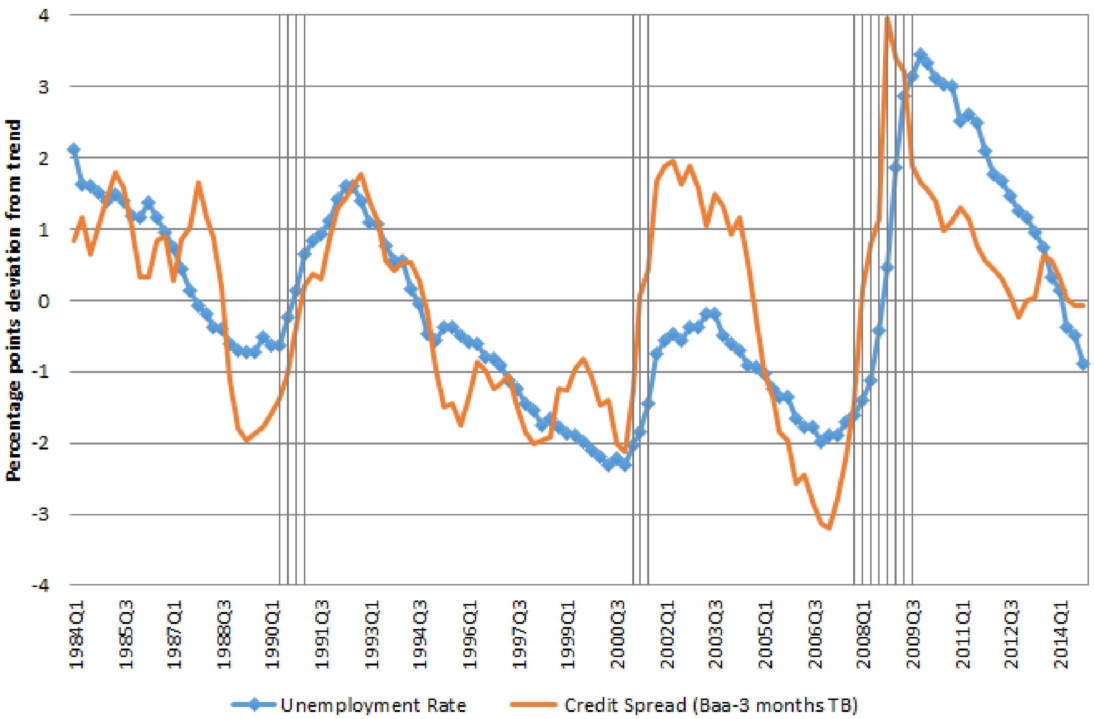


Figure 1.2: Detrended unemployment rate and average weekly hours for nonfarm business sector.

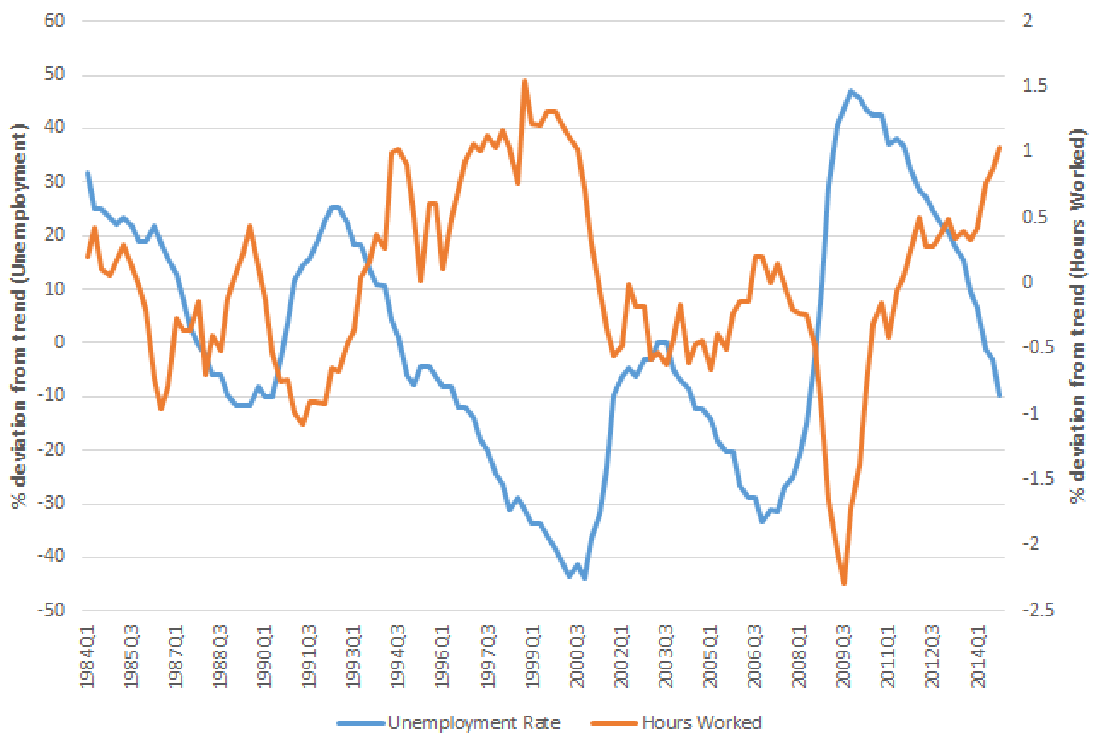
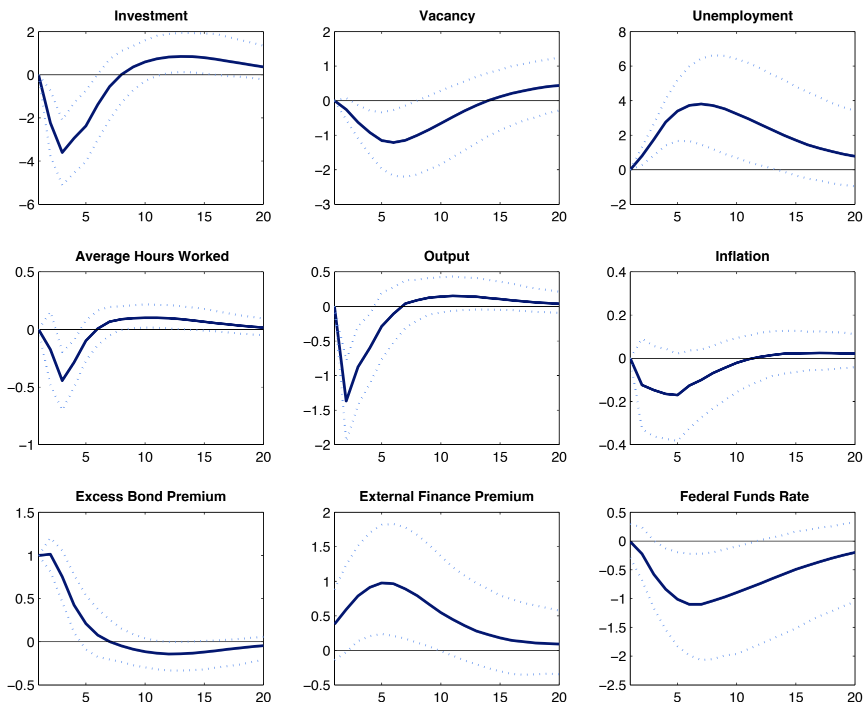


Figure 1.3: VAR Evidence for the United States (1984Q1 - 2014Q4).



Note: The figure shows the impulse responses to a one percentage point increase in the excess bond premium. The dashed lines represent 95-percent confidence intervals based on 2,000 bootstrap replications. The Y-axis is expressed in percentage points.

Figure 1.4: Brooks and Gelman's convergence diagnostics

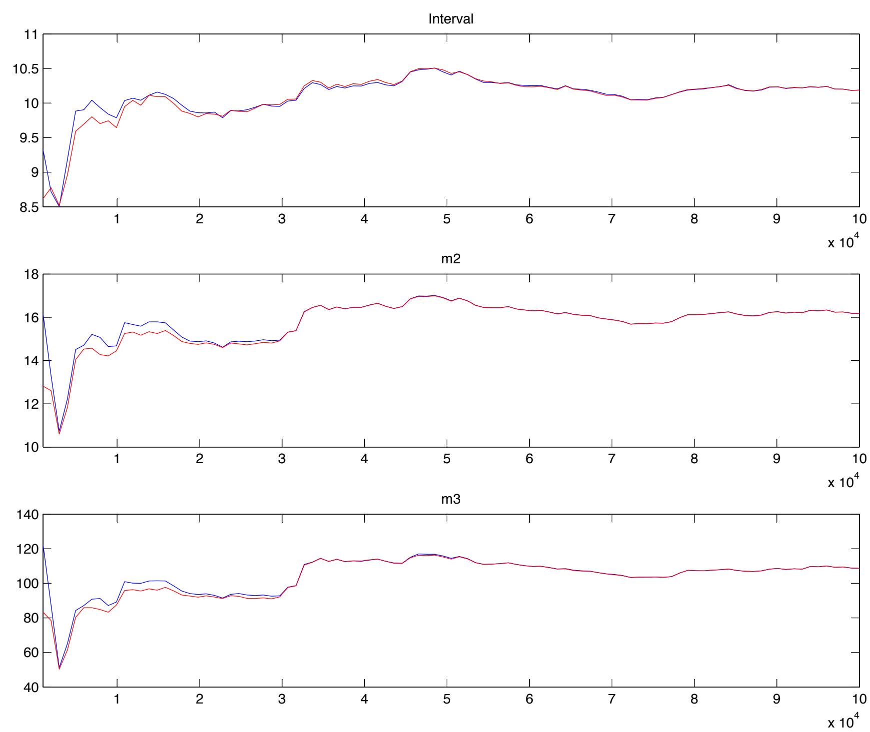


Figure 1.5: Output and Investment growth in the US

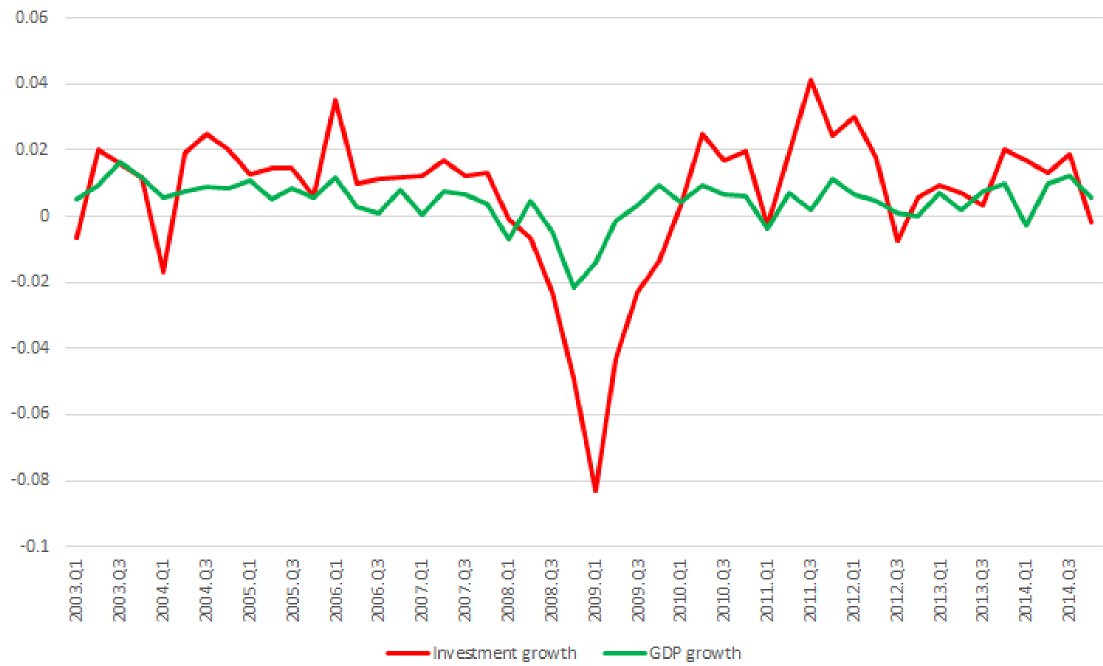


Figure 1.6: Smoothed Default cost shocks

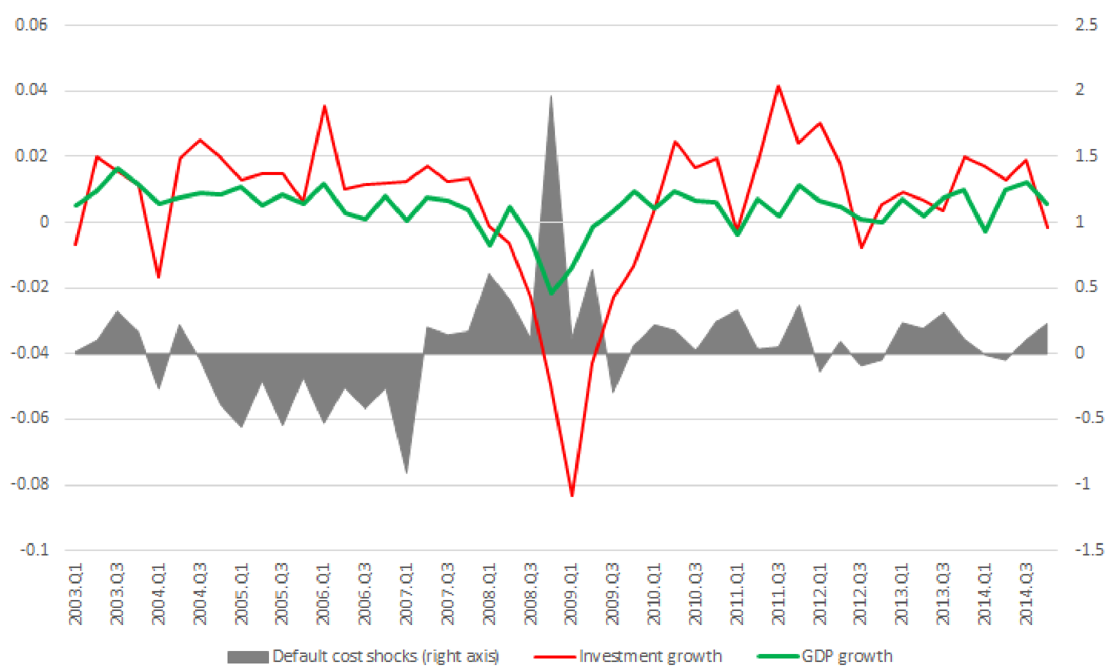


Figure 1.7: IRFs to one standard deviation default cost shock.

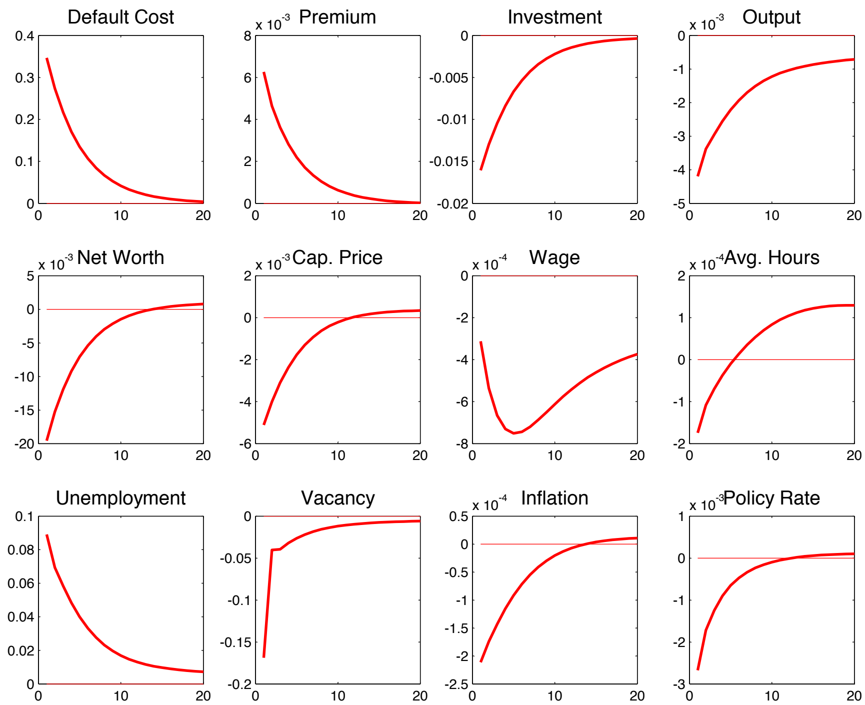


Figure 1.8: IRFs to one standard deviation negative productivity shock.

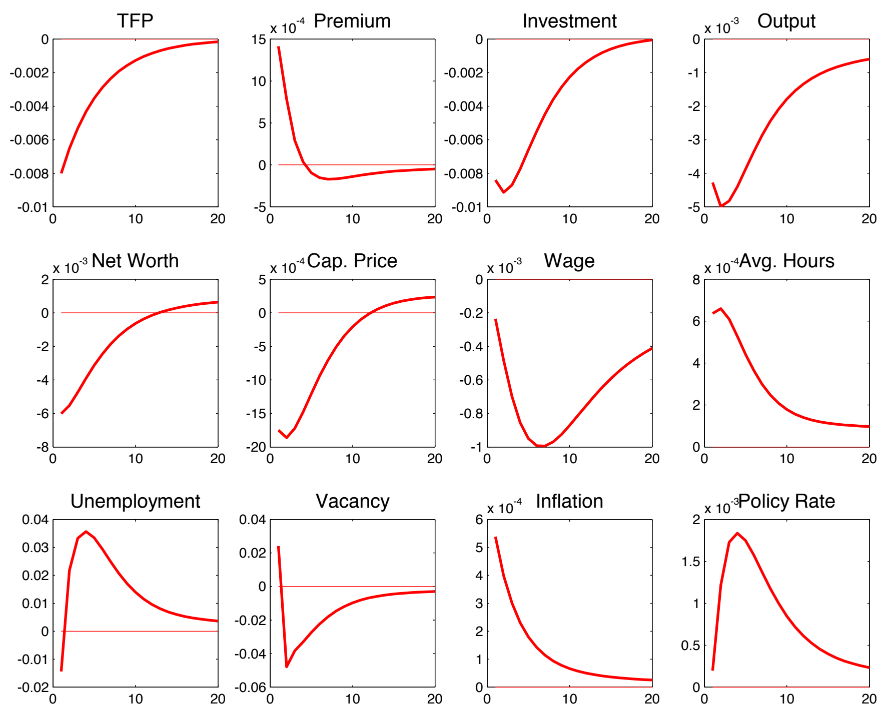


Figure 1.9: IRFs to one standard deviation negative MEI shock.

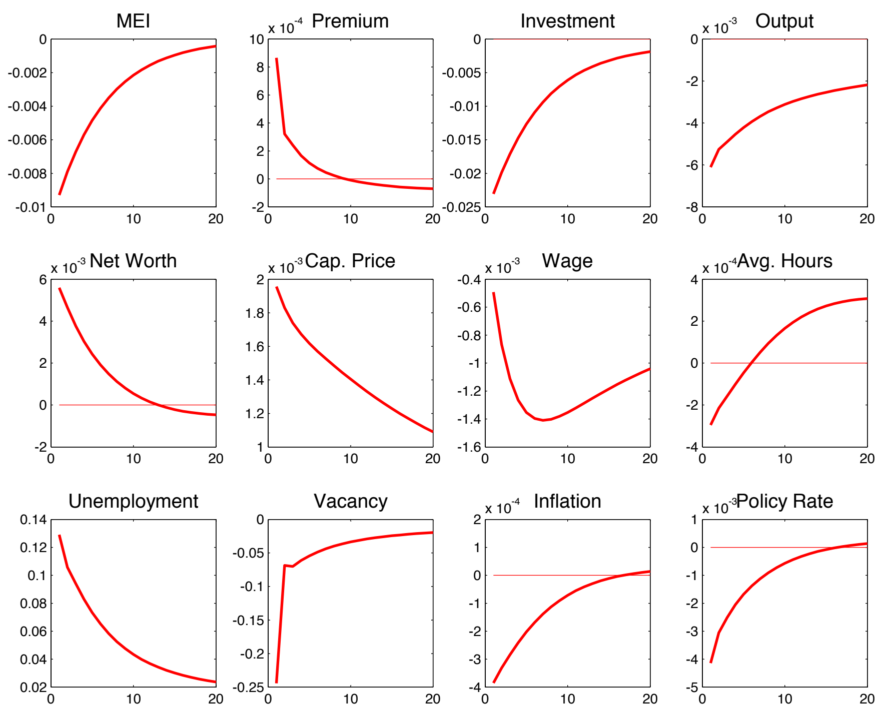


Figure 1.10: IRFs to one standard deviation negative capital quality shock.

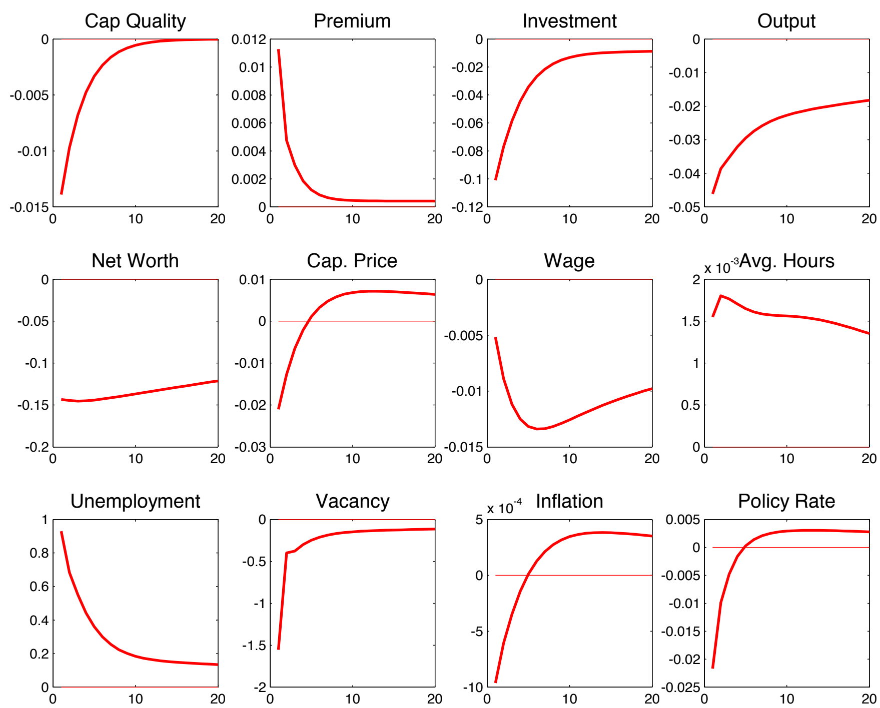
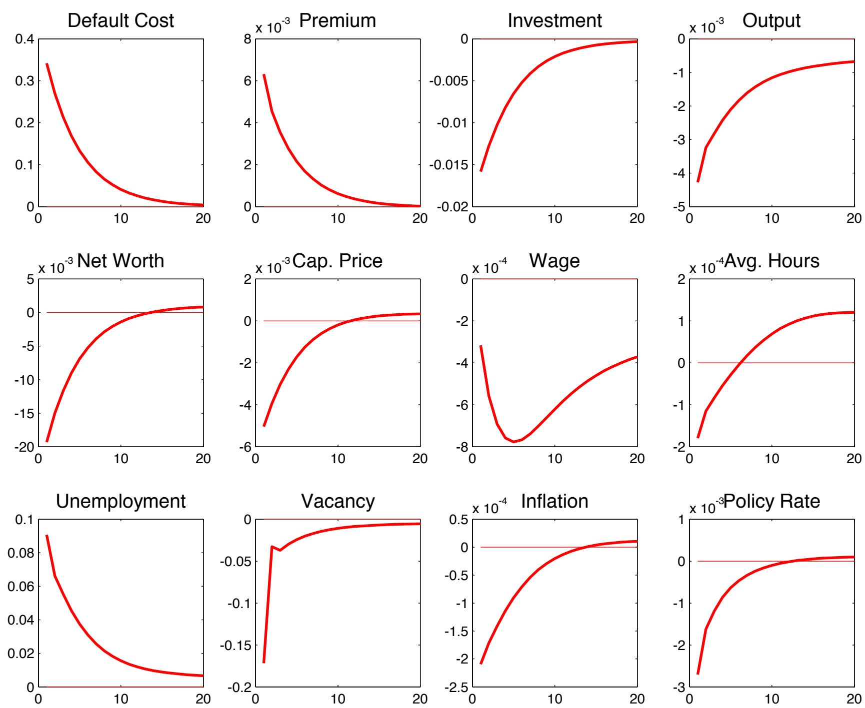


Figure 1.11: IRFs to one standard deviation default cost shock in a model with consumption habit.



Chapter 2

Financial Shocks, Labor Market Fluctuations and Monetary Policy Rules

2.1 Introduction

The financial crisis that commenced in 2007 has challenged the central banks of many countries, especially the United States, with a number of obstacles to conduct monetary policy. One particularly important feature of that crisis was that a sharp increase in the credit spread had been associated with a significant rise in the unemployment rate. For instance, in the United States, while the credit spread[1] increased by 5.4 percentage points from 2007Q4 to 2008Q4, the unemployment rate more than doubled from 4.7 percent in the beginning of the recession to 10 percent in the last quarter of 2009 (see Figure 2.1). Although real

[1] Credit spread or the external finance premium is measured by the difference between Moody's seasoned Baa corporate bond yield and 3-month treasury bill rate.

GDP and inflation measured by many indicators did not show any significant sign of economic downturn in late 2007, the Federal Reserve belligerently decreased its operating target for the federal funds rate in late 2007 and beginning 2008. According to Curdia and Woodford (2010), this large reduction exceeded what was required according to the standard Taylor rule. Definitely, the monetary authorities considered other objectives than stabilizing inflation and the output gap after noticing the development of financial imbalances in late 2007. In the aftermath of the crisis, many researchers have also recommended to revise the conventional monetary policy objectives in the presence of financial turmoil, such as

"Now, however, there is growing recognition that the conventional approach to central banking needs to be rethought. The relationship between price stability and the broader goals of macroeconomic and financial stability clearly needs to be redefined."

Eichengreen et al. (2011)

"Although price and output stability are surely beneficial, the recent crisis indicates that a policy focus solely on these objectives may not be enough to produce good economic outcomes."

Mishkin (2011)

The conventional monetary policy rule ("Taylor rule") that responds only to inflation and the output gap is thus found to be ineffective to explain the Fed's action at that time. To what extend do augmented Taylor type interest rules featuring financial variables such as credit spread or asset prices provide reasonable explanations for the Fed's policy actions? The objective of this paper is to explore the interaction of financial and labour market frictions, and assess how modified

Taylor type interest rules are more efficient than the standard Taylor rule to combat a financial crisis.

Motivated by these facts, I first embed labor market frictions, as in Mortensen and Pissarides (1994), and financial frictions, as in Bernanke et al. (1999; hereafter BGG) and Gunn and Johri (2013), in a monetary dynamic stochastic general equilibrium (DSGE) model to study how these two frictions interact with each other to generate fluctuations in both financial and real variables following an adverse financial shock. I then assess the performance of different monetary policy rules with and without reaction to financial variables. I define two monetary policy rules that not only respond to output and inflation fluctuations but also react to financial variables such as credit spread or asset prices, and that meet the central bank's mandate as specified in the Federal Reserve Act - "maximum employment, stable prices, and moderate long-term interest rate." In doing so, I assume that monetary policy should minimize some quadratic loss function, where losses are caused by inflation, output, and unemployment being away from their respective targets. My approach is different from many studies who derive the central bank's objective function directly from the welfare of the representative agent. I find that an augmented Taylor rule that responds to financial variables other than output and inflation fluctuations is more efficient than the standard Taylor rule to combat a financial crisis.

The model considers two financial shocks - the default cost (or the bankruptcy cost) shock and the bank intermediation cost shock, which have been studied very little in the literature. These costs are imposed on the model through a financial contract between financial intermediaries and entrepreneurs. Following BGG (1999), I assume that lenders must incur a default cost to observe and retrieve borrowers' realized returns when borrowers default. Hence, asymmetric information between borrowers and lenders creates a financial wedge between the risk-free rate and the rate of return of capital, also known as the external finance premium, to compensate lenders for default risks. In my model, this cost varies over time and thus creates a time-varying wedge between the external finance premium and the entrepreneur's leverage ratio, whereas this negative relationship is fixed in BGG(1999). As a result, the contract menu offered to entrepreneurs changes over time, and this can endogenously explain movements in the external finance premium, the leverage ratio, net worth, credit quantity, and the price of capital, without having to assume exogenous movements in these variables.

Both shocks are motivated by the sharp increases in credit spread that was observed during the post-2008 financial crisis. Some existing studies have also documented the importance of these shocks on the economy. For instance, Carlstrom and Fuerst (1997) document that the default cost reflects auditing, accounting, legal expenditures associated with liquidation, and losses associated with business interruption. Levin et al. (2004) first document evidence about the time variation in the marginal bankruptcy cost parameter by estimating a partial framework of the BGG model with a panel of 900 nonfinancial firms in the U.S. for the periods 1997:Q1 to 2003:Q3. They find a significant time variation in the marginal bankruptcy cost and conclude that a model implied external finance premium is mainly driven by fluctuations of this parameter.

On the other hand, Cooper and Ejarque (2000) provide a quantitative assessment of models in which shocks to the financial intermediation process generate aggregate fluctuations. Dib (2010) develops a micro-founded dynamic stochastic general equilibrium model for the U.S. economy that incorporates an active banking sector in which shocks to the financial intermediation process are exogenous events that affect the credit supply of lending banks. He interprets these shocks as perceived changes in creditworthiness, advances in financial engineering and refined methods for risk sharing. Similarly, Gunn and Johri (2011, 2013) define the bankruptcy cost and bank intermediation cost as stochastic processes, and interpret shocks to these processes as stochastic variation in financial innovation. They show that a change in expectations about these parameters can explain the boom-bust cycle episodes observed in the U.S. economy before and after the recent financial crisis. Most recently, Ajello (2016) constructs a dynamic general equilibrium model with financial frictions in which entrepreneurs trade financial assets through banks. In doing so, he assumes that banks charge an intermediation cost premium, which can vary exogenously over time and defines these disturbances as financial shocks. Following these studies, I add these shocks to my model.

The rest of the paper is structured as follows. Section 2.2 discusses connections to the literature. Sector 2.3 presents the model. Section 2.4 outlines the parametrization. Section 2.5 reports and discusses results. Section 2.6 concludes.

2.2 Related Literature

This paper complements a large number of studies that show the importance of financial frictions and labor market frictions in explaining aggregate fluctuations. For instance, Wasmer and Weil (2004), Christensen and Dib (2008), De Graeve (2008), Nolan and Thoenissen (2009), Christiano et al. (2011), Jermann and Quadrini (2012), Gunn and Johri (2011, 2013), Jorda et al. (2013), Christiano et al. (2014), and Kaihatsu and Kurozumi (2014) show that frictions and shocks in the financial sector are major sources of macroeconomic fluctuations. This paper is also motivated by several papers related to labor market frictions. For instance, the influential work of Merz (1995) and Andolfatto (1996) embed labor search friction in business cycle models. Papers such as those by Cooley and Quadrini (1999), den Haan, Ramey, and Watson (2000), Krause and Lubik (2007), Gertler, Sala, and Trigari (2008), Trigari (2009), Gertler and Trigari (2009), Leduc and Liu (2016), among others, incorporate search-and-matching in many different macroeconomic models. This paper combines the approaches of these two strands of literature and is therefore related to studies that incorporate both labor market and financial frictions in one framework such as Monacelli et al. (2011), Christiano, Trabandt and Walentin (2011), Chugh (2013), Petrosky-Nadeau (2014), and Mumtaz and Zanetti (2016), among others.

Several recent papers suggest that central banks should react to financial variables to ensure macroeconomic stability, such as Faia and Monacelli (2007), Adrian and Shin (2010), Castelnuovo and Nistico (2010), Furlanetto (2011), Mishkin (2011), Finocchiaro and von Heideken (2013), Borio (2014), and Gali and Gambetti (2015). This paper is particularly related to Faia and Monacelli (2007) who develop a New Keynesian (NK) DSGE model with credit frictions following the agency cost framework of Carlstrom and Fuerst (1997). In their study of optimal Taylor-type interest rate rules, they find that monetary policy should respond to increases in asset prices. However, they also suggest that when monetary policy strongly reacts to inflation, the marginal welfare gain of responding to asset prices disappears. My paper is different in two aspects. First, they consider productivity shocks as opposed to financial shocks to evaluate different welfare-maximizing interest rate rules. Second, as the extensive labor input margin is absent in their model, they could not measure the welfare gains of stabilizing unemployment fluctuations under different policy rules.

Some recent papers also find that policy rules that react to financial variables allow macroeconomic stabilization and increase social welfare relative to conventional Taylor type interest rate rules, such as Curdia and Woodford (2010), Gilchrist and Zakrajsek (2012), Nistico (2012), Andres et al. (2013), Blanchard et al. (2013), de Fiore and Tristani (2013), Finocchiaro and von Heideken (2013), Gambacorta and Signoretti (2014), Adrian and Duarte (2016), and Adrian and Liang (2017), among others. This paper is related to Gilchrist and Zakrajsek (2012) and de Fiore and Tristani (2013) who find that the monetary policy rule that reacts to credit spread dampens adverse effects of financial disruptions and this helps to stabilize the macroeconomy. Similarly, Curdia and Woodford (2010) develop an NK DSGE model with credit frictions and consider a time-varying spread that is determined by the difference between two interest rates - the interest paid by the impatient households and interest received by the patient households. They find that an augmented Taylor rule with variations in credit spread improves welfare, with the magnitude of the adjustment depending on the source and persistence of shocks.

This paper is also closely related to McCulley and Toloui (2008) and Taylor (2008) who propose a modification of a standard Taylor rule to incorporate adjustments to credit spread. They suggest that the intercept term in a Taylor type interest rate should be adjusted downward in line with perceived increases in spread. Amano and Shukayev (2012) develop a standard DSGE model that is capable of capturing the relevance of the zero bound on nominal interest rates. They find that unlike productivity, government spending, and money demand shocks, risk premium shocks push nominal interest rates close to zero by increasing the spread between the rates of return on private capital and risk-free government bonds. Similarly, Teranishi (2012) constructs an otherwise NK model with heterogeneous loan interest rate contracts. He finds that the spread-adjusted Taylor rule is a theoretically optimal monetary policy rule, but the policy response to the credit spread can be positive or negative, depending on the financial structure. Hirakata et al. (2013), on the other hand, find that the spread-adjusted Taylor rule and capital injections dominate the standard Taylor-type interest rule depending on the source of economic downturn. Again, all these papers developed optimal policy rules in a model with frictionless labor market and thus cannot capture any gains of minimizing unemployment fluctuations when the policy rule responds to financial variables following a financial crisis.

Another strand of literature examines the interaction between monetary policy and macroprudential policy to examine the impact of financial shocks on the macroeconomy. However, such analysis is beyond the scope of this paper as my model does not consider macroprodudential policy instruments.

2.3 The Model

The model is characterized by three main blocks: financial frictions in the financial market, nominal rigidities in price setting, and search and matching frictions in the labor market. There are eight types of agents in the model: households, entrepreneurs, capital producers, intermediate goods producers, retailers, financial intermediaries, a government, and a monetary authority.

The goods market is composed of four types of producers: intermediate firms, capital producers, entrepreneurs, and retailers. At the beginning of each period, intermediate firms hire new workers by posting vacancies in the labor market, which is costly. These firms produce intermediate goods in competitive markets, using labor and capital as their inputs. They sell their output to retailers who are monopolistically competitive. Retailers sell the final goods to the households and capital producers, and set nominal prices in a staggered fashion ‘a la Calvo (1983).

Entrepreneurs accumulate physical capital and rent it to intermediate firms. They purchase new capital from capital producers and finance this purchase by borrowing from financial intermediaries and using their net worth. The presence of asymmetric information between entrepreneurs and financial intermediaries creates a financial wedge between borrowing and lending rates. That is, financial intermediaries charge a premium over the risk-free rate to compensate for default risks. Capital producers build new capital by combining old capital purchased from entrepreneurs and investment goods purchased from retailers; they then sell this capital to entrepreneurs.

Government spending is financed by issuing government nominal bonds to households and through lump-sum taxes. The monetary policy follows a modified Taylor (1993) rule. The nominal interest rate adjusts in response to output and inflation fluctuations from their steady-state values.

In the following, I discuss in detail the behavior of each of these agents and the structure of the goods, labor and credit markets.

2.3.1 Households

The economy consists of a continuum of households with a unit measure. Each household has an infinite number of identical members. Every member of a household is either employed or is looking for work. Those who are employed receive wage income, w_t, and those who are unemployed receive unemployment insurance, b, from the government. I assume that workers incur disutility from exerting effort once they are employed. Each household member's utility is additively separable in consumption and leisure, and there is perfect risk-sharing among members of the household, yielding the same consumption for everyone in the household.

Let C_t denotes consumption. Conditional on N_t, the number of employed members, households' objective function can be written as:

$$E_t[\sum_{t=0}^{\infty} \beta^t \Big[ln(C_t) - \kappa_h N_t\Big] \tag{2.1}$$

where β is the discount factor; κ_h is the scale parameter for disutility of work; and ϕ is the inverse of the Frisch labor supply elasticity.

The household chooses to consume, C_t, purchase new government bonds, B_t and deposit funds, D_t at the financial intermediary to maximize the utility function in (2.1) subject to a sequence of flow budget constraints

$$C_t + \frac{D_t}{R_t} + \frac{B_t}{R_t^n P_t} \leq D_{t-1} + w_t N_t + b(1 - N_t) + \frac{B_{t-1}}{P_t} + \Pi_t - T_t \tag{2.2}$$

where P_t denotes the price level, w_t denotes the real hourly wage, R_t^n denotes the risk free nominal interest rate[2], R_t denotes the real interest rate paid by the financial intermediary on households deposits and b denotes an unemployment benefit. The household also pays a lump-sum tax T_t to the government and receives aggregate dividend, Π_t from ownership of all firms as lump-sum income.

First order conditions for the household optimization problem are:

$$\frac{1}{C_t} = \lambda_t \tag{2.3}$$

$$\frac{1}{R_t^n} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} \tag{2.4}$$

$$\frac{1}{R_t} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \tag{2.5}$$

where λ_t is the lagrangian multiplier which represents the marginal utility of consumption and $\pi_t \equiv \frac{P_t}{P_{t-1}}$ denotes the inflation rate.

2.3.2 Intermediate Good Producers

There is a continuum of intermediate firms measured on the unit interval. Each firm i produces output $y_t(i)$ using capital $K_t(i)$, and labor $N_t(i)$. Let A_t denotes total factor productivity. The production function is given by

$$y_t(i) = A_t N_t(i)^{\alpha} K_t(i)^{1-\alpha} \tag{2.6}$$

[2] The link between nominal and real interest rates gives the Fisher relation. See Gertler and Karadi (2011).

where A_t follows AR(1)stationary stochastic process with ρ_a measures the persistence of the technology shock and $\epsilon_{a,t} \sim i.i.d.N(0,1)$.

I assume that capital is perfectly mobile across firms and that there is a competitive rental market for capital. But hiring a worker is costly. Firms post vacancies at a real cost per hire k and unemployed workers search for jobs. Vacancies are matched with searching workers at a rate that depends on the number of searches on each side of the market. I assume that the matching function takes the Cobb-Douglas form so that the flow m_t of successful matches are formed within period t as follows

$$m_t(u,v) = \nu_m u_t^{\alpha_m} v_t^{1-\alpha_m} \tag{2.7}$$

where ν_m is a scale parameter represents the efficiency of the matching process, $u_t = \int_0^1 u_{jt}dj$ is the number of unemployed workers and $v_t = \int_0^1 v_{jt}dj$ is the total number of vacancies posted by all firms, $0 < \alpha_m < 1$ is the match elasticity of the unemployed worker.

Defining labor market tightness as $\tau_t \equiv \frac{v_t}{u_t}$, the probability that any open vacancy is matched with a searching worker is given by

$$p^v(\tau_t) = \frac{m_t}{v_t} = \nu_m \tau_t^{-\alpha_m} \tag{2.8}$$

This implies that firms with vacancies can hire workers more easily when the labor marker tightness is relatively low, that is, when the number of searching workers is higher than the number of job postings. Similarly, the probability that any worker who is looking for a job is matched with an open vacancy is given by

$$p^u(\tau_t) = \frac{m_t}{u_t} = \nu_m \tau_t^{1-\alpha_m} \tag{2.9}$$

Analogously, this implies that job-searching workers find employment more easily when the labor marker tightness is relatively high, that is, when the number of job postings is higher than the number of job-seekers.

Matches are destroyed at a rate ρ_s. I set ρ_s to be constant and exogenous following Hall (2005) and Shimer (2007), who argue that the movements in the separation rate play a minor role in explaining the movements in unemployment. The firm begins t with $N_{1,t-1}$ workers, a fraction $(1-\rho_s)N_{t-1}$ of them survives to the next period. At the same time, m_t new matches are formed and newly hired workers become immediately productive. Hence, employment evolves according to the following dynamic equation.

$$N_t(i) = (1-\rho_s)N_{t-1}(i) + p^v(\tau_t)v_t(i) \tag{2.10}$$

Firm's Optimization Problem

The firm's problem is to choose number of employees, $N_t(j)$, number of vacancies, $v_t(j)$, and capital stock $K_t(j)$ to maximize the present value of future discounted profits and takes the wage schedules and capital rental rate as given. The wages are determined by a bargaining process which will be discussed shortly. Defining the competitive price for intermediate goods as mc_t and the vacancy posting cost per hire as k the firm j's problem can then be written as:

$$\max E_t \sum_{s=0}^{\infty} \beta^s \frac{\lambda_{t+s}}{\lambda_t} \left\{ mc_{t+s}(j)y_{t+s}(j) - w_{t+s}(j)N_{t+s}(j) - kv_{t+s}(j) - r_{t+s}K_{t+s}(j) \right\} \tag{2.11}$$

subject to the production function (equation 2.6), and the law of motion for employment (equation 2.10).

Let's define $V_t^f(j)$, the lagrange multiplier on employment, as the marginal value of additional worker. Since all firms will choose same allocation in equilibrium, I can assume symmetry and drop index j hereafter. The first order conditions with respect to K_t, v_t and N_t are given by

$$r_t = \alpha \frac{y_t}{K_t} mc_t \tag{2.12}$$

$$V_t^f = \frac{\kappa}{p_t^v} \tag{2.13}$$

$$V_t^f = \alpha \frac{y_t}{N_t} mc_t - w_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \Big[(1-\rho_s) V_{t+1}^f\Big] \tag{2.14}$$

Equations (2.13) and (2.14) equate the marginal cost of hiring a new worker to the value of hiring an additional worker. Equation (2.14) shows that the current period marginal value of employment equals to the marginal revenue product of employment net of wage payments, plus the expected value of the worker in the next period if the job survives.

Worker's Problem

To derive the wage schedule, I also need to consider the marginal values of a match for workers. If a worker is employed, he receives wage income less the disutility of working. In period t+1, the match is separated with probability ρ_s but the separated worker can get a new match with p_{t+1}^u. Thus with probability $\rho_s(1-p_{t+1}^u)$ the separated worker remains in the unemployment pool. Otherwise, with probability $1-\rho_s(1-p_{t+1}^u)$ the worker continues in the match in t+1. Therefore, the value of being employed is given by:

$$V_t^n = w_t - \frac{\kappa_h}{\lambda_t} + \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[[1-\rho_s(1-p_{t+1}^u)] V_{t+1}^n + \rho_s(1-p_{t+1}^u) V_{t+1}^u \right] \right\} \tag{2.15}$$

where V_t^u denotes the value of an unemployed worker.

An unemployed worker receives real unemployment benefit, b and expected to move into employment with probability, p_{t+1}^u. Therefore, the value of being unemployed is given by:

$$V_t^u = b + \beta E_t \Big\{ \frac{\lambda_{t+1}}{\lambda_t} \Big[p_{t+1}^u V_{t+1}^n + (1 - p_{t+1}^u) V_{t+1}^u \Big] \Big\} \tag{2.16}$$

The worker's surplus is determined by the difference between equation (2.15) and (2.16).

Bargaining

In equilibrium, a job match strictly yields higher returns for both firms and workers, rather than otherwise. This is because the hiring process is costly for firms and when workers go through an unemployment spell they receive a small fraction of the income they would otherwise be earning. Hence, when both parties form a match through bargaining they take into account the expected costs of an unmatched outcome. I assume that workers and firms bargain period-by-period at the individual level, over their joint matching surplus, according to the Nash Bargaining solution. The Nash bargaining problem can be written as

$$\max_{w_t} \Big[V_t^n - V_t^u \Big]^{\eta} \Big[V_t^f \Big]^{1-\eta} \tag{2.17}$$

The parameter, $\eta \in (0, 1)$, reflects the bargaining power of the worker. The wage chosen by the match satisfies the optimal sharing rule between firm and worker:

$$V_t^n - V_t^u = (\frac{\eta}{1-\eta}) V_t^f \tag{2.18}$$

In equilibrium, I assume that real wage equals the Nash bargaining wage. Using equations (2.13)-(2.18) and setting $w_t = w_t^N$, I can obtain the equilibrium Nash bargaining wage bill per worker as follows:

$$w_t^N = (1-\eta)\Big[\frac{\kappa_h}{\lambda_t} + b\Big] + \eta\Big[\alpha\frac{y_t}{n_t}mc_t + \beta\kappa(1-\rho_s)E_t\Big(\frac{\lambda_{t+1}}{\lambda_t}\Big)\tau_{t+1}\Big] \tag{2.19}$$

It shows that the Nash bargaining wage is a weighted average between the marginal revenue product of the worker plus the expected savings in terms of future hiring costs if the match continues in t+1, and the unemployment benefits plus the disutility of working.

2.3.3 Entrepreneurs and Financial intermediaries

The entrepreneurial sector closely follows the framework of BGG (1999) and Gunn and Johri (2013). There is a continuum of risk neutral entrepreneurs who accumulate physical capital. At the beginning of period t, the entrepreneurs rent their capital $K_t(i)$ to the intermediate goods-producers at rental rate r_t. At the end of period t, the entrepreneurs sell all of their accumulated capital to capital producers at price, Q_{t+1} and then repurchase new capital, $K_{t+1}(i)$ at price Q_t. This purchase is financed with entrepreneurial net worth, X_{t+1} and external financing from a financial intermediary, $B_{t+1}(i)$, such that it satisfies

$$Q_tK_{t+1}(i) = X_{t+1}(i) + B_{t+1}(i) \tag{2.20}$$

I also assume that each entrepreneur has a finite planning horizon, which ensures that he will never accumulate enough net worth to fully finance the new capital acquisition. The probability that an entrepreneur will survive until the next period is η^e; newly born entrepreneurs replace the existing ones, thus the expected lifetime horizon is $\frac{1}{1-\eta^e}$.

The gross return to holding capital from t to t+1 is given by

$$R^k_{t+1} = \frac{r_{t+1} + (1-\delta)Q_{t+1}}{Q_t} \tag{2.21}$$

where $(1-\delta)Q_{t+1}$ is the return to selling the undepreciated capital stock to capital producers.

Following BGG(1999), I assume the existence of an agency problem between entrepreneurs and intermediaries, which makes the external financing more expensive than the internal funds. At the beginning of period, t+1, the entrepreneur is hit by an idiosyncratic shock such that it transformed one unit of capital from the end of time t into ω_{t+1} units of capital in time t+1, where ω^i_{t+1}, for all i, is i.i.d. across firms and time with c.d.f. $F(\omega)$ and is normalized such that $E[\omega] = 1$. The realization of ω_{t+1} is freely observed by the entrepreneur but financial intermediary incurs a monitoring cost, μ, to observe this realization. In the literature, this cost is called bankruptcy cost which captures the financial rigidity and is assumed to be constant. But, following Levin et al. (2004) and Johri and Gunn (2013), I assume that μ_t is time varying and it follows a stochastic process such that an exogenous changes in the level of this parameter will affect the business cycle properties of the model.

Given that the entrepreneur is risk neutral, she is willing to bear all the aggregate risks on its loans, thus offers a debt contract that ensures the financial intermediary receives an expected return equal to its opportunity cost of funds. On the other hand, the financial intermediary can diversify idiosyncratic risks by holding a perfectly diversified portfolio, thus offers a risk-free rate on deposits to households. The debt contract is thus characterized by the loan amount B_{t+1}, contractual rate of gross interest rate, R^l_{t+1} and a reservation value of the idiosyncratic shock

$\overline{\omega}_{t+1}(i)$ such that

$$R^{l}_{t+1}(i)B_{t+1}(i) \equiv \overline{\omega}_{t+1}(i)R^{k}_{t+1}Q_{t}K_{t+1}(i) \tag{2.22}$$

If idiosyncratic shock exceeds the reservation value such that $\omega_{t+1}(i) \geq \bar{\omega}_{t+1}(i)$, the financial intermediary will be repaid the full loan amount $R^{l}_{t+1}(i)B_{t+1}(i)$, and if idiosyncratic realization falls below the cuttoff, $\omega_{t+1}(i) < \bar{\omega}_{t+1}(i)$, the entrepreneur will default, and the financial intermediary steps in, seizes the entrepreneurs' assets net of monitoring costs, $(1-\mu_{t})\omega_{t+1}(i)R^{k}_{t+1}(i)Q_{t}K_{t+1}(i)$.

Given this set up, the expected gross return on the loan to the financial intermediary, before intermediation costs are paid, can be written as

$$\left[[1-F(\bar{\omega}_{t+1})]\bar{\omega}_{t+1}(i) + (1-\mu_{t+1})\int_{0}^{\bar{\omega}(i)} \omega_{t+1}(i)dF(\omega)\right] R^{k}_{t+1}(i)Q_{t}K_{t+1}(i) \tag{2.23}$$

Defining

$$\Gamma(\bar{\omega}_{t+1}) = [1-F(\bar{\omega}_{t+1})]\bar{\omega}_{t+1}(i) + \int_{0}^{\bar{\omega}(i)} \omega_{t+1}(i)dF(\omega), \tag{2.24}$$

and

$$G(\bar{\omega}_{t}) = \int_{0}^{\bar{\omega}} \omega dF(\omega) \tag{2.25}$$

I can re-write the financial intermediary's expected return on the loan contract, before intermediation costs are paid, as

$$\left[\Gamma(\bar{\omega}_{t+1}) - \mu_{t+1}G(\bar{\omega}_{t+1})\right] R^{k}_{t+1}Q_{t}K_{t+1}(i) \tag{2.26}$$

The terms of the debt contract are chosen to maximize expected entrepreneurs profits conditional on the expected return of the lender, for each aggregate state of the world, being equal to the opportunity costs of funds, denoted as $(\Upsilon_{t+1} + R^{d}_{t+1})B_{t+1}(i)$. That is, the participation constraint is given by the zero profit condition for the financial intermediary. Accordingly, the loan contract must satisfy

$$[\Gamma(\bar{\omega}_{t+1}) - \mu_{t+1}G(\bar{\omega}_{t+1})]\, R^k_{t+1} Q_t K_{t+1}(i) = (\Upsilon_{t+1} + R^d_{t+1})\,(Q_t K_{t+1}(i) - X_{t+1}(i)) \tag{2.27}$$

where Υ_{t+1} represents the bank's intermediation cost. This parameter captures the costs associated with screening and monitoring of loans, and transaction of services to manage funds between savers and borrowers. As in Dib (2010), we can also define shocks to bank intermediation cost as exogenous factors that affect loan production and the bank's balance sheet, such as technological advances or disruptions in the intermediation process, credit rationing, and sophisticated methods for risk sharing.

Defining leverage ratio as, $\kappa_{t+1}(i) = \frac{Q_t K_{t+1}(i)}{X_{t+1}(i)}$, I can rearrange equation (2.27) as follows

$$\frac{R^k_{t+1}}{R^d_{t+1}}\Big[\Gamma(\bar{\omega}_{t+1}) - \mu_{t+1}G(\bar{\omega}_{t+1})\Big] = \left(1 + \frac{\Upsilon_{t+1}}{R^d_{t+1}}\right)\left(1 - \frac{1}{\kappa_{t+1}(i)}\right) \tag{2.28}$$

Equation (2.28) implies that financial intermediaries charge a premium over the risk-free rate, also known as the external finance premium, $\frac{R^k_{t+1}}{R^d_{t+1}}$ to provide funds to entrepreneurs for a risky project. It affects the demand for capital by making a linkage between entrepreneur's leverage ratio and the cost of external finance. The above equation also states that the risk premium can be affected by three channels: (i) through elasticity of the external finance premium with respect to the leverage ratio, $\frac{1}{\Gamma(\bar{\omega}_{t+1})-\mu_{t+1}G(\bar{\omega}_{t+1})}$ (ii) through bank's intermediation cost channel, Υ_{t+1}, and (iii) through changes to the leverage ratio.

The marginal bankruptcy cost or default cost, μ_t, which is assumed to be time-varying can affect the external finance premium through changes to the elasticity of external finance premium with respect to the leverage ratio. Following Gunn and Johri (2013), I assume μ_t evolves according to the stationary AR(1) process

$$ln(\mu_t) = \rho_\mu \mu_{t-1} + \varepsilon_\mu \tag{2.29}$$

where $\rho_\mu < 1$ and ε_μ is an i.i.d innovation to the default cost shock and is a standard normal process.

On the other hand, the intermediation cost, Υ_t, which represents the efficiency of the banking sector can affect the external finance premium directly. The bank intermediation cost process is also assumed to evolve according to the stationary AR(1) process

$$ln(\Upsilon_t) = \rho_\Upsilon \Upsilon_{t-1} + \varepsilon_\Upsilon \tag{2.30}$$

where $\rho_\Upsilon < 1$ and ε_Υ is an i.i.d innovation to the bank intermediation shock and is a standard normal process.

Given the state-contingent debt form of the optimal contract, the expected return to the entrepreneur can be expressed as

$$\int_{\bar{\omega}_{t+1}}^{\infty} \omega_{t+1}(i) R^k_{t+1}(i) Q_t K_{t+1}(i) dF(\omega_{t+1}) - R^l_{t+1}(i) B_{t+1}(i). \tag{2.31}$$

Using definitions above, I can simplify equation (2.31) such that the entrepreneur's objective is to choose $K_{t+1}(i)$ and $\bar{\omega}_{t+1}(i)$ for a given level of net-worth $X_{t+1}(i)$ to maximize

$$\left[1 - \Gamma(\bar{\omega}_{t+1}(i))\right] R^k_{t+1} q_t K_{t+1}(i). \tag{2.32}$$

subject to the set of state-contingent constraints implied by equation (2.28). Letting $\gamma_{t+1}(i)$ be the ex-post value of the Lagrange multiplier conditional on realization of the aggregate state, the first-order conditions are then

$$\Gamma'(\bar{\omega}_{t+1}) - \gamma_{t+1}\left[\Gamma'(\bar{\omega}_{t+1}) - \mu_{t+1}G'(\bar{\omega}_{t+1})\right] = 0 \tag{2.33}$$

$$E_t\left\{[1-\Gamma(\bar{\omega}_{t+1})]\frac{R^k_{t+1}}{(\Upsilon_{t+1}+R^d_{t+1})} + \gamma_{t+1}\left([\Gamma(\bar{\omega}_{t+1}) - \mu_{t+1}G(\bar{\omega}_{t+1})]\frac{R^k_{t+1}}{(\Upsilon_{t+1}+R^d_{t+1})} - 1\right)\right\} = 0 \tag{2.34}$$

2.3.4 Capital Producers

Capital producers are competitive. At the end of the period t, they buy the depreciated capital from entrepreneurs and combine a fraction of final goods purchased from retailers as investment goods, I_t, to produce new capital goods, K_{t+1} and sell at price Q_t. The capital accumulation is given by

$$K_{t+1} = (1-\delta)\xi_t K_t + \Phi(\frac{I_t}{K_t})K_t \tag{2.35}$$

where $\Phi(.)$ is increasing and concave, satisfies $\Phi(I/K) = I/K$ and $\Phi'(I/K) = 1$, where I/K is the net investment to capital ratio. The optimal condition for capital producers is as follows:

$$Q_t = \left[\Phi'(\frac{I_t}{K_t})\right]^{-1} \tag{2.36}$$

2.3.5 Retailers

There is a continuum of monopolistically competitive retailers of measure 1. Retailers buy intermediate goods from intermediate producers and produce a good of variety i. Let $Y_t(i)$ be the retail good sold by retailer i to households and let $P_t(i)$ be its nominal price. The final good, Y_t, is the composite of the individual retail goods,

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}}di\right]^{\frac{\theta}{\theta-1}} \tag{2.37}$$

where θ is the elasticity of demand for each intermediate good.

The demand that each retailer faces is as follows:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta} Y_t \tag{2.38}$$

where the price index is given by

$$P_t = \left[\int_0^1 P_t(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}} \tag{2.39}$$

Following Calvo (1983), I assume that each period, each retail firm sets prices such that a fraction $(1-\zeta)$ of retail firms sets a new price, whereas the remaining fraction ζ of firms keeps the price unchanged. Therefore, firm i sets a new price $P_t(i)$ at time t and maximizes its profit, as follows:

$$E_0 \sum_{j=0}^{\infty} (\beta\zeta)^j \frac{\lambda_{t+j}}{\lambda_t} \left\{ \left(\frac{P_t(i)}{P_t}\right)^{-\theta} Y_{t+j} \left[\frac{P_t(i)}{P_{t+j}} - mc_{t+j}\right]\right\} \tag{2.40}$$

The first-order condition is

$$P_t^*(i) = \frac{\theta}{\theta-1} \frac{E_t \sum_{j=0}^{\infty} (\beta\zeta)^j \left[\lambda_{t+j} mc_{t+j} y_{t+j}(j) p_{t+j}^{\theta}\right]}{E_t \sum_{j=0}^{\infty} (\beta\zeta)^j \left[\lambda_{t+j} y_{t+j}(j) p_{t+j}^{\theta-1}\right]} \tag{2.41}$$

where the retailer chooses price $P_t^*(i)$. The aggregate price index follows

$$P_t = \left[\zeta P_{t-1}^{1-\theta} + (1-\zeta) P_t^{*1-\theta}\right]^{\frac{1}{1-\theta}} \tag{2.42}$$

These equations lead to the following New Keynesian Phillips curve:

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1-\beta\zeta)(1-\zeta)}{\zeta} \hat{mc}_t \tag{2.43}$$

where mc_t is the real marginal cost, and the variables with hats are log deviations from the steady-state values.

2.3.6 Government Policy

Households buy nominal government bonds, B_t, and pay real lump-sum taxes, T_t, to the government. With this income, the government finances real exogenous spending, G_t, and the amount of real unemployment benefits, $b(1-N_t)$, for the unemployed members of households. Hence the government budget constraint at time t follows:

$$G_t + b(1-N_t) + \frac{B_{t-1}R^n_{t-1}}{P_t} = T_t + \frac{B_t}{P_t} \tag{2.44}$$

The monetary authority adjusts the nominal interest rate, R^n_t in response to deviations of inflation and output from their steady state values. It evolves according to

$$log(\frac{R^n_t}{R^n}) = \phi_\pi log(\frac{\pi_t}{\pi}) + \phi_y log(\frac{Y_t}{Y}) \tag{2.45}$$

where R^n, π, and Y are the steady state values of R^n_t, π, and Y_t. ϕ_π and ϕ_y are the response coefficients to inflation and output. Later, in the paper I redefine the policy rule to assess whether an augmented policy rule featuring financial variables could be more effective than a simple rule to combat against a financial crisis.

2.3.7 Equilibrium

Equilibrium is defined by a contingent sequence of decision rules that satisfy the following conditions: (i) the allocations solve all eight agents' problems; (ii) all markets clear; and (iii) the resource constraint holds. Good market clearing implies that the final good is the sum of consumption, investment, government expenditures, the labor hiring cost, the aggregate cost of monitoring associated with bankruptcies and the bank intermediation cost. Therefore, the aggregate resource can be defined as follows:

$$Y_t = C_t + I_t + G_t + kv_t + \mu_t \int_0^{\bar{\omega_t}} \omega dF(\omega) R_t^k Q_{t-1} K_t + \Upsilon_t B_t \tag{2.46}$$

2.4 Parameterization

I calibrate some structural parameters to match several steady-state observations. I also calibrate the parameters related to labor search frictions based on existing studies. The preference and production parameters are standard in business cycle model. I set the discount factor $\beta = 0.99$, to generate an annual real interest rate of 4%, as in the data. I set the matching elasticity parameter α_m to 0.5 and the wage bargaining parameter η to 0.50, which are standard in the literature. I calibrate the job separation rate, ρ_s to 0.10, so that an average monthly job separation rate is about 3.5 percent, as observed in the data.

I calibrate the unemployment benefit, b to 0.25, which implies that the unemployment benefit is on average about 25 percent of wage earnings, which is consistent with other studies such as Hall and Milgrom (2008). The vacancy posting cost κ is set to 0.05 as in Merz (1995). I target a steady-state unemployment rate of 0.064, to be consistent with the average unemployment rate in the data. Accordingly, I obtain the steady state values of matching as follows, $m = \rho_s * (1 - u) = 0.936$. I calibrate the steady-state number of vacancies, v, such that the probability of filling a vacancy, p^v, equals to 0.70, as in Cooley and Quadrini (1999) and den Haan, Ramey and Watson (2000). This implies that the steady-state number of vacancies, $v = 0.0936/0.70 = 0.134$.

I set the share of labor in production, α, to 0.67, as in data and the depreciation rate of physical capital, δ, to 0.025, to produce a 10% annual depreciation rate. I set the elasticity of the price to capital with respect to the investment ratio,

$\eta_{\frac{i}{k}}$, to 0.25, as suggested in BGG (1999). The steady-state value of the elasticity of substitution between intermediate goods, θ, is set to 11, so that the average markup, $\frac{\theta}{\theta-1}$, is about 10 percent, as suggested in Rotemberg and Woodford (1999). The steady-state government spending - output ratio, $\frac{G}{Y}$, is set to 0.20, as in the data. I set the probability that a firm does not change its price within a given period, ς, equal to 0.85, implying that the average period between price adjustments is around 6.5 quarters, which lies in the range used by other studies. For the Taylor rule parameters, I set $\phi_\pi = 1.50$ and $\phi_y = 0.125$ as in Taylor (1993).

I follow BGG (1999) to set parameters associated with financial contract and entrepreneurs. I set the quarterly survival rate of entrepreneurs to 0.979, the variance of the log-normally distributed productivity variable, $log\overline{w}$ to 0.1660, the steady state bankruptcy cost to 0.060 and the steady state bank's intermediation cost to 0.028 to target the steady state external finance premium of 200 basis points annually, leverage ratio of 0.50 and entrepreneurs default rate of 0.076 quarterly. Gilchrist and Zakrajsek (2012) constructed a data series of excess bond premium to measure the credit supply condition. I use this data series to estimate the μ_t process. I regress this data series on its first lag without a constant using ordinary least square. The estimate of the autoregressive coefficient is 0.75 with a standard deviation of 0.051. Analogously, I use financial intermediation data from WORLD KLEMS for the U.S. to estimate the bank intermediation cost process. The estimate of the autoregressive coefficient is 0.62 with a standard deviation of 0.104.

2.5 Results and Analysis

In this section, I use a linearized and parameterized version of the model economy to illustrate how adverse financial shocks - the bankruptcy cost shock and the bank intermediation cost shock, can lead to a persistent increase in the unemployment rate and a fall in economic activity.

2.5.1 Impulse Responses to Financial Shocks

Figures 2.2 and 2.3 show the impulse response functions (IRFs) of the model in response to an exogenous increase in the marginal bankruptcy cost and bank intermediation cost of sizes that increase the external finance premium by 4 percentage points in the first period.

These shocks create an immediate fall in economic activity with the largest impact in the period of the shock and a persistent decline towards steady state. The fall in real activity is accompanied by lower credit, the lower asset price and lower net-worth. A higher risk premium combined with a lower net worth decrease entrepreneurs' demand for new capital. This has two effects. First, a lower demand for capital decreases the investment incentive of capital producers. Second, intermediate firms do not get enough capital goods as inputs of production. As a result, the demand for labor inputs fall as well. Firms fire workers and decrease the vacancy postings. This action decreases the labor market tightness and the probability of a worker finding a job, which leads to an increase in the unemployment rate. Accordingly, the demand for intermediate goods falls, thereby deceasing the price of intermediate and final goods. Since prices are set based on the expected future marginal costs, the inflation rate also falls. Finally, the monetary authority responds to the fall in economic activity by reducing the policy rate.

During the recovery phase, when the risk premium begins to fall, the demand for capital begins to rise, which in turn drives up the price of capital. As a consequence, entrepreneurs' net worth increases and this leads them to accumulate more capital. Accordingly, firms increase their production by renting capital from entrepreneurs and by hiring more workers. This leads to a fall in the unemployment rate, and the economy eventually moves to its initial steady state.

2.5.2 Monetary Policy Analysis

In this section, I assess the performance of different monetary policy rules to combat a financial crisis. In particular, I compare the policy outcomes of the conventional Taylor rule with those of rules augmented with financial variables. I consider two augmented Taylor type monetary policy rules, one responds to credit spread and another responds to asset prices, as follows:

$Rule1$:

$$log(\frac{R_t^n}{R^n}) = \phi_\pi log(\frac{\pi_t}{\pi}) + \phi_y log(\frac{Y_t}{Y}) - \phi_s log(\frac{S_t}{S}) \tag{2.47}$$

$Rule2$:

$$log(\frac{R_t^n}{R^n}) = \phi_\pi log(\frac{\pi_t}{\pi}) + \phi_y log(\frac{Y_t}{Y}) + \phi_p log(\frac{Q_t}{Q}) \tag{2.48}$$

where Q is the steady-state value of asset prices, $S \equiv \frac{R_k}{R_d}$ is the steady-state value of risk premium, $0 < \phi_p < 1$ is the response coefficients to asset prices, and $0 < \phi_s < 1$ is the response coefficients to credit spread or the external finance premium.

There are several studies that consider similar augmented Taylor rules in their policy evaluation. For instance, McCulley and Toloui (2008), Taylor (2008), Curdia and Woodford (2010), Gilchrist and Zakrajsek (2011, 2012b), and Hirakata et al. (2013) use credit spread in their policy rules. Faia and Monacelli (2007) include asset prices, along with inflation, as a separate argument in the policy rule. Similarly, Nistico (2012), Gelain et al. (2013), Finocchiaro and von Heideken (2013), and Lambertini et al. (2013) include growth in asset prices in the policy rule.

Since I compare the policy outcomes of the augmented Taylor rules with the standard Taylor rule, I set $\phi_\pi = 1.5$ and $\phi_y = 0.1250$, as used in the benchmark model. However, in order to decide on what is the best monetary policy, that is, what should be the ϕ_s and ϕ_p in the above policy rules, we need to define some target for what monetary policy is trying to achieve. For this purpose, I consider a central bank with a mandate similar to that of the U.S. Federal Reserve as specified in the Federal Reserve Act, that is, "maximum employment, stable prices, and moderate long-term interest rate." I formulate this mandate with an objective that the central bank should minimize some quadratic loss function, where losses are caused by output, inflation rate and unemployment rate being deviation from their respective targets as follows.

$$Loss = \sum_{t=0}^{\infty} \beta^t [\Lambda_1 (Y_t - Y)^2 + \Lambda_2 (\pi_t - \pi)^2 + \Lambda_3 (u_t - u)^2] \tag{2.49}$$

where Λ's represent the weights placed on the three variables.

In the model, both financial shocks affect the economy in a similar way, so I focus only on the marginal bankruptcy cost shock to evaluate the effectiveness of different policy rules. I also assume that the weights on these three variables are the same. Figures 2.4 and 2.5 show the responses of the endogenous variables under two policy rules to an exogenous increase in marginal bankruptcy cost, of a size that increase the external finance premium by 4 percentage points. The responses are shown in the case of the different possible values of ϕ_p and ϕ_s, in the range between 0 and 0.50. Under the baseline Taylor rule, $\phi_p = 0$ or $\phi_s = 0$, such adverse shocks not only lead to a fall in asset prices and total credit, but also dampen real economic activity. However, when the interest rate rule responds more to the asset prices or the external financial premium movements, this allows for an improvement in economic stabilization.

Figures 2.6 and 2.7 plot the value of loss functions under two policy rules with respect to different possible values of ϕ_p and ϕ_s . Once I minimize the loss function over policy rules with alternative values of ϕ_p and ϕ_s, the loss minimization is reached at $\phi_p = 0.28$ and $\phi_s = 0.42$. The optimal response coefficients on spread and asset prices are found to be different (0.42 versus 0.28) because they affect the model economy through two different channels. For instance, a rise in spread directly increases the cost of external finance, which in turn induces entrepreneurs to borrow less and reduce their capital accumulation. On the other hand, a fall in asset prices reduces the net worth of entrepreneurs, therefore they need more external finance to purchase capital, which in turn forces them to reduce their capital accumulation. Figures 2.8 and 2.9 compare the response of the model under the conventional Taylor rule and the augmented Taylor rules featuring financial variables. Compared to the standard Taylor rule, the impact of an adverse financial shock is dampened when the central bank follows the credit spread or asset prices adjusted Taylor rule.

The model's responses to the proposed augmented Taylor rules are consistent with other related studies that find similar results. For instance, McCulley and Toloui (2008) and Taylor (2008) propose $\phi_s = 1$. They essentially recommend that the policy rate should be adjusted by the size of the increase in credit spread. Following their studies, Gilchrist and Zakrajsek (2011, 2012b) use $\phi_s = 1$ and find that spread-adjusted monetary policy rules improve equilibrium responses of the macroeconomy to shocks originating from the financial sector. Curdia and Woodford (2010), on the other hand, set $\phi_\pi = 1.5$ and $\phi_y = 0.1250$, and then consider a variety of types of disturbances and find different optimal spread adjustment coefficients such as 0.21, 0.30, 0.74, 0.82, -0.30, and -1.47, for different shocks. Similarly, Hirakata et al. (2013) first compute a set $\{\phi_\pi = 4.0, \phi_y = 0.01\}$ that is optimal under the economy, and then set a value, $\phi_s = 0.40$, for the policy weight attached to the credit spread. Clearly, the spread adjustment coefficient in my policy rule 1, $\phi_s = 0.42$, which is sufficiently larger than zero, lies in the range recommended by other studies. Also, it is also clear from these studies that the optimal spread adjustment coefficient in the policy rule depends mostly on the structure of a model as well as types of disturbances are used in the model.

Faia and Monacelli (2007) argue that if the policy rate responds to inflation in the range of those typically assigned in standard Taylor-type rules, responding to a rise in the asset price improves welfare. However, my findings differ in several ways. First, they consider three fixed response coefficients, such as -0.20, 0, 0.20 on asset prices under five different policy rules instead of calculating an optimal asset price adjustment coefficient in the policy rule. Second, they prescribe that the monetary authority should lower the interest rate when the asset price rises. However, I find that that the monetary authority should reduce the interest rate when the asset prices falls due to a financial crisis. There are two possible explanations for getting such different results. First, I evaluate the performance of different policy rules in response to adverse financial shocks, whereas they conduct their policy evaluation in the presence of positive productivity shocks. Second, I develop policy rules that meets the central bank's objectives, that is, to minimize some quadratic loss function; whereas their approach is to find optimal policy rules that maximize welfare of the representative agent.

A few studies, however, find no significant gains when financial variables are included in monetary policy rules. For instance, Bernanke and Gertler (1999, 2001) argue that the stabilization of inflation and output provides a substantial contribution to financial stability and there are little if any gains to responding to asset prices. My results differ because they have considered different types of disturbances such as asset price bubble shocks and technology shocks to perform their analysis. Similarly, Faia and Monacelli (2007) recommend that when monetary policy strongly responds to inflation, the marginal gain of responding to asset prices vanishes. They compute a robust welfare metric in the presence of productivity shocks and conclude that strict inflation stabilization offers the best solution. To check whether this policy prescription still holds in my framework, I next examine whether a basic Taylor rule with fixed $\phi_y = 0.1250$ but alternative higher values of ϕ_π can improve economic stabilization following a similar adverse financial shock as described before. Figure 2.10 plots the impulse responses when ϕ_π falls to within the range of between 1.50 and 3.0. As seen in the figure, when monetary policy strongly responds to inflation, following an adverse financial shock, not much improvement is observed in the labor and financial market variables.

Now, I set $\phi_\pi = 3.0$ and $\phi_y = 0.1250$ and apply rules 1 and 2 to examine whether there are any gains if the policy rule responds to the financial variables while also strongly responding to inflation. Figures 2.11 and 2.12 show that the policy rules that respond strongly to inflation can still improve economic stabilization, following an adverse financial shock, when they also respond to financial variables. Thus, a policy rule that responds to financial variables in addition to inflation and output fluctuations following a financial crisis, can improve macroeconomic stabilization relative to the conventional Taylor rule.

Sensitivity Analysis

In this section, I examine the robustness of the model results with respect to one key parameter in the model, that is, the elasticity of the price of capital with respect to the investment capital ratio, $\eta_{i/k}$. It is also known as capital adjustment cost.

As mentioned earlier, I set $\eta_{i/k} = 0.25$ following BGG (1999) but there is no firm evidence in the literature about what this parameter value should be. So, I conducted an experiment to examine how the model responds with respect to a bankruptcy cost shock when $\psi_{i/k}$ equals to 0.20, 0.25, and 0.30. Figures 2.13, 2.14 and 2.15 show the impulse responses for three scenarios (a) model with a standard Taylor rule, (b) model with an augmented Taylor Rule1, and (c) model with an augmented Taylor Rule2, to an exogenous increase in marginal bankruptcy cost, of a size that increase the external finance premium by 4 percentage points. As shown in the figures, a higher capital adjustment cost reduces the severity of the recession, whereas a lower capital adjustment cost dampens the economy activity even further. A higher capital adjustment cost prevents capital producers from changing their capital stock too quickly. Therefore, investment and economic activity fall less in response to an adverse shock when the capital adjustment cost is relatively higher. The response of the model is consistent with what we observe in the data and the model's dynamics and qualitative results are unaffected by changes in this parameter.

2.6 Conclusion

This paper constructs a New Keynesian model with capital market imperfections and labor market frictions to explore how shocks originating from banking sectors affect the real economic activity. I evaluate the links between labor market and financial frictions on aggregate fluctuations. The main feature of the model is that it considers two financial shocks - the bankruptcy cost shock and the bank intermediation cost shock, which directly originate in the banking sector. These shocks create a time varying wedge between the leverage ratio and the external finance premium. As a result, the contract menu offered to entrepreneurs' changes over time, and this can endogenously explain the movements in the external finance premium, the leverage ratio, net worth, credit quantity, and the price of capital, without having to assume exogenous movements in these variables. I show that an adverse financial shock in the model can account for the key business cycle features of an economic downturn.

A central objective of this paper is to develop monetary policy rules in the context of financial crisis. In particular, this paper seeks to analyze whether and how the monetary policy rules react to adverse financial shocks. I evaluate the performance of different Taylor-type interest rules, with and without reaction to financial variables with an objective to minimize some quadratic loss function. I find that a policy rule that responds to financial variables such as credit spread or asset prices in addition to inflation and output fluctuations could improve macroeconomic stabilization by reducing the effects of financial disruptions following an adverse financial shock.

The paper uses the financial accelerator mechanism as in BGG (1999) to incorporate financial market frictions within the DSGE framework. But the major weakness of the financial accelerator mechanism is that it only deals with one of many possible financial frictions such as the balance sheets in the banking sector, portfolio choice issue with complete or incomplete markets or collateral constraints. It would be interesting to examine whether the same results hold in other frameworks. I keep this task for future research.

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Appendix

Data Construction

1. Unemployment: Civilian Unemployment Rate (UNRATE). Source: Federal Reserve Bank of St. Louis, Federal Reserve Economic Data (FRED, http://www.stlouisfed.org/).

2. 3-Month Treasury Bill, Secondary Market Rate. Source: FRED

3. Moody's Seasoned Baa Corporate Bond Yield. Source: FRED.

4. Credit Spread: constructed as (4) = (3) - (2).

Table 2.1: Calibrated Values

Parameter	Description	value
	Structural parameters	
β	Discount factor	0.99
α	Labor share	0.67
δ	Capital depreciation rate	0.025
θ	Elasticity of substitution between intermediate goods	11.0
$\frac{G}{Y}$	Steady-state government spending-output ratio	0.20
u	Steady-state unemployment rate	0.064
b	Unemployment benefits	0.25
p^v	Vacancy filling rate	0.70
ρ_s	Job separation rate	0.10
κ	Cost of vacancy posting	0.05
ς	Price stickiness	0.85
η^e	Survival rate of entrepreneurs	0.979
$log\overline{w}$	Variance of the log-normally distributed productivity variable	0.166
μ_{ss}	Steady-state bankruptcy cost	0.060
Υ_{ss}	Steady-state intermediation cost	0.028
ϕ_π	Taylor-rule coefficient for inflation	1.50
ϕ_y	Taylor-rule coefficient for output	0.125
	Shock parameters	
ρ_μ	Persistence of default cost shock	0.75
σ_μ	Standard deviation of default cost shock	0.051
ρ_Υ	Persistence of bank intermediation cost	0.62
σ_Υ	Standard deviation of bank intermediation shock	0.104

Figure 2.1: Unemployment Rate and Credit Spread (Baa - 3 month T-bill rate) for the United States

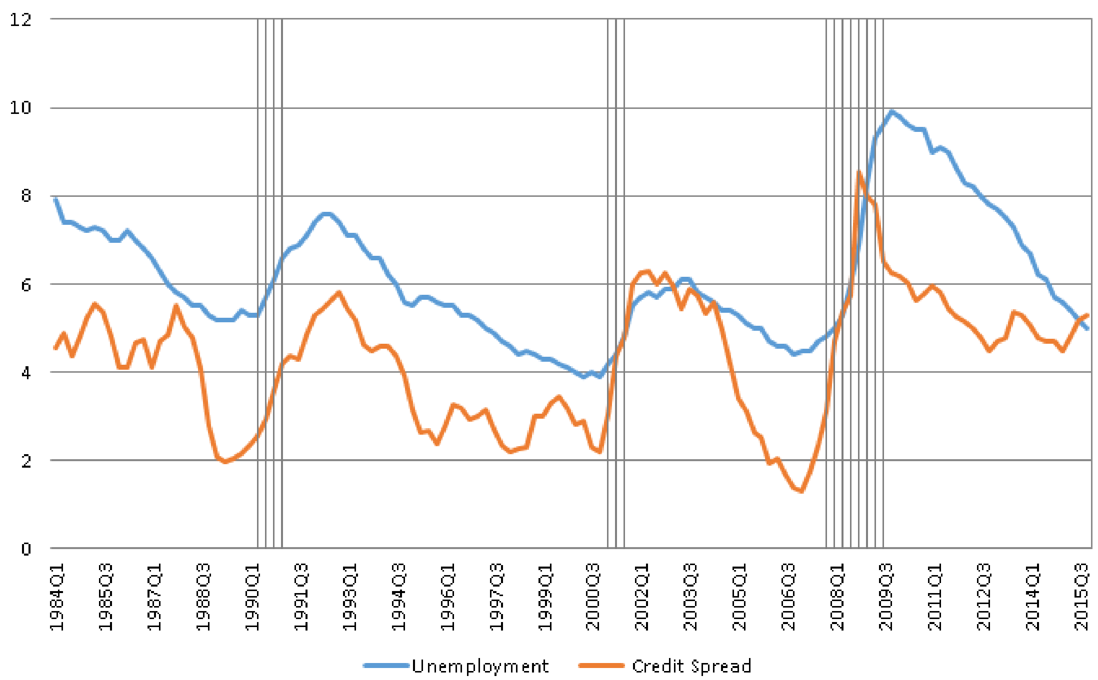


Figure 2.2: IRFs to a bankruptcy cost shock

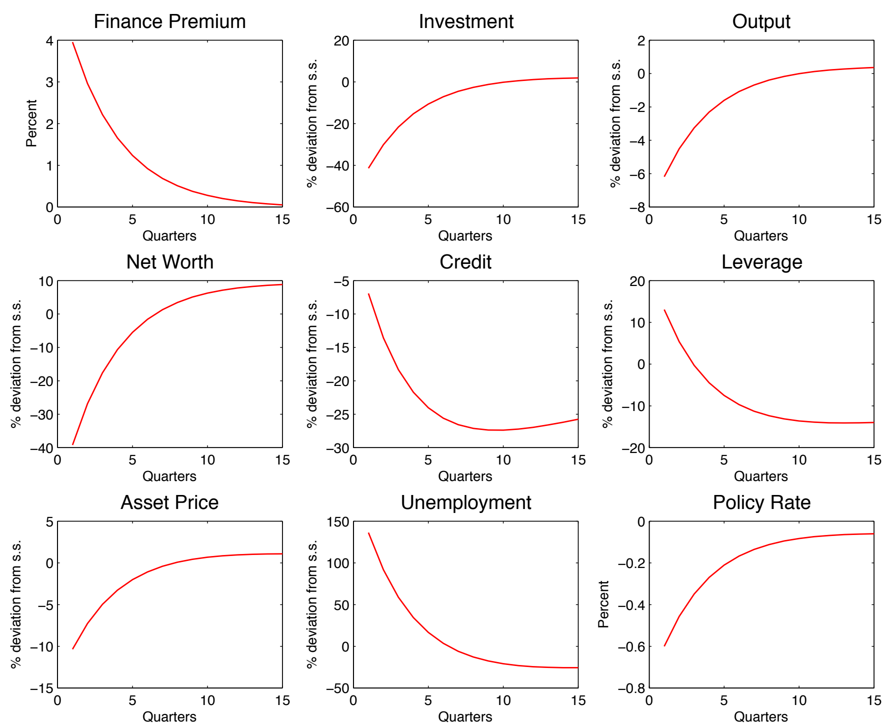


Figure 2.3: IRFs to a bank intermediation cost shock

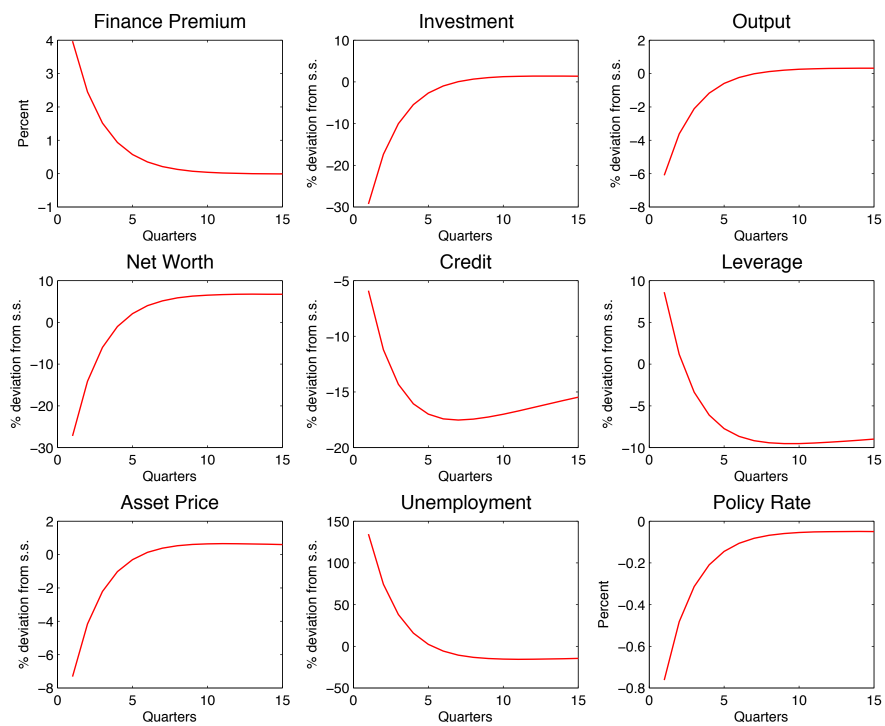


Figure 2.4: IRFs to a bankruptcy cost shock: Rule1

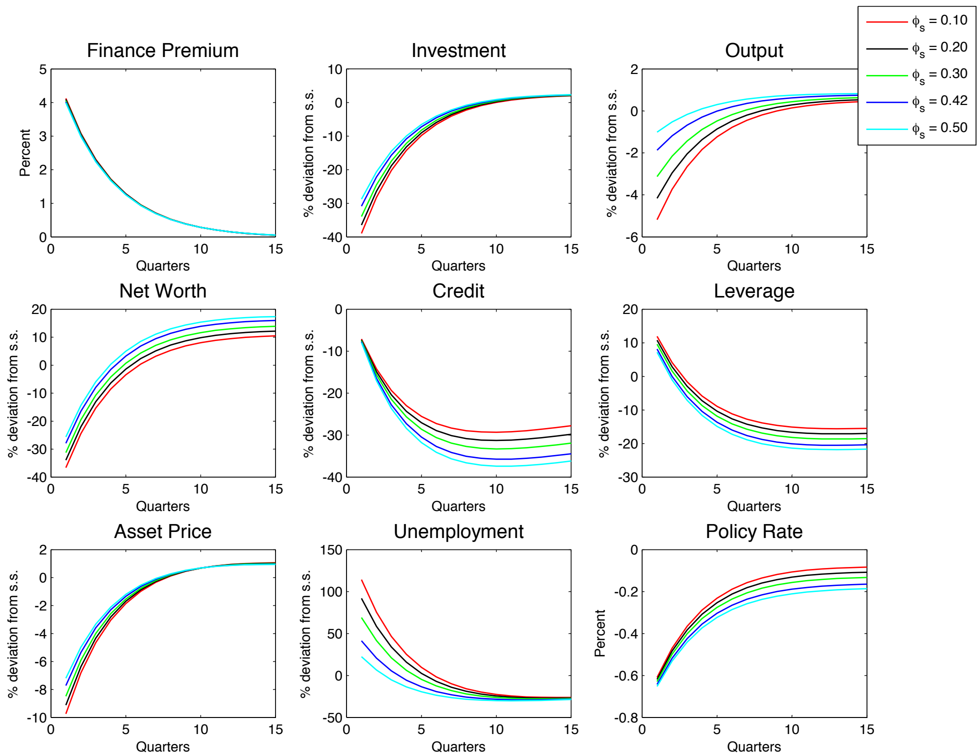


Figure 2.5: IRFs to a bankruptcy cost shock: Rule2

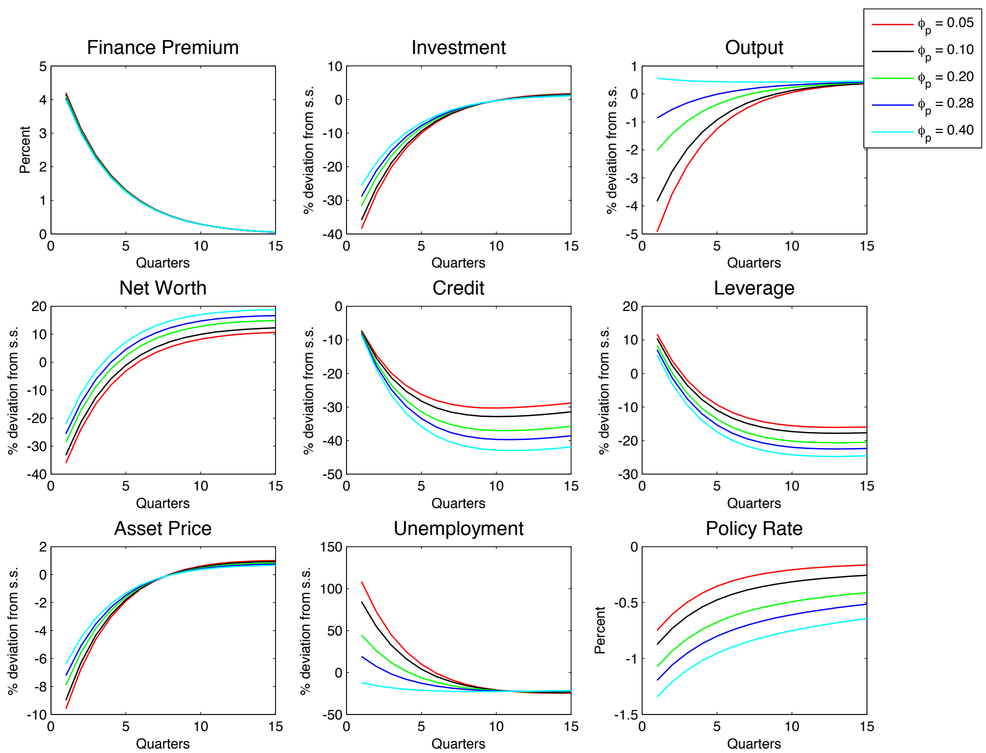


Figure 2.6: Loss function minimization: Rule1

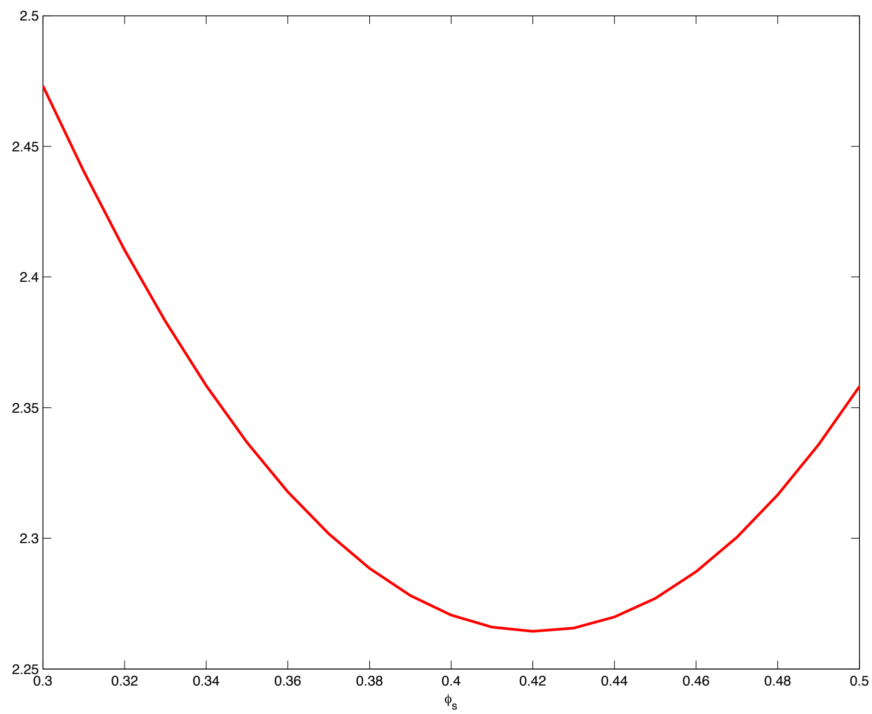


Figure 2.7: Loss function minimization: Rule2

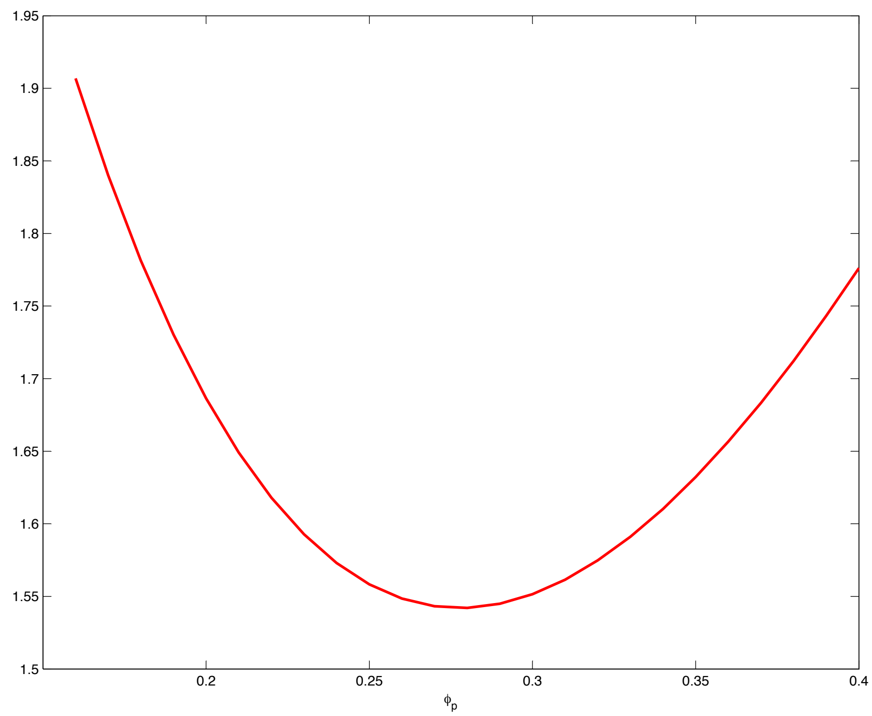


Figure 2.8: IRFs to a bankruptcy cost shock: a basic Taylor Rule versus an augmented Taylor Rule1

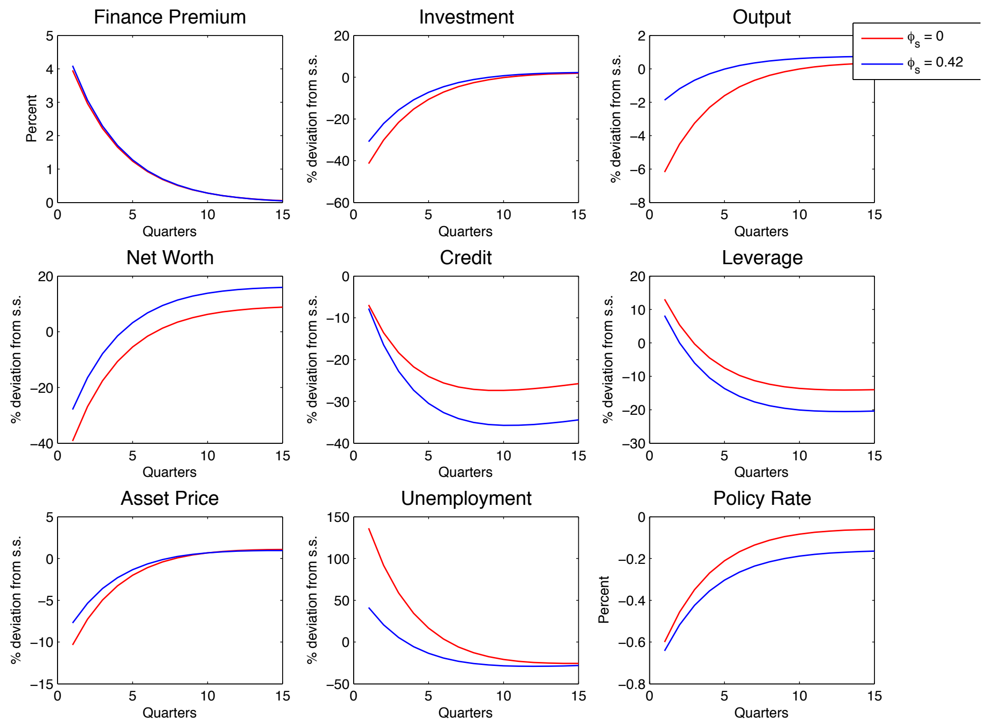


Figure 2.9: IRFs to a bankruptcy cost shock: a basic Taylor Rule versus an augmented Taylor Rule2

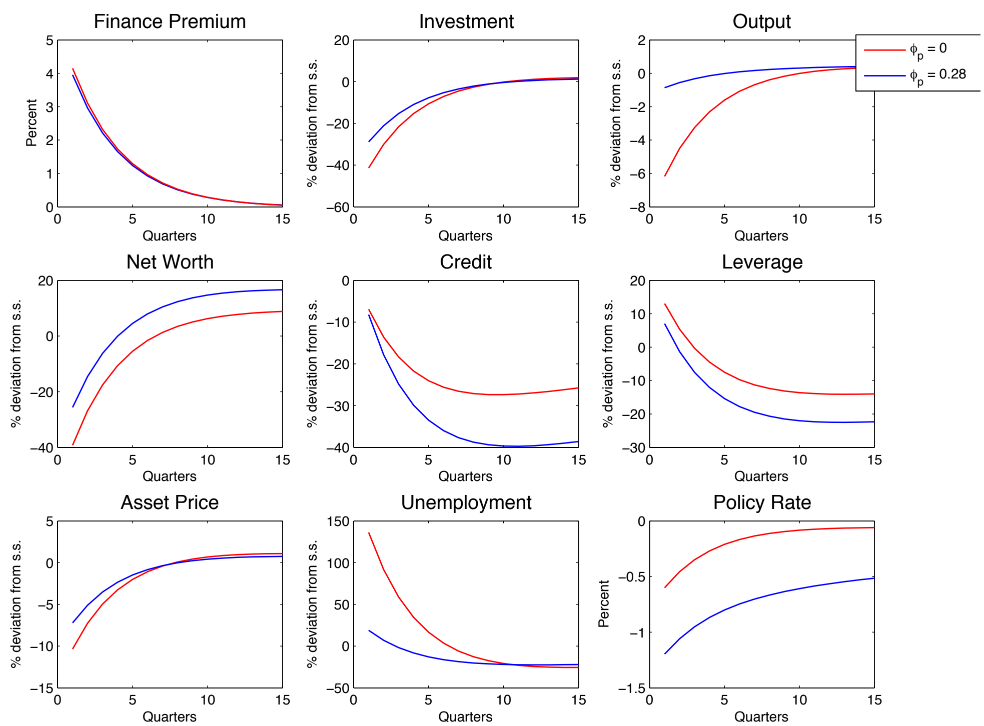


Figure 2.10: IRFs to a bankruptcy cost shock: standard Taylor Rule with varying responses to inflation

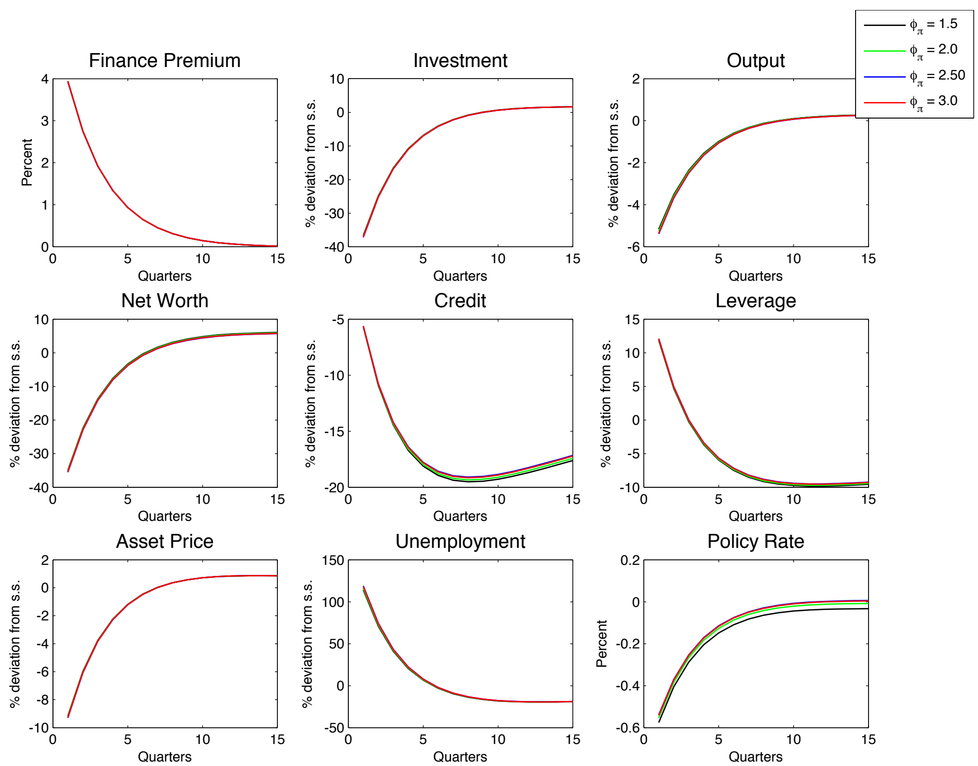


Figure 2.11: IRFs to a bankruptcy cost shock: Rule1 with strong response to inflation, $\phi_\pi = 3.0$

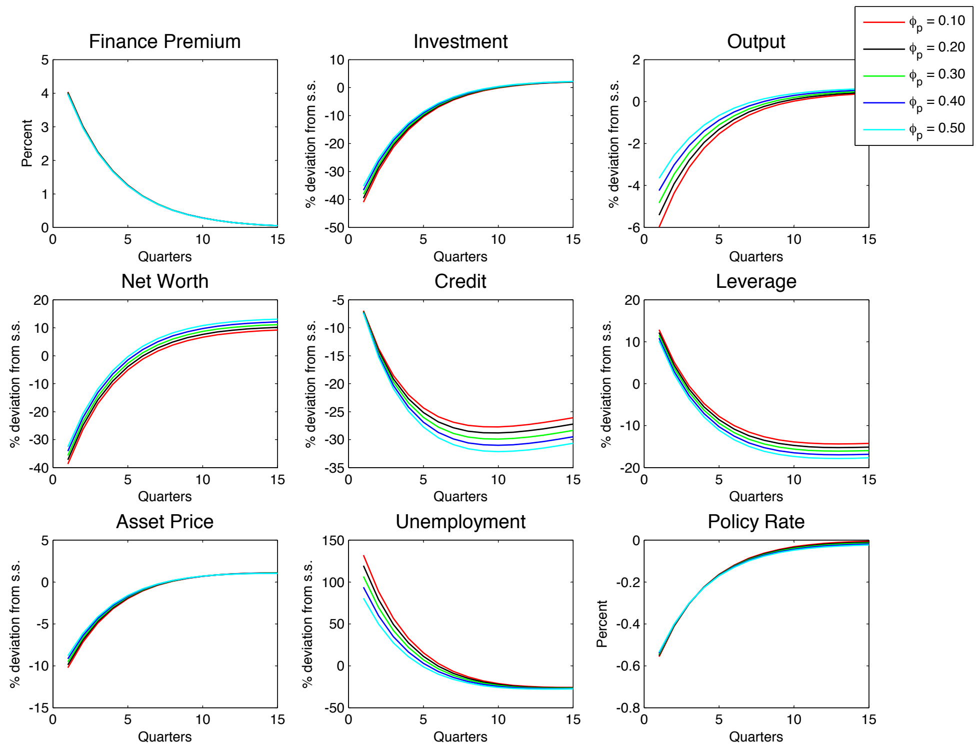


Figure 2.12: IRFs to a bankruptcy cost shock: Rule2 with strong response to inflation, $\phi_\pi = 3.0$

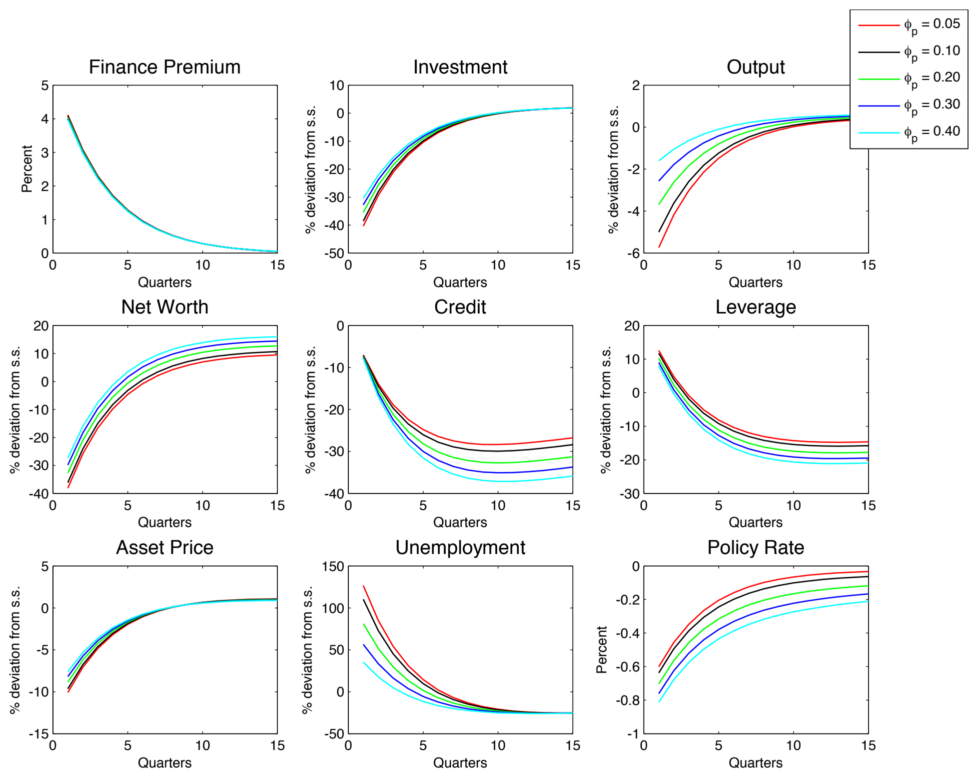


Figure 2.13: Model sensitivity with respect to capital adjustment cost: a basic Taylor Rule

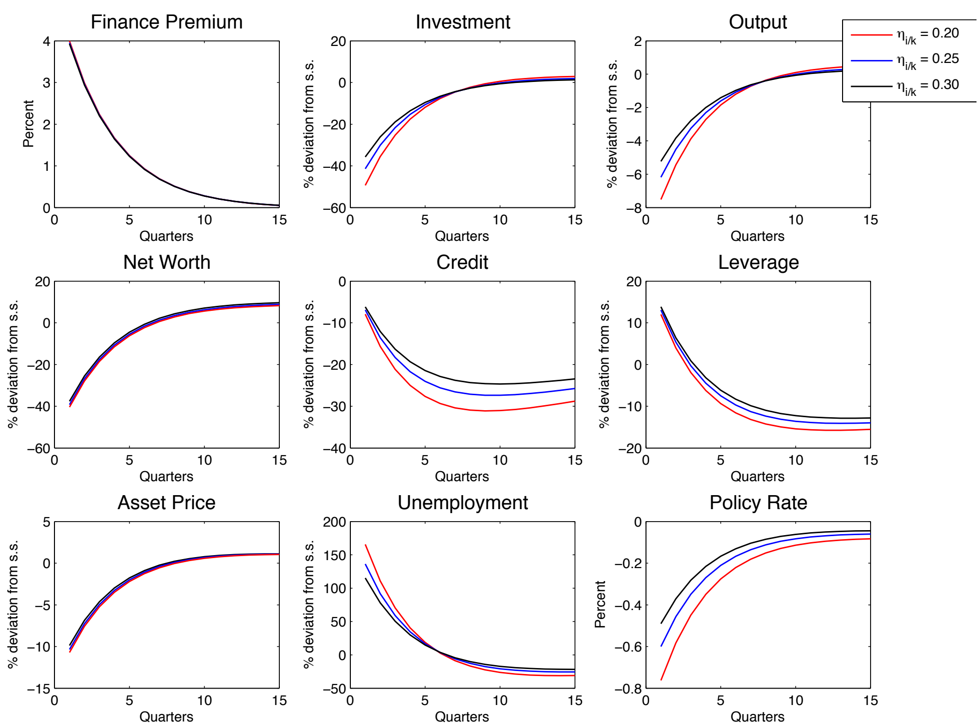


Figure 2.14: Model sensitivity with respect to capital adjustment cost: an augmented Taylor Rule1

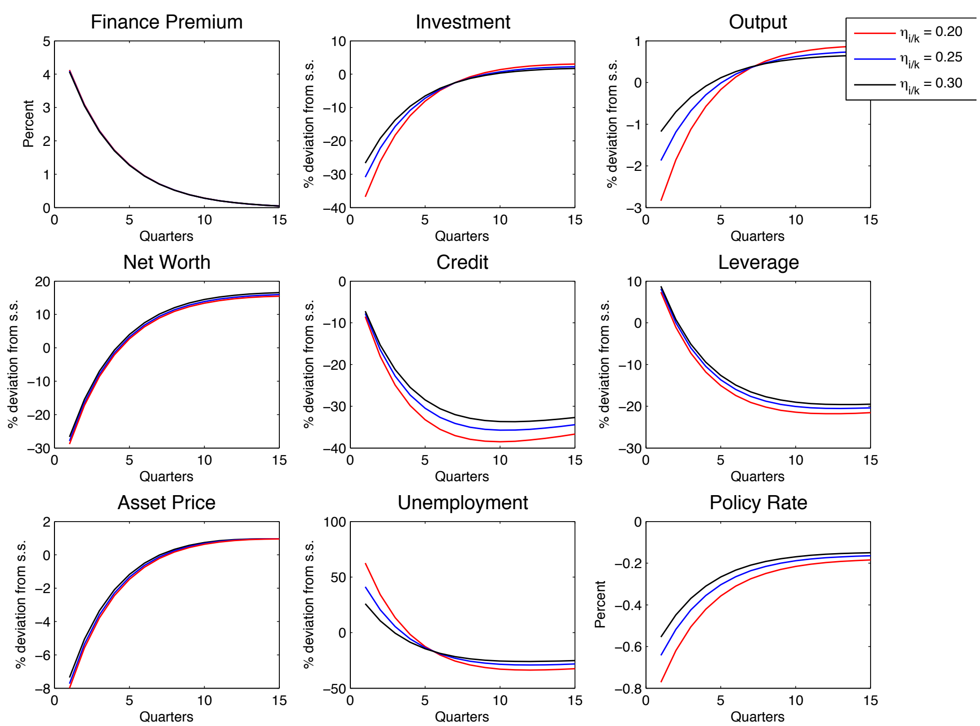
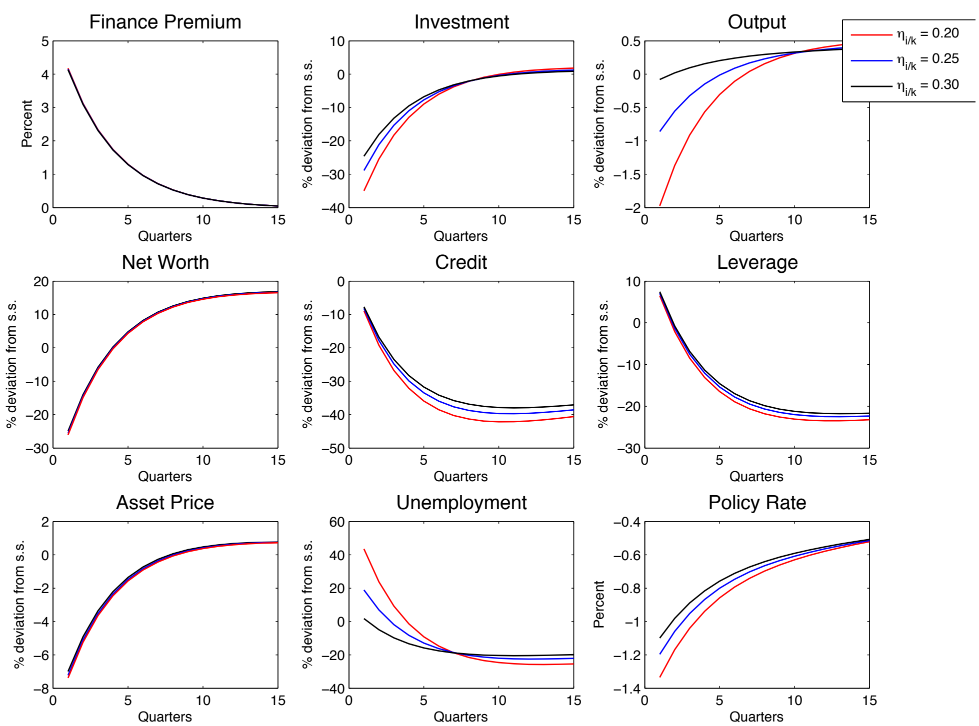


Figure 2.15: Model sensitivity with respect to capital adjustment cost: an augmented Taylor Rule2



Chapter 3

Interest Rate Uncertainty and Sovereign Default Risk

3.1 Introduction

The behavior of the T-bill rate is always on the watch-list of policy makers and investors, both in advanced and developing countries. As the United States emerged from the recent Great Recession, there was considerable uncertainty around the future direction of U.S. monetary policy as well as much speculation about when and how would the U.S. Fed unwind its quantitative easing (QE) program. For instance, the reaction of global markets (particularly in emerging market economies, EMEs) after the summer of 2013's "tapering talk" was uncommon and different from the usual market response to Fed monetary policy actions.[1] A sharp market adjustment followed in EMEs, including a reversal in capital flows, and a spike in

[1] In his May 22, 2013 testimony to Congress, Fed chairman Ben Bernanke suggested the possibility of a tapering (i.e. a reduction in bond purchases by the Fed). This testimony together with the release of federal open market committee (FOMC) minutes triggered a global reassessment of expectations around the timing and path of adjustment in U.S. monetary policy. See Mishra et al. (2014).

government bond yields (see Figure 3.1). EMEs perceived this "tapering talk" as a sign of earlier than anticipated tightening of U.S. monetary policy and reacted in response. On average, sovereign spreads across EMEs rose by 1%, currencies depreciated by 3%, and equities fell by 7%.

That uncertainty has not gone away and, as is usually the case, if the markets care about it so do policy makers. Throughout the emerging world voices have recently been raised calling for a decision to be made about the future of the U.S. monetary policy and urging the Federal Reserve to put an end to the uncertainty. The following quotes (taken from a recent article on the Financial Times) summarize these concerns:[2]

"We think US monetary policymakers have got confused about what to do. The uncertainty has created the turmoil."

Mirza Adityaswara, Senior Deputy Governor, Indonesia Central Bank.

"The uncertainty about when the Fed hike will happen is causing more damage than the Fed hike will itself."

Julio Velarde, Governor, Peru Central Bank.

Motivated by these facts and policy concerns, we develop an equilibrium model of sovereign default to study the relationship between endogenous country spreads and world interest rate uncertainty. To do so, we introduce stochastic volatility into the world interest rate process (as modeled by Fernandez-Villaverde et al., 2011) in an otherwise standard quantitative model of sovereign debt and default that produces an endogenous sovereign spread, in the Eaton and Gersovitz tradition. Since debt contracts are not enforceable in the model, defaults can occur in equilibrium and the spread charged to the sovereign captures this probability of

[2] Financial Times, September 9, 2015.

default. We analyze the role that shocks to both the level and the volatility of the world interest rate play in explaining the long run dynamics of the sovereign spread and the default risk of emerging economies. In particular, we explore the impact of an unexpected increase in interest rate uncertainty on the macroeconomic dynamics of a small open economy (SOE).

We make two contributions. First, we develop a general equilibrium model of sovereign debt with endogenous default and endogenous country spreads wherein investors face a stochastic world interest rate rather than a constant one, which provides a more accurate representation of the market conditions. Our framework is able to quantify the impact of such shocks and inform the policy discussion about the effects of uncertain unwinding of the Fed's quantitative easing. Second, this paper provides a mechanism by which changes in world interest rate *uncertainty* could affect the sovereign default risk, a country's borrowing decisions, and the sovereign bond spread even when the *level* of the interest rate itself is fixed.

A version of our model, calibrated to Argentina, generates the following main findings: (i) introducing uncertainty about world interest rate fluctuations (measured by both interest level and volatility shocks) more than doubles the default risk, increases the mean spread by 115% and the volatility of the spread by 126%; (ii) in response to uncertain world interest rates the country optimally decides to lower its "exposure" and decrease the average debt-to-income ratio from 60% to 49%; (iii) the volatility of the world interest rate alone is responsible for between 24% and 39% of the observed variations in average debt-to-income ratio, mean spread and volatility of the spread; and (iv) we show that the welfare gains of eliminating world interest rate uncertainty are sizable, amounting up to a 1.8% permanent increase in consumption. Moreover, the model matches well the other business cycle moments observed in the data.

The rest of the paper is organized as follows. Section 3.2 briefly reviews the related literature. Section 3.3 describes the model and defines the equilibrium. Section 3.4 discusses the numerical solution and the calibration. Section 3.5 presents the results and section 3.6 concludes.

3.2 Related Literature

There is ample evidence that movements in the international risk-free rate (i.e. the T-bill rate) have macroeconomic consequences for emerging economies. Neumeyer and Perri (2005) report that real country interest rates in emerging economies are strongly countercyclical and tend to lead the cycle. They also find that an exogenous interest rate shock can account for up to 50 percent of the volatility of output in Argentina. Uribe and Yue (2006) report that a strong relation exists among the world interest rate, the country spread and emerging market fundamentals. In particular, they show that U.S. interest rate shocks and country spread shocks can explain the large movements in aggregate activity in emerging economies. Garcia-Cicco et al. (2010) also find that the country spread shock is one of the most important drivers of emerging economies business cycles. They show that an exogenous country spread shock and a preference shock can explain a large fraction of aggregate fluctuations in Argentine business cycles. All these papers take the country spread as an exogenous variable with a time-invariant volatility, while our work endogenizes the spread (as a result of default incentives on the part of the sovereign) and especially endogenizes the time varying volatility of the spread.

Fernandez-Villaverde et al. (2011) study the impact of time-varying volatility on the macroeconomic dynamics of a SOE. They examine the effects on the business cycles of four emerging economies - Argentina, Ecuador, Venezuela and Brazil. We follow Fernandez-Villaverde et al. (2011) in the approach to modeling the stochastic behavior of the world interest rate, while departing from their approach to modeling the country spread: as already noted above, our model is one of endogenous spreads. Then, we explore the mechanism by which world interest rate uncertainty affects the country spread and default risk in emerging economies, and uncertainty in the spread. We see our work to be complementary to the analysis in Neumeyer and Perri (2005), Garcia-Cicco et al. (2010), and Fernandez-Villaverde et al. (2011).

Within the quantitative literature on sovereign defaults (following Eaton and Gersovitz, 1981, Aguiar and Gopinath, 2006, and Arellano, 2008) our paper is particularly related to two other studies. The first one is by Seoane (2014). He studies how changes in aggregate income volatility affect sovereign spreads of four European economies: Greece, Italy, Portugal and Spain. He presents a model in the spirit of Arellano (20008) and incorporates time-varying volatility of the income process which generates substantial variability in spreads. Our work complements his by keeping the income process with a time-invariant volatility and putting the time-varying volatility in the world interest rate process. We share results on the precautionary savings motive that makes sovereigns borrow less when facing a more uncertain environment. The second paper in the default literature to which our work relates is the one by Pouzo and Presno (2012). These authors study the problem of a SOE that can default on its obligations, under model uncertainty: lenders fear that the probability model of the underlying state of the borrowing economy is misspecified and hence may demand higher returns on their investments. Even though our paper tackles a different type of uncertainty (i.e. time-varying volatility of the world interest rate) the results are consistent: more uncertainty leads to higher and more volatile spreads while maintaining historically low default rates.

Finally, this paper is also related to the literature on uncertainty shocks. For instance, Justiniano and Primiceri (2008), and Bloom (2009) study the effect of changes in the volatility of technology shocks in general equilibrium models for closed economies. Justiniano and Primiceri (2008) study the changes in volatility in postwar U.S. data by estimation of a large-scale dynamic stochastic general equilibrium model (DSGE) allowing for time variation in the structural innovations. They find that shocks specific to investment are mostly responsible for the observed "great moderation." Bloom (2009), on the other hand, shows that uncertainty shocks can generate short sharp recessions and recoveries.

3.3 Model

Our environment follows closely the model in Arellano (2008). We study a real model of a SOE that trades one-period non-contingent bonds with a large pool of international investors. Bond contracts are not enforceable. Time is discrete and goes on forever.

3.3.1 Households

The economy is populated by identical households. They rank consumption streams according to

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t) \tag{3.1}$$

where $0 < \beta < 1$ is the subjective discount factor, c denotes consumption, and $u(\cdot)$ is a period utility function which satisfies $u' > 0$, $u'' < 0$.

Households receive an exogenous stream of income which follows a log-normal AR(1) process:

$$log(y_t) = \rho_y log(y_{t-1}) + \varepsilon_{y,t} \tag{3.2}$$

where ε_y is an $i.i.d.$ $N(0, \sigma_\varepsilon^2)$.

The government has access to the international financial market where it trades one-period non-contingent bonds, b_{t+1}, with risk neutral competitive foreign investors at a price, q_t. Given that bond contracts are not enforceable, the government can decide whether to repay its debts. Consequently, every period t the government is in one of two states: default or non-default. If the government chooses to repay its outstanding debt, b_t, then it has access to the international credit market and the resource constraint of the economy is given by:

$$c_t = y_t + b_t - q_t b_{t+1} \tag{3.3}$$

If the government declares a default, it remains in default for a stochastic number of periods. While the government is in default, it cannot issue debt and domestic aggregate income is reduced by $\phi(y)$. As in Arellano (2008) and Chatterjee and Eyigungor (2012), we assume that it is proportionally more costly to default in good times ($\phi(y)/y$ is increasing in y).[3] The resource constraint for the default case can then be written as:

$$c_t = y_t - \phi(y_t) \tag{3.4}$$

3.3.2 Foreign Investors

There are a large number of risk neutral international investors who trade bonds with the domestic economy. These lenders have deep pockets and face an opportunity cost of funds given by a time-varying world risk free interest rate, r_t. They maximize expected profits taking prices as given, that is:

[3] Arellano (2008) and Chatterjee and Eyigungor (2012) show that this property is important in accounting for the dynamics of the sovereign debt interest rate spread. Mendoza and Yue (2012) show that this property of the cost of defaulting arises endogenously in a setup in which defaults affect the ability of local firms to acquire a foreign intermediate input good. Sosa-Padilla (2012) shows that a model of a sovereign defaulting on its own financial sector can generate endogenous default costs that share this property.

$$\max_{b_{t+1}} \Pi_t = q_t b_{t+1} - \frac{1-\delta_{t,t+1}}{1+r_t} b_{t+1} \tag{3.5}$$

where $\delta_{t,t+1}$ is the probability of default in period $t+1$, as of period t. The first order condition implies a bond price function as follows:

$$q_t = \frac{1-\delta_{t,t+1}}{1+r_t} \tag{3.6}$$

Equation (3.6) is the pricing equation found in most of the sovereign default literature. It states that risk-neutral investors will price bonds as the discounted repayment probability.

3.3.3 Law of Motion for the World Interest Rate

Following Fernandez-Villaverde et al. (2011) we specify the international risk-free rate faced by investors as:

$$r_t = \bar{r} + \varepsilon_{r,t} \tag{3.7}$$

where $\bar{r}$ is the mean of world risk-free real rate, and $\varepsilon_{r,t}$ represents deviations from this mean. In particular, we assume the following AR(1) behavior for $\varepsilon_{r,t}$:

$$\varepsilon_{r,t} = \rho_r \varepsilon_{r,t-1} + e^{\sigma_{r,t}} u_{r,t} \tag{3.8}$$

where $u_{r,t}$ is a normally distributed shock with mean zero and unit variance. The crucial ingredient in this stochastic process is that the standard deviation ($\sigma_{r,t}$) is not constant but time-varying and itself follows another (independent) AR(1) process:

$$\sigma_{r,t} = (1-\rho_{\sigma_r})\bar{\sigma}_r + \rho_{\sigma_r}\sigma_{r,t-1} + \eta_r u_{\sigma_r,t} \tag{3.9}$$

where $u_{\sigma_r,t}$ is a normally distributed with mean zero and unit variance. We further assume that $u_{r,t}$ and $u_{\sigma_r,t}$ are independent of each other. The parameters $\bar{\sigma_r}$ and η_r measure the degree of mean volatility and stochastic volatility in the international risk free rate. A high $\bar{\sigma_r}$ corresponds to a high mean volatility and a high η_r corresponds to a high degree of stochastic volatility in the international risk free rate.

3.3.4 Timing

The timing of events, for a government that is not excluded from financial markets, is as follows. The government starts with an initial bond position b_t and observes the realizations of the income level (y_t), the world interest rate level (r_t) and the interest rate volatility shock ($\sigma_{r,t}$), and then decides whether to repay its outstanding debt. If it decides to repay, it chooses b_{t+1} subject to the resource constraint, taking the bond price schedule $q_t(b_{t+1}; y_t, r_t, \sigma_{r,t})$ as given. Finally, consumption takes place.

On the other hand, if the government decides to default it gets excluded from financial markets and suffers a direct income loss. In case of default, there is no other decision to be made as the level of consumption equals the (reduced) income level. At the end of the period, a re-access coin is tossed, and the government will re-access (remain excluded from) financial markets in the following period with probability μ $(1-\mu)$.

3.3.5 Recursive Equilibrium

We now turn to recursive notation, where *primes* denote next-period value of the variables. Let $\Theta = \{y, r, \sigma_r\}$ denote the aggregate exogenous state. Given a next-period bond position b' and a realization of Θ, the price of a bond satisfies:

$$q(b'(b;\Theta);\Theta) = \frac{1-\delta(b'(b;\Theta);\Theta)}{1+r} \tag{3.10}$$

The optimal default decision is taken as:

$$v^0(b;\Theta) = \max_{d\in\{0,1\}} \{(1-d)v^c(b;\Theta) + dv^d(\Theta)\} \tag{3.11}$$

where d equals 1 (0) if the government chooses to (not to) default. Under no-default, the government solves the following problem:

$$v^c(b;\Theta) = \max_{b'} \left\{u\left(y + b - q(b';\Theta)b'\right) + \beta\mathbb{E}_{\Theta'}\left[v^0(b';\Theta') \mid \Theta\right]\right\} \tag{3.12}$$

Under default, the value function is given by:

$$v^d(\Theta) = u(y - \phi(y)) + \beta\mathbb{E}_{\Theta'}\left[\mu v^0(0;\Theta') + (1-\mu)v^d(\Theta') \mid \Theta\right] \tag{3.13}$$

where, in order to keep the environment as simple as possible, we assume that when the government gains re-access to financial markets it does so with no debt obligations (i.e. it gets a "fresh start").[4]

The government default policy can then be characterized by repayment sets, $A(b)$, and default sets, $D(b)$, for a given level of assets b as follows:

$$A(b) = \{\Theta \in \mathbb{Y}\times\mathbb{R}\times\Sigma : v^c(b;\Theta) \geq v^d(\Theta)\} \tag{3.14}$$

$$D(b) = \{\Theta \in \mathbb{Y}\times\mathbb{R}\times\Sigma : v^c(b;\Theta) < v^d(\Theta)\} \tag{3.15}$$

[4]For studies with positive recovery rates and renegotiation between sovereigns and lenders see for example Yue (2010), D'Erasmo (2011), and Hatchondo et al. (2016)

where $\mathbb{Y}$, $\mathbb{R}$, and Σ are the sets of possible realizations for y, r and σ_r, respectively. Next, we define the recursive equilibrium of this economy.

Definition 1 *The recursive equilibrium for this economy is a set of policy functions for (i) consumption $c(b;\Theta)$; (ii) government's asset holdings $b'(b;\Theta)$, repayment sets $A(b)$, and default sets $D(b)$; and (iii) the price function for bonds $q(b',\Theta)$ such that:*

1. *Households' consumption $c(b;\Theta)$ satisfies the resource constraint, taking the government policies as given.*
2. *The government's policy functions $b'(b;\Theta)$, repayment sets $A(b)$, and default sets $D(b)$ satisfy the government optimization problem, taking the bond price function $q(b',\Theta)$ as given.*
3. *Bonds prices $q(b',\Theta)$ reflect the government's default probabilities and satisfy creditors' expected zero profits.*

The equilibrium bond price must satisfy the government's optimization problem and the lenders' expected zero profit condition, such that bond prices reflect the default probabilities. The default probabilities $\delta(b'(b;\Theta);\Theta)$ and the default set $D(b^{'})$ are then related as follows:

$$\delta\left(b'(b;\Theta);\Theta\right) = \mathbb{E}_{\Theta'}\left\{\mathbb{1}_{\Theta'\in D(b')}\right\} \tag{3.16}$$

where $\mathbb{1}_x$ is an indicator function that takes the value of 1 if x is true, and 0 otherwise.

3.4 Numerical Solution

We solve the model numerically using value function iteration with a discrete state space.[5] We focus on Markov-perfect equilibria. We use Tauchen (1986)'s method to discretize the income shock, the interest level shock and the interest rate volatility shock.[6] We solve for the equilibrium of the finite-horizon version of our economy, and we increase the number of periods of the finite-horizon economy until value functions and bond prices for the first and second periods of this economy are sufficiently close. We then use the first-period equilibrium objects as the infinite-horizon economy equilibrium objects.

The functional form for the period utility is:

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma} \tag{3.17}$$

where γ is the coefficient of relative risk aversion. As in Chatterjee and Eyigungor (2012), we assume a quadratic loss function for income during a default episode:

$$\phi(y) = \max\{0, d_0 y + d_1 y^2\} \tag{3.18}$$

As explained by Chatterjee and Eyigungor (2012), this functional form for the income loss $\phi(y)$ is flexible enough to accommodate many cases. If $d_0 > 0$ and $d_1 = 0$, then the cost is proportional to income; if $d_0 = 0$ and $d_1 > 0$, then the cost

[5] The algorithm computes and iterates on two value functions: v^0 and v^d. Convergence in the equilibrium price function $q(\cdot)$ is also assured.

[6] We use grids of evenly distributed points. For the endogenous state variable (b), we use a grid of size N_b. We then follow Seoane(2014)'s strategy to discretize the exogenous state space. We begin by creating a grid of size N_y for the income process. We then discretize the space for the world interest rate volatility shocks, σ_r, creating a grid of size N_{σ_r}. Finally, in order to discretize the space for the interest rate level we need to create a grid (of size N_r) for *each* possible level of the interest rate volatility, $\sigma_r(i)$, $i = 1, .., N_{\sigma_r}$. So, in effect we have a matrix of possible values of interest rate levels (of size $N_{\sigma_r} \times N_r$). The results presented in Section 5 are obtained using $N_b = 150$, $N_y = 300$, $N_{\sigma_r} = N_r = 10$.

increases more than proportionately with income; if $d_0 < 0$ and $d_1 > 0$, then the cost is zero in a region ($0 < y < -d_0/d_1$) and then increases faster than income (for $y > -d_0/d_1$). This last case is very similar to Arellano (2008)'s cost-of-default function.

3.4.1 Calibration

We define our baseline economy as one in which there are no interest rate level shocks (i.e. $u_r = 0$) nor interest rate volatility shocks (i.e. $u_{\sigma_r} = 0$). This baseline economy is calibrated to a quarterly frequency using data for Argentina from the period 1983.Q4 - 2001.Q4. Table 3.1 summarizes the parameter values.

We estimate equation (3.2) using quarterly real GDP per capita for Argentina ranging from 1983.Q4 till 2001.Q4. The data counterpart of $log(y)$ is the deviation of the natural logarithm of GDP per capita from its trend (computed using HP-filter, with smoothing parameter $1,600$). The re-entry probability μ is set to 0.0385 according to Chatterjee and Eyigungor (2012), which implies an average period of 6.5 years of financial exclusion.[7]

We assume that the representative agent in the sovereign economy has a coefficient of relative risk aversion γ of 2 and a discount factor β of 0.95. The average risk free rate ($\bar{r}$) is 1 percent. Those values are within the range of accepted values in studies of business cycles in small open economies.[8]

We are left with two parameters (the coefficients of the default cost function, d_0 and d_1) to assign values to. We calibrate these two parameters to match an annual default frequency of 3% and an average debt-to-income ratio of 60%. Argentina

[7]Benjamin and Wright (2008) report Argentina as being in a state of default between 1982 and 1992 and between 2001 and 2005. The average exclusion period is 7.5 years by these measures. Gelos et al. (2011) report an average exclusion of 4 years for emerging economies.

[8]The value for the subjective discount factor may appear low for typical business cycle models. However it is relatively large for the quantitative sovereign default literature: for example Yue (2010) uses .7, Aguiar and Gopinath (2006) use .8, and Arellano (2008) uses .953.

has defaulted 3 times on its external debt in the last 100 years, giving rise to our targeted default frequency. With respect to the indebtedness statistics, Cowan et al. (2006) report a debt-to-output ratio of 59.87% for the period 1990–2004.

Table 3.2 presents the parametrization of the stochastic processes that govern the behavior of the world interest rate. All the values in Table 3.2 come from Fernandez-Villaverde et al. (2011).[9] These authors estimate (the equivalent to) equations (3.8) and (3.9) using a likelihood-based approach. Parameter values reported correspond to the median of the posterior estimates.[10] It is important to note that none of the parameters in Table 3.2 are relevant for the computation of our baseline economy (where there are no interest level nor volatility shocks, i.e. $u_r = u_{\sigma_r} = 0$); they only affect the quantitative performance of what we later on define as the "full model", where all shocks are present.

3.5 Results

In this section we present the main results of our paper. Firstly, we show the ability of the baseline model to account for salient features of business cycle dynamics in Argentina. Secondly, we study the effect of introducing volatility shocks: in particular, we see how policy functions, default incentives and the overall quantitative performance of the model change. Thirdly, we present results for an 'intermediate' version of our model, where only level (but not volatility) shocks affect the world interest rate. Fourthly, we present a measure of the welfare cost of interest rate volatility.

[9]Fernandez-Villaverde et al. (2011) estimate equations (3.8) and (3.9) using monthly data for the T-bill rate. Their posterior estimates imply annualized average standard deviations for the risk-free interest rate of 38 basis points (with only mean volatility) and 44 basis points with both mean and stochastic volatility. We adjust their estimates of mean and stochastic volatility (η and $\bar{\sigma_r}$) so that our quarterly model produces the same average standard deviations in annualized terms. We keep the persistence of both shocks unchanged.

[10]For more details on the estimation of the stochastic process of the world interest rate, see Fernandez-Villaverde et al. (2011) and their online appendix.

3.5.1 Performance of the Baseline Economy

Table 3.3 reports moments in the data and in our simulations of the baseline economy (as well as in our 'full model' which is described below). As in previous studies, we report results for pre-default simulation samples. The only exception is the default rate, which we compute using all simulation periods. We simulate the model for 1,500 samples of 3,000 periods each. We then discard the initial 1,500 periods as a burn-in and from the remaining periods we extract 1,000 samples of 32 consecutive quarters before a default.

The moments reported in Table 3.3 are chosen to illustrate the ability of the model to replicate distinctive business cycle properties of economies with sovereign risk. The third column of the table shows that the baseline economy approximates well the moments used as targets (the default frequency and the debt-to-income ratio) and it is broadly consistent with non-targeted moments in the data: consumption is more volatile than income, the trade balance is countercyclical and the sovereign spread is also countercyclical (as is often the case in economies facing sovereign risk, see Neumeyer and Perri (2005) and Uribe and Yue (2006).

Two moments of the data proved particularly difficult to account for (by the baseline model): the mean and the volatility of the sovereign spread. The baseline economy can only produce 2% of the observed spread and 9% of the observed volatility of the spread. It is by now well understood that a standard model of sovereign default (in the tradition of Eaton and Gersovitz (1981)) with one-period debt and risk-neutral lenders cannot produce spread levels and volatilities in line with the data while simultaneously matching the observed debt-to-income level and a historically low default frequency.[11] It is important to highlight that these two

[11] Hatchondo and Martinez (2009), Hatchondo et al. (2016), and Chatterjee and Eyigungor (2012) (among others) study related models with long-duration bonds and show that having

moments are explicitly un-targeted: we are specially interested in understanding how shocks to both the level and the volatility of the world interest rate affect the mean and volatility of the spreads payed by a sovereign borrower under risk of default. Next, we turn to studying these effects.

3.5.2 Shocks to the World Interest Rate

Next, we measure the effects of introducing a time-varying level and volatility in the world interest rate. We do so by comparing the baseline simulation results with the simulation results for the “full model" (where all shocks are present).

We simulate and compute statistical moments from the full model in the same way as we did for the baseline model. The stochastic processes for the world interest rate (described in equations 3.7 – 3.9) take the values in the aforementioned Table 3.2.[12]

What are quantitative effects of introducing shocks to the world interest rate? The fourth column in Table 3.2 shows that shocks to the world interest rate generate increases in the mean spread, the volatility of the spread, the default frequency; and at the same time generate a decrease in the level of debt.

The full model features roughly 170% more default risk than the baseline model with the annual default rate increasing from 2.9% to 7.9%. This increased default risk translates into higher sovereign spreads. The mean spread observed in the full model simulations is 115% higher (.28 vs .13), and the volatility of the spread is 126% higher (.52 vs .23).[13]

long-term debt can account for high and volatile spreads.

[12] It is important to note that there is no re-calibration across models, only the baseline economy is calibrated to match the observed debt-to-income ratio and default frequency. The only difference between the baseline and full models is the absence/presence of shocks to the world interest rate.

[13] Even though the relative changes in the spread statistics are significant, the absolute magnitudes are rather small: average spread increases roughly by 15 basis points, while the volatility of the spread went up by 29 basis points. These results are not entirely surprising: as explained above, sovereign default models with one-period debt have a very hard time in

The sovereign borrowing optimally responds to changes in the conditions: faced with higher prices and increased uncertainty (about what is going to be the world interest rate in the future), the government engages in precautionary behavior by decreasing the average indebtedness level (the mean debt-to-income level falls from 60% to 48.7%).

In order to shed more light on the workings of how shocks to the level and to the volatility of the world interest rate we next examine how borrowing opportunities, default incentives and savings functions change.

Effect on Borrowing Opportunities and Policies

In Figure 3.2 we present the spread demanded by lenders as a function of the face value of next-period debt. The figure also shows the combination of spread levels and next-period debt chosen by the government when its initial debt level is the average level in the simulations of each case considered in the graph (i.e. baseline and full models).

Figure 3.2 shows that a shift in the government's choice set plays an important role in accounting for the increase in spreads implied by the incorporation of shocks to the world interest rate: Even for the same debt levels as in the baseline economy, spread levels are higher in the full model than in the baseline model. For the equilibrium debt levels in the baseline, equilibrium spread levels would be about 8,000 basis points higher in the economy with world interest rate shocks (implying that for that debt level the country will almost surely default).

Next, we turn to analyzing how stochastic volatility affects the savings policy function, $b'(b, \Theta)$, and the bond price paid in equilibrium, $q\left(b'(b, \Theta), \Theta\right)$. Figure 3.3 shows the behavior of these two functions. Contrary to Figure 3.2 which presented a comparison across models (baseline vs. full economies), we now are focusing

generating sizable and volatile spreads. See footnote 11.

only on the full economy in order to see how the government's saving decisions (and the bond price it faces) change at different levels of stochastic volatility.

The left panel of Figure 3.3 shows that (given the mean level of income and the mean realization of the interest rate level shock) facing increased stochastic volatility the government optimally decides to borrow less: it engages in "precautionary savings." On the other hand, the right panel of the figure presents the bond prices faced by the government in cases of low and high stochastic volatility: the higher the volatility the worse the prices offered for its sovereign bonds.

Effect on Default Sets

Figure 3.4 plots the default sets for both the baseline and the full models. These default sets have the expected shape: for a given level of debt-to-income ratio, the country is more likely to default when it gets low realizations of income; for a given level of income, the country is more likely to default when facing higher indebtedness. We can see from this figure that the default set expands when moving from the baseline to the full model: there are more states of the world where the country will prefer to default (for a given interest rate level). This figure helps us understand the role that interest rate uncertainty plays on default incentives and explains in part why the average default frequency observed in the full model simulations is higher than in the baseline model.

3.5.3 Disentangling the Shocks: Intermediate Model

How important is the contribution of stochastic volatility shocks (i.e. the shocks to the volatility of the world interest rate) over and above mean volatility shocks (i.e. deviations from mean of the world interest rate)? In other words, we want to disentangle the results of the full model to study the relative contribution of u_r vs u_{σ_r}.

Table 3.4 presents simulations results for the three models: baseline, intermediate and full.[14] We can see that, as expected, the intermediate version of our model (one in which there are interest rate level shocks but not volatility shocks, $u_{\sigma_r} = 0$) produces business cycle statistics that are in between the baseline and the full model.

From studying this table we can measure the incremental effect of volatility shocks to the world interest rate: in particular, we see that including volatility shocks increases the mean spread by 6 basis points, the volatility of the spread by 11 basis points, and the default frequency by 1.8 percentage points; while reducing the mean debt-to-income ratio by 3 percentage points. Put in different terms, volatility shocks are responsible for 39% of the increase in the mean spread, 36% percent of the increase in the volatility of the spread, 36% of the increase of the default frequency and 24% of the reduction in average debt-to-income ratio.

Figure 3.5 shows that the intermediate model in fact lies 'in the middle.' This figure presents default sets and borrowing opportunities in the three versions of the model, and confirms the basic intuition that a model with some (but not all of the) shocks to the world interest rate will exhibit larger default sets and more constrained borrowing opportunities than an otherwise identical model without any shocks to the risk-free rate.[15]

The take-away message from this subsection is that third order shocks, while relatively small when compared to shocks to the first and second moments, are still relevant: they explain between 24% and 39% of the variation in the statistics of interest.

[14] In the interest of avoiding unnecessary cluttering, Table 3.4 does not have a column with Argentine data.

[15] The stochastic modeling of the world interest rate process is simple and parsimonious, so it is reassuring that feeding an intermediate version of it into out sovereign default model produces in fact 'intermediate' results.

3.5.4 Welfare Gains of Eliminating Interest Rate Uncertainty

Following the previous results it is then natural to ask: what is the welfare cost of being exposed to shocks to the world interest rate? Or equivalently, what are the welfare gains of getting rid of the uncertainty in the world interest rate? We compute these welfare gains as follows:

$$\left(\frac{v^0_{\text{baseline}}(b,\Theta)}{v^0_{\text{alternative}}(b,\Theta)}\right)^{\frac{1}{1-\gamma}} - 1 \tag{3.19}$$

where alternative $= \{\text{full}, \text{intermediate}\}$. Equation (3.19) measures the welfare gains of moving to the baseline economy. The gain is expressed as the constant proportional change in consumption that would leave a consumer indifferent between continuing living in the alternative economy (either full or intermediate) and moving to the baseline economy.

Figure 3.6 plots these gains as a function of the income level. The top panel of the figure shows gains attained by moving both from the full and the intermediate economies to the baseline economy (assuming zero initial debt). Both gains are positive and sizable. They are also decreasing functions of the level of income: interest rate volatility is much costlier at low levels of income (as expected). The average welfare gains of moving to the baseline economy are 1.1% (from the full model) and 0.9% (from the intermediate model).

The bottom panel of Figure 3.6 presents the welfare gains of eliminating both shocks to the world interest rate (i.e. moving from the full to the baseline model) for two different levels of initial debt: zero and the average debt level observed in the full model (48.7% of mean annual income). The figure gives interesting insights into the welfare gains. Eliminating all the interest rate uncertainty is less valuable when the indebtedness level is high and the income is low, this is because in those states the government will likely default anyway and the value of defaulting ($v^d(\Theta)$) under no interest rate uncertainty is not dramatically higher than with uncertainty. However, for intermediate levels of income, the welfare gains are much higher (than in the zero initial debt case): it is precisely in those states where not being exposed to uncertainty makes the government able to repay and also to borrow at cheaper rates. The average welfare gain of eliminating all uncertainty about the world interest rate in this case (with initial debt equal to the mean level observed in the simulations) is equal to a 1.8% constant increase in consumption.

3.6 Conclusion

We have introduced world interest rate uncertainty in a standard sovereign default framework à la Eaton and Gersovitz (1981). The process for the world interest rates follows the work of Fernandez-Villaverde et al. (2011) and includes both mean volatility (i.e. shocks to the level of the interest rate) and stochastic volatility (i.e. shocks to the volatility of the interest rate). We measure the effects of the increased uncertainty by comparing the simulations of this model with the ones of the baseline model without a time-varying risk-free rate. We find that introducing uncertainty about the world interest rate the model produces a mean sovereign spread that is 115% larger and 126% more volatile. The model also predicts that countries default more than twice as frequently. Moreover, the equilibrium debt-to-income ratio is 19% lower. The welfare gains from eliminating uncertainty about the world interest rate amount up to a 1.8% permanent increase in consumption. Taking these results into account, we do find quantitative support for the policy concerns (in EMEs) regarding the uncertainty about the future directions of the

Fed monetary policy, and in particular about the unwinding of its quantitative easing.

Looking forward, we plan to incorporate long-duration bonds to the model. Doing so will improve the quantitative fit of the baseline economy. Furthermore, given that shocks to the world interest rate (both level and volatility ones) can be understood as a form of 'roll-over risk' (because they affect negatively the lender's willingness to invest in the country), incorporating long-term bonds will allow us to study how uncertainty about the world interest rate affects the optimal maturity structure of government debt.

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Table 3.1: Parameters of the Baseline Economy

Household risk aversion	γ	2	Standard value
Household's discount factor	β	0.95	Standard value
Income auto-correlation coefficient	ρ_y	0.9317	Argentina's GDP
Std. dev. of income innovations	σ_ε	0.037	Argentina's GDP
Mean int'l risk-free rate	$\bar{r}$	0.01	Average world interest rate
Prob. of re-entry	μ	0.0385	Chatterjee and Eyigungor (2012)
Default cost parameter	d_0	-1.45	Calibrated to fit targets
Default cost parameter	d_1	1.50	Calibrated to fit targets

Table 3.2: Parametrization of the World Interest Rate Process

Autocorrelation risk-free rate	ρ_r	0.95
Mean volatility of int'l risk-free rate	$\bar{\sigma_r}$	-6.959
Autocorrelation interest vol. shock	ρ_{σ_r}	0.94
Stochastic vol. of int'l risk-free rate	η_r	0.1466

Note: The calibration of the stochastic process governing the world interest rate and its time-varying volatility are adapted from Fernandez-Villaverde et al. (2011). This parameter values do not affect the performance of the baseline economy (as this economy has neither time-varying level of the interest rate nor time-varying volatility of the interest rate).

Table 3.3: Business Cycle Statistics

	Data	Baseline Model	Full Model
$sd(c)/sd(y)$	1.59	1.68	1.85
$corr(c, y)$	0.72	0.93	0.88
$corr(tb/y, y)$	-0.64	-0.67	-0.59
$E(R_s)$ (in %)	7.44	0.13	0.28
$sd(R_s)$ (in %)	2.51	0.23	0.52
$corr(R_s, y)$	-0.62	-0.57	-0.55
$E(b/y)$ (in %)	59.9	60.0	48.7
Default frequency (in %)	3.0	2.9	7.9

Note: The mean and the standard deviation of a variable x are denoted by $E(x)$ and $sd(x)$, respectively. The coefficient of correlation between two variables x and z is denoted as $corr(x, z)$. All variables are logged (except those that are ratios) and then de-trended using the Hodrick-Prescott filter, with a smoothing parameter of 1,600. We report deviations from the trend.
R_s stands for sovereign bond spread. The data for sovereign spreads is taken from J.P. Morgan's EMBI+, which represents the difference in yields between an Argentine bond and a US bond of similar maturity.
Only Baseline model is calibrated to match $E(b/y)$ and default frequency. Parameters are kept unchanged across models (except for those that turn on/off shocks to the world interest rate).

Table 3.4: Simulation Results: Baseline, Intermediate and Full Models

	Baseline Model	Intermediate Model	Full Model
$sd(c)/sd(y)$	1.68	1.80	1.85
$corr(c, y)$	0.93	0.89	0.88
$corr(tb/y, y)$	-0.67	-0.61	-0.59
$E(R_s)$ (in %)	0.13	0.22	0.28
$sd(R_s)$ (in %)	0.23	0.41	0.52
$corr(R_s, y)$	-0.57	-0.55	-0.55
$E(b/y)$ (in %)	60.0	51.4	48.7
Default frequency (in %)	2.9	6.13	7.9

Note: The mean and the standard deviation of a variable x are denoted by $E(x)$ and $sd(x)$, respectively. The coefficient of correlation between two variables x and z is denoted as $corr(x, z)$. All variables are logged (except those that are ratios) and then de-trended using the Hodrick-Prescott filter, with a smoothing parameter of 1,600. We report deviations from the trend.
R_s stands for sovereign bond spread. The data for sovereign spreads is taken from J.P. Morgan's EMBI+, which represents the difference in yields between an Argentine bond and a US bond of similar maturity.
Only Baseline model is calibrated to match $E(b/y)$ and default frequency. Parameters are kept unchanged across models (except for those that turn on/off shocks to the world interest rate).

Table 3.5: Correlation Coefficients Among Key Macro Variables for Argentina

	Int. volatility	Country rate	Spread	GDP	$\frac{TB}{GDP}$
Int. volatility	1.00				
Country rate	0.28	1.00			
Spread	0.31	0.99	1.00		
GDP	-0.22	-0.77	-0.72	1.00	
$\frac{TB}{GDP}$	0.52	0.78	0.81	-0.64	1.00

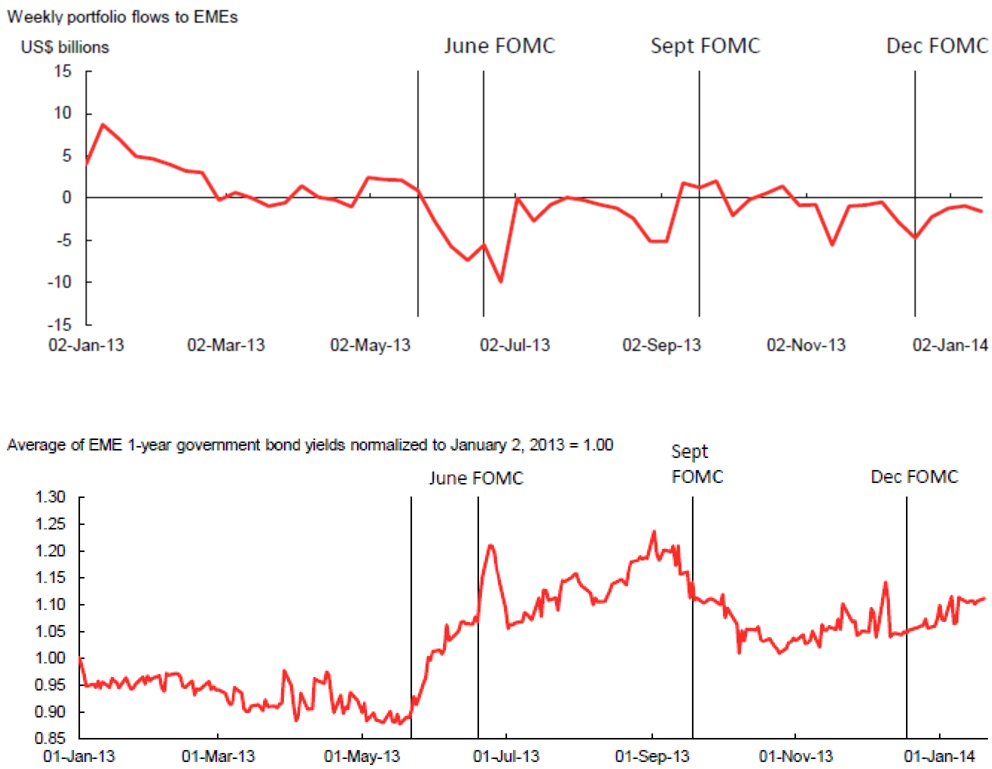
Note: World interest rate volatility is computed as the standard deviation of U.S. 3-month T-bill real interest rate growth series. GDP is seasonally adjusted and de-trended using a log-linear trend.
Time-period: 1994.Q4–2012.Q4. Data sources: NIPA, IFS, J.P. Morgan EMBI+, FRB St. Louis.

Table 3.6: Correlations Between World Interest Rate Volatility and Country Spreads in Latin-America

	Int. volatility	Argentina	Brazil	Colombia	Ecuador	Uruguay
Int. volatility	1.00					
Argentina	0.19	1.00				
Brazil	0.41	0.75	1.00			
Colombia	0.48	0.78	0.94	1.00		
Ecuador	0.57	0.18	0.35	0.52	1.00	
Uruguay	0.46	0.81	0.85	0.84	0.44	1.00

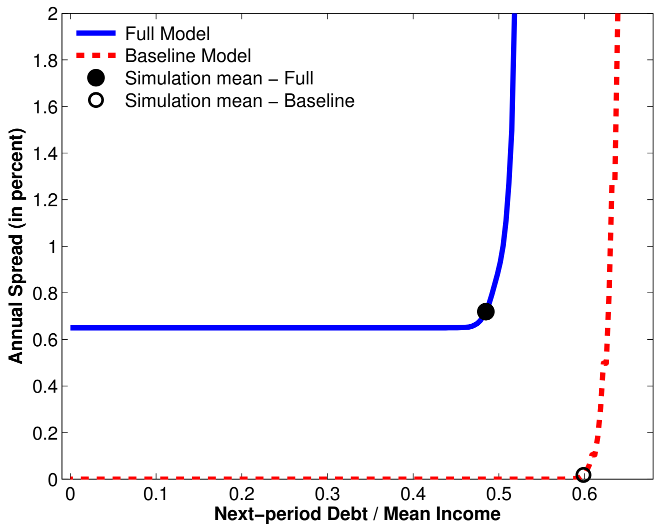
Note: World interest rate volatility is computed by taking the standard deviation of U.S. 3-month T-bill real interest rate growth series. Spread is the difference between real yields on country dollar-denominated bonds and U.S. treasuries.
Time-period: 2001.Q2–2012.Q4. Data sources: IFS, J.P. Morgan EMBI+, FRB St. Louis.

Figure 3.1: Capital flows reversals and sovereign bond yield increases on tapering announcement.



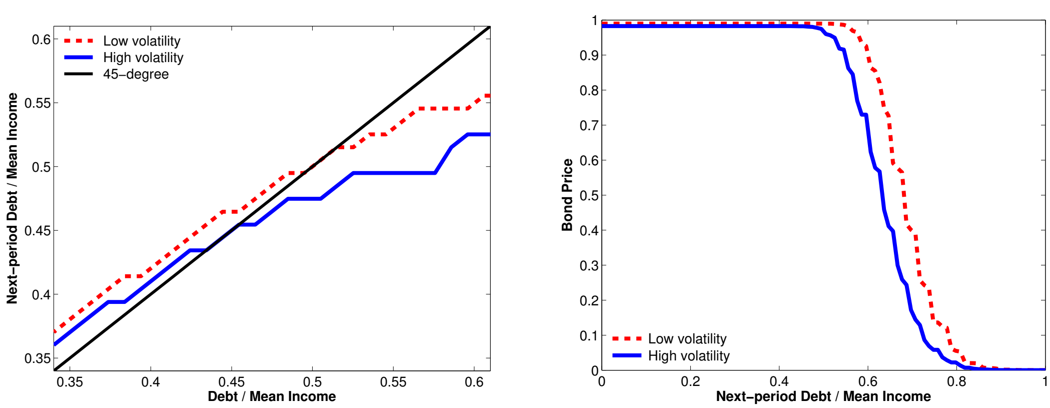
Source: Rai and Suchanek (2014)
Note: The top (bottom) panel shows data on capital flows (sovereign bond yields). Calculations based on 19 EMEs (Brazil, China, Chile, Columbia, Czech Republic, Hungary, India, Indonesia, Korea, Malaysia, Mexico, Peru, Philippines, Poland, Russia, Taiwan, Thailand, Turkey, and South Africa).
Data sources: Bloomberg, Bank of Canada, and EPFR.

Figure 3.2: Menu of combinations of spreads and next-period debt levels from which the government can choose.



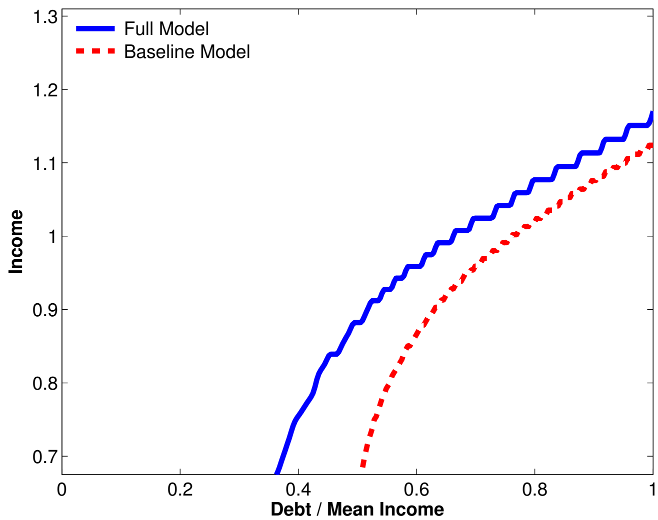
Note: The solid blue (dashed red) line corresponds to the full (baseline) model.

Figure 3.3: Savings and Bond Price functions in the Full Model.



Note: The left panel corresponds to the equilibrium savings function, $b'(b,\Theta)$. The right panel corresponds to equilibrium bond price function, $q\left(b'(b,\Theta),\Theta\right)$. The solid blue (dashed red) line corresponds to high (low) volatility, $\bar{\sigma_r} = -5.24$ ($\bar{\sigma_r} = -8.68$). Both panels assume the average income level and the average interest rate level shock.

Figure 3.4: Default sets.



Note: The solid blue (dashed red) line corresponds to the full (baseline) model. Each line is the respective default set contour: country defaults *south* of the line. The figure assumes the average mean and stochastic volatility for the world interest rate.

Figure 3.5: Default sets and borrowing opportunities: baseline, intermediate and full models.

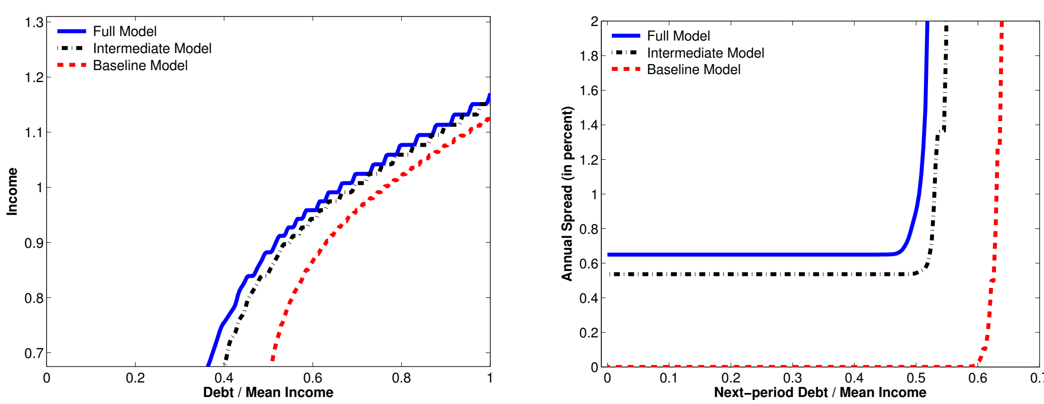
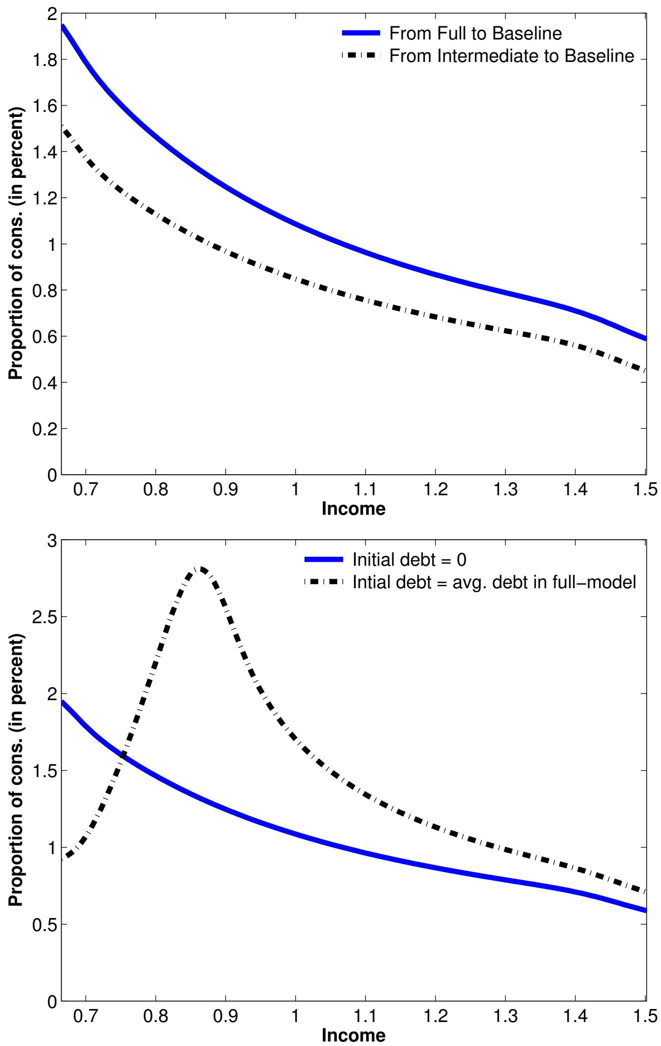


Figure 3.6: Welfare gains of moving to the baseline economy.



Note: The top panel assumes a zero initial debt and plots the gains of moving to the baseline economy from the full model (solid line) and from the intermediate model (dashed line). The bottom panel plots only gains of moving from the full to the baseline economy, for two levels of initial debt: zero (solid line) and the avg. debt level in the simulations of the full-model (dashed line).

Conclusion

The financial crisis of 2007–2009 is widely considered as the worst crisis since the Great Depression of the 1930s. This crisis was especially severe in the U.S. because of the prolonged slump in employment that followed even after the recession was officially over. The official unemployment rate, which was below 5% right before the crisis, reached almost 10% at its peak. It began to fall, but was still recorded above 7% in 2013. One possible explanation of such slow recovery in the labor market is that businesses avoided hiring extra labors at the start of a recovery because they could ask workers to do more work or work longer hours.

At the beginning of the recession, the Federal Reserve responded aggressively by slashing the interest rates to nearly zero. Later on, they implemented unconventional monetary policy programs, also known as QE1, QE2, and QE3, to support the liquidity of financial institutions and to rescue various companies from bankruptcy which posed a threat to the entire financial system. However, these programs also led to a significant expansion of the Federal Reserve's balance sheet, which created uncertainty around the future direction of U.S. monetary policy – when and how would the Fed unwind the QE program. In this thesis, I have addressed three issues that we observed in the beginning and aftermaths of the recent financial crisis.

In the first chapter, I use VAR methodologies with nine quarterly U.S. time series from 1984 to 2014 to examine the macroeconomic effects of an adverse financial shock, and then develop a New Keynesian DSGE model with explicit financial and labor market frictions to uncover these facts. The model introduces a new financial shock - the default cost shock, which directly originates in the credit market. I estimate the model using Bayesian methods with ten quarterly time series and a similar number shocks for the time periods 1984:Q1 to 2014:Q4. The main contribution of this chapter is a model that captures the VAR evidence. In particular, it can explain why the unemployment rate is more persistent than average hours worked following a financial crisis. Moreover, the variance decomposition of my Bayesian estimation shows that the default cost shock accounts for a significant portion of business cycle fluctuations over the sample period, even in the presence of other important demand and supply shocks used in the literature. This shock has substantial explanatory power in explaining the fluctuations in unemployment growth, vacancy growth and other key macro variables, such as output growth, investment growth, the federal funds rate, and the external finance premium at business cycle frequencies. The theoretical moments of the key variables generated by model are also closely matched with the data.

In the second chapter, I evaluate the performance of different monetary policy rules in response to adverse shocks. To do that, I first construct a monetary DSGE model as in Chapter 1 and propose two monetary policy rules that not only respond to output and inflation fluctuations but also react to financial variables such as credit spread or asset prices. The objectives of the central bank is to minimize some quadratic loss function, where losses are caused by inflation, output, and unemployment being away from their respective targets. The model introduces two financial shocks - the bankruptcy cost shock and the bank intermediation cost shock, which have been explored very little in the literature. I calibrate the model to the U.S. data and find that augmented Taylor rules that respond to financial variables rather than output and inflation fluctuations are more efficient to combat a financial crisis relative to the conventional Taylor rule. My results support a large number of studies that find that policy rules featuring financial variables improve equilibrium responses of the macroeconomy to shocks originating from the financial sector.

In the third chapter, we introduce world interest rate uncertainty in a standard model of sovereign default to explore the mechanism by which world interest rate uncertainty affects the country spread and default risk in emerging economies. We measure the effects of the increased uncertainty by comparing the simulations of this model with the ones of the baseline model without a time-varying risk-free rate. We calibrate the economy to Argentina and find that the model with world interest rate uncertainty features roughly 170% more default risk than the baseline model with the annual default rate increasing from 2.9% to 7.9%. This increased default risk translates into higher sovereign spreads. The mean spread observed in the full model simulations is 115% higher (.28 vs .13), and the volatility of the spread is 126% higher (.52 vs .23). The sovereign borrowing optimally responds to changes in the conditions: faced with higher prices and increased uncertainty about what is going to be the world interest rate in the future, the government engages in precautionary behavior by decreasing the average indebtedness level from 60% to 48.7%. Moreover, the welfare gains from eliminating uncertainty about the world interest rate amount up to a 1.8% permanent increase in consumption. Overall, our findings indicate quantitative support for the policy concerns (in EMEs) regarding the uncertainty about the future directions of the Fed monetary policy.

Some avenues for future research are as follows. Firstly, I want to extend the first chapter of my thesis in two dimensions, (i) endogenize the wage rigidity by using staggered multi-period wage contracting, and (ii) explore micro level data to examine how differently labor inputs move in the intensive and extensive margins across different sectors following a financial crisis. Secondly, I would like to extend the policy analysis in Chapter 2 under different financial market structures. For instance, it would be worthwhile to compare the results of my second chapter with the ones when financial frictions are incorporated in the model through other channels, such as the balance sheets in the banking sector, portfolio choice issue with complete or incomplete markets or collateral constraints. Thirdly, we plan to include long-duration bonds to our sovereign default risk paper. This will help to improve the quantitative fit of the baseline economy and will allow us to study how uncertainty about the world interest rate affects the optimal maturity structure of government debt. Fourthly, I am interested to do further research on sovereign default risk by incorporating labor market frictions into a standard model of sovereign default. The motivation of this research is that sovereign default episodes are characterized by a sharp increase in the country spread along with a large drop in employment. I would like to explore how the links between a government's default decision and labor market outcome drive the default risk and labor market dynamics of an economy.