Three essays on banking regulation, financial crisis and sovereign debt

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THREE ESSAYS ON BANKING REGULATION, FINANCIAL CRISIS
AND SOVEREIGN DEBT

by

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DEDICATION

I would like to dedicate this work to my dear parents, Changcai and Ruiping, my loving husband, Xue Qian, my wonderful son, Ethan, and my dog Barbie.

During the first year of my Ph.D study, I had tremendous doubt of whether I would be able to complete the program. With a non-economics undergraduate degree, the lacks of solid economic theory and mathematical training have constantly challenged my survival. Nevertheless, the continuous support from my parents has pulled me through the toughest year of my life. The then boyfriend of mine, Xue Qian, also showed endless patience and endurance by travelling thousands of miles between Toronto and Boston, bearing through all kinds of weather conditions. Looking back to the past five years, we have harvested our love and will continue to cherish every moment with our new family member, Ethan.
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THREE ESSAYS ON BANKING REGULATION, FINANCIAL CRISIS
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ABSTRACT

This thesis consists of three chapters on macroeconomics and international economics. The first studies the effectiveness of macroprudential policies in a New Keynesian dynamic stochastic general equilibrium framework with financial frictions. Profit-maximizing banks with endogenous leverage ratio expand credit lending during economic booms and become increasingly vulnerable to unanticipated economic shocks. Countercyclical macroprudential instruments are found to be effective in dampening economic fluctuations and stabilizing the credit cycle. However, a policy regulating the loan-to-value ratio of the residential households causes a credit shift towards the business sector. Optimal simple rules are selected using welfare analysis to provide practical implications for the evaluation, estimation and future implementation of macroprudential policies in alleviating economic risk of financial intermediaries.

The second chapter examines the impact of political risk on sovereign default. An economic model with endogenous default decisions shows that political instability increases the likelihood of sovereign default. A quantitative analysis using data from 68 countries in the period from 1970 to 2010 finds that both short and long-run aspects of the political environment have significant effects. The findings suggest that a country is
more likely to experience default when i) it has a relatively younger political regime in place; ii) it faces a higher chance of political turnover; and iii) it has a less democratic political system.

The third chapter investigates the bidirectional relationship between banking and sovereign debt crisis. An economic model with financial intermediaries and a government sector shows that sovereign default may cause a banking crisis as banks hold a large amount of government bonds. Nevertheless, a significant amount of bailouts or bank guarantees may constrain the short-term liquidity of the government sector and trigger a sovereign debt crisis. Empirical studies using the credit default swap spreads of the Eurozone support the two-way linkage. Quantitative results also show increasing spillover effects across borders as globalization leads to greater integration of financial markets.
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Chapter 1

Evaluating Macroprudential Policy in a DSGE Framework with Financial Frictions

1. Introduction

The 2008 financial crisis and the subsequent Global Recession have generated discussion among researchers and policymakers regarding the role of traditional monetary policy and the need for macroprudential policy to restore economic stability. Blanchard et al. (2010) discuss the failure of financial regulation to prevent or reduce systematic risk in financial markets. In addition, traditional monetary policy was insufficient to achieve a quick and effective recovery. The crucial role of the financial system in this crisis has prompted a search for macroprudential tools to promote financial and economic stability. These tools target broad financial markets instead of individual institutions. The objective of this type of supervision and regulation is to mitigate the transmission of shocks to the general economy. However, arguments have been raised regarding the design of macroprudential instruments and their interaction with monetary policy.

Figure A.1 displays the real Housing Price Index of the U.S. from 1980 to 2013, and Figure A.2 illustrates the Case-Shiller U.S. National House Price Index from 1987 to 2013. Evidently from the graphs, U.S. housing price has increased dramatically during the first half of the 2000s and its collapse in 2007 marked the official start of the financial crisis. During the booming years, many economists and policymakers have overlooked the growing trend and maintained that the housing market could be explained by strong economic fundamentals. Jurgilas and Lansing (2012) document the 2005 media interview of Ben Bernanke, then Chairman of the President’s Council of Economic Advisory, who argued that the housing boom was the result of strong growth in jobs and income, along with low mortgage rates. He further commented that a substantial nationwide decline in housing prices was “a pretty unlikely possibility.” Similar comments were made by Alan
Greenspan, then Chairman of U.S. Fed, that the lending industry has been dramatically improved by advances in information technology. He stated that lenders were now able to efficiently judge mortgage applications and issue loans to the “once more-marginal” applicants. McCarthy and Peach (2004) also comment on the unlikely existence of a home price bubble. Nonetheless, the over-optimistic view of economists and policymakers did not prevent the start of the Great Recession in late 2007.

In the booming years, the debt service ratio of U.S. households have grown dramatically. Figure A.3 displays the ratio of mortgage payment to household income during the period of 2000 to 2013. The graph shows that mortgage expenditures rose more than 20% since the beginning of the 2000s. In the peak of 2007, average household spent more than 11% of disposable income to service home debt in comparison to only 8.7% in 2000. Higher leverage imposes a significant distortion on consumer spending and bank lending, which further prevents a healthy recovery from the crisis. Controlling financial imbalances during economic booms is critical for the prevention of future crisis and it is important for policymakers to explore lean-against-the-wind policy measures that can be used to effectively control the credit market.

This paper contributes to the literature by addressing three key issues. First, it incorporates the housing sector to study the interaction between asset prices and business cycle fluctuations. This should shed some light on the recent financial crisis, which was initiated by a housing boom in the United States. A major portion of domestic borrowing is secured by real estate (Iacoviello 2005) and the housing market has been found to play an important role in driving business cycles (Case 2000, Higgins and Osler 1997). Second, this paper models financial frictions in the traditional New Keynesian DSGE framework. Incorporating the financial market captures a key element of the recent crisis and can be used to study the impact of financial regulation on the transmission of shocks. Furthermore, this paper examines two types of macroprudential instruments: a countercyclical loan-to-
value (LTV) ratio rule that targets households’ borrowing constraints, and a lump-sum tax policy that directly affects the balance sheet of financial intermediaries. Using both monetary and macroprudential tools, I conduct a welfare analysis to determine the optimal and implementable rules that can effectively dampen economic fluctuations.

The economy consists of two types of households (as in Iacoviello 2005). Patient households own financial intermediaries and operate monopolistic competitive firms. They deposit savings into the banks each period, and serve as lenders of the economy. In contrast, impatient households make labor and consumption decisions and face borrowing constraints attached to the market value of their housing stock. The maximum allowable fraction of housing stock used as collateral is defined as the loan-to-value ratio, which is controlled by regulatory authorities.

The financial intermediaries are modeled similar to Gertler and Karadi (2011) with moral hazard and costly enforcement. They collect deposits from patient households each period and lend funds to impatient households and non-financial firms. The maximum amount of lending equals to the sum of household deposits and banks’ own net worth. The lending-to-net-worth ratio is defined as the banks’ leverage ratio and serves as a signal for the credit condition in the economy. In each period, managers of banks can choose to divert a fraction of available assets to their corresponding households. The depositors can force diverted managers to resign but the transferred assets are non-recoverable under costly enforcement. Financial intermediaries face an incentive compatibility constraint, which implies that managers will only stay in operation when the continuing value of banks exceeds the value of diverted assets. Financial frictions create a wedge between saving and lending rates in the economy and introduce endogenous constraints on the intermediary leverage ratio, which is tied to the equity capital of the financial sector.

The model mechanism works as follows. Suppose there is a positive housing demand shock. Consumption and housing prices increase in response, expanding the borrowing
constraint of the households. Higher consumer prices reduce the net value of debt and cause the lender’s balance sheet to deteriorate. Facing higher demand for loans, profit-maximizing banks optimally expand lending in the economy and raise their leverage ratios. This leads to a greater liquidity risk in the financial market and increases the systematic risk. Nonetheless, macroprudential policy can be used to mitigate the impact from the positive demand shock. More specifically, the regulatory authority lowers the target LTV ratio of the households, causing the collateral value to drop. This generates a contractionary effect on the borrowing constraint, which relieves the tension on financial intermediaries. Credit expansion is limited which alleviates the liquidity risk in the financial market. The opposite applies for negative shocks. The target LTV ratio is raised to stimulate lending in the economy, which promotes a fast and effective recovery. Nonetheless, when the household credit market is regulated, profit-maximizing banks seek to expand lending in the business sector. This creates a credit shift from restricted sector to unregulated sector. As a result, business lending and aggregate credit market can be more volatile in response to shocks. Policymakers have to consider the trade-off between different sectors when designing the appropriate macroprudential instrument.

The tax policy allows regulatory authorities to directly control the endogenous leverage ratio of banks. During economic booms, the government initiates a positive tax on banks’ lending and use the proceeds to subsidize intermediary equity capital. This policy targets the credit condition of financial intermediaries and is successful in creating direct control of banks’ leverage ratio. With a lower level of lending, the overheated credit market is calmed and the liquidity risk is reduced. Changes in the housing prices and household lending are significantly dampened, which could prevent the formation of asset bubbles. In comparison to the countercyclical LTV ratio rule, the tax policy demonstrates little evidence of credit shift towards the business sector as the policy targets the aggregate credit market. However, implementation may be difficult and costly. The full functionality of this policy relies on
the direct control of banks’ balance sheet in a dynamic setting. The tax rate changes period by period and the subsidies must be provided in a timely manner. The collection and distribution of taxes and subsidies are the major obstacles for the implementation of this policy. In addition, the cost of administering such complicated process may be significantly high.

The objective of this paper is to provide a preliminary theoretical analysis of potential macroprudential instruments that can be effective in preventing asset bubbles and possible financial crisis, which may be useful to policymakers in the search for an appropriate and operative macroprudential policy. To provide practical suggestions, a welfare analysis has been performed in this paper to identify the optimal policies. Using second-order approximation, the welfare function is maximized with respect to the coefficients entering various feedback rules. The numerical values indicate the degree of intervention for policymakers to consider. Findings suggest that countercyclical policy is desired and effective in mitigating economic fluctuations from unexpected shocks, and the macroprudential policies suggested in this paper can be used jointly with traditional monetary policy that targets inflation and output gap.

This paper is organized as follows. Section 2 reviews the existing literature on housing market, financial frictions and macroprudential policies. Section 3 presents the model. Section 4 reports the calibration of key parameters. Section 5 analyzes the model implications. Section 6 conducts the welfare analysis and Section 7 concludes.

2. Literature Review

This paper is related to at least three major strands of literature. The first strand of research studies the relationship between credit and housing. From the theoretical perspective, Kiyotaki and Moore (1997) consider collateral constraints tied to the real estate value of entrepreneurs. Iacoviello (2005) and Iacoviello and Neri (2010) discuss the importance of housing in business cycle fluctuations. More recently, Liu, Wang and Zha (2013) also
report the crucial role of land prices in driving macroeconomic variables arguing that land
price is the dominant factor that affects housing price. Davis and Heathcote (2007) find
similar results using empirical analysis. Liu et al. (2013) recently find that land price is
capable of generating large volatility in unemployment. Research by the IMF finds that
credit and housing cycles are closely linked to business cycles (IMF 2009). Fitzpatrick and
McQuinn (2007) also find that the housing boom and credit liberalization are mutually re-
inforcing in the long-run using data from Ireland. Similar results are reported for Norway
in Anundsen and Jansen (2011). Favara and Imbs (2010) suggest bank deregulation in the
United States has a significant impact on housing price.

This model is also closely related to the growing literature that incorporates financial
frictions into DSGE models. Carlstrom and Fuerst (1997), Kiyotaki and Moore (1997) and
Bernanke, Gertler and Gilchrist (1999) are among the pioneering works on this topic. The
important role of financial friction has been stressed and carefully studied in a variety of
contexts in the last decade\(^1\). Recent studies also focus on the important role of financial
intermediation in driving business cycles. Christiano, Motto and Rostagno (2010) highlight
the nominal friction (as lending contracts are denominated in nominal terms) that accounts
for a significant portion of business cycle fluctuations. Gertler and Kiyotaki (2010) inves-
tigate how interruptions in the financial market could lead to a crisis and the effectiveness
of several types of market intervention in mitigating the crisis. Gertler and Karadi (2011)
further explore an effective but unconventional monetary policy in a simulated financial
crisis.

Macroprudential policy refers to the financial regulation that directly targets financial
stability and systematic risk. It is often mentioned as an alternative or complementary ap-
proach to traditional monetary policy. Common macroprudential tools target banks’ capital

\(^1\)See, for example, Christiano, Trabandt and Walentin 2011, Smets and Wouters 2007, Gilchrist, Ortiz and
buffer and leverage ratio as well as households’ debt-to-income and LTV ratios. Gelati and Moessner (2013) provide an excellent survey of macroprudential policy research and comment on the current policy debate. Suh (2012) studies the interaction between monetary and macroprudential policy in a DSGE model with the financial accelerator. The findings suggest that macroprudential policy is effective in stabilizing the economy but creates a regulatory arbitrage that reallocates credit to a less regulated sector. Gelain et al. (2013) incorporate housing into a standard DSGE model and find that a permanent tightening of households’ collateral constraint is most effective in reducing excessive volatility. Gertler et al. (2012) examines a Pigouvian tax-subsidy transfer on banks’ balance sheet and find the policy to be successful in reducing aggregate volatility. Using similar measures, Lima et al. (2012) attempt to determine the optimal monetary and macroprudential policy in a DSGE model with financial frictions. The authors find that the lump-sum tax-subsidy scheme aiming to reduce bank’s leverage ratio is effective in stabilizing the economy and is also welfare-improving. Nonetheless, common ground concerning the most effective and appropriate macroprudential policy has not been reached in the literature. Some policies are sector-specific while others can be difficult to implement. The objective of this paper is to find a practical, effective and welfare-improving macroprudential policy that can be used jointly with traditional monetary policy. In the next section, I present a model that is useful in addressing the recent financial crisis and can be utilized to study the issues mentioned above.

3. The Model

There exists two types of households differ by their discount factors. The impatient households (indexed $j = b$) are subject to a higher discount factor than the patient households (indexed $j = s$), and borrow funds to consume each period ($\beta_b < \beta_s$). Patient households optimally choose the amount of savings each period, earning the risk-free rate $R_t$. Using capital, household labor and housing input, the non-financial firms produce
intermediate goods and sell to monopolistically competitive retailers. The capital good producers purchase used capital from intermediate-good producers, buy new capital, refurbish the old capital and sell to firms in the next period. The financial sector is modeled following Gertler and Karadi (2011). The existence of credit friction creates a wedge between the saving and lending rates. The central bank conducts monetary policy via a simple feedback rule that responds to the deviations of output and inflation. The model is then augmented to include macroprudential policies, with restrictions on the LTV ratio of borrowers and the leverage ratio of financial intermediaries. Figure A.4 displays the basic framework and key agents of the model.

Figure A.4: Basic Framework of Model

3.1 Households

There exists two types of infinitely lived, utility-maximizing households. Patient households deposit savings into the banking sector and receive the risk-free interest rate. Impatient households borrow from banks to consume and face a credit constraint limited by the value of their house, which serves as collateral. The difference in time preferences implies that in the equilibrium around the steady states, patient households will always save and impatient households will always borrow. I assume a continuum of households in each
type with equal population. Both types of households obtain utility from housing goods and offer labor services in a competitive labor market.

3.1.1 Patient Households

Patient households, denoted by \( s \), are subject to a discount rate \( \beta_s \). In addition, they lease a fraction \((1 - \kappa)\) of housing goods to non-financial firms and earn rent \( r_t^h \). Firms use this real estate for the production of intermediate goods. The representative household makes consumption, \( C_{t,s} \), housing, \( H_{t,s} \) and labor, \( L_{t,s} \) choices each period by maximizing the life-time expected utility, which is given by

\[
\max_{C_{t,s},H_{t,s},L_{t,s},D} E_0 \left\{ \sum_{t=0}^{\infty} \beta_s^t \left[ v_c \log C_{t,s} + v_h \varepsilon_H^t \log(\kappa H_{t,s}) - v_l \frac{1 + \varphi_L}{1 + \varphi_L} \right] \right\}
\]

subject to budget constraint

\[
C_{t,s} + P_t^H (H_{t,s} - H_{t-1,s}) + D_t \leq R_t D_{t-1} + W_{t,s} L_{t,s} + r_t^h (1 - \kappa) P_t^H H_{t-1,s} + \Pi_t
\]

\( \varepsilon^H \) is a preference shock on housing goods, where a positive \( \varepsilon^H \) leads to a rise in housing demand. The parameter \( v_c \) controls the utility from consumption, \( v_h \) governs the utility from housing goods and \( v_l \)dictates the disutility of labor supply. \( P_t^H \) denotes the housing price in units of consumption. Patient households make real bank deposit \( D_t \), earning real return \( R_{t+1} \) in the following period. In addition, \( W_s \) is the real wage and \( \Pi_t \) denotes the net profits received from owning financial and non-financial firms. All variables are in real terms and the optimal choices are characterized by the following first-order conditions:

\[
v_l L_{t,s}^{\varphi_L} = \frac{v_c}{C_{t,s}} W_{t,s}
\]

\[
\frac{1}{C_{t,s}} = \beta_s E_t \frac{1}{C_{t+1,s}} R_{t+1}
\]
\[
\frac{v_c}{C_{t,s}} P^H_t = \frac{v_h \varepsilon^H_t}{H_{t,s}} + \beta_s E_t \frac{v_c}{C_{t+1,s}} P^H_{t+1}[1 + r_{t+1}^h(1 - \kappa)]
\]  

Equation (3) is the labor supply decision and (4) is the standard Euler equation. (5) characterizes the housing demand for patient households, which shows that the shadow price of housing goods in period \( t \) is the sum of the period-\( t \) marginal utility from housing goods and the discounted value of the shadow price in \( t + 1 \).

3.1.2 Impatient Households

Impatient households make consumption, labor and housing decisions every period. The representative household, denoted by \( b \), is subject to a discount factor \( \beta_b \) and maximizes the expected utility given by

\[
\max_{C_{b,t}, H_{b,t}, L_{b,t}, B_t} E_0 \left\{ \sum_{t=0}^{\infty} \beta_b^t [v_c \log C_{t,b} + v_h \varepsilon^H_t \log H_{t,b} - v_t \frac{L_{t,b}^{1+\varphi_L}}{1 + \varphi_L}] \right\}
\]  

\[
C_{t,b} + P^H_t (H_{t,b} - H_{t-1,b}) + R^L_t B_{t-1,b} \leq W_{t,b} L_{t,b} + B_{t,b}
\]  

\[
B_{t,b} \leq m_t E_t \left[ \frac{P^H_{t+1}}{R'^L_{t+1}} H_{t,b} \right]
\]

In equation (8), \( m_t \) represents the maximum allowable LTV ratio and \( E_t P^H_{t+1} H_{t,b} \) is the expected future value of the borrower’s real estate. Households borrow \( B_{t,b} \) in period \( t \) and repay \( R'^L_{t+1} B_{t,b} \) in period \( t + 1 \). Constraint (8) implies that during period \( t \), the impatient households may only borrow up to a fraction \( m_t \) of the expected value of their housing stock in period \( t + 1 \), less the interest payment. In the equilibrium, this constraint binds under the assumption that borrowers are less patient than the savers. Let \( \lambda_t \) be the Lagrange multiplier associated with the borrowing constraint; then, the first-order conditions that characterize the optimal choices are:

\[
v_t L_{t,b}^{\varphi_L} = \frac{v_c}{C_{t,b}} W_{t,b}
\]
Comparing the first-order conditions of the patient and impatient households, the importance of the collateral constraint emerges. From (10), a strictly positive $\lambda_t$ associated with the binding constraint implies that the traditional intertemporal optimal condition fails to hold with equality. In addition, the marginal utility of investment in housing increases with the magnitude of the Lagrange multiplier. Moreover, equation (11) shows that the borrower’s marginal return on housing goods depends on the LTV ratio. In a financially frictionless economy, the borrowing rate would be equivalent to the saving rate, $R_{t+1}^L = R_t$.

3.2 Financial Intermediaries

The banking sector modeled in Gertler and Karadi (2011) is introduced in this section to create a wedge between deposit and lending rates. Credit friction is essential to capture the role of bank capital in the transmission of shocks to the economy. Financial frictions are embedded in the funds available to banks, but I assume frictionless transfer of funds between financial intermediaries and borrowers. There exists a continuum of mass-one banks owned by the households with the timeline summarized as follows:

- In the beginning of period $t$, bank $j$ raises deposit $D^j_t$ from the patient household at deposit rate $R_{t+1}$ payable in period $t+1$

- Bank $j$ issues one-period loans to the impatient households with real estate collateral, $B^j_{t,b} = m_t E_t [\frac{P^{H}}{R_{t+1}} H^j_{t,b}]$

- Bank $j$ also issues one-period loans to non-financial firms backed by equity capital, $B^j_{t,e} = Q_t K^j_{t+1}$

- All loans are subject to interest rate $R_{t+1}^L$ payable in period $t+1$
Here, $K_{t+1}$ is the capital holding of firms with unit price $Q_t$. This can be interpreted as the value of the financial claims that banks hold against non-financial firms. Intermediary $j$’s balance sheet consists of assets given by

$$B^j_t = B^j_{t,b} + B^j_{t,e} = m_t E_t \left( \frac{P^H_{t+1}}{R^L_{t+1}} H^j_{t,b} \right) + Q_t K^j_{t+1}$$  \hspace{1cm} (12)

In addition, with liabilities $D^j_t$ and residual net worth $N^j_t$, the following condition holds for every period:

$$B^j_t = D^j_t + N^j_t$$  \hspace{1cm} (13)

The balance sheet of intermediary $j$ is as follows:

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^j_t$</td>
<td>$D^j_t$</td>
</tr>
<tr>
<td>Net Worth</td>
<td>$N^j_t$</td>
</tr>
</tbody>
</table>

The law of motion of intermediary $j$’s net worth is simply

$$N^j_{t+1} = R^L_{t+1} B^j_t - R_{t+1} D^j_t$$  \hspace{1cm} (14)

The banker will only fund projects with an expected return of no less than the discounted cost of borrowing. Therefore, the following inequality must hold:

$$E_t \Lambda_{t,t+1+i} (R^L_{t+1+i} - R_{t+1+i}) \geq 0, \ i \geq 0$$  \hspace{1cm} (15)

where $\Lambda_{t,t+1+i}$ is the stochastic discount factor applied in period $t$ to earnings in $t + 1 + i$. The survival rate of the financial intermediary is $\theta$, a probability that is independent of job history. This implies that the average lifetime of a banker in any period is $\frac{1}{1-\theta}$. Similar
to the birth-and-death assumption of banks in Bernanke, Gertler and Gilchrist (1999), a positive exit probability prevents bankers from accumulating sufficient net worth to finance equity investments internally. In each period, \((1 - \theta)\) of bankers exit and become workers, while a similar number of workers take up jobs as financial intermediaries. Bankers who exit from the financial sector transfer their earnings back to their corresponding households, and the households provide some startup funds for new bankers.

Financial intermediary \(j\) maximizes the expected discounted terminal net worth, \(V^j_t\), by choosing the amount of assets to purchase:

\[
V^j_t = \max E_t \sum_{i=0}^{\infty} (1 - \theta)^i \beta s^i \Lambda_{t,t+1+i} \left[ (R_{t+1+i}^L - R_{t+1+i})B_t^j + R_{t+1+i}N_t^j \right]
\]

(16)

Similar to Gertler and Karadi (2011), \(V^j_t\) can be rewritten as follows:

\[
V^j_t = \nu_t B_t^j + \eta_t N_t^j
\]

(17)

with

\[
\nu_t = E_t[(1 - \theta)\beta_s \Lambda_{t,t+1}(R_{t+1}^L - R_{t+1}) + \beta_s \Lambda_{t,t+1}\theta \frac{B_{t+1}^j}{B_t^j} v_{t+1}]
\]

(18)

\[
\eta_t = E_t[(1 - \theta) + \beta_s \Lambda_{t,t+1}\theta \frac{N_{t+1}^j}{N_t^j} \eta_{t+1}]
\]

(19)

\(\nu_t\) is the expected discounted marginal benefit to banker \(j\) for a unit increase in asset holdings \(B_t^j\), keeping \(N_t^j\) constant. Analogously, \(\eta_t\) is the expected discounted marginal gain for a unit increase in net worth, holding total assets constant.

Following Gertler and Karadi (2011), I introduce a moral hazard with costly enforcement problem to limit the liability of financial intermediaries. This aims to prevent intermediaries from borrowing indefinitely from households given a positive expected risk premium, as shown in (15). At the beginning of any period, the banker can choose to divert a
fraction $\lambda$ of all available funds from the projects and transfer them back to the corresponding household. Upon this action, depositors can force the intermediary into bankruptcy and recapture the remaining fraction $1 - \lambda$ of total assets. Costly enforcement implies that it is too expensive for depositors to recover the diverted fraction $\lambda$ of total assets. To ensure that depositors are willing to supply funds to bankers in each period, the following incentive constraint must be satisfied:

$$V_t^j = v_t B_t^j + \eta_t N_t^j \geq \lambda B_t^j \quad (20)$$

The left-hand side of (20) is the cost of diverting funds for banker $j$, which is equivalent to the value of operating the intermediary. The right-hand side is the gain from diverting a fraction $\lambda$ of available assets. The financial intermediary chooses not to divert only when the value of operating the intermediary is greater than or equal to the benefit from diverted assets.

Free of agency problems, the financial intermediary would continue to expand borrowing until $R_{t+1}^L$ is adjusted to ensure $v_t = 0$. With the incentive compatibility constraint in place, the intermediary’s asset holdings are restricted by the equity capital. When the constraint binds, (20) can be rewritten as

$$B_t^j = \frac{\eta_t}{\lambda - v_t} N_t^j \quad (21)$$

$$= \phi_t N_t^j$$

where $\phi_t$ is the endogenous leverage ratio of the banks that depositors will tolerate.

**Proposition 1** The incentive compatibility constraint binds if and only if $0 < v_t < \lambda$.

**Proof.** This is proven by contradiction. Suppose $v_t \geq \lambda$. Then given $\eta_t N_t^j > 0$, the left-hand side of (20) is always greater than the right-hand side. Therefore the constraint
is not binding. This implies that the value of operating a bank is always greater than the benefit from diverting funds. Now, suppose \( \nu_t \leq 0 \). Then the marginal gain of increasing investment in financial assets is less than or equal to zero, implying that the financial intermediary will not take deposits from households to acquire assets \( B_t^j \), which results in a slack constraint. It is important to emphasize that the credit condition tightens when \( \lambda \) increases.

When the constraint binds, the law of motion of intermediary \( j \)'s net worth becomes:

\[
N_{t+1}^j = [(R_{t+1}^L - R_{t+1})\phi_t + R_{t+1}]N_t^j
\]

(22)

The leverage ratio does not depend on any bank-specific characteristics, therefore aggregate variables can be obtained simply by summing across all intermediaries. Let \( N_t \) be the aggregate net worth of all banks, it can be written as the sum of the net worth of existing bankers, \( N_{et} \), and the net worth of new bankers, \( N_{nt} \).

\[
B_t = \phi_t N_t = \phi_t (N_{et} + N_{nt})
\]

(23)

Given that only a fraction \( \theta \) of bankers at \( t-1 \) survive through period \( t \), along with equation (22), \( N_{et} \) can be expressed as

\[
N_{et} = \theta N_t = \theta [(R_t^L - R_t)\phi_{t-1} + R_t]N_{t-1}
\]

(24)

New bankers receive startup funds from their respective households. It is assumed that these funds equal a fraction of the value of assets that exiting bankers intermediated in their final operating period, which is given by \((1-\theta)B_t\). Households are assumed to transfer \( \frac{\theta}{1-\theta} \) of the total final-period assets of exiting bankers to newly entering financial intermediaries.
$N_{nt}$ can then be written as

$$N_{nt} = \varpi B_t$$ (25)

Therefore, we can rewrite the law of motion for $N_t$ as follows

$$N_t = \theta[(R^L_t - R_t)\phi_{t-1} + R_t]N_{t-1} + \varpi B_t$$ (26)

### 3.3 Entrepreneurs

There is a continuum of infinitely lived entrepreneurs of measure one, who produce a homogeneous good utilizing household labor, capital and housing stock. Entrepreneurs use a standard Cobb–Douglas production function with constant return-to-scale. Note that there is imperfect substitution between impatient and patient household labor, which may be explained by assuming the patient households to be managers of firms and impatient households to be workers. The representative entrepreneur produces an intermediate good $Y_t$, using capital goods $K_t$, housing stock leased from patient households, $(1 - \kappa)H_{t,s}$, and the labor input of the patient and impatient households according to the production function:

$$Y_t = A_t(U_t\xi_t K_t)^\eta[(1 - \kappa)H_{t,s}]^\nu L_{t,s}^{\alpha(1-\eta-\nu)}L_{t,b}^{(1-\alpha)(1-\eta-\nu)}$$ (27)

$A_t$ is the technology shock, $\xi_t$ is an exogenous shock to the quality of capital and $U_t$ is the utilization rate of capital. $\xi_t K_t$ is the effective quantity of capital at time $t$. Firms raise funds from financial intermediaries by issuing claims against working capital $K_{t+1}$ at price $Q_t$. More specifically,

$$B_{t,e} = Q_t K_{t+1}$$ (28)

The endogenous borrowing constraints are only applicable to banks since non-financial firms face no credit friction. Banks have perfect information about firms and there is perfect enforcement. The financial constraints discussed in Section 3.2, however, directly affect the
supply of funds to the firms.

Intermediate-good producers choose a capital utilization rate $U_t$, capital $K_t$, housing goods $H_{t,s}$ and labor rate $(L_{t,s}, L_{t,b})$ to produce $Y_t$, and sells this product at price $P_{mt}$. The firm solves

$$
\max_{U_t, L_{t,s}, L_{t,b}, K} P_{mt}Y_t + Q_t \xi_t K_t - \delta(U_t) \xi_t K_t - W_{t,s} L_{t,s} - W_{t,b} L_{t,b} - R^L_{t+1} Q_{t+1} K_t - \nu_t^h (1 - \kappa) P^H_t H_{t-1,s}
$$

where $\delta(\cdot)$ is the depreciation rate on capital. The first-order conditions are given by

$$L_{t,s} : W_{t,s} = P_{mt}(1 - \eta - \upsilon) \alpha \frac{Y_t}{\xi_t L_{t,s}}$$

$$L_{t,b} : W_{t,b} = P_{mt}(1 - \eta - \upsilon)(1 - \alpha) \frac{Y_t}{\xi_t L_{t,b}}$$

$$U_t : \delta'(U_t) \xi_t K_t = P_{mt} \eta \frac{Y_t}{\xi_t U_t}$$

The representative firm pays out the ex-post return to capital to the banks and earns zero profit. The ex-post return to capital is given by

$$R^L_{t+1} = \frac{[P_{mt+1} \eta \xi_{t+1} K_{t+1} + Q_{t+1} - \delta(U_{t+1})] \xi_{t+1}}{Q_t}$$

The intuition is that the ex-post gross rate of return on capital equals the sum of the marginal productivity of capital goods and the capital gain from changes in price. Note that the valuation shock $\xi_{t+1}$ provides additional variation to the return on capital. The value of capital stock at the end of period $t + 1$ is $\xi_{t+1} U_{t+1} [Q_{t+1} - \delta(U_{t+1})]$.

Similarly, the non-financial firm pays ex-post return to housing stock as rents to the
patient households. Taking the derivative with respect to \( H_t; s \), the ex-post rent is given by

\[
\rho_{t+1}^h = \nu \frac{P_{mt+1} Y_{t+1}}{(1 - \kappa) P_{mt+1} H_{t; s}}
\]  

(34)

3.4 Capital Producers

Capital producers are essential to introduce capital adjustment costs in a tractable way. Following the literature on financial accelerators, capital adjustment costs induce additional variations in the price of capital in response to changes in capital stock. At the end of period \( t \), competitive capital-producing firms purchase used capital from intermediate-good producers, refurbish the old and produce new capital. They sell both repaired and new capital. Assuming the cost of replacing depreciated capital is one, the price of a unit of new or repaired capital is denoted by \( Q_t \). Let \( I_t \) be the gross capital created, \( I_{nt} \) the net capital created and \( \bar{I} \) the steady state value of \( I_t \), then the capital-good producer solves

\[
\max_{I_{nt}} E_0 \sum_{t=0}^{\infty} \beta_s^t A_{0,t} [(Q_t - 1)I_{nt} - \Phi\left(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}}\right)(I_{nt} + \bar{I})]
\]

(35)

\[
s.t. I_{nt} = I_t - \delta(U_t) \xi_t K_t
\]

(36)

\( \Phi(\cdot) \) is the capital adjustment cost function, with \( \Phi(1) = \Phi'(1) = 0 \) and \( \Phi''(1) > 0 \). The first-order condition that characterizes the net investment Q relation is given by

\[
Q_t = 1 + \Phi\left(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}}\right) + \Phi'\left(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}}\right)\left(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}}\right) - E_t \beta_s \Lambda_{t,t+1} \Phi'\left(\frac{I_{nt+1} + \bar{I}}{I_{nt} + \bar{I}}\right)\left(\frac{I_{nt+1} + \bar{I}}{I_{nt} + \bar{I}}\right)^2
\]

(37)

Note that given no idiosyncratic shock among capital-good producers, all firms choose the same net investment rate. In this setup, the price of capital increases when total investment expenditure expands.

The depreciation rate and adjustment cost function are assumed to take the following
functional forms:

\[ \delta(U_t) = \bar{\delta} - \frac{\delta}{1 + \omega} + \frac{\bar{\delta}}{1 + \omega} U_t^{1+\omega} \]  
(38)

\[ \Phi(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}}) = \frac{\phi_f}{2} (\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}} - 1)^2 \]  
(39)

where \( \bar{\delta} \) is determined by the steady state and \( \omega \) and \( \phi_f \) are parameters.

3.5 Retail Firms

Retail firms are present in the model to introduce sticky prices. There is a continuum of monopolistic competitive retailers who purchase intermediate output from intermediate-good producers and produce the final output, \( Y_t \). The CES composite of final goods is given by

\[ Y_t = \left[ \int_0^1 Y_{st}^{\frac{\varepsilon - 1}{\varepsilon}} ds \right]^{\frac{1}{\varepsilon}} \]  
(40)

\( Y_{st} \) is the output by retailer \( s \),

\[ Y_{st} = (\frac{P_{st}}{P_t})^{-\varepsilon} Y_t \]  
(41)

\[ P_t = \left[ \int_0^1 P_{st}^{1-\varepsilon} ds \right]^{\frac{1}{1-\varepsilon}} \]  
(42)

One unit of intermediate goods can be used to produce one unit of final goods. The marginal cost is simply the price of intermediate output, \( P_{mt} \). To introduce nominal rigidities, only a fraction \( 1 - \gamma \) of retailers can reset the price freely in any period (Calvo 1983). Retailers that do not re-optimize prices will index their prices with respect to inflation and parameter \( \gamma_P \). Specifically, the retailer chooses the optimal reset price \( P_t^* \) to solve

\[ \max_{P_t^*} E_t \sum_{i=0}^{\infty} \gamma^i \beta_s^i \Lambda_{t,i} + i \left[ \frac{P_t^*}{P_t} \prod_{k=1}^{\pi_{t+k-1}} (1 + \pi_{t+k-1})^{\gamma_P} - P_{mt+i} \right] Y_{st+i} \]  
(43)
\( \pi_t \) is the rate of inflation from \( t - 1 \) to \( t \). The first-order condition is

\[
E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[ \frac{P_t^*}{P_{t+i}} \right] \prod_{k=1}^{i} (1 + \pi_{t+k-1})^{\gamma \rho} [1 - \frac{1}{1 - 1/\varepsilon} P_{mt+i}] Y_{st+i} = 0
\] (44)

Using the law of large numbers, the law of motion for the price level can be derived:

\[
P_t^{1-\varepsilon} = (1 - \gamma)(P_t^*)^{1-\varepsilon} + \gamma((1 + \pi_{t-1})^{\gamma \rho} P_{t-1})^{1-\varepsilon}
\] (45)

Let \( \bar{P}_t^* = P_t^*/P_t \), then the law of motion for the relative price level is given by

\[
1 = (1 - \gamma)(\bar{P}_t^*)^{1-\varepsilon} + \gamma \left[ \frac{(1 + \pi_{t-1})^{\gamma \rho}}{1 + \pi_t} \right]^{1-\varepsilon}
\] (46)

### 3.6 Central Bank and Monetary Policy

The central bank in this economy administers a log-linearized Taylor rule of the following form:

\[
\hat{i}_t = \rho_r (\hat{i}_{t-1}) + (1 - \rho_r) [\gamma_\pi \hat{\pi}_t + \gamma_Y \hat{Y}_t] + \varepsilon_t^R
\] (47)

where \( \hat{i}_t \) is the nominal interest rate. The central bank adjusts interest rates according to the log deviation of inflation and output from their steady-state levels. \( \gamma_\pi > 0 \) and \( \gamma_Y > 0 \) are the parameters chosen by the central bank to conduct the monetary policy. When \( \rho_r > 0 \), this rule also includes a first-order autoregressive component that captures the interest rate inertia à la Woodford (2000). The relationship between real and nominal interest rates is characterized by the Fisher equation

\[
1 + i_t = R_{t+1} \frac{E_t P_{t+1}}{P_t} = R_{t+1} E_t (1 + \pi_{t+1})
\] (48)

\( \varepsilon_t^R \) is a random monetary shock with zero mean and variance \( \sigma_R^2 \).

### 3.7 Macroprudential Policy
3.7.1 Dynamic Loan-to-Value (LTV) Ratio

Impatient households can only borrow up to a fraction of the expected value of their housing stock, which is characterized by equation (8). The regulatory authority controls for the loan-to-value ratio in order to moderate credit growth in the economy. Under the assumption that the impatient households are subject to a lower discount factor than the patient households, the borrowing constraint will always bind. Therefore, a high LTV ratio releases the tension of the collateral constraint and induces borrowing. A lower LTV ratio implies a tighter constraint that restricts the amount of lending in the real economy. The first experiment is to allow a fixed LTV ratio for the impatient households. More specifically, I set $m_t = m$ in the baseline model, where $m$ is the steady-state value of $m_t$. With the constraint binding, changes in the maximum LTV ratio directly signal credit liberalization or tightening policies. This assists the study of the impact of credit conditions on the real economy.

The 2008 financial crisis grew out of great economic conditions associated with a period of housing price boom and credit liberalization. A fixed LTV ratio is unable to capture the dynamic and corrective measures policymakers may want to implement. A countercyclical LTV ratio is thus desired to limit lending during booms and stimulate the economy during downturns. In an alternative experiment, I adopt a dynamic simple feedback rule of the form:

$$\dot{m}_t = \rho_m \dot{m}_{t-1} - \varphi_Y \dot{Y}_t - \varphi_P \dot{P}_t^H$$

(49)

where $\varphi_Y > 0$ and $\varphi_P > 0$ are the parameters chosen by the regulatory authority. In this setup, policymakers adjust the LTV ratio corresponding to the log deviations of output and housing price from their steady-state values. In the literature, Gerlach and Peng (2005) also document the regulation of household credit as a stabilizing tool for housing prices in Hong Kong and South Korea during the 1997 East Asian crisis.
3.7.2 Pigouvian Lump-Sum Tax

The financial intermediaries face an endogenous capital-to-loan ratio of \( \frac{N_t}{B_t} = \frac{1}{\varphi_t} \), which is the reciprocal of their leverage ratio. Similar to the discussion above, the regulatory authority wants to raise banks’ capital and restrict credit growth during economic upturns. Here, I introduce a Pigouvian lump-sum tax scheme adapted from Gertler et al. (2012) and Lima et al. (2012). In this setup, the government collects tax on banks’ loans and uses the proceeds to subsidize the banks’ net worth. This tax-subsidy policy directly affects the leverage ratio and allows policymakers to stabilize the credit market via the balance sheets of financial intermediaries.

Let \( \tau_t^s \) be the subsidy rate on net worth and \( \tau_t \) be the tax rate on loans, then the balance sheet of the bank (equation 13) can be rewritten as follows:

\[
(1 - \tau_t)B_t = D_t + (1 - \tau_t^s)N_t
\] (50)

The new law of motion for the banks’ net worth is given by

\[
N_{t+1} = (R_{t+1}^L - R_{t+1})(1 - \tau_t)B_t + (1 - \tau_t^s)R_{t+1}N_t + \tau_t^sN_t
\] (51)

The last term on the right-hand side of equation (51) is the lump-sum subsidy. Intermediary \( j \) now solves a new problem

\[
V_t^j = \max E_t \sum_{i=0}^{\infty} (1 - \theta)^i \beta^i \lambda_{t+1+i}[((R_{t+1+i}^L - R_{t+1+i})(1 - \tau_{t+i})B_{t+i}^j
\]

\[
+((1 - \lambda_{t+i})R_{t+1+i} + \lambda_{t+i}N_{t+i}^j)]
\]

\[
= u_t^m B_t^j + \eta_t^m N_t^j
\]
with
\[ v_t^m = E_t[(1 - \theta)\beta_s\Lambda_{t,t+1}(R^L_{t+1} - R_{t+1})(1 - \tau_t) + \beta_s\Lambda_{t,t+1}\theta\frac{B_{t+1}}{B_t}v_{t+1}] \] (53)

\[ \eta_t^m = (1 - \theta)(1 - \tau_t^s) + E_t[(1 - \theta)\beta_s\Lambda_{t,t+1}\tau_t^s + \beta_s\Lambda_{t,t+1}\theta\frac{N_{t+1}^j}{N_t^j}\eta_{t+1}] \] (54)

Equation (26) can also be rewritten as
\[ N_t = \theta[(R^L_t - R_t)(1 - \tau_{t-1})\phi_{t-1} + (1 - \tau_{t-1}^s)R_t + \tau_{t-1}^s]N_{t-1} + \omega(1 - \tau_t)B_t \] (55)

The aggregation across banks is identical to section 3.2 with a newly added balanced budget condition
\[ \tau_tB_t = \tau_t^sN_t \] (56)

In addition, there exists a cost of administering this tax scheme, which is quadratic in the tax rate, \( \psi\tau_t^2B_t \). The tax rate is administered through a feedback rule that corresponds to changes in output. The log-linearized rule is given by
\[ \hat{\tau}_t = \rho_{r}\hat{\tau}_{t-1} + \theta_Y\hat{Y}_t \] (57)

where \( \theta_Y > 0 \) is a parameter selected by the regulatory authority. When output increases above its steady-state level, the positive tax rate imposed on bank’s lending asserts a negative pressure on the leverage ratio. Subsequent subsidies of banks’ net worth lead to a further decrease in leverage, which increases the capital-to-loan ratio. During economic recessions, the tax and subsidy reverse their positions, and a tax will be imposed on banks’ capital holdings to stimulate borrowing. As a result, the leverage ratio falls, and aggregate lending is expanded to enhance economic recovery. Unlike in Lima et al. (2012), the steady-state tax rate in this model is zero instead of some small positive value. This implies that the economy bears no cost of raising taxes in the equilibrium and only faces
such a burden in response to a random shock. This allows better comparison across models because the steady-state values remain unchanged.

The central bank, regulatory authority, and government play different roles in shaping the economy. First, the central bank determines the nominal interest rate through monetary policy, which affects the real interest rate via the Fisher equation. This influences the funding cost of financial intermediaries and their lending rates. Second, regulations on the LTV ratio have a direct impact on household borrowing, which is then passed on to banks’ balance sheet. However, the borrowing condition of entrepreneurs is only influenced indirectly through lending rates. The Pigouvian tax scheme targets the leverage ratio of financial intermediaries directly, which has an impact on both business and household borrowing conditions. With the understanding that each policy affects different agents via different channels, the interaction between monetary policy and macroprudential tools is further examined in Section 6.

3.8 Competitive Equilibrium

The shocks to productivity, housing preference, monetary policy and the quality of capital follow the AR(1) process in a log-linearized form:

\[
\dot{a}_t = \rho_A \dot{a}_{t-1} + \epsilon_t^A \tag{58}
\]

\[
\dot{\epsilon}_t^H = \rho_{\epsilon^H} \dot{\epsilon}_{t-1}^H + \epsilon_t^H \tag{58.1}
\]

\[
\dot{\epsilon}_t^R = \rho_{\epsilon^R} \dot{\epsilon}_{t-1}^R + \epsilon_t^R \tag{58.2}
\]

\[
\dot{\xi}_t = \rho_{\xi} \dot{\xi}_{t-1} + \epsilon_t^\xi \tag{58.3}
\]
A competitive equilibrium is a sequence of allocations

$$\{H_{t,s}, H_{t,b}, L_{t,s}, L_{t,b}, C_{t,s}, C_{t,b}, D_t, B_{t,t,b}, B_{t,t,e}, B_t, K_{t+1}, Y_t, N_t, I_t, I_{nt}, \nu_t, \eta_t, \phi_t, \tau_t, \tau_t^s, m_t\}_{t=0}^{\infty}$$

(59)

together with a sequence of prices

$$\{W_{t,s}, W_{t,b}, A_{t,t+1}, U_t, P_t^H, P_{nt}, P_t^s, Q_t, \lambda_t, R_{t+1}, R_{t+1}^L, i_t, \pi_t^h, \pi_t\}_{t=0}^{\infty}$$

(60)

and exogenous processes

$$\{A_t, \varepsilon_t^R, \varepsilon_t^H, \xi_t\}_{t=0}^{\infty}$$

such that i) the allocations solve each household’s, bank’s, entrepreneur’s, capital-good producer’s, and retailer’s maximization problem at equilibrium prices given pre-determined variables and ii) all markets clear. The aggregate clearing conditions are given by

$$H_{t,s} + H_{t,b} = \bar{H}$$

(61)

$$L_{t,s} + L_{t,b} = 1$$

(62)

$$Y_t = C_{t,s} + C_{t,b} + I_t + \Phi(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}})(I_{nt} + \bar{I}) + \psi \tau_t^2 B_t$$

(63)

$$\tau_t B_t = \tau_t^s N_t$$

(64)

Equation (64) and the term $\psi \tau_t^2 B_t$ in (63) only appear when the Pigovian tax scheme is imposed. The full log-linearized model is presented in Appendix A.2.

4. Calibration

Table 1 in the appendix provides a summary of the parameters and their calibrated values. The time period in the model is one quarter. Parameter values are mostly taken from Gertler and Karadi (2011) and Iacoviello (2005). The discount factors for saving and
borrowing households are chosen to be 0.985 and 0.95, respectively. This implies that the annual net equity return for the patient households is 6.1%. The weights of consumption goods and housing goods in the utility function \((v_c, v_h)\) are calibrated as 0.9 and 0.1, respectively. The weight of labor in the utility function \((v_l)\) is set to 2. The inverse of the Frisch elasticity of labor supply \((\varphi_L)\) is 0.276. According to the Bureau of Economic Analysis, investments in commercial real estates as a percentage of GDP are, on average, twice that of investments in residential property. In this model, I assume that patient households lease a fraction \(1 - \kappa = 0.67\) of housing stock to firms. This is also consistent with the estimation results from Yepez (2012), where the posterior mean of \(1 - \kappa\) from the Bayesian estimation is around 0.6.

The financial sector consists of three suggestive parameters \((\theta, \lambda, \varpi)\), which are the survival rate of bankers, the fraction of wealth a banker could divert and the proportional wealth transfer to the entering banks, respectively. The parameters are chosen to meet two goals. First, the steady-state interest rate spread is 1%. Moreover, the steady state leverage ratio of banks is four. In Gertler and Karadi (2011), the fraction of assets a banker can divert \((\lambda)\) is extraordinarily high, more than 30%. This is set to achieve a life expectancy of ten years for bankers. In this model, I set the survival rate of bankers \((\theta)\) to be 0.948, which implies an average career horizon of five years. This lowers the fraction of assets a banker can divert to 17%. Entering bankers get a wealth transfer \(\varpi \frac{1}{1 - \theta}\) with \(\varpi = 0.002\).

In the production sector, the share of capital \((\eta)\) and housing stock \((\nu)\) in the Cobb-Douglas production function are set to be 0.33 and 0.03, respectively. Patient household’s labor share \((\alpha)\) is set to 0.64. The steady-state utilization rate is normalized to 1 with rate of depreciation \(\delta(U) = 0.025\). This implies that capital takes an average of ten years to fully depreciate. The capital adjustment cost parameter \(\phi_I\) is 4 and the elasticity of marginal depreciation with respect to the utilization rate \((w)\) is 7.2. Retail firm’s elasticity of substitution is 4.167, implying a steady-state real markup of 1.316. The probability of
keeping prices fixed ($\gamma$) is 0.779 and the measure of inflation indexation ($\gamma_P$) is 0.241.

The baseline calibration for the degree of intervention in monetary policy is set following Gertler and Karadi (2011) where $\gamma_n = 1.5$ and $\gamma_Y = 0.125$. The degree of inertia ($\rho_r$) is 0.8. The autoregressive coefficients in the exogenous processes are $\rho_A = 0.85$, $\rho_H = 0.95$, $\rho_R = 0.8$ and $\rho_\xi = 0$.

The steady-state consumption ratio between impatient and patient households ($C_b/C_s$) is 0.89 and the ratio of labor supply ($L_b/L_s$) is 1.55. The annualized household debt-to-GDP ratio ($B_b/Y$) is 0.26 and the business-to-household credit ratio ($B_e/B_b$) is 3.9. The aggregate consumption-to-GDP ratio ($C/Y$) is 0.84, the investment-to-GDP ratio ($I/Y$) is 0.16 and the capital-to-GDP ratio ($K/Y$) is 5.02. The steady-state LTV ratio ($m$) and leverage ratio ($\phi$) are 0.7 and 4, respectively. The tax and subsidy rates are zero in equilibrium. The real interest rate ($R$) is 1.015 and the lending rate ($R^L$) is 1.025.

5. Model Analysis

This section reports the simulation results from three alternative specifications with four shocks. First, the baseline model ("BLM") considers a fixed LTV ratio with $m = 0.7$, which is the steady-state value for $m_t$. This implies that the impatient households can only borrow up to 70% of the expected value of their housing stock. In fact, this number is compatible with the average LTV ratio for U.S. residential mortgages (76%) before the recession in 2008 (IMF 2011). The central bank conducts monetary policy according to equation (47) with no other active regulatory policy. The second model adopts a dynamic LTV ratio rule ("LTVM"), which is characterized by (49). The regulatory authority lowers the LTV ratio during economic booms to limit credit expansion and increases the ratio during recessions. The degree of inertia ($\rho_m$) is 0.85 and the degrees of intervention are

\footnote{The results from a model with both macroprudential policies are not reported here because the impulse response functions with both policies are indistinguishable from those of the tax policy alone. Since the tax policy targets the aggregate credit market and directly controls the balance sheet of financial intermediaries, the LTV ratio rule becomes uneffective as it targets only the housing market.}
\( \varphi_P = 1.5 \) and \( \varphi_Y = 0.15 \). In the last specification, the baseline model is augmented with the Pigovian tax scheme ("PTM"), which is characterized by equation (57). The government sets positive tax and subsidy rates during economic booms to increase the capital-to-loan ratio of financial intermediaries. The degree of inertia \( (\rho_r) \) is 0.75 and the degree of intervention \( (\theta_Y) \) is 0.57. These values are taken from Lima et al. (2012). The monetary policy is effective in all three models with no change in the parameter values.

The impulse response functions from positive productivity, housing demand, capital quality shocks and expansionary monetary policy are displayed in Figures 1 to 4 in the appendix. The standard deviation for each shock is \( \sigma_A = \sigma_\xi = 0.01 \), \( \sigma_R = 0.01 \) (annualized) and \( \sigma_H = 0.0021 \). The magnitude of the housing demand shock is taken from Suh (2012), who matches the historical volatility of U.S. housing prices. Moreover, 1% productivity and capital quality shocks are standard as in Gertler and Karadi (2011). The macroprudential policies, if effective, should stabilize the economy relative to the baseline model. Furthermore, fluctuations of household lending and housing prices should be significantly dampened.

5.1 Technology Shock

In the baseline model, output, consumption, and investment increase, while inflation decreases in response to a 1% technology shock (Figure 2 solid lines). An increase in consumption drives up housing demand, causing housing prices to rise under a fixed housing supply. Consequently, household lending expands resulting in a higher leverage ratio for financial intermediaries. It should be emphasized that the leverage ratio has increased more than 150% in comparison to the steady-state level, creating excessive liquidity risk in the credit market. Consistent with findings in Gertler and Karadi (2011), the credit spread falls in response to positive productivity shock that causes the banks’ net worth to decrease. With a dynamic LTV ratio rule, the impulse response functions are moderately dampened for consumption, investment, output, inflation and housing price (Figure 1 dashed lines).
The LTV ratio decreases by around 6% in response to higher output and housing price. The contractionary LTV ratio further leads to a decrease in household lending since impatient households now face a lower collateral value. However, decreasing net worth and an increasing leverage ratio cause the aggregate lending to increase in response to the shock (as is evident from equation 21). This suggests that financial intermediaries seek to expand business lending when the household credit market is regulated. This creates a credit shift from the impatient households to entrepreneurs, which is consistent with findings in Suh (2012). The regulatory authorities should consider this possibility when choosing the appropriate macroprudential policy.

The tax policy, PTM, is comparably more effective (Figure 1 dash-dotted lines). The leverage ratio remains stable as the government imposes a 1% tax on aggregate lending and simultaneously subsidizes the banks’ net worth. Furthermore, the percentage change in all other variables is significantly smaller than that of the BLM and LTVM. Household lending and housing prices increase slightly in response to the technology shock but revert back to the steady state levels quickly. Comparatively, small changes in the leverage ratio and banks’ net worth provide minimal evidence of credit shift. Both macroprudential policies are effective in stabilizing the economy, but the tax policy may be more desirable in this particular setup.

5.2 Housing Demand Shock

Figure 3 displays the impulse response functions from a housing demand shock of 21 bps, calibrated following Suh (2012). A positive shock implies that both patient and impatient households now obtain more utility from housing stock. Given an exogenous and fixed housing supply, the price is completely driven by demand. In the BLM, consumption, output and inflation increase while investment falls. As more people demand housing goods, prices increase and lending expands. Financial intermediaries also become more leveraged. In the LTVM, impatient households face a 1% drop in the target LTV
ratio, which limits the maximum loan size. This reduces household lending and dampens
the growth of housing prices. In addition, the increase in the leverage ratio is reduced by
more than 50% in comparison to the BLM. This significantly limits the liquidity risk of
financial intermediaries. Similar to the technology shock, a small decrease in banks’ net
worth and a relatively large increase in the leverage ratio imply a rise in aggregate lending.
Growing business lending is the result of banks’ profit-maximizing behavior. In this model,
the entrepreneurs face no credit constraint and the amount of lending depends solely on the
price and quantity of capital. This setup allows the banks to seek alternative markets to
expand asset holdings. It should be emphasized that the steady-state business-to-household
lending ratio is 3.9, which implies that a more volatile credit market in the business sector
increases the volatility of the overall financial market, despite of the dampened effect in
household lending.

In contrast, the PTM is also effective in response to a housing demand shock. All
variables other than housing price are associated with small fluctuations, and the tax rate is
positive at around 30 bps. Housing price increases slightly less than the LTVM, but reverts
to the steady-state level quickly. Figures 1 and 2 suggest that the dynamic LTV ratio rule
is effective in controlling for household lending and housing price, but creates additional
volatility in the business sector. The tax policy is effective under both shocks but achieves
a better stabilizing role in response to technology disturbance.

5.3 Capital Quality Shock

In Figure 4, a 1% capital quality shock is imposed to examine the effects on the
housing market. With an autoregressive coefficient of zero, the disturbance is considered
temporary. The overall effect has two stages. First, a positive shock to quality increases the
effective quantity of capital, which enhances the balance sheet of financial intermediaries.
Consequently, increasing demand for capital drives up the price, \( Q_t \), and banks’ leverage
ratios. The effects of the shock are amplified by the presence of financial frictions. Demand
for housing drops initially as resources are directed toward the production sector, causing the housing price to fall. In the second stage, positive income growth naturally induces greater housing demand and puts additional pressure on the credit market. In the BLM, the housing prices first decreases by 4%, and then quickly rises to 2% above the steady-state level. Consumption and the leverage ratio are hump-shaped given the two-stage adjustment process and the banks’ net worth grows by 30%.

The introduction of the dynamic LTV ratio effectively dampens the effects from the shock and restricts credit expansion. Because the housing price falls immediately after the shock, the target LTV ratio first increases above its steady-state level, then drops significantly. The borrowing limit for impatient households increases first, which leads to greater household lending. As output and housing prices both increase, the LTV ratio falls below the long-run level, which leads to a gradual decrease in household loans. This macroprudential policy actively adjusts the borrowing constraints to reduce fluctuations in the credit market. As a result, disturbances in the economy are effectively mitigated. In contrast with technology and housing demand shocks, business lending expands naturally in response to the higher price and quantity of capital with little evidence of credit reallocation.

The tax policy is more effective in stabilizing the credit market but not the aggregate economy. A positive tax on total lending reduces the growth of household borrowing and alleviates the increase in housing price. Changes in the net worth of financial intermediaries have two parts. The first part comes from increases in the quantity and price of capital, as shown in the BLM. However, the positive subsidy further enhances the banks’ net worth. As a result, the net present value of financial intermediaries increases by nearly 40% in response to the capital quality shock. Consequently, the credit market is more restricted with a smaller increase in the leverage ratio. Since households own the financial intermediaries, consumption and output growths are higher in comparison to the LTVM, but are still noticeably smaller than those from the BLM.
5.4 Monetary Shock

Figure 5 displays the impulse response functions from an unexpected 1% (annualized) decline in the nominal interest rate. Consumption, investment, output and inflation rise in response to the shock. This expansionary shock lowers the borrowing expense of banks and induces more lending. The leverage ratio, housing price and household lending increase significantly in the BLM. The greater risk premium also increases banks’ net worth. With monetary policy solely in effect, the economy experiences large fluctuations and faces higher financial risk. In contrast, the countercyclical loan-to-value ratio policy is effective in stabilizing the economy. In the LTVM, the percentage deviations are clearly smaller. The LTV ratio decreases by around 2% before gradually returning to the steady-state level. The housing price and household lending increase by about 50% less than in the baseline case. However, business lending significantly expands, creating the aforementioned credit shift issue. As the cost of borrowing decreases, financial intermediaries have a larger incentive to expand lending in all sectors. Regulatory control in the housing sector promotes active lending in the business sector.

The tax scheme is effective in mitigating the economic response to disturbances, as demonstrated in previous sections. The tax rate increases by 1% in response to a 2% rise in output. Although the initial deviation of output is greater than in the LTVM, the recovery is also more rapid. The tax policy effectively reduces the changes to banks’ balance sheets, resulting in small fluctuations of the housing price and household lending. In this case, business lending also expands more than household lending because of the lower borrowing cost for banks, suggesting some evidence for a credit shift. However, the magnitude is smaller in comparison to the LTVM.

5.5 Volatility of Economic Variables

Macroprudential policy aims to stabilize the economy and dampen fluctuations caused by unexpected shocks. The impulse response functions presented above provide di-

rect measures of the percentage change of major variables in response to shocks. However, evaluation of the relative volatility is essential for a complete assessment. More specifically, a successful macroprudential policy should not only reduce the relative change of an economic variable, but also lessen the overall variation. Table 2 summarizes the unconditional standard deviation of consumption, output, investments, inflation, housing price, banks’ net worth, household lending and business lending. The percentage differences between the baseline model and other models are listed in brackets.

Both the dynamic LTV ratio rule and Pigovian tax policy significantly reduce the volatility of the housing price. In addition, household lending is around 10% less volatile in models with macroprudential policy. However, the results are not uniform among the other variables. In the LTVM, the standard deviations of investment and business lending are higher than the baseline model. This suggests that banks reallocate towards the less regulated production sector when a restriction is applied to the housing market. Financial intermediaries expand business lending to maximize profit, which leads to a more volatile credit market. Since the ratio of business-to-household lending is 3.9 in the steady state, aggregate lending in the economy fluctuate even more than in the case with a fixed LTV ratio.

The tax policy is more effective in stabilizing the economy. All variables are less volatile in comparison to the BLM and LTVM. Furthermore, the standard deviation of business lending and investments are significantly lessened. In summary, the regulatory authority needs to consider the possible trade-off between the business and household sectors when choosing the appropriate policy. In the following section, I search for the optimal degree of intervention for each model by maximizing the social welfare of the economy. This provides a more practical suggestion for policymakers seeking an effective and implementable macroprudential policy.
Table 2: Unconditional Standard Deviation of Major Economic Variables

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Y</th>
<th>I</th>
<th>π</th>
<th>PH</th>
<th>N</th>
<th>Bb</th>
<th>Be</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLM</td>
<td>0.01356</td>
<td>0.01621</td>
<td>0.01296</td>
<td>0.0079</td>
<td>0.0197</td>
<td>0.0780</td>
<td>0.1036</td>
<td>0.0908</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LTVM</td>
<td>0.01302</td>
<td>0.01603</td>
<td>0.01383</td>
<td>0.0075</td>
<td>0.0164</td>
<td>0.0659</td>
<td>0.0939</td>
<td>0.1216</td>
</tr>
<tr>
<td></td>
<td>(-3.9%)</td>
<td>(-1.1%)</td>
<td>(6.7%)</td>
<td>(-5.1%)</td>
<td>(-16.8%)</td>
<td>(-15.5%)</td>
<td>(-9.4%)</td>
<td>(33.9%)</td>
</tr>
<tr>
<td>PTM</td>
<td>0.01229</td>
<td>0.01581</td>
<td>0.01250</td>
<td>0.0073</td>
<td>0.0141</td>
<td>0.0683</td>
<td>0.0930</td>
<td>0.0735</td>
</tr>
<tr>
<td></td>
<td>(-9.4%)</td>
<td>(-2.5%)</td>
<td>(-3.5%)</td>
<td>(-7.6%)</td>
<td>(-28.4%)</td>
<td>(-12.4%)</td>
<td>(-10.2%)</td>
<td>(-19.1%)</td>
</tr>
</tbody>
</table>

6. Optimal Policy and Welfare Analysis

In this section, I conduct welfare analysis to search for the optimal monetary and macroprudential policies outlined in Section 3. The policy problem faced by the central bank and regulatory authority is essentially the choice of the optimal coefficients entering the feedback rules. More specifically, I look for the optimal monetary, LTV ratio and tax rules described in equations (47), (49), and (57). In most DSGE models, a practical and implementable rule is optimal if it yields the highest value for an appropriate welfare criterion. The traditional linear-quadratic approach introduced by Rotemberg and Woodford (1997) has been criticized for producing inaccurate results, as it neglects the higher moments necessary for the evaluation of risk and welfare. Kim and Kim (2003) show that in a two-agent economy, welfare evaluation based on linear approximation to the policy function may yield biased result that an autarky economy generates a higher welfare in comparison with an economy under risk sharing. In this paper, I follow Schmitt-Grohe and Uribe (2004) and use the second-order approximation method for welfare comparison.

In this model, both monetary and macroprudential policy are based on observable variables to allow better implementation. In addition, the parameter values are restricted in a pre-set range to ensure a unique solution. Welfare is measured using the unconditional expectation of the aggregate household utility at period zero. Equation (65) characterizes
the social welfare function.

\[ W_0 = E_0 \left\{ \sum_{t=0}^{\infty} \beta_t^t \left[ \nu_c \log C_{t,s} + \nu_h \log H_{t,s} \right] - \frac{L_{t,s}^{1+\varphi_L}}{1 + \varphi_L} \right\} + E_0 \left\{ \sum_{t=0}^{\infty} \beta_t^b \left[ \nu_c \log C_{t,b} + \nu_h \log H_{t,b} \right] - \frac{L_{t,b}^{1+\varphi_L}}{1 + \varphi_L} \right\} \]

(65)

The sum of household utility arises from the assumption that the population of patient and impatient household are equalized. The objective is to calculate the welfare measure using different combination of policy parameters to select the optimal rules.

For monetary policy, the values of \( \gamma_\pi \) and \( \gamma_Y \) are set to be within the ranges of \([1, 2]\) and \([0, 1]\), respectively. This is consistent with the findings of Schmitt-Grohe and Uribe (2004). For macroprudential policy parameters, the range of \( \varphi_Y \) (the response of the LTV ratio rule to output), \( \varphi_P \) (the response of the LTV ratio rule to housing price), and \( \theta_Y \) (the response of the tax rate to output) are restricted to be within \([0, 2]\). In the numerical search for optimal parameters, the grid size is chosen to be 0.05 and \( W_0 \) is calculated for each combination. The optimal combination of monetary and macroprudential policy is identified at the maximum welfare measure. The results are presented in Table 3.

Table 3: Optimal Policy and Welfare Comparison

<table>
<thead>
<tr>
<th>Model</th>
<th>( \gamma_\pi )</th>
<th>( \gamma_Y )</th>
<th>( \varphi_Y )</th>
<th>( \varphi_P )</th>
<th>( \theta_Y )</th>
<th>Welfare</th>
<th>% Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1.5</td>
<td>0.125</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>-107.11</td>
<td>–</td>
</tr>
<tr>
<td>Monetary Policy only</td>
<td>1.65</td>
<td>0.105</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>-106.09</td>
<td>0.95%</td>
</tr>
<tr>
<td>Monetary + LTV Ratio</td>
<td>1.9</td>
<td>0.15</td>
<td>0.13</td>
<td>1.45</td>
<td>–</td>
<td>-105.96</td>
<td>1.07%</td>
</tr>
<tr>
<td>Monetary + Tax Scheme</td>
<td>1.85</td>
<td>0.1</td>
<td>–</td>
<td>–</td>
<td>0.35</td>
<td>-105.82</td>
<td>1.20%</td>
</tr>
</tbody>
</table>

Four different models are considered here. In the baseline model, the central bank administers only monetary policy which is calibrated according to Gertler and Karadi (2011).
The "Monetary Policy only" panel presents the optimal parameters for monetary policy, where $\gamma_\pi = 1.65$ and $\gamma_Y = 0.105$. These two models utilize a fixed LTV ratio and consider no macroprudential tools. The optimal monetary policy found implies that the central bank responds more than one-to-one to changes in inflation, which is consistent with the Taylor principle. The second last column reports the welfare measure characterized by equation (65). The percentage gains in the last column are the percentage increase in welfare compared to the baseline model. For the optimal monetary policy, the net welfare gain is 0.95%.

In the "Monetary + LTV Ratio" panel, the central bank administers monetary policy along with the dynamic LTV ratio rule presented in Section 3.7.1. The regulatory authority adopts a countercyclical target LTV ratio rule to reduce credit expansion during economic booms. The optimal monetary policy responds more aggressively to inflation but less to output. The optimal parameters for the LTV ratio rule are $\varphi_Y = 0.13$ and $\varphi_P = 1.45$. This implies that the regulatory authority lowers the target LTV ratio more than 1% for a 1% increase in housing price. The welfare gain compared to the baseline case is 1.07%.

In the last model, monetary policy and the Pigovian tax-subsidy scheme operate jointly to stabilize the economy. The optimal parameters for monetary policy remain similar to the model with a dynamic LTV ratio rule. For the tax policy, the optimal parameter value for $\theta_Y$ is 0.35. This implies that the policymakers should increase the tax rate by 0.35% per 1% increase in output. The welfare gain amounts to 1.20% in this model, the highest among all models. This result reinforces the previous findings that the tax scheme is more effective in stabilizing the economy and also improves social welfare. The optimal simple rules provide policymakers with practical and implementable policies to effectively mitigate fluctuations from shocks to the economy.

7. Conclusion

This paper models a New Keynesian DSGE economy with the housing sector and
financial frictions to examine the implication of macroprudential policies. Findings suggest that the countercyclical loan-to-value ratio rule responding to output and housing price changes is effective in stabilizing the economy but causes a credit shift to the business sector. Profit-maximizing banks expand lending in the business sector when restrictions are applied in the housing market. The policy that subsidizes the net worth of banks financed by a tax on lending appears to be more efficient. A welfare analysis shows that macroprudential policies are welfare-improving and that credit stabilization should be an objective for policymakers in the design of regulatory instruments. In addition, optimal macroprudential policies are countercyclical aiming to create a buffering effect for the economy under shock. They help to limit credit growth and price boom in good economic conditions while facilitating more lending in downturns.

The main contribution of this paper is the examination of an economy that is closely related to the recent financial crisis, which began with a housing price boom and coupled with the failure of financial regulation. This model explicitly addresses the financial sector and housing market. Macroprudential instruments target the financial market directly, and can help to reduce systematic risk. The results suggest that if these policies had been preventively adopted before the housing boom in 2007, the housing price and credit growth may have been significantly limited to prevent the later crash. However, the implementation of macroprudential policies may pose a challenge to policymakers because of the great administration and monitoring cost. Nonetheless, this paper offers preliminary insights into the implications of macroprudential tools in a New Keynesian DSGE model with housing and financial frictions. An alternative consideration of financial frictions such as the financial accelerators (Suh 2012) can also be utilized to address the issues studied here. Moreover, investment in housing is not incorporated in this paper and can be extended further to study the real economy more extensively. In addition, explicit credit constraints on non-financial firms are not modeled. The credit shift phenomenon can be further examined when the
firms are regulated jointly with the housing sector.

Further research is needed to study the issues related to macroprudential policy. Appropriate and effective financial regulation poses a challenge to many countries with active financial markets. The literature has not yet reached a consensual view toward the design and implementation of regulatory instruments, and future research is strongly desired to promote financial stability.
Table 1: Parameter Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_a$</td>
<td>0.985</td>
<td>saver’s discount factor</td>
</tr>
<tr>
<td>$\beta_b$</td>
<td>0.95</td>
<td>borrower’s discount factor</td>
</tr>
<tr>
<td>$v_c$</td>
<td>0.9</td>
<td>weight of consumption in utility</td>
</tr>
<tr>
<td>$v_h$</td>
<td>0.1</td>
<td>weight of housing in utility</td>
</tr>
<tr>
<td>$v_l$</td>
<td>2</td>
<td>weight of labor in utility</td>
</tr>
<tr>
<td>$\varphi_L$</td>
<td>0.276</td>
<td>inverse Frisch’s elasticity of labor supply</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.33</td>
<td>fraction of leased housing stock</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.948</td>
<td>survival rate of banker</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.17</td>
<td>fraction of asset that can be diverted</td>
</tr>
<tr>
<td>$\varpi$</td>
<td>0.002</td>
<td>proportional transfer to entering bankers</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.64</td>
<td>patient household’s labor share</td>
</tr>
<tr>
<td>$U$</td>
<td>1</td>
<td>steady state capital utilization rate</td>
</tr>
<tr>
<td>$\delta(U)$</td>
<td>0.025</td>
<td>steady state rate of depreciation</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.03</td>
<td>share of housing in production function</td>
</tr>
<tr>
<td>$\phi_I$</td>
<td>4</td>
<td>capital adjustment cost parameter</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.779</td>
<td>probability of keeping price fixed</td>
</tr>
<tr>
<td>$w$</td>
<td>7.2</td>
<td>elasticity of marginal depreciation</td>
</tr>
<tr>
<td>$\gamma_p$</td>
<td>0.241</td>
<td>measure of inflation indexation</td>
</tr>
<tr>
<td>$\gamma_{\pi}$</td>
<td>1.5</td>
<td>degree of intervention for inflation</td>
</tr>
<tr>
<td>$\gamma_Y$</td>
<td>0.125</td>
<td>degree of intervention for output</td>
</tr>
<tr>
<td>$\rho_r$</td>
<td>0.8</td>
<td>degree of inertia, nominal interest rate</td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>0.85</td>
<td>autocorrelation, technology shock</td>
</tr>
<tr>
<td>$\rho_H$</td>
<td>0.95</td>
<td>autocorrelation, housing shock</td>
</tr>
<tr>
<td>$\rho_R$</td>
<td>0.8</td>
<td>autocorrelation, monetary shock</td>
</tr>
<tr>
<td>$\rho_\xi$</td>
<td>0</td>
<td>autocorrelation, capital shock</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.33</td>
<td>share of capital in production function</td>
</tr>
</tbody>
</table>

Figure A.1: U.S. real housing price index from 1980 to 2013, with 1980=100. Data is taken from the St. Louis Fed.
Figure 1: Figure A.2: Case-Shiller U.S. national house price index, with 2000=100. Data is taken from the St. Louis Fed.

Figure A.3: U.S. mortgage payment to income ratio from 2000 to 2013. Data is taken from the Federal Reserve Board.
Figure 2: Impulse response functions given a productivity shock
Figure 3: Impulse response functions given a housing demand shock
Figure 4: Impulse response functions given a capital quality shock
Figure 5: Impulse response functions given a monetary shock
Chapter 2

Determinants of Sovereign Default– Do Political Factors Matter?

1. Introduction

Sovereign debt crisis has captured the center of attention in the recent global economic recession as several European states fell on the edge of default. Debt restructuring and default have occurred frequently between 1980 and 2000. Specifically, several Latin American countries suffered with debt issues in the late 1980s followed by similar phenomenon in numerous Asian countries during the 1997 East Asian Crisis. Stepping into the 21st century, sovereign debt problems have been rather uncommon and limited in impact until the outbreak of the 2008 Global Recession. At the end of 2009, fears of sovereign debt crisis developed among global investors as the debt level rose around the world accompanied by the downgrading of government bonds in Greece and Spain. International borrowing is subject to a special risk factor referred to as the sovereign risk, which captures the possibility of debt default and restructuring posing significant losses to investors. Global credit market operates distinctively as government borrowings are usually lack of physical collateral. Creditors have limited ability to penalize a country in default and minimal means to recoup lost value. The government plays a critical role in the event of default since it is the ultimate decision maker in this situation. This paper studies both theoretically and empirically the determinants of sovereign default with special focus on political factors. The objective is to explore the effect of political risk on the probability of sovereign default.

A debtor country could default either due to lack of economic resources to repay, or simply unwilling to fulfill the responsibility when capable. Eaton and Gersovitz (1981) is the first to distinguish between ‘ability to pay’ and ‘willingness to pay’. The former is determined by macroeconomic conditions and the latter by political factors. A default

\textsuperscript{3}See Reinhart and Rogoff (2009) for a survey
decision could be highly influenced by political conditions\textsuperscript{4}. Outright example includes default occurred during war time or significant transition of power. A government with sufficient liquidity may be unwilling to render debt incurred by its predecessor. Indirect effects of political orientation are evident from two examples. First, Hungary suffered a consecutive negative GDP growth from 1990 to 1994 after the collapse of the former Soviet Union, and struggled with a prolonged hyperinflation era. The country was on the verge of default several times but managed to find an alternative because the government was in fear of losing support from the Western world in light of default (Verma 2002). On the contrary, Russia voluntarily defaulted on foreign-denominated debt in 1998. The country engaged in an unrealistic fixed-exchange rate regime that was draining out the foreign reserves. The government was capable of making repayments in domestic currency but chose to default on foreign-denominated bonds, which later concluded with a floating currency at the expense of global investors. Argentina fell in similar circumstance later in 2001. Some restructuring and dispute over the Argentinian default even remain unresolved today\textsuperscript{5}. Political consideration has significant impact on the decision of default but is not well studied in the literature. The most common empirical challenge researchers encounter is the ability to accurately measure political risk.

Recent development in constructing large panel data to measure political uncertainty has assisted the study of its impact on sovereign default. This paper utilizes data from the Polity IV project and Freedom House to infer about a country’s political stability by examining "concomitant qualities of democratic and autocratic authority" (Polity IV Project, 2012). Along with other macroeconomic factors, the objective of this paper is to investigate how political characteristics affect the probability of sovereign default. Prior empirical

\textsuperscript{4}Hatchondo and Martinez (2010) discuss the politics of sovereign default in detail. They argue that political turnover causes sovereign default risk to increase dramatically, where a more stable political system reduces the likelihood of default.

\textsuperscript{5}An Argentinian vessel was seized in October, 2012 by debtors from previous default. See http://www.reuters.com/article/2012/10/24/ghana-argentina-ship-idUSL5E8LOHS20121024
research on sovereign debt crisis mostly focus on bond spreads. A surge in bond spread is interpreted as an increase in the probability of default. Political implications may not always be well-represented in bond spreads, but have direct impact on default decisions. In this paper, I use a panel logit model to study the direct link between sovereign default and political characteristics while taking consideration of relevant macroeconomic conditions. Some key findings suggest that a country is more likely to default when i) it has a relatively younger political regime in place; ii) it faces a higher chance of political turnover; and iii) it has a less democratic political system. Economic and liquidity factors are also vital in the sense that a country with stronger growth and less external debt is less likely to experience sovereign default.

This paper also provides a theoretical framework that extends the model by Alesina and Tabellini (1990) to study the effect of political uncertainty on sovereign default decisions. The theoretical connections between political risk and default analyzed in the paper are supported by empirical findings. First, within the model, there is a positive relationship between the probability of potential change in the political party in power and sovereign default. Moreover, consumption falls in light of default. This is consistent with findings from Mendoza and Yue (2011).

The rest of the paper is organized as follows. Section 2 provides an overview of the literature on the determinants of sovereign default. Section 3 discusses the theoretical framework that links sovereign default and political stability. Data, descriptive statistics and empirical specifications are presented in Section 4. Section 5 summarizes the empirical results obtained from the logit model. Robustness and sensitivity analyses are reported in Section 6. Section 7 concludes.

2. Literature Review

This paper builds on the foundation laid by prior work. The first related strand of literature is the theoretical model of sovereign default. Eaton and Gersovitz (1981) emphasizes
on the reason why international lending takes place, and discusses the incentive to repay external debt. Distinction between solvency and political influences is carefully explained. In a follow up paper, Eaton, Gersovitz and Stiglitz (1986) states that 'willingness to pay' contributes more to a default than simple insolvency or illiquidity. In the presence of moral hazard and adverse selection, incomplete information available to lenders also presents difficulties in assessing the borrower’s true ability to pay. One of the pioneer theoretical models taking political risk into consideration is Alesina and Tabellini (1990), which considers the effect of political uncertainty on debt levels and fiscal policy. Ozler and Tabellini (1991) finds the existence of multiple equilibria involving default, when two types of government rotate in power. Following this initial setup, Cuadra and Sapriza (2008) shows that a government may choose to default in light of uncertainty in election results, caused by the ruling party optimally taking excessive debt under precautionary motive. Hotchondo et. al (2009) discusses how the presence of heterogeneous borrowers affects the probability of default when one type of borrower is more patient than the other one. The authors argue that debt level goes up when the patient incumbent fears to be replaced by the impatient whose optimal allocations are less favorable. Arellano and Kocherlakota (2008) models an economy where sovereign default is the result of coordination of domestic entrepreneurs facing difficulties in liquidating large-scale assets.

Numerous research papers try to empirically assess the determinants of credit spreads in emerging markets. Edwards (1984) finds that external debt, debt service, current account balance and international reserves are key factors. Min (1998) studies a broader set of macroeconomic variables and find that in addition to Edwards’ findings, inflation rate, exchange rate and terms of trade also have significant impact on credit spreads. Nonetheless, Westphalen (2001) tests the variables identified in the structural models (funding costs, interest rate, market illiquidity, etc) and finds that these factors only account for one fifth of the variations in sovereign bond spreads. Similarly, Eichengreen and Mody (1998) finds
that changes in macroeconomic variables only explain a fraction of spread variation between 1991 and 1996. In a more recent study, Rowland and Torres (2004) finds that credit ratings are also influenced by macroeconomic variables. Among these empirical papers, political risk factors have received limited attention. Ferrucci (2003) comments on the importance of political factor in explaining the residuals of bond spreads but presents no empirical assessment. Recent development in this matter is presented in Baldacci, Gupta and Mati (2011), which uses a panel of 46 emerging markets from 1997 to 2008 to study the specific impact of political risk and fiscal stability on EMBI spreads\(^6\). The authors find that lower political risk and less effort on fiscal consolidation are associated with tighter spreads.

Quantitative studies on determinants of sovereign default in the past usually focus on specific events. Cline (1995) and Aggarwal (1996) discuss the 1980s’ South American crisis, while Roubini and Setser (2004) and Sturzenegger and Zettelmeyer (2006) focus on more recent cases of crisis. Although many researchers try to find the determinants of sovereign risk and default, few have focused on political and institutional factors. The findings also appear highly inconsistent. Verma (2002) uses a panel of 30 developing countries from 1975 to 1995 to study the determinants of sovereign default and finds that more democratic countries tend to default more. He comments on the inefficient use of borrowed money in countries with higher level of democracy that leads to more defaults. When designing an early warning system for debt crisis, Manasse, Roubini and Schimmelpfennig (2003) finds that before and during a debt crisis, the probability of default is higher for countries with lower ranking in the index of freedom status. By studying 73 countries from 1974 to 2000, Van Rijckegehem and Weder (2009) find that countries with parliamentary system are safe from default when their economic fundamentals are sound. In a related work, Manasse

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\(^6\)EMBI spread is defined as the difference between sovereign bond yield of emerging markets and the US treasury bill rate with comparable maturities.
and Roubini (2009) finds that political instability aggravates illiquidity problem for defaulting countries. Bordo and Oosterlinck (2005) studies a panel of 29 countries from 1880 to 1913 and finds that half of the default incidents occurred during the sample period were around political turnovers. Inconsistent findings motivate further research on the possible link between default and political characteristics.

Among the few work that takes consideration of political risk factors, none of which emphasizes on its direct impact on the probability of sovereign default. Moreover, these studies tend to utilize a narrow period and focus only on developing countries. As mentioned in the introduction, developed countries are also vulnerable to default risk and may be subject to political instability. In addition, the measures of political risk presented in these papers are rather limited with many focus only on the level of democracy and political freedom. The main novelty of this paper is to use a broader set of data with a variety of direct political risk and government stability measures to assess the impact on sovereign default.

3. Theoretical Framework

This section outlines a simple theoretical framework that illustrates the role of macroeconomic conditions and political stability on sovereign default, adapted from Alesina and Tabellini (1990), Ozler and Tabellini (1991) and Cuadra and Sapriza (2008). A survey by Carmignani (2003) reviews the literature on political models involving policy design and macroeconomic outcomes. According to these papers, sovereign borrower faces uncertainty in next period’s election result and is motivated to implement policies to restrain resources available to the potential successor. The strategic use of debt may be helpful in explaining deficit and debt build-up in industrialized countries, as well as default decisions. Political economy theories suggest that elections, government stability and characteristics of the policy maker help to explain debt, deficit and fiscal policy\textsuperscript{7}.

Political uncertainty and instability arise when parties who are heterogeneous in political views compete for power. The timing of election and fragmentation of the government affect the choice of optimal level of debt. In this section, I present a simple two-period model to illustrate the impact of political risk on default decisions.

Consider a two-period model where the generic voter $i$ maximizes:

$$U_i = E \left\{ \sum_{t=1}^{2} \alpha_i u(x_t) + (1 - \alpha_i) u(y_t) \right\} \tag{1}$$

where $E$ is the expectation operator, $x$ and $y$ are two types of public goods consumed each period, $t$ denotes time, and $\alpha_i \in [0, 1]$ is the weight placed on good $x$. The utility function is increasing and concave with $u'(\cdot) > 0$ and $u''(\cdot) < 0$. Without loss of generality, we assume $u(0) = 0$.

There are two political parties, $X$ and $Y$ who compete in the election held at the end of period 1. Each generic party maximizes the same utility function with $\alpha_j, j = X, Y$, where $0 \leq \alpha_Y \leq \alpha_X \leq 1$. In words, this implies party $X$ cares more about good $x$ while party $Y$ emphasizes on $y$. Given the structure of this model, the parameter $\alpha_i$ fully characterizes individual preference and voting behavior, which implies that the median voter theorem applies\(^8\). To create instability, let us assume that the position of the median voter changes with probability $\pi \in [0, 1]$. The existence of $\pi$ creates election uncertainty, where the incumbent party in period 1 is not guaranteed to stay in power next period. Moreover, the difference in $\alpha$ between the two parties create political fragmentation. Both factors are important in determining the probability of default.

In order to finance public expenditure, the government is entitled to one unit of output in period 1, and $e$ units in period 2 where $e \in [1, \bar{e}]$ and is uniformly distributed with a continuous positive density function $dF(e) = 1/(\bar{e} - 1)$. The amount of endowment in

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\(^8\)See Drazen (2000, Chapter 14) for the proof and explanation.
period 2 is designed to be more than that of period 1 in order to induce borrowing for consumption-smoothing. In the beginning of the second period, the value of $e$ is revealed and the incumbent party maximizes its utility taking $e$ as given. The incumbent in the first period can issue debt, which is to be repaid by the incumbent in period 2. Facing a higher endowment in the subsequent period, the party in office in period 1 optimally chooses to incur debt to smooth the supply of public goods. Default occurs when $e$ is less than the amount of debt plus associated interests. In a world without political risk, the government simply borrows to the level where the expected utility of each period is equalized.

The incumbent in period 1 issues bond to foreign risk-neutral creditors facing a real interest rate of zero. Let $b$ be the amount of bond issued in period 1 at price $q(b)$, the government borrows $q(b)b$ and is expected to repay $b$ in period 2. The probability of default is defined by

$$Pr(e \leq b) = F(b) = (b - 1)/(\bar{e} - 1)$$

which increases monotonically with the level of debt. There is zero recovery for lenders when the incumbent defaults. Loans are provided as long as the expected return equals to the gross world interest rate, or

$$1 = \frac{b(1 - F(b))}{q(b)b}$$

this defines the price of the bond $q(b) = 1 - F(b) = (\bar{e} - b)/(\bar{e} - 1)$. As more bonds are issued, the price of bond decreases monotonically to compensate for the default risk that lenders take.

The incumbent in period 1 chooses $(x_1, y_1, b)$ to maximize the total expected utility given the probability of staying in office next period, subject to government budget constraints. Similarly, the incumbent in period 2 observes $(b, e)$ and chooses $(x_2, y_2)$ to maximize the objective function. If $e \leq b$, the government defaults and $x_2 = y_2 = 0$. 
Proposition 2. In the extreme case where \( \alpha_X = 1 \) and \( \alpha_Y = 0 \), the level of optimal debt chosen in period 1 increases with \( \pi \), which is the probability that the incumbent will be replaced in the subsequent period. This implies that the probability of default also increases with \( \pi \).

Proof. When \( \alpha_X = 1 \) and \( \alpha_Y = 0 \), this setup implies that party \( X \) only cares about good \( x \) and party \( Y \) obtains utility solely from good \( y \). Suppose party \( X \) is in power in period 2, then it solves

\[
\max_{x_2, y_2} u(x_2)
\]

s.t. \( x_2 = \begin{cases} 
  e - b - y_2, & \text{if } e \geq b \\
  0, & \text{otherwise} 
\end{cases} \)

The solution to (4) is trivial. \( x_2 = e - b \) if \( e \geq b \) and \( y_2 = 0 \). Party \( X \) only cares about good \( x \), thus it will allocate all available resources net of debt repayment to good \( x \). There is no public supply of good \( y \) in period 2. The opposite applies when party \( Y \) is in office. In the case of full divergence, only the type of good that the government cares about will be supplied in the second period. 

Now, suppose party \( X \) is the office in period 1. It solves

\[
\max_{x_1, y_1, b} u(x_1) + (1 - \pi) E[u(x_2)]
\]

s.t. \( x_1 = 1 + q(b) b - y_1 \)

\[
x_2 = \begin{cases} 
  e - b, & \text{if } e \geq b \\
  0, & \text{otherwise} 
\end{cases} 
\]

With probability \( \pi \), the incumbent loses the election and obtains zero utility since \( x_2 = 0 \) when party \( Y \) is in office. Equilibrium conditions \( y_1 = 0 \) and \( x_1 = 1 + q(b) b \) hold under the case of full divergence. Taking account of the distribution of \( e \) and substitute in the budget constraints from both periods, we can rewrite the problem as
\[
\max_b u(1 + q(b)b) + \frac{1 - \pi}{\bar{e} - 1} \int_b^{\bar{e}} u(e - b) \, de
\]  

(6)

Without loss of generality, assume the discount factor for both parties are 1. The first order condition is

\[
0 = u'(1 + q(b)b)[q'(b)b + q(b)] - \frac{1 - \pi}{\bar{e} - 1} \int_b^{\bar{e}} u'(e - b) \, de
\]  

(7)

Equation (7) characterizes the optimal choice of debt subject to \(\pi\). If \(\pi = 1\), party X is certain that it will be replaced in period 2, then the economy has maximum instability. It is clear that the utility of party X in period 2 will be zero given that no supply of good x will be offered. The first order condition is then reduced to

\[
0 = u'(1 + q(b)b)[q'(b)b + q(b)]
\]  

(8)

An interior solution \(b^*\) is guaranteed given the concavity of \(u(\cdot)\) and the fact that \(q'(b)b + q(b) = 1 - F(b) - dF(b)b = (\bar{e} - 2b)/(\bar{e} - 1)\) in decreasing in \(b\). In this case, party X is only maximizing its utility in the first period where maximum debt would be issued to ensure marginal utility equals to zero. When \(\pi\) moves away from 1, \(-\frac{(1-\pi)}{\bar{e} - 1} \int_b^{\bar{e}} u'(e - b) \, de\) appears making the first order condition to become negative at \(b^*\). The right hand side of equation (7) decreases with \(b^9\), which implies that in order to maintain equality, a lower level of \(b\) is desired.

When \(\pi = 0\), the value of the right hand side of equation (7) is minimized, implying a minimal level of optimal debt. Political instability provides a distorted incentive for the benevolent social planner. When \(\pi > 0\), instability leads to over-issue of government

\footnote{Take derivative of the first order condition with respect of \(b\) and evaluated at \(b^*\) obtains \(2u''(1 + q(b)b)[q'(b)b + q(b)] + 2u'(1 + q(b)b)q'(b) + \frac{(1-\pi)}{\bar{e} - 1} \int_b^{\bar{e}} u''(e - b) \, de < 0\)}
bonds relative to first-best choice under $\pi = 0$. Moreover, a higher level of debt implies a higher probability of default, evidently from the fact that $\Pr(e \leq b) = F(b)$. Note that the symmetric considerations hold if party $Y$ is in office in period 1.

In words, when the probability of being replaced in period 2 decreases, higher political stability implies that the incumbent in period 1 will issue less debt to increase the available resource in the second period. In contrast, when the incumbent is certain to be replaced in period 2, the fact that there would be zero utility provides incentive to issue maximum level of debt to maximize period 1 utility. Moreover, a higher $\pi$ implies less public goods offered in the second period, reducing household consumption.

The general case with $\alpha_j \in (0, 1)$ is mathematically more involved, but the intuition stands unchanged. Political instability induces the incumbent to issue excessive debt to increase consumption while in office and reduce the total resource available for the new party in power next period.

**Proposition 3** When $\alpha_j \in (0, 1)$, there are two opposing effects on the optimal level of debt from an increase in $\pi$. The "composite effect" motivates the incumbent to issue more debt to reduce total resources in period 2, similar to the extreme case before. However, as Party X and Y now care about both goods, the "level effect" implies less debt is desirable to allow more of preferred goods to be offered in period 2. A sufficient condition for the "composition effect" to dominate found by Tabellini and Alesina (1990) is when $-u''(c)/[u(c)]^2$ is decreasing in $c$, where $c$ is the public goods offered.

**Proof.** Suppose party $j$ is in office in period 2. It chooses $(x_2, y_2)$ to solve the problem

$$
\max_{x_2, y_2} \alpha_j u(x_2) + (1 - \alpha_j) u(y_2)
$$

$$s.t. \quad x_2 = \begin{cases} 
    e - b - y_2, & \text{if } e \geq b \\
    0, & \text{otherwise}
\end{cases}
$$
Similar to the full divergence case, when $e < b$, the government defaults and $x_2 = y_2 = 0$. Substitute in the budget constraint, we get the first order condition

$$\alpha_j u'(x_2) - (1 - \alpha_j)u'(e - b - x_2) = 0 \quad (10)$$

Equation (10) explicitly defines the optimal choice of $x_2$ and $y_2$, which are functions of predetermined variables, $(\alpha_j, b, e)$. We can express the policy functions as $x_2 = A(\alpha_j, b, e)$, and $y_2 = B(\alpha_j, b, e)$. It is trivial to see that $\partial A / \partial b < 0$, $\partial B / \partial b < 0$, $\partial A / \partial \alpha_j > 0$, and $\partial B / \partial \alpha_j < 0$. The intuition is that a higher debt level incurred in period 1 reduces the resources to supply either type of public goods in the subsequent period, and a greater weight on good $x$ (higher $\alpha_j$) leads to more supply of this good and less of good $y$. ■

The incumbent in period 1 takes account of political instability and chooses the optimal amount of debt. Again, let party $X$ be in office and $\pi$ be the probability that party $Y$ will win the election next period. Party $X$ chooses $(x_1, y_1, b)$ and solves the problem

$$\max_{x_1; y_1; b} EU^X_{1} = \alpha_X u(x_1) + (1 - \alpha_X)u(y_1)$$

$$+ \frac{1 - \pi}{\bar{e} - 1} \int_b^e [\alpha_X u(A(\alpha_X, b, e)) + (1 - \alpha_X)u(B(\alpha_X, b, e))]de$$

$$+ \frac{\pi}{\bar{e} - 1} \int_b^e [\alpha_X u(A(\alpha_Y, b, e)) + (1 - \alpha_X)u(B(\alpha_Y, b, e))]de$$

$$s.t. y_1 = 1 + q(b)b - x_1$$

Substitute in the budget constraint, we can obtain the first order conditions as:

$$x_1 : 0 = \alpha_X u'(x_1) - (1 - \alpha_X)u'(1 + q(b)b - x_1) \quad (12)$$
\[ b : 0 = (1 - \alpha_X)u'(1 + q(b)b - x_1)(q(b) + q'(b)b) \] (13)
\[ + \frac{1 - \pi}{\bar{e} - 1} \int_b^e [\alpha_X u'(A(\alpha_X, b, e)) \frac{\partial A(\alpha_X, b, e)}{\partial b} + (1 - \alpha_X)u'(B(\alpha_X, b, e)) \frac{\partial B(\alpha_X, b, e)}{\partial b}] de \\
+ \frac{\pi}{\bar{e} - 1} \int_b^e [\alpha_X u'(A(\alpha_Y, b, e)) \frac{\partial A(\alpha_Y, b, e)}{\partial b} + (1 - \alpha_X)u'(B(\alpha_Y, b, e)) \frac{\partial B(\alpha_Y, b, e)}{\partial b}] de \]

Utilizing equation (12), we can rewrite (13) as

\[ 0 = \alpha_X u'(x_1)(q(b) + q'(b)b) \] (14)
\[ + \frac{1 - \pi}{\bar{e} - 1} \int_b^e [\alpha_X u'(A(\alpha_X, b, e)) \frac{\partial A(\alpha_X, b, e)}{\partial b} + (1 - \alpha_X)u'(B(\alpha_X, b, e)) \frac{\partial B(\alpha_X, b, e)}{\partial b}] de \\
+ \frac{\pi}{\bar{e} - 1} \int_b^e [\alpha_X u'(A(\alpha_Y, b, e)) \frac{\partial A(\alpha_Y, b, e)}{\partial b} + (1 - \alpha_X)u'(B(\alpha_Y, b, e)) \frac{\partial B(\alpha_Y, b, e)}{\partial b}] de \]

When \( \pi = 0 \), algebraically, we can reduce equation (13) to be

\[ 0 = \alpha_X u'(x_1)(q(b) + q'(b)b) \] (15)
\[ + \frac{1}{\bar{e} - 1} \int_b^e [\alpha_X u'(A(\alpha_X, b, e)) \frac{\partial A(\alpha_X, b, e)}{\partial b} + (1 - \alpha_X)u'(B(\alpha_X, b, e)) \frac{\partial B(\alpha_X, b, e)}{\partial b}] de \]

It is easy to see that since \( \partial A/\partial b < 0 \) and \( \partial B/\partial b < 0 \), the second term on the right hand side is negative and the first term has to be sufficiently large and positive to ensure an interior solution. Similar to the full divergence case, a solution exists and the incumbent optimally chooses a relatively small \( b^* \). When \( \pi > 0 \), the direction of change in \( b \) with response to an increase in \( \pi \) is ambiguous. First, as indicated in the full divergence case, when the incumbent faces a positive probability of being replaced in the subsequent period, there is an incentive to issue more debt to reduce the total amount of resources available for period 2. The is referred by Carmignani (2003) as the "composition effect". Even party X now cares about both types of public good offered in the second period, the fact that \( \alpha_Y < \alpha_X \) implies that it still prefers good x to good y. This fundamental preference
difference induces the incumbent to issue more debt when facing a possibility of being replaced later. This is the sole effect evident in the full divergence case.

On the other hand, the second effect is exactly opposite in the sense that party Y will provide more of good $x$ when there are more resources available in economy in period 2. Party X has the incentive to reduce borrowing or even save to provide more supply of good $x$ in the future when party Y is in office. This effect is referred to as the "level effect", which takes consideration that when the desired amount of good $x$ is offered in period 2, party X is satisfied even when party Y spends more on good $y$. A sufficient condition for the "composition effect" to dominate found by Tabellini and Alesina (1990) is when $-u''(c)/[u(c)]^2$ is decreasing in $c$, where $c$ is the public good offered in this case.

When there is full stability in the economy, the problem is reduced to a two-period consumption-savings model as the incumbent chooses the optimal amount of borrowing to ensure expected utility of the two periods are identical. Minimal debt will be issued since increasing the amount of debt in period 1 reduces the available resources in period 2. However, the effect on debt of positive values of $\pi$ is more complex. When the "composition effect" dominates, the incumbent in period 1 issues more debt when facing a higher chance of political turnover. Alternative and more complicated formulation provides similar intuition. Hotchondo et. al (2009) find that default may be triggered when there is change in office from patient to impatient type of government when facing high political instability and poor economic fundamentals. The general conclusion is that higher political instability is associated with higher level of optimal government debt, hence greater probability of default. The rest of the paper is dedicated to test the theory empirically taking consideration of political risk factors and macroeconomic fundamentals. The key question to study is whether political instability increases the likelihood of sovereign default.

4. Data and Empirical Specification

A panel logit model is adopted in this paper to find key determinants of sovereign
default. This study is based on data from 68 countries over a 40-year period from 1970 to 2010. Among these countries, 25 are developed nations and 43 are emerging markets. Overall, 95 incidents of external and domestic defaults were identified during this period. This implies that the probability of sovereign default is about 2.74%, which appears to be consistent with existing literature\textsuperscript{10}. This time interval is chosen to cover major defaulting events in the 1980s and 1990s, as well as the recent financial recession to shed lights on the ongoing Eurozone debt crisis.

The dependent variable is probability of default. In recent empirical studies, serious debt renegotiation and rescheduling agreements also count towards default. In this paper, default data is taken from Reinhart and Rogoff (2009), which includes episodes of both domestic and external default for 70 countries from 1800 to 2010. External default is defined according to IMF’s definition, which includes "failure to meet principal or interest payment and rescheduled debt that is in terms less favorable than the original obligation" on foreign debt. Domestic debt crisis includes similar definitions applied to government bonds issued in domestic markets and also considers "freezing of bank deposits and/or forcible conversions of these deposits from dollars to local currency"\textsuperscript{11}.

For example, Argentina has experienced a domestic default in the end of 2001 when the government declared state emergency to prevent bank runs and limited conversion of pesos to USD. The government later defaulted on parts of its external debt in the beginning of 2002, causing massive capital flight and currency devaluation. It is evident that in many cases, domestic and external default occurred in close proximity of each other. In the timespan covered in this paper, only three distinctive domestic defaults were found: El Salvador in 1981, Myanmar in 1984 and Sri Lanka in 1996 (See Table 1 for a full list).

\textsuperscript{10}Benjamin and Wright (2009) estimates the default rate across countries to be 4.4% for the period 1989-2006. Yue (2010) reports the average default rate of Argentina since 1824 is 2.7%. 3% is the conventional rate preferred by most papers.

\textsuperscript{11}These definitions are taken from IMF, 2003, External Debt Statistics: Guide for Compilers and Users, Appendix III, Glossary, IMF, Washington DC.
To avoid double-counting, we aggregate over both domestic and external defaulting events and construct a new binary variable, Default, where

\[
Default_{t,i} = \begin{cases} 
1 & \text{if a country } i \text{ is in domestic and/or external default in year } t \\
0 & \text{otherwise}
\end{cases}
\]

The logit model assumes that the probability of default is related to a set of political and macroeconomic variables, \( X_i \), in the following form:

\[
\text{prob.} = P(\text{Default}_{t,i} = 1 \mid X_i) = \frac{e^{X_i'\beta}}{1 + e^{X_i'\beta}} = \Lambda(X_i'\beta)
\]  

(16)

where \( X_i \) is a vector of independent variables, \( x_k \) for all periods up to \( t - 1 \). The estimated coefficients, \( \beta_k \), is the percentage effect of a change in \( x_k \) on the odds ratio defined as

\[
\text{Odds Ratio} = \frac{P(\text{Default}_{t,i} = 1 \mid X_i)}{P(\text{Default}_{t,i} = 0 \mid X_i)}
\]  

(17)

In a panel logit model, these estimates only provide the direction of impact from a change in \( x_k \), rather than magnitudes of change in the probability of default. In contrast, the marginal effect measures the elasticity of an exogenous variable with respect to the probability. Specifically, it is defined as

\[
\text{Marginal Effect} = \frac{dP(\text{Default}_{t,i} = 1 \mid X_i)}{dX_i} = \beta_i \Lambda(X_i'\beta)
\]  

(18)

Both the estimated coefficients, \( \beta_k \), and marginal effects are reported in this paper. The explanatory variables are:

**External Debt Conditions:** these variables account for the liquidity and solvency of the borrowing nation, which have been found significant in Manasse, Roubini and Schimmelpfennig (2003) and include: i) external debt as a percentage of GDP, which is an indi-
cator of 'ability to pay'; ii) (log) interest in arrears for public and publicly guaranteed debt, which measures the amount of interest payments not paid during any given year. A country is highly likely to experience a debt crisis when the interest owed is high.

**Macroeconomic Conditions:** these variables measure the economic performance of a borrowing nation and include: i) trade openness, which is the sum of imports and exports as percentage of GDP and is expected to have negative effect on default; ii) GDP growth, which is a key indicator for economic condition. A faster economic growth implies greater ability to generate cash flow and attract investments.

**Government/Election Conditions:** these variables measure political stability and election competitiveness, which include i) duration of current political regime. For example, Turkey held a general election in 1983 after the military took over the government in 1980. It has been running the same political regime for the 27th year in 2010. A more tenured political system implies less regime changes and higher long-run stability; ii) years in office, which is the number of years the current incumbent party is in office. The longer the ruling party stays in power, the higher the likelihood of an election or change in government executive in the near future, which then implies greater short-run instability; and iii) executive electoral competitiveness, which is measured on a scale of 1 to 7, with 1 implying no election (in the case that rival chief executive in power) and 7 referring to executives being elected competitively by the general population. A communist country like China gets a score of 3 as the chief is elected by the Party Congress. The expected effect is two-fold: higher electoral competitiveness implies greater political liberty and democracy, but induces higher instability as elections are more frequent. Data is taken from Beck et al. (2001) and updated by the author using the Database of Political Institutions (DPI) complied by the World Bank.

**Investment Conditions:** these variables capture the general condition of investments, which include i) the 6-month US T-bill rate, which is expected to have positive impact on
default probability as a higher borrowing rate implies greater difficulties for debtor countries to service their obligations; and ii) the net foreign direct investment as a percentage of GDP. Higher inflow of foreign capital serves as a positive sign for investment, which should have a negative effect on sovereign default probability.

**Political risk:** political factors are captured by the Polity score developed under the Polity IV Project, which is a data series commonly used in political science research. The new dataset contains an aggregate score that measures a country’s level of democracy based on evaluations on the competitiveness, openness and level of participation in elections\textsuperscript{12}. This score is centered around 0 and has positive values for high level of democracy, implying lower political risk, and negative score for autocratic countries. For robustness test, two alternative measures constructed from data published by the Freedom House, a US-based non-for-profit organization, are used: i) freedom of the world, which is the average of the political rights and civil liberty scores published in the annual *Freedom in the World* survey since 1970. It is reformatted to take values 1 to 7 with 7 implying highest level of freedom; ii) freedom of the press, which is the average of freedom in public print and broadcast. The data is taken from the annual *Press Freedom* survey since 1980 and takes on the value of 1 to 3 with 3 being free and 1 as not free.

All data is taken from the *International Financial Statistics* and the *World Development Indicators* published by the World Bank unless otherwise noted. Table 1 summarizes the events of default for 68 countries from 1970 to 2010 and Table 2 presents the descriptive statistics of variables included in the regression. The baseline model is estimated using random effects panel logit regression with maximum likelihood estimators. All explanatory variables are lagged one period to predict for the probability of default in the subsequent period. Robustness test includes fixed effects estimation, two alternative measures of political risk and panel OLS regression on EMBI (Emerging Market Bond Index) bond spreads

\textsuperscript{12}See the description of the project at http://www.systemicpeace.org/polity/polity4.htm
5. Estimation Results

Panel regression results are presented in this section. Table 3 presents results of the baseline model using random effects estimation. The first column reports the impact of Polity score on the probability of default, the second column analyzes the additional effect from external debt conditions (external debt to GDP and interest in arrears). The third column takes consideration of macroeconomic conditions (trade and GDP growth). The fourth and fifth column report the augmented model where the significance of political factor is assessed while controlling for government stability and investment conditions.

The results show that the political factors remain significant under all specifications with the expected signs. The probability of default is higher for countries with lower Polity scores. Moreover, duration of the political system is another key variable that measures stability. The results show that a country with longer political regime in place has less chance to default. The external debt to GDP ratio and interest in arrears have positive impact on sovereign default as they are the first and foremost indicators of a nation’s liquidity condition. GDP growth and trade volume exert negative pressure on the probability of default as these are measures of overall economic health of the borrowing country. In terms of global investment conditions, the US short-term policy rate serves as a proxy for the international credit market, and higher rate implies a higher probability of default. This finding shows that when the borrowing condition is tightened, countries face extensive barriers to raise new debt or renew their existing obligations, which may ultimately lead to a default. Net foreign direct investment is also significant and has negative impact on default risk. A slump in net inflow of foreign capital stalls domestic economic growth, causing greater difficulties to generate sufficient cash flow to service debt obligation. This is especially evident in developing countries experiencing sudden stops and flight to quality.

\footnote{I thank Ying Chen and Xin Yan for collecting these data from Bloomberg Terminal.}
It is clear to see that years in office exert a positive pressure on default. Consistent with the hypothesis made previously, when the current ruling party stays in power for an extensive period, the chance of running an election in the immediate future increases. According to the model in Section 3 and findings by Hotchondo et.al (2009), this is a clear sign of short-term political instability and has a positive influence on the probability of default.

The impact of electoral competitiveness shows mixing results. It appears to be have a significant and positive influence on default in column (5) but is not significant in (4). Positive signs associates higher probability of default with competitive elections, but the inconsistent significance level provides us with no further inference. In summary, most results are consistent with the hypotheses and there is a strong, positive relationship between political risk and the probability of default, consistent with the theoretical model presented in Section 3.

Nonetheless, the estimated coefficients of the logit model offer only the direction of impact but no inference on the magnitude. To study quantitatively the effect of these explanatory variables on the probability of default, marginal effects must be carefully examined. Table 4 reports the marginal effects corresponding to the regressions in Table 3.

Theoretically,

$$\text{Marginal Effect} = \frac{\partial}{\partial X} P(Default_{i} = 1 | X_{i})$$

(19)

which measures the elasticity with respect to the independent explanatory variable. For the full model specification shown in column (5) of Table 4, a 1% improvement in GDP growth decreases the probability of default by 1.71%. A country with 1% higher debt to GDP ratio is 0.8% more likely to default next year. Similarly, an one-year increase in duration of political regime decreases the probability of default by 1.45%. Since the
Polity score is centered around 0 and ranges from -9 to 10, a more autocratic country such as Zimbabwe (score of -4) is nearly 7% more likely to default in any particular year than a highly democratic country like the US (score of 10), ceteris paribus. In terms of government stability, one additional year in office for the ruling party increases the chance of default by 1.2%. More significant impact comes from investment conditions where a 1% increase in net foreign direct investment to GDP ratio implies a drop of 2.96% in the likelihood of default. A 25-basis point increase in the 6-month US T-bill rate implies an increase of nearly 1% in the probability of default.

Overall, the baseline model provides empirical evidence that supports the theoretical framework presented in Section 3. The next section presents several sensitivity analyses.

6. Robustness Tests

This paper focuses on finding the impact of political risk on the probability of sovereign default and our results are robust to various alternative specifications. Table 5 presents alternative results of the full model (as in Column (5), Table 3). First, in addition to the random effects estimation in the baseline model, fixed effects model is also used to ensure consistency of the model in presence of country-specific effects. To check if these country-specific effects are orthogonal to other covariates in the model, a Hausman specification test is conducted to verify if the random effects model is biased. The test fails to reject the null hypothesis that both models are correctly specified and shows that the fixed effects model is no more efficient than its counterpart. The results presented in Column Fixed Effects show that all variables remain significant with consistent signs.

Political risk can be assessed in multiple dimensions. Common factors include the level of democracy, freedom in the society, and freedom of speech (Howell, 2002). The Polity score measures the degree of democracy in the political system and elections, but is limited in the assessment of civil liberties. The regime duration variable measures the long-run stability of a political system, but does not evaluate the level of efficiency. To
explore a broader valuation of political risk, we have included two alternative measures for robustness check. The *Freedom in the World* survey conducted annually provides scores on the level of political rights and civil liberties in participating nations, and the *Press Freedom* survey assesses the degree of print, broadcast and internet freedom of countries across the world. The estimation results using these two measures are presented in Table 5, Columns *Freedom in the World* and *Freedom of the Press*. The alternative political risk measures and other variables remain significant with the expected signs. Overall, political factors have significant impact on the probability of default. A country is more likely to experience a default when it is less free and democratic, and with greater political instability.

The last robustness test utilizes selected sovereign bond spreads (annual averages) obtained from EMBI for 25 countries\(^{14}\). When the borrowing condition worsens, bond spreads in EMBI increases as the debtor nation has to offer a higher rate to obtain new funding. Similar to the probability of default, we should observe a negative relationship between the spreads and political risk. A high level of bond spread is a clear indicator of sovereign debt issues and one of the earliest signs of default. Balacci et. al (2011) finds that political and fiscal risk factors are key determinants of quarterly EMBI spreads using a different set of measures for political uncertainty. Taking the spreads expressed in percentage and running a panel OLS regression on the same set of explanatory variables used in the previous analyses, it is evident to see that Polity IV score remains significant with a negative sign. However, interest in arrears, political system duration, years in office and foreign direct investments become insignificant. One explanation for this is that the bond spreads taken are annual averages, which may not reflect the spontaneous effect of certain news coming into the market. Given that we are using lagged variables to project for future default risk, the effects from these variables may have already been incorporated into the spreads at an

\(^{14}\)The countries included are: Argentina, Brazil, Chile, China, Columbia, Cote D’Ivoire, Dominican Republic, Ecuador, Egypt, El Salvador, Ghana, Hungary, Indonesia, Malaysia, Mexico, Nigeria, Panama, Peru, Phillips, Poland, Russia, South Africa, Turkey, Uruguay, Venezuela
early time of the year. The remaining variables are significant with the correct signs.

A 1% increase in the US T-bill rate would cause the bond spreads to go up by 64 basis points. With other variables held constant, an one-unit improvement on the Polity score lowers the spreads by 7 basis points. Moreover, an one-percent increase in GDP growth implies a drop of 61 basis points in annual bond spreads. These findings suggest that the Polity score along with liquidity and macroeconomic conditions are significant determinants of sovereign bond spreads, which implies that these variables are tightly connected to default. It is interesting to see that electoral competitiveness remain weakly significant for all alternative specifications with a positive sign, implying that a more competitive executive election system increases the probability of default, which may be caused by having more complex and frequent elections.

Two additional sensitivity analyses are performed using data from only developing countries and considering external and domestic defaults separately. There are no evident changes in the results considering only developing countries, which implies that since most incidents of sovereign default occurred in emerging markets, the additional data from developed countries adds no significant value to the explanatory power. Nevertheless, this does not conclude that developed countries are free of default risk. The baseline results presented in Section 5 suggests that we should focus on the political and economic conditions when assessing the probability of default, rather than the country’s name. Moreover, no significant change is found when regressing against external default only. However, many variables fail to remain significant when regressing against domestic default only. During the period of 1970 to 2010, there were only 26 incidents of default on domestic bonds compared to 69 external defaults. In most cases, domestic debt crises occur in near vicinity of external default when countries suffer from political and economic challenges. Given that only three incidents of domestic defaults occurred independently, finding the determinants of these events remains outside the scope of this paper.
7. Conclusion

This paper utilizes a new set of panel data constructed under the Polity IV project to study the specific effect of political risk on domestic and external default. The findings suggest that political stability is a significant factor in determining the probability of sovereign default. Liquidity measures, macroeconomic variables and the world economic condition are also strong indicators of potential debt issues and should be carefully assessed. Most papers in this literature focus only on economic factors and overlook the importance of political characteristics, or only study the effect on sovereign bond spreads. This paper fills the gap and examines the direct effect of political and institutional factors on the probability of default. To conclude, a country with higher level of democracy and freedom, along with consistent political regime is less likely to experience sovereign default. In contrast, near-future elections and higher debt to GDP ratio imply greater chance of default.

Sovereign default incidences are usually followed by immense economic cost to the country. Hatchondo et al. (2010) also describes the significant political cost accompanying credit default. This paper provides inevitable evidence in which political factors have substantial influence on default decisions. Nevertheless, more attention is desired in the research of the potential effect of political characteristics on sovereign credit crisis. Several challenges remain with the collection of quality measurements to measure different aspects of political risk, along with the small amount of actual default episodes. In addition, sovereign default usually occurs jointly with currency or banking crises. Thorough consideration of the financial and trade sectors in the context of political environment may contribute to dismantling the logistics behind sovereign default. Future research on the political influence on twin crises can be beneficial for policymakers in evaluating the cost and benefits associated with default and make economically efficient decisions.
Table 1 – Episodes of Sovereign Default from 1970 to 2010

<table>
<thead>
<tr>
<th>Country*</th>
<th>Year of External Default</th>
<th>Year of Domestic Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>1991-96</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>1983-90</td>
<td>1986-87, 1990</td>
</tr>
<tr>
<td>Chile</td>
<td>1972, 1974-75, 1983-90</td>
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</tr>
<tr>
<td>Cote D’Ivoire</td>
<td>1983-98, 2000-09</td>
<td></td>
</tr>
<tr>
<td>Egypt</td>
<td>1984</td>
<td></td>
</tr>
<tr>
<td>El Salvador</td>
<td></td>
<td>1981-96</td>
</tr>
<tr>
<td>Greece</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>Guatemala</td>
<td>1986, 1989</td>
<td></td>
</tr>
<tr>
<td>Honduras</td>
<td>1981-2010</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>1972-76, 1989-90</td>
<td></td>
</tr>
<tr>
<td>Kenya</td>
<td>1994-98, 2000-01</td>
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</tr>
<tr>
<td>Mexico</td>
<td>1982-90</td>
<td>1982</td>
</tr>
<tr>
<td>Morocco</td>
<td>1983, 1986-90</td>
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Table 1 – Episodes of Sovereign Default from 1970 to 2010 (con’d)

<table>
<thead>
<tr>
<th>Country*</th>
<th>Year of External Default</th>
<th>Year of Domestic Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myanmar</td>
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<td>1984</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>1979-2010</td>
<td>1985-90</td>
</tr>
<tr>
<td>Panama</td>
<td>1983-96</td>
<td>1988-89</td>
</tr>
<tr>
<td>Paraguay</td>
<td>1986-92, 2003-04</td>
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<tr>
<td>Phillipines</td>
<td>1981-92</td>
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<tr>
<td>Poland</td>
<td>1981-94</td>
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<tr>
<td>Romania</td>
<td>1981-83, 1996</td>
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</tr>
<tr>
<td>South Africa</td>
<td>1985-87, 1989, 1993</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>1997-98</td>
<td></td>
</tr>
<tr>
<td>Tunisia</td>
<td>1979-82</td>
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<tr>
<td>Zambia</td>
<td>1983-94</td>
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<tr>
<td>Zimbabwe</td>
<td>1965-74, 2000-09</td>
<td>2006</td>
</tr>
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</table>

*Countries without default: Austrilia, Austria, Belgium, Canada, China, Columbia, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Korea, Mauritius, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, UK and USA.
Table 2  Summary of Descriptive Statistics

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<th>Obs.</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<th>Max</th>
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<td>Trade</td>
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<td>4.2222</td>
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<td>27.4240</td>
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<td>201</td>
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<td>13.8000</td>
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<td>Foreign direct investment/GDP</td>
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<td>4.0663</td>
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Table 3 Logit Estimation Results – Baseline Model

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<td>Polity</td>
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<td>-0.0184**</td>
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<td></td>
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<td>(0.0083)</td>
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<td>(0.0102)</td>
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<td>Debt/GDP</td>
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<td>0.0186***</td>
<td>0.0188***</td>
<td>0.0303***</td>
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<td>(0.0036)</td>
<td>(0.0038)</td>
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<td>Interest in Arrears</td>
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<td>0.4087***</td>
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<tr>
<td></td>
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<td>-0.0300***</td>
<td>-0.0203**</td>
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<td>(0.0072)</td>
<td>(0.0079)</td>
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<td>-0.0558**</td>
<td>-0.0695***</td>
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<td>(0.0215)</td>
<td>(0.0222)</td>
<td>(0.0249)</td>
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<td>-0.0589***</td>
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<tr>
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<td>(0.0139)</td>
<td>(0.0154)</td>
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<td>Year in Office</td>
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<td>0.0487**</td>
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<td>(0.0206)</td>
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<td>Electoral Comp.</td>
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<td>(0.0849)</td>
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<tr>
<td>US Policy Rate</td>
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<td></td>
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<td></td>
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<tr>
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<td>958</td>
<td>894</td>
<td>853</td>
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<td>Pseudo R²</td>
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<td>0.3361</td>
<td>0.3468</td>
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standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01
Table 4  Marginal Effects – Baseline Model

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<th>Variable*</th>
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<th>(5)</th>
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<td>-0.0043**</td>
<td>-0.0047**</td>
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<td>(0.0020)</td>
<td>(0.0024)</td>
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<td>Debt/GDP</td>
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<td>0.0045***</td>
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<td>(0.0016)</td>
<td>(0.0018)</td>
<td>(0.0020)</td>
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Observations 2715 962 958 894 853

standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01
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<th>Variable</th>
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<th>FP</th>
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<td>Polity Factors</td>
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standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01
Chapter 3

Eurozone Sovereign and Bank Interdependencies: Evidence from the CDS Market

1. Introduction

The outbreak of the 2007 subprime crisis in the United States has soon escalated to a global disease that weakened the world financial market and threatened to derail the economies across the globe. At the early stage of the crisis, financial challenges were relatively contained in the US with minimal spillover effects to the European economies. Between 2007 and 2008, some international banks and institutions fell on the verge of collapse and significantly increased the tension of the world financial market. Credit default swap (CDS) spreads of major European banks evidently increased after July 2007 when S&P issued a credit watch alert for mortgage-backed securities (MBS). However, investors remained insensible to the European sovereign credit risk at this stage as reflected by the low levels of sovereign CDS spreads. Nonetheless, the bankruptcy of Lehman Brothers acted as a turning point in the market sentiment and sovereign credit risk has soon became a serious problem in many European countries.

Figure 1 plots the sovereign and bank CDS spreads for eleven developed countries in the eurozone from 2006 to 2012. Bank CDS spreads dramatically increased in mid-2007 when the sovereign CDS spreads remained relatively stable. On September 15, 2008, the day when Lehman Brothers filed for Chapter 11 protection in the US, the Greek sovereign CDS spreads were only around 50 basis points, or equivalent to 0.5%. Similar patterns were found for Ireland where the CDS spreads remained steady at around 30 basis points. Nonetheless, as more European banks became affected by the financial condition in the US, the "too big to fail" syndrome emerged and followed by banks’ requests for substantial government bailout. Consequently, as the cost of bank bailouts evolved into an unbearable burden, sovereign debt markets in several countries came under immense stress in early 2010. Massive sell-off of Greek government bonds has led to a jump in CDS spread to over
1000 basis points.

Archarya et al. (2013) describe a two-way feedback effect between banking and sovereign risk. They present a model in which bank guarantees by sovereigns were carried out by excessive debt that had a negative impact on public finances. As a result, the value of bailout eventually diminished and the increasing sovereign credit risk has deteriorated the banks’ balance sheet. Gennaioli et al. (2012) present a contrary model where sovereign default risk is the primary factor of banking crisis. In their model, banks hold significant amount of government bonds and become highly sensitive to sovereign credit risk. When fiscal condition worsens, default risk increases and subsequently leads to a rise in bank credit risk.

The existing literature suggests that bank and sovereign credit risks should be interlinked with an increasing correlation during crisis. If we follow the timeline of the recent experiences, the subprime crisis first affected major banks and institutions across the world. Subsequently, massive bailout programs structured by sovereigns were financed by excessive borrowings that tightened the fiscal constraints. During this process, a risk transfer between banks and sovereigns should be observed as bailouts reduce financial fragility at the cost of public finances. Nevertheless, investors incorporate the increasing sovereign risk when pricing bank bonds, resulting in a looping effect between banks and sovereigns.

This paper studies the interdependence between sovereigns and the financial sector using evidence from the European CDS market for the period between 2006 and 2012. This time frame is selected to provide a full analysis of the before, during and after effects of the crisis. The existing literature primarily focuses on the crisis episode and lacks investigation of the potential changes over time. In addition, this paper explores the relative speed of price adjustment in bank and sovereign CDS markets and uses this information to study the changes in the bidirectional relationship between sovereigns and banks over the course of the crisis, which has not yet been examined in the current literature.
The first part of this paper presents a stylized model to illustrate the two-way relationships between sovereign and the financial sector. Based on the theoretical framework, empirical analysis begins with the examination of the comovement patterns between sovereign and bank CDS spreads and their changes over time. The study then proceeds to investigate whether a common set of risk factors can be used to explain changes in the two CDS spread series. The lead-lag relationship in the price adjustment process is examined next. A leading role in price discovery implies a faster response to permanent shocks and may suggest that the crisis affects the leading sector first. This provides additional information in determining the direction of impact between the sovereign and bank CDS spreads. The last section studies the effect of sovereign bond yield on bank CDS spreads to identify possible evidence of a risk transfer as suggested by Archarya et al. (2013).

There are three main findings in this paper. First, there was minimal comovement between bank and sovereign CDS spreads at the country level before the crisis. Correlations increased significantly after the outbreak of the subprime crisis but notably dropped in the periods between the Lehman Brothers bankruptcy and first Greek bailout in May, 2010. Since then, the correlations have remained high until the end of 2012. Secondly, the same set of global risk factors could explain variations in both bank and sovereign CDS spreads after 2007 and both time series became highly sensitive to the financial sector since the Lehman Brothers bankruptcy. Lastly, the study of price dynamics revealed that bank CDS spreads assumed the leading role prior to the subprime crisis but gradually faded out during the course of the eurozone debt crisis. This suggests that after the outbreak of the financial crisis, investors have interpreted the sovereign credit risk as the main source of banking risk and traded sovereign CDS contracts to hedge financial risk. These results suggest that the financially stressed banks were initially relieved by the governments’ implicit and explicit guarantees and experienced a temporary risk transfer to the sovereigns. However, as massive bailout programs were structured and implemented, the deteriorating fiscal conditions
have led to a reverse spillover effect from the sovereigns to the financial sector. As globalization unites the world financial sector, a small problem in a country’s banking sector could quickly turn to serious challenges across the world and aggravates to affect countries’ credit risk. Policymakers should take careful consideration of the potential spillover costs when evaluating government policies.

The rest of this paper is organized as follows: section 2 provides a literature review of related works and section 3 presents the theoretical framework linking sovereigns and banks. Section 4 describes the data and methodology and section 5 analyzes the results. Section 6 concludes.

2. Literature Review

This paper is related to at least two main strands of literature. The first line studies the relationship between sovereign and bank risk. Reinhart and Rogoff (2011) study the debt cycles underlying serial debt and banking crisis using a large set of panel data covering over 70 countries that spans over two centuries. They find that banking crisis usually precedes or accompanies sovereign debt crisis, and may contribute to the prediction of the latter. Their findings suggest that the 2010 eurozone sovereign debt crisis was typical following a global financial crisis. Erce and Balteanu (2012) explore the empirical link between banking crisis and sovereign default, and distinguish between independent crises and twin crises. They find that among the twin crises, the conditional probability of a bank crisis following sovereign default is similar to the conditional probability of the other direction. In addition, twin crises are found to cause greater aftermath cost to the economy, along with higher fiscal imbalances than independent crises. Bolton and Jeanne (2011) study the role of banks in transmitting effects from government default in financially integrated countries. They find that banks optimally diversify their holdings of sovereign debt in financially integrated economies. However, a lack of fiscal integration results in an ineffective supply of government bonds even without bailout. Gennaioli et al. (2012) present a model of
sovereign debt crisis in which it deteriorates the balance sheet of domestic banks and may lead to a financial sector meltdown. Historical events in Russia, Ecuador, Pakistan, Ukraine and Argentina support this model. In contrast, Archarya et al. (2013) supports the other direction where public debt rises dramatically after the issuance of implicit and explicit guarantees to rescue troubling banks. The worsening fiscal conditions in turn add additional pressure on the fragile financial sector, suggesting the presence of a two-way feedback effects between banks and the government.

Empirical analyses of the direction of effect between sovereign debt and banking crisis also show contradicting evidence. Alter and Schuler (2012) find that bank bailout programs could change the balance sheets of both banks and sovereigns, leading to greater linkage between the two sectors. Before bailout, the contagion disperses from bank CDS spreads to the sovereign, but the direction reverses after bailout programs are implemented. However, Bai and Wei (2012) find evidence of a transfer from the sovereign risk to corporate default risk using CDS spreads. Beirne and Fratzscher (2013) analyze the determinants of sovereign risk of 31 countries during the eurozone sovereign debt crisis and find that the deterioration in countries’ fundamentals, including the banking sector, are the main drivers of the rise in sovereign bond yields. Mody and Sandri (2012) also find that financial stress was the main driver of changes in sovereign bond spreads during the crisis period. Their empirical analyses show that bond spreads have became increasingly sensitive to the financial risk over the course of the crisis. Von Hagen et al. (2011) find that investors have strongly penalized fiscal imbalances when pricing sovereign bonds after the collapse of Lehman Brothers. Nonetheless, Longstaff et al. (2011) study the determinants of sovereign credit risk and find that macroeconomic variables and global financial risk factors were the main driver of sovereign bond spreads. Gerlach et al. (2010) find that the same set of risk factors can explain changes in both sovereign bond spreads and yield spreads of the banking sector.
The second strand of literature relates to the study of sovereign risk spillover across countries in the recent crisis. Kalbaska and Gatkowski (2012) use CDS data from 8 European countries and find that correlation and cross-country interdependencies have increased significantly after August 2007. Similar results are found in Calice, Chen and Williams (2011). Manasee and Zavalloni (2013) address the question of whether there is evidence of financial contagion in the eurozone, and to what extent can market fundamentals explain the increasing correlations. They find that the effect of Greek crisis was largely contained in the eurozone, in contrary to the US subprime crisis. In addition, market fundamentals can explain up to 80% of cross-country variations in idiosyncratic risks. Mink and de Haan (2013) examine the impact of news about Greece and Greek bailout on 48 bank stock prices. They find that news about bailout have led to abnormal returns in eurozone countries and investors consider bailout as a signal of governments’ willingness to combat financial crisis. As a result, sovereign bond prices of some eurozone countries have reacted negatively to news concerning Greek bailout. This supports the presence of a risk transfer between banks and sovereigns, at least in the case of Greece. Fontana and Scheicher (2010) study the price dynamics of the European sovereign CDS and bond markets and find that the recent reprising of sovereign debt is largely due to common risk factors. They also find that since late 2008, CDS spreads have exceeded bond spreads, which may have been caused by "flight to liquidity" effects in the sovereign bonds market.

3. A Stylized Model

This section presents an extended model of Bolton and Jeanne (2011) that explores the bidirectional linkage between government debt and financial risk. In this setup, bankers with an investment opportunity use their holding of government bonds as collateral to borrow in the interbank market. When sovereign default is expected, the collateral value falls to zero and interbank lending ceases. Aggregate investment and consumption falls as bankers can only invest their endowment. Nevertheless, banking risk may also have a direct
impact on sovereign debt. When the banking sector faces liquidity challenges, the govern-
ment terminates its investment project prematurely to obtain fundings to bailout banks.
Loss of revenue from the investment project leads to higher taxation to finance government
expenditures and lowers aggregate consumption. This also aggravates financial risk as the
value of government bonds erodes. The feedback effect is also found in Acharya et. al
(2011), which models the two-way linkage more explicitly through optimal bailout size
and tax rate. A simple model is presented next to establish theoretical guidelines for the
subsequent empirical analyses.

Consider an economy with three periods, $t = 0, 1, 2$, and consists of a government and
a private sector where each has an investment opportunity. There is a public good and
a homogeneous consumption good. Private consumption takes place in all three periods
but government consumes only in the last period. The government takes its investment
opportunity in period 0, and captures the realized returns in period 2. Interim withdrawl in
period 1 would terminate the investment project and provide no excess return. In contrast,
the private sector makes investment decisions in period 1 and realizes the returns in period
2.

The government issues debt, $g$, to the private sector to raise funding for investment. In
period 2, the government uses investment return, $G$, where $g < G < 2g$, to finance an
equal and fixed level of expenditures on public goods. The government can only recover
the initial investment $g$ in the event of an early termination. In addition, the level of debt
repaid by the government in the final period is $b$. The government is risk-neutral and seeks
to maximize total consumption in the economy.

The private sector consists of a continuum of identical agents of mass 1. Let $c_t \geq 0$ be
the private consumption in period $t$, then the utility function of the private agents is given
by

$$U = c_0 + c_1 + c_2$$ (1)
All agents serve as both households and bankers, and only a fraction has access to an investment opportunity available in period 1. The existence of the banking sector is merely for the purpose of reallocating savings from banks without investment opportunities to banks with an investment opportunity, thus differs from the traditional independent financial intermediaries. Let $y_t$ and $p_t$ denote respectively bankers’ endowment and the price of government debt in period $t = 0, 1$, then the budget constraints for individual bankers and the government are respectively given by

$$g = p_0 b$$  \hspace{1cm} (2)$$

and

$$c_0 + p_0 b = y_0$$  \hspace{1cm} (3)$$

Banks purchase government debt securities in period 0 to use as collateral to borrow in the interbank market. This assumption directly links the value of government debt to aggregate investments and the banking sector. Bankers remain identical until the beginning of period 1 when they are divided into two groups. The first group of bankers with mass $0 < m < 1$ has access to an investment opportunity that pays $I + f(I)$ in period 2, with an investment of $I \geq 0$ in period 1. The return function of investment satisfies the usual INADA condition, and reaches its maximum at $I = I^*$. The second group of bankers with mass $1 - m$ has no access to the investment opportunity, and will lend to first group. Interbank loans are limited by the collateral value of the government bonds in period 1, or $p_1$. A lower price reduces bankers’ investment and affects private consumption. Assume that the collateral has to be held to maturity, then the maximum amount of investment for each banker is

$$I = y_1 + p_1 b$$  \hspace{1cm} (4)$$
The aggregate demand for loans must be equal or less than the total supply to ensure each banker can borrow up to the maximum value. Therefore, the following condition is assumed to hold:

\[ md = m p_1 b \leq (1 - m) y_1 \]  
\[ \text{or } y_1 \geq \frac{m}{1 - m} d \]  

where \( d \) is the amount of interbank loans between bankers. Interbank loans are assumed to be riskless, and bankers with an investment opportunity would repay their debtors \( d \) in period 2. Bankers with an investment opportunity seek to invest the optimal amount \( I^* \) if they have sufficient funding. To ensure all interbank loans are utilized, another condition must hold:

\[ m I^* < y_1 < I^* \]

This condition implies that bankers cannot finance the optimal level of investment without borrowing on the interbank market. To further explore the linkage between sovereign risk and conditions in the financial sector, two versions of the model will be presented next.

3.1 Sovereign to Bank

Sovereign risk refers to the possibility of government defaulting on its loans. To illustrate this idea, an exogenous default probability is introduced in this model. Let \( \pi \in [0, 1] \) denote the ex-ante probability that the government’s investment fails in period 2, where no initial capital is recovered. This implies that the government has no resources to make repayment and defaults on its debt. In addition, no public goods are provided and \( G = 0 \). In the case of no default, the government obtains investment income \( G \) and purchase an equal amount of public goods. Assume further that the private sector receives a signal about this probability in period 1. This signal has a direct impact on the collateral value of...
government bonds and affects aggregate investment. For simplicity, assume the signal to be perfectly informative, in which bankers in period 1 have full knowledge of whether the government will default next period. Let dummy variable $D = 1$ represent no default and 0 otherwise. The government levies a lump-sum tax in the amount $T = Db$ to repay bankers in period 2. To derive a competitive Perfect Bayesian Equilibrium, agents’ behavior in each period must be studied backward.

In period 2, consumption of bankers with an investment opportunity is given by

$$c_2 = I + f(I) - d - T + Db$$

$$= I + f(I) - d$$

(6)

Since $I = y_1 + p_1b$, and $d = p_1b$, then

$$c_2 = y_1 + f(y_1 + d)$$

(7)

In contrast, bankers with no investment opportunities consume

$$c_2 = d - T + Db = d$$

(8)

In period 1, household-banker agents receive a perfect signal about whether the government will default in the following period. This implies that the equilibrium price of government bond simply equals to the dummy variable, $p_1 = D$. In the case of no default, bankers with an investment opportunity invests all of their endowment and postpone consumption with $c_2 = y_1 + f(y_1 + b)$. In contrast, bankers without investment opportunities consume $c_1 = y_1 - d$. If bankers learn that the government’s investment will fail in period 2, the collateral value of sovereign debt falls to zero. Interbank lending seizes and bankers with an investment opportunity can only invest their endowment, $y_1$. Consumption
in period 2 is then given by $c_2 = y_1 + f(y_1)$. For the other bankers, $c_1 = y_1$ and $c_2 = 0$.

In the first period, households purchase government bonds and consume the remaining goods,

$$c_0 = y_0 - p_0 b$$

With a positive probability of default, the expected value of government debt is given by $(1 - \pi)(b - T)$. In this setup, the ex-ante expected utility of a representative banker is given by

$$U = y_0 - p_0 b + \pi[m(y_1 + f(y_1)) + (1 - m)y_1] + (1 - \pi)[m(y_1 + f(y_1 + b)) + (1 - m)y_1 + b - T]$$

$$= y_0 - p_0 b + y_1 + \pi mf(y_1) + (1 - \pi)[mf(y_1 + b) + b - T]$$

The price of government bond in period 0, $p_0$, can be determined by taking the first-order condition with respect to $b$,

$$\frac{\partial U}{\partial b} = -p_0 + (1 - \pi)[mf'(y_1 + b) + 1] = 0$$

$$p_0 = (1 - \pi)[mf'(y_1 + b) + 1]$$

Further, market clearing in the first period implies that $b = g/p_0$. Therefore, the equilibrium price of government debt can be explicitly determined as a function of the probability of default and the level of the government’s initial investment. Higher default risk or greater level of government debt translate into lower price of government debt and reduce the collateral value.

In this model, sovereign risk is a critical factor in determining the level of investment. When a default is anticipated, the collateral value of government debt falls to zero and pre-
vents bankers with an investment opportunity to access additional funding in the interbank market. Since \( f(I) \) is an increasing function, \( f(y_1 + b) > f(y_1) \), which implies a higher aggregate consumption in the event of no default. This simple setup illustrates the transmission of risk from the government to the banking sector, and the reverse direction will be studied in the next subsection.

3.2 Bank to Sovereign

In the previous section, the government defaults with an exogenous probability \( \pi \) when its investment project fails. Nonetheless, there is no risk associated with the investment opportunity for bankers. In this section, we explore the opposite channel with risk originated from the banking sector. Assume now that there is no uncertainty in the returns of government’s investment. In period 0, the government raises \( g \) from bankers from issuing sovereign bonds and invest in the investment project. In period 2, the government uses the project return, \( G \), to pay for public goods. However, the investment return is only guaranteed if the government holds the project to maturity. In the event of an early withdrawal in period 1, the government loses the extra return and only recovers the initial investment, \( g \).

For the private sector, households purchase government bonds in the initial period. In the beginning of period 1, agents learn about whether they have access to investment opportunities and trade bonds in the interbank market. Bankers with an investment opportunity uses the government bonds as collateral and borrow \( d \) to invest. With no expectation of a government default, the price of bond is always 1, or \( p_0 = p_1 = 1 \). Bankers invest \( I = y_1 + d \) in the investment project and expects to receive \( I + f(I) \) in period 2. Now, a financial risk is introduced in this model by assuming that the probability of a liquidity crisis on the banking sector is \( \gamma \in [0, 1] \). In case of a crisis, the bankers with an investment opportunity needs to temporarily inject more capital to ensure project returns. If no additional capital is invested in the project, then the bankers default with zero return and also lose the initial investment. In this model, the bankers borrow up to the maximum in the
interbank market and invest all resources in the investment opportunity. With lack of additional collateral, they have no access to further funding in the interbank market. If there is a default, then the period-2 consumption of the entire private sector will be zero. The only source of funding is to request the government to repay its debt early in period 1.

The government receives a perfectly informative signal in the end of period 1, after the bankers settle on the interbank loans and invest in the project. Therefore, a critical decision must be made by the government of whether to withdraw from its own project to free up capital to bailout the banks. With an early termination, the government pays back sovereign debt, \( g \), to the banks and will not be entitled to investment returns, \( G \), in the final period to finance the expenditures on public goods. However, the government can then impose a lump-sum tax in the amount of \( G \) from banks’ investment returns. Assume that the government is risk-neutral and seeks to maximize aggregate consumption over the three periods, the total consumption without bailout is given by

\[
C_N = y_0 - p_0 b + (1 - m)(y_1 - d) \tag{12}
\]

where \( d = b \) when there is no government risk. In comparison, the total consumption with bailout is

\[
C_B = y_0 - p_0 b + y_1 + mf(y_1 + b) + b - G \tag{13}
\]

Assume that \( y_1 \geq y_0 \), then \( C_B > C_N \) holds and the government optimally chooses to bailout banks in a liquidity crisis. In this model, the risk originated in the banking sector has a direct impact on the fiscal condition of the government. With the bailout, there is insufficient revenue for the government to cover the expenditures on public goods in the final period. As a result, increase in taxation after a financial crisis is consistent with the experience of Greece and Portugal in the recent eurozone debt crisis. Another implication
of this stylized model is the government’s choice to bailout the banks. The idea of "too big to fail" applies in this situation and by committing to save the financial sector, the government essentially transfers a fraction of risk from the banks to itself. It would be more evident if the government cannot terminate the investment project early and has to borrow from foreign sources to bailout the financial sector. Even with a bailout, the aggregate consumption of private goods is smaller in comparison to the case of no liquidity crisis due to higher taxation to finance the public goods. This suggests that bailout is costly to the economy and has a feedback effect on the financial sector.

The two highly stylized models presented above illustrate the transmission of risk between government and the financial sector. Default risk of the government has a direct effect on banks' investment whereas liquidity risk from the financial sector reduces aggregate consumption and deteriorates fiscal conditions of the government under bailout. The relationship remains unclear in the recent eurozone debt crisis and we devote the remainder of this paper to examine empirically using evidence from the CDS market.

4. Empirical Analysis

4.1 CDS Spreads

A credit default swap is a financial agreement that transfers risk from the "protection buyer" to the "protection seller" in the event of a loan default. In exchange for a regular fee, also known as the spread, the seller of the CDS provides full compensation to the buyer if the underlying entity defaults and takes possession of the asset. CDS serves as an insurance contract that limits the risk exposure of the debtor. The CDS spread is thus equivalent to an insurance premium that can be viewed as a proxy for credit risk. The reference entity can be a corporation, an index or a sovereign, and the magnitude of the spread indicates investors’ perception of the underlying risk of the entity.

If a credit event occurs, then CDS contracts can be settled in one of two ways: physically or cash. Physical settlement occurs when the seller pays the buyer par value, in
exchange for the possession of the defaulted assets. Cash settlement refers to when the protection seller pays the buyer the difference between the par value and the post-default market value of the debt. The post-default market value is determined by an auction procedure. In October 2008, Lehman Brothers and Washington Mutual have both undergone the auction procedure. In the case of sovereign bonds, the first auction was held for the Republic of Ecuador on January 14, 2009. On December 9, 2010, defaulted bonds from Anglo Irish Bank of Ireland were up for auction and elevated the tension in the already trembling European financial market.

This paper uses daily 5-year CDS spreads of eleven European countries together with 26 banks. Data is collected from Datastream and Bloomberg, and covers the period from January 1, 2006 to December 31, 2012. There is a total of 37 institutions with 1826 observations of daily data for each series. The sample includes Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. The inclusion of PIIGS countries is critical to reflect the core of the eurozone sovereign debt crisis. Table 1 provides a list of institutions included in the study and their summary statistics. For countries with multiple banks, the CDS spreads are generated using the average of individual banks at the country level. In general, the CDS spreads for banks are consistently higher than their sovereign counterpart, along with greater volatility.

4.2 Correlation and Comovements

Figure 1 plots the time series of sovereign and bank CDS spreads for the eleven countries of interest. It is evident to see a significant increase of spreads since the start of the US subprime crisis in mid-2007. Closer examination reveals that the correlation between sovereign and bank CDS spreads before the crisis remain small but has increased significantly until the end of the sample. To study the change of comovement patterns between sovereign and banks, we separate the crisis into four stages: pre-crisis, subprime to Lehman, Lehman to Greek bailout and post-Greek bailout. The financial crisis in the US started with
the subprime crisis in July 2007, when Standard and Poor placed 612 securities backed by the subprime residential mortgages on a credit watch. On July 31, 2007, Bear Stearns has liquidated two hedge funds highly invested in MBS. The crisis has escalated to a new level when Lehman Brothers filed for Chapter 11 bankruptcy protection on September 15, 2008. During this stage, financial risk associated with the US banks was the main driver of the global financial market and their CDS spreads were highly correlated with spreads of banks in the rest of the world (Eichengreen et al., 2009). The eurozone sovereigns have also borne the global financial risk, evidently from the rising CDS spreads. A series of government rescue of US banks in 2008 has marked the start of the eurozone financial crisis. European banks holding MBS were weakened and the bailout of Anglo Irish bank of Ireland in January 2009 has officially connected the eurozone sovereigns to the financial turbulence. The third phase of the crisis started with the bailout agreement reached between the International Monetary Fund (IMF) and eurozone members to a 110 billion euro rescue package to save Greece in May 2010. The financial market reacted positively to the news with a temporary drop in both sovereign and bank CDS spreads. However, the tension soon escalated to a new level as Ireland and Portugal subsequently requested bailouts from the IMF. This period is thus considered as the eurozone sovereign debt crisis. The eurozone economy has started to recover since the beginning of 2012, notably from the significant decline of CDS spreads. However, at the end of this sample, CDS spreads remained persistently higher than the pre-crisis level.

Table 2 reports the correlation matrix of sovereign and bank CDS spreads for the four phases of crisis. Banks are listed vertically in the left column and sovereigns are presented horizontally in the first row. Bank-sovereign correlations at the country level are reported on the diagonal. In the pre-crisis phase (Panel A), most of the cross-correlations fall in the range of $[-0.1, 0.3]$. The country-specific correlations were also evidently below 0.6. These results suggest that the sovereign bond market remained highly distinctive of the
financial market, even at the country level. However, the outbreak of the subprime crisis in July 2007 has significantly increased the link between the two markets. Panel B of Table 2 shows that most of the correlations increased to levels between \([0.7, 0.9]\). In this period, the global financial risk originated in the US was the main driver of CDS markets, leading to higher comovements among sovereign and bank CDS spreads.

An interesting pattern emerges in the third phase between the Lehman Brothers bankruptcy and Greek bailout. Panel C shows that the correlation statistics have notably dropped to a range of \([0.5, 0.7]\). Furthermore, the correlation between Greek, Portugal banks and other sovereigns appear smaller in general, with some negative signs. This finding suggests that there exists a risk transfer between the troubled banks and sovereigns. European banks were largely exposed to the financial risk associated with the deteriorating value of MBS. The presumption that the European authorities would bailout the banks has pushed the sovereign CDS spreads to a high level. The nationalization of Anglo Irish in January 2009 has served as a even stronger positive signal that the government was ready to provide guarantee to troubling banks. For a short period of time, the market sentiment has driven the bank CDS spreads down moderately at the expense of a rising sovereign CDS spread. Acharya et. al (2013) also find that the average changes in bank CDS and sovereign CDS spreads during the bailout period had opposite signs from September 26, 2008 to October 21, 2008. For most countries, bank CDS spreads have significantly decreased while sovereign CDS spreads significantly increased. In the extreme case of Ireland, the average bank CDS spreads decreased by 150 basis points accompanied by a 50 bps rise in Irish sovereign spreads. Similar patterns are found in other countries. This finding suggests that bank guarantees have led to a notable reduction in banks’ credit risk at the cost of their corresponding sovereigns.

In the post-bailout period, both sovereign CDS and bank CDS spreads increased with a greater comovement (Panel D of Table 2). The cross-correlations on average have risen
to 0.9 and exceeded the levels of the subprime period. Higher comovement between bank and sovereign CDS spreads at the country level in the post-bailout period provides evidence of the feedback effect. The increasing sovereign debt have led to greater concern about the fiscal conditions and the banking sector was then affected when sovereigns were perceived with higher stress. The weakened public finances has created an adverse impact on the financial sector as banks now face greater cost of borrowing and for holding large amount of sovereign bonds with higher risk of default. This feedback effect partially explains the rapid increase of both CDS spreads with greater comovement. However, it still remains ambiguous of the lead-lag relationship between banks and sovereigns. In the following subsection, we first explain the empirical methodology adopted to study the pricing dynamics in the CDS market and report results in Section 5.

4.3 Data and Methodology

The objective of this paper is to study in the interdependencies of European bank and sovereign CDS spreads. The first step is to verify the unit-root non-stationarity of the time series. Two non-stationary variables have a cointegration relationship when a linear combination of these variables is stationary. When both variables are determined by the same risk factors, cointegration suggests that there exists a long-run relationship between the two CDS spreads. Cointegrated variables share the same stochastic trend in the long-run, with deviations only in the short-run as an adjustment process towards equilibrium. Cointegration analysis in this paper follows the framework suggested by Johansen (1991). The statistical test is a multivariate Dickey-Fuller test that determines the cointegration rank, also known as the number of cointegrating equations, by performing a calculation of the likelihood ratio for each added cointegration equation. Cointegration relationship is found to exist for each of the eleven country’s pair of bank and sovereign CDS spreads, which implies that both variables are driven by the same set of risk factors in the long run. To examine this finding more explicitly, a panel OLS regression is performed separately for
the sovereign and bank CDS spreads. Consider the following specification to be estimated:

\[
\Delta S_{it} = \sum_{j=1}^{p} \alpha_{i,t-j} \Delta S_{i,t-j} + \sum_{j=0}^{m} \beta_{i,t-j} \Delta I_{i,t-j} + \sum_{j=0}^{n} \gamma_{i,t-j} \Delta W_{i,t-j} + \phi_i + D_t \tag{14}
\]

\(\Delta S_{it}\) is the daily change of CDS spreads, which is found to be stationary for all countries in the sample. The lagged values capture the possible persistence in CDS spreads. \(I_{it}\) is the daily stock market index of each country, and regressors \(W_t\) include global risk factors proxied by the volatility of the S&P 500 (VIX), the ratio of the iTraxx Non-Financials CDS and the iTraxx Europe CDS index, along with the 5-year US treasury bill rates. Longstaff et. al (2011) also use the VIX as a proxy of the global risk premium. Pan and Singleton (2008) use VIX to reflect global investors’ risk aversion. The Markit iTraxx is a family of CDS indices that incorporates a variety of CDS agreements for sovereign, corporate and banks. The ratio between the financial sector and the overall index indicates the degree of financial weakness. When the ratio falls, the financial sector is expected to underperform than others and should lead to an increase in bank CDS spreads.

It is evident from Figure 1 that the collapse of Lehman Brothers has led to a downward pressure on the global market coupled with a significant increase in CDS spreads across Europe. To capture this shift, a dummy variable \(D_t\) is also included in the regression for the period between Lehman and the nationalization of Anglo Irish bank of Ireland. The inclusion of this dummy variable implies that the estimation of equation (14) explains the deviations from the period average of all countries, taking account of the change in common trend. \(\phi_i\) is the country dummy included to capture the unobserved country-specific factors that may have direct effects on the changes of CDS spreads. All data is obtained from Datastream and Bloomberg.

The cointegration relationship between bank and sovereign CDS spreads suggest that at least one of the two series contributes to the pricing dynamics and the other adjusts in
the short-run. Next, a model selected to represent the adjustment process of cointegrated variables is the vector error correction model (VECM). The general specification of the model can be written as:

\[
\Delta Bank_t = \delta_1 + \lambda_1 Z_{t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta Bank_{t-j} + \sum_{j=1}^{p} \gamma_{1j} \Delta Sov_{t-j} + \varepsilon_{1t} \tag{15}
\]

\[
\Delta Sov_t = \delta_2 + \lambda_2 Z_{t-1} + \sum_{j=1}^{p} \beta_{2j} \Delta Bank_{t-j} + \sum_{j=1}^{p} \gamma_{2j} \Delta Sov_{t-j} + \varepsilon_{2t} \tag{16}
\]

\[
Z_{t-1} = Bank_{t-1} - \alpha_0 - \alpha_1 Sov_{t-1} \tag{17}
\]

where \(\varepsilon_{1t}\) and \(\varepsilon_{2t}\) are i.i.d errors and \(p\) is the optimal number of lags for each cointegration relation selected by AIC. Equation (15) and (16) describe the dynamics of changes in the bank and sovereign CDS spreads, denoted by \(\Delta Bank_t\) and \(\Delta Sov_t\), respectively. Coefficients \(\beta\) and \(\gamma\) capture the short-run dynamics, whereas \(\alpha\) represents the long-run deviations. To study the lead-lag relationships, coefficient \(\lambda\) is the critical term to investigate. This model is similar to the Granger causality relationship suggested by Engle and Granger (1987), but for cointegrated variables. \(\lambda\) represents the error correction term that defines the direction of adjustment for each series. If the sovereign CDS is contributing significantly to price discovery, then \(\lambda_1\) will be negative and statistically significant. In this case, the bank CDS spreads adjust whenever they deviate from the sovereign CDS spreads to return to the long-run equilibrium. In contrast, if the bank CDS is more prominent in generating pricing dynamics, then \(\lambda_2\) will be positive and statistically significant. If both coefficients are statistically significant with the correct signs, then both series contribute to the price discovery. To investigate the mechanics of price discovery in this case, the measure suggested by Gonzalo and Granger (1995) will be used to describe the relative
contribution of the bank CDS spreads. More specifically, define

\[ G_{Bank} = \frac{\lambda_2}{\lambda_2 - \lambda_1} \]  

(18)

For a robustness check, I use the daily 5-year sovereign bond yields for each country as a proxy of the CDS spreads. Cointegration test reveals that there is no cointegration relationship between the bank CDS spreads and bond yields at the country level. Therefore, a panel regression is conducted to examine the relationship between government bond and the financial sector. The next section discusses the empirical results and implications.

5. Results

5.1 Regression Results

The first step of the empirical analysis is to ensure that the CDS spreads are non-stationary using the Augmented Dickey Fuller (ADF) test. In fact, all 37 time series are found to be non-stationary at the 10% significance level or less, but the changes in CDS spreads are stationary. The results also hold for different phases of the crisis.

Table 3 reports the estimation results of equation (14) with changes in sovereign CDS spreads as the dependent variable. The explanatory variables are: lags of the dependent variable, domestic stock market index and its lags, the VIX index, ratio of non-financial iTraxx CDS index to the overall Europe CDS index and the US 5-year treasury bill (tbill) rate. All variables are express in log differences, except for the ratio and US tbill rate, which are in nominal differences. Table 4 reports the regression results with changes in average bank CDS spreads at the country level as the dependent variable.

In the pre-crisis phase, no variables other than lags of the dependent variable appear statistically significant. This result is consistently found for both sovereign and bank CDS spreads. This finding along with a low R-square of 0.07 suggest that changes in the spreads were quite random, consistent with the findings of Codogno et al. (2003) and Aizenman
et al. (2013). These papers suggest that the determinants of CDS spreads are mostly macroeconomic fundamentals such as debt-to-GDP ratio and GDP growth. The European CDS market remained essentially separated from the stock market and unrelated to the US treasury bond yield.

Since the outbreak of the US subprime crisis in July 2007, the sovereign and bank CDS spreads have became increasingly related to the stock market as indicated in column (2) of Table 3 and 4. Changes in the domestic stock market index have a negative impact on the CDS spreads. This implies that investors perceive lower risk when the stock market performs well. In addition, the coefficients of index change and its lags appear significantly greater for the bank CDS spreads in comparison to the sovereign counterpart. This is consistent with common belief that the financial sector is more integrated with the stock market. Moreover, changes in the VIX index are positively related to the sovereign CDS spreads. Higher volatility in the US stock market associated with the subprime crisis has led to a rising global risk aversion, leading to higher CDS premium.

The third phase of the crisis began with the bankruptcy of Lehman Brothers in September 2008 and ended with the Greek bailout in May 2010. The sovereign CDS spreads are found to increase with declining stock market returns, higher risk aversion, a weakening financial sector and lowering US treasury bond yield (column (3), Table 3). Similarly, the bank CDS spreads are significantly related to these variables with identical signs (except for the US bond yield), shown in column (3) of Table 4. These findings suggest that the European CDS market have then reflected the increasing risk perceived by global investors. As more banks’ liquidity became constrained by the sunken mortgage-backed securities and investors’ greater expectation of government guarantee programs, the spreads have risen with the market sentiment. The R-squares for the sovereign and bank CDS spreads have respectively increased to 0.20 and 0.13.

Column (4) of Table 3 and 4 report the estimation results with the inclusion of the crisis
dummy variable for the period between Lehman and Anglo Irish bailout. During this time, the CDS market has became increasingly sensitive with a notable risk shift. If this is true, then the coefficients in the regression with the dummy variable should appear less in magnitude in comparison to the those reported in column (3). A reduction in the strength of the explanatory variables is only evident for the changes in sovereign CDS spreads. This provides evidence for a notable upward adjustment of the European sovereign risk due to the crisis, even when no official bank bailout was initiated. This finding also suggests that there exits a presumption that authorities would provide sufficient financial support to troubled banks to ensure the safety of banks’ creditors, which could help to explain the increasing trend of the sovereign CDS spreads far ahead of any structural government guarantees. Insignificant crisis dummy in explaining bank CDS spreads implies that the financial sector has already responded to the crisis before the Lehman Brothers bankruptcy. Since many European banks were highly involved in the subprime mortgages, the increasing risk should have already been incorporated at the start of the subprime crisis.

The last column of Table 3 and 4 report results for the period after the Greek bailout. For the sovereign CDS spreads, all of the explanatory variables are statistically significant with the correct signs. The R-square has increased to 0.33. It is important to note that there appears to be a much stronger relationship between the financial distress, proxied by the ratio between the iTraxx non-financial and overall indices, and both bank and sovereign risks. The coefficients have respectively increased to –0.53 and –0.35 post-Greek bailout in comparison to only –0.01 before. This finding supports previous findings that there have been a stronger interaction and greater comovement between bank and sovereign CDS spreads since the start of the eurozone debt crisis.

The regression results for different phases of the crisis suggest that the CDS market has became increasingly connected to the global risk factors over the course of the crisis. In addition, the financial distress of European countries has significant effects on both the bank
and sovereign CDS spreads after the Greek bailout, implying greater spillover between the conditions of the banking sector and sovereign debt. The next section adopts the VECM framework and closely examines the price discovery of the CDS market.

5.2 Price Discovery

The core question of this paper is to study the direction of effect between banks and sovereigns. Government guarantee and bailouts may create excessive burden for the government and tighten public finances. However, as banks hold large amount of sovereign bonds, increasing sovereign risk has a direct impact on the financial sector. This section explores the price discovery of the CDS market and aims to shed some light on the bidirectional relationships.

Table 5 reports the trace test statistics of the Johansen cointegration test. The results suggest that one cointegration equation is found for each pair of bank and sovereign CDS spreads. After ensuring the cointegration relationship, a VECM described in Section 4.3 is applied at the country-level. To closely examine the changes of price discovery over time, the sample period is subdivided into the four stages outlined in Section 4.2 and studied independently. Table 6 reports the estimated error correction coefficients, $\lambda_1$ and $\lambda_2$, along with their t-statistics. If the sovereign CDS is contributing significantly to the price discovery, then $\lambda_1$ would be negative and statistically significant. In contrast, if the bank CDS is more prominent in generating pricing dynamics, then $\lambda_2$ would be positive and statistically significant. If both coefficients are statistically significant with the correct signs, then both series contribute to the price discovery. In this scenario, the Gonzalo-Granger ratio defined in equation (18) is reported, describing the fraction of contribution from bank CDS spreads.

The pre-crisis period starts from January 1, 2006 and ends with the liquidation of hedge funds by Bear Stearns on July 31, 2007. 8 of 11 countries reported positive and statistically significant $\lambda_2$, whereas $\lambda_1$ is found to be negative and significant for only 2 countries (Table 6a). For Ireland, the estimation fails to conclude and it remains unclear which CDS spreads
led the price dynamics. Prior to the subprime crisis, the evidence suggests that bank CDS
spreads held a more prominent role in price adjustment processes. This is consistent with
the higher level and greater volatility as shown in Figure 1.

Table 6b reports the estimated results for the subprime crisis period leading up to the
bankruptcy of Lehman Brothers. 7 out of 11 countries reported negative and significant $\lambda_1$
compared to 8 cases with positive and significant $\lambda_2$. More specifically, Austria, Belgium,
France and the Netherlands were found to be significant in both directions. A closer exam-
ination of $G_{\text{Bank}}$ reveals that there is more evidence for the leading role of sovereign CDS
spreads. Consider all facts together, there is greater evidence for sovereigns to lead the
price discovery. This is a dramatic shift from the pre-crisis period when bank CDS spreads
were dominating the price dynamics. During this stage, many banks underperformed due
to the rapid devaluation of MBS. Explicit and implicit bank guarantees may have diverted
financial risk to sovereigns. When investors presume that sovereigns would rescue the fi-
nancial sector at the cost of public finances, concerns of their fiscal condition have became
the main source of financial risk.

The third sub-period covers the time between Lehman Brothers and Greece’s request
for IMF bailout (Table 6c). During this stage, the US subprime crisis has spreaded to
the eurozone and escalated to a full-blown global financial crisis. The empirical analysis
provides further evidence of the leading role of sovereign CDS spreads. All countries other
than Italy are found with negative and statistically significant $\lambda_1$. In contrast, only Greece
and Spain reported positive and significant $\lambda_2$. Nonetheless, $G_{\text{Bank}}$ for these two countries
show that sovereign CDS spreads retained the leading role in price discovery. These results
further suggest that investors incorporate the financial risk in pricing sovereign bonds and
there exists a risk transfer from the banks to sovereigns even before any official bailout
program was announced.

Sovereign CDS spreads strongly dominated the price dynamics in the post-Greece
bailout periods. In this stage, only Greek banks were found to be leading the price discovery (Table 6d). This finding shows that the eurozone sovereign debt crisis has officially began after Greece requested bailout. Similar to findings in Archarya et al. (2013), the feedback effects from the bailout have became more evident and investors were seriously concerned with the excessive debt sovereigns have incurred to save the financial sector. The case of Greece, however, was different in nature. As the Greek government secured relief funds and initiated fiscal tightening, investors redirected their concerns over the performance of Greek banks. As the government had limited resources for further bailout, risk transfer was no longer feasible and the bank CDS spreads resumed the leading role in price dynamics. The similar patterns of price discovery across eurozone countries are also consistent with the increasing comovements found in Table 2.

5.3 Robustness Test

The previous section reports the results of the price discovery process in different stages of the crisis and these findings suggest that sovereign CDS spreads essentially led the price adjustment after the outbreak of the subprime crisis. To investigate this relationship further, a set of panel regressions are estimated using the average bank CDS spreads as the dependent variable. The daily 5-year sovereign bond yields for each country is used as the independent variable to study their effects on financial risk. ADF tests confirm that bond yields are non-stationary in levels but the changes appear to be stationary. Nonetheless, sovereign bond yields are not cointegrated with the average bank CDS spreads at the country level, and a panel OLS regression can be applied to study the impact of sovereign risk on the financial sector. The specification of this regression is given by:

$$\Delta Bank_{it} = \sum_{j=1}^{p} \delta_{i,t-j} \Delta Bank_{i,t-j} + \sum_{j=0}^{p} \alpha_{i,t-j} \Delta S_{i,t-j} + \sum_{j=0}^{m} \beta_{i,t-j} \Delta I_{i,t-j} + \sum_{j=0}^{n} \gamma_{i,t-j} \Delta W_{i,t-j} + \phi_{i}$$ (19)
where $\Delta S_{it}$ is the daily changes of the sovereign bond yield, $I_{it}$ is the daily changes of domestic stock market indices, and regressors $W_t$ include global risk factors proxied by changes in VIX and the 5-year US treasury bill rates. Country dummy $\phi_i$ is included to capture unobserved country-specific factors. Figure 2 plots the daily sovereign bond yields of 11 countries from 2006 to 2012.

Table 7 reports the estimation results for four sub-periods of the crisis. Before July 2007, changes in bank CDS spreads were not explained by any of the independent variables. This is consistent with the previous findings that the CDS market was essentially random. Sovereign bond yields and stock market indices became statistically significant after the subprime crisis. However, the sign of bond yields appear to be negative. This finding provides additional evidence for the existence of a risk transfer between the financial sector and sovereigns. Investors perceive greater risk of sovereigns when explicit and implicit bank guarantees are presumed. After the Greek bailout, changes in sovereign bond yields have became positively related to the average bank CDS spreads, consistent with the increasing comovement between the two CDS spreads. As sovereigns became overly constrained with public finances, the excessive risk has also driven up the bank CDS spreads.

In summary, the empirical analysis of this paper draws two main conclusions. First, there exists a period of risk transfer from banks to sovereigns. At the start of the subprime crisis, financial risk has been incorporated in the pricing of sovereign bonds and reflected the market presumption about bank bailouts. Long before any bailout program was officially carried out, investors traded sovereign CDS agreements as a proxy for bank risks. According to Acharya et al. (2013), European bank CDS spreads lowered shortly after a series of bailout programs were structured in the US while the sovereign spreads increased significantly. The second conclusion is the increasing comovements between bank and sovereign CDS spreads after the Greek bailout. Sovereign risk was the main source of banking risk, and the sovereign CDS spreads have led the price discovery process in the CDS mar-
ket. These results suggest that the worsening public finances of eurozone countries partly due to bank rescue programs have led to greater feedback effects on the financial sector.

6. Conclusion

This paper investigates the interdependencies of bank and sovereign credit risks using evidence from the European CDS market. The main contribution to existing literature is the study of the change of comovement patterns before and after the financial crisis. In addition, price discovery of bank and sovereign CDS spreads is studied in detail to reflect their relative speed of adjustment to shocks. Lastly, this paper investigates the effect of changes in sovereign bond yields on bank CDS spreads and finds that a risk transfer has existed between the two sectors as government bailout programs temporarily reduced the banking fragility at the cost of increasing sovereign credit risk. However, the fiscal burden of sovereigns soon became a risk factor that affected both the sovereign and bank CDS spreads. This finding is consistent with the two-way feedback results presented in Archarya et al. (2013).

The model presented in this paper outlines the potential link between the government and banking sectors. When banks use their holdings of government bonds as collateral to access loans for investment, higher sovereign default risk deteriorates the value of the collateral and affects aggregate investment. This further leads to reduced consumption and taxes, which would also worsen the government budget. In contrast, when government has to inject temporary liquidity in troubled banks, the public finances become constrained and the fiscal burden is transferred to the private sector. Higher taxation then affects private savings and reduces banks’ investments.

Based on the theoretical guidelines outlined in the stylized model, the empirical analyses using CDS spreads in eurozone countries show that correlations between bank and sovereign credit risks increased dramatically during the crisis. A set of common risk factors are also found to explain the changes in both spreads. Prior to July 2007, both the
sovereign and bank CDS spreads were essentially random and shared an independent relationship. During this period, bank CDS spreads assumed the leading role of price discovery. The subprime crisis served as a turning point and increased the comovement significantly. However, there was a temporary period of risk transfer that reduced the correlations. Sovereign CDS spreads had since led the price adjustment process largely due to the explicit and implicit bank guarantees provided by the governments. As a result, investors incorporated sovereign credit risk when pricing bank bonds and traded sovereign CDS contracts to hedge financial risk.

This paper provides evidence that interdependencies between bank and sovereign CDS markets have escalated significantly after the US subprime crisis. The start of the crisis has led to an increase in comovements with a temporary adjustment due to risk transfer. Government bailout programs were only effective in the short-run but soon led to a feedback effect as the fiscal conditions deteriorated rapidly. In conclusion, policymakers should weigh the cost and benefit of bank guarantees taking consideration of the potential effect on the sovereign credit risk and use changes in the sovereign CDS market as a proxy for the banking sector.
Table 1: Summary statistics of levels of CDS spreads

<table>
<thead>
<tr>
<th>Sovereign</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>65.51</td>
<td>62.09</td>
<td>0.5</td>
<td>273</td>
</tr>
<tr>
<td>Belgium</td>
<td>87.47</td>
<td>90.90</td>
<td>1</td>
<td>398.78</td>
</tr>
<tr>
<td>Denmark</td>
<td>43.35</td>
<td>41.70</td>
<td>1.6</td>
<td>200.56</td>
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<tr>
<td>France</td>
<td>58.89</td>
<td>62.51</td>
<td>0.5</td>
<td>245.27</td>
</tr>
<tr>
<td>Germany</td>
<td>33.01</td>
<td>30.11</td>
<td>0.6</td>
<td>118.38</td>
</tr>
<tr>
<td>Greece</td>
<td>5220.90</td>
<td>11871.60</td>
<td>4.4</td>
<td>37081.41</td>
</tr>
<tr>
<td>Ireland</td>
<td>253.97</td>
<td>275.27</td>
<td>1.5</td>
<td>1249.30</td>
</tr>
<tr>
<td>Italy</td>
<td>150.08</td>
<td>155.60</td>
<td>5.3</td>
<td>586.7</td>
</tr>
<tr>
<td>Netherlands</td>
<td>40.11</td>
<td>37.15</td>
<td>1</td>
<td>133.84</td>
</tr>
<tr>
<td>Portugal</td>
<td>309.28</td>
<td>402.79</td>
<td>3.4</td>
<td>1600.98</td>
</tr>
<tr>
<td>Spain</td>
<td>156.84</td>
<td>162.34</td>
<td>1.5</td>
<td>634.35</td>
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<table>
<thead>
<tr>
<th>Bank</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>151.79</td>
<td>92.92</td>
<td>3.83</td>
<td>510.25</td>
</tr>
<tr>
<td>Belgium</td>
<td>156.20</td>
<td>117.80</td>
<td>6.9</td>
<td>508.39</td>
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<td>Portugal</td>
<td>322.19</td>
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<td>9.32</td>
<td>1385.38</td>
</tr>
<tr>
<td>Spain</td>
<td>198.74</td>
<td>194.09</td>
<td>5.53</td>
<td>707.78</td>
</tr>
</tbody>
</table>

Source: Datastream and Bloomberg

1 The banks included are: Erste, Raiffeisen Zentralbank Oesterreich, KBC, Danske, BNP Paribas, Crédit Agricole, Société Générale, Natixis, Deutsche Bank, National Bank of Greece, Alpha, Bank of Ireland, Allied, Monte dei Paschi di Siena, Banco Popolare, UniCredit, ING, De Nederlandsche Bank, Rabobank, SNS, Fortis, Banco Espiritu Santo, Caixa Geral de Depósitos, Banco Comercial Português, Banco Santander, Banco Popular Espanol

2 The average bank CDS spreads at the country level are reported
Figure 6: Bank and sovereign CDS spreads in basis points between 2006 to 2012

Figure 7:
Table 2: Correlations of bank and sovereign CDS spreads

<table>
<thead>
<tr>
<th>Panel A: 01/01/2006-07/31/2007</th>
<th>Austria</th>
<th>Belgium</th>
<th>Denmark</th>
<th>France</th>
<th>Germany</th>
<th>Greece</th>
<th>Ireland</th>
<th>Italy</th>
<th>Netherlands</th>
<th>Portugal</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria (^1)</td>
<td>0.16</td>
<td>-0.36</td>
<td>0.03</td>
<td>0.07</td>
<td>0.15</td>
<td>-0.70</td>
<td>0.35</td>
<td>-0.60</td>
<td>-0.03</td>
<td>-0.63</td>
<td>0.18</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.09</td>
<td>0.14</td>
<td>0.12</td>
<td>-0.03</td>
<td>-0.18</td>
<td>0.07</td>
<td>-0.17</td>
<td>0.02</td>
<td>0.00</td>
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<td>Denmark</td>
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<td>0.52</td>
<td>0.10</td>
<td>-0.07</td>
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<td>0.92</td>
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<td>0.72</td>
<td>0.04</td>
<td>0.87</td>
<td>-0.22</td>
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<tr>
<td>France</td>
<td>0.09</td>
<td>0.20</td>
<td>0.16</td>
<td>0.00</td>
<td>-0.10</td>
<td>0.06</td>
<td>-0.16</td>
<td>-0.04</td>
<td>0.03</td>
<td>0.13</td>
<td>0.10</td>
</tr>
<tr>
<td>Germany</td>
<td>0.06</td>
<td>0.27</td>
<td>0.14</td>
<td>0.09</td>
<td>0.13</td>
<td>0.44</td>
<td>-0.07</td>
<td>0.17</td>
<td>0.09</td>
<td>0.34</td>
<td>-0.10</td>
</tr>
<tr>
<td>Greece</td>
<td>0.05</td>
<td>0.01</td>
<td>-0.11</td>
<td>0.07</td>
<td>-0.12</td>
<td>-0.18</td>
<td>0.03</td>
<td>-0.05</td>
<td>0.04</td>
<td>-0.05</td>
<td>0.11</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.10</td>
<td>0.02</td>
<td>0.16</td>
<td>0.02</td>
<td>-0.16</td>
<td>-0.18</td>
<td>-0.05</td>
<td>-0.25</td>
<td>0.03</td>
<td>-0.10</td>
<td>0.17</td>
</tr>
<tr>
<td>Italy</td>
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<td>0.55</td>
<td>0.24</td>
<td>-0.10</td>
<td>-0.18</td>
<td>0.84</td>
<td>-0.51</td>
<td>0.64</td>
<td>0.09</td>
<td>0.79</td>
<td>-0.16</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.05</td>
<td>0.34</td>
<td>0.22</td>
<td>0.03</td>
<td>-0.18</td>
<td>0.51</td>
<td>-0.32</td>
<td>0.27</td>
<td>0.07</td>
<td>0.51</td>
<td>-0.02</td>
</tr>
<tr>
<td>Portugal</td>
<td>-0.01</td>
<td>0.35</td>
<td>0.16</td>
<td>-0.03</td>
<td>-0.16</td>
<td>0.31</td>
<td>-0.30</td>
<td>0.28</td>
<td>0.10</td>
<td>0.42</td>
<td>0.04</td>
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<tr>
<td>Spain</td>
<td>0.11</td>
<td>-0.24</td>
<td>0.01</td>
<td>0.07</td>
<td>-0.03</td>
<td>-0.56</td>
<td>0.17</td>
<td>-0.47</td>
<td>0.02</td>
<td>-0.46</td>
<td>0.21</td>
</tr>
</tbody>
</table>

\(^1\) First row of each panel reports sovereign CDS spreads, and first column reports average bank CDS spreads.
<table>
<thead>
<tr>
<th>Panel B</th>
<th>08/01/2007-</th>
<th>09/15/2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Austria</td>
<td>Belgium</td>
</tr>
<tr>
<td>Austria</td>
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<td>0.73</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.22</td>
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<tr>
<td>Denmark</td>
<td>0.82</td>
<td>0.76</td>
</tr>
<tr>
<td>France</td>
<td>0.83</td>
<td>0.88</td>
</tr>
<tr>
<td>Germany</td>
<td>0.86</td>
<td>0.92</td>
</tr>
<tr>
<td>Greece</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.86</td>
<td>0.84</td>
</tr>
<tr>
<td>Italy</td>
<td>0.68</td>
<td>0.84</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.79</td>
<td>0.91</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.83</td>
<td>0.88</td>
</tr>
<tr>
<td>Spain</td>
<td>0.70</td>
<td>0.52</td>
</tr>
</tbody>
</table>

1 First row of each panel reports sovereign CDS spreads, and first column reports average bank CDS spreads.
<table>
<thead>
<tr>
<th>Panel C</th>
<th>09/15/2008- 05/02/2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Austria</td>
</tr>
<tr>
<td>Austria</td>
<td>0.80</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.63</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.74</td>
</tr>
<tr>
<td>France</td>
<td>0.64</td>
</tr>
<tr>
<td>Germany</td>
<td>0.72</td>
</tr>
<tr>
<td>Greece</td>
<td>-0.36</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.73</td>
</tr>
<tr>
<td>Italy</td>
<td>0.82</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.84</td>
</tr>
<tr>
<td>Portugal</td>
<td>-0.07</td>
</tr>
<tr>
<td>Spain</td>
<td>0.64</td>
</tr>
</tbody>
</table>

1 First row of each panel reports sovereign CDS spreads, and first column reports average bank CDS spreads
<table>
<thead>
<tr>
<th>Panel D</th>
<th>05/02/2010-12/31/2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Austria</td>
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<tr>
<td>Austria¹</td>
<td>0.97</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.88</td>
</tr>
<tr>
<td>Denmark</td>
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</tr>
<tr>
<td>France</td>
<td>0.94</td>
</tr>
<tr>
<td>Germany</td>
<td>0.89</td>
</tr>
<tr>
<td>Greece</td>
<td>0.89</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.38</td>
</tr>
<tr>
<td>Italy</td>
<td>0.92</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.96</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.79</td>
</tr>
<tr>
<td>Spain</td>
<td>0.86</td>
</tr>
</tbody>
</table>

¹ First row of each panel reports sovereign CDS spreads, and first column reports average bank CDS spreads
Table 3: Determinants of Changes in Sovereign CDS Spreads in Different Phases of the Crisis

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Pre-Crisis(^2)</th>
<th>Subprime to Lehman</th>
<th>Lehman to Greek bailout</th>
<th>Lehman to Greek bailout with crisis dummy</th>
<th>Post-Greek bailout</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.Sov</td>
<td>-0.36***</td>
<td>-0.21***</td>
<td>0.19***</td>
<td>0.19***</td>
<td>0.13***</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>L2.Sov</td>
<td>-0.25***</td>
<td>-0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.05***</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Index</td>
<td>0.16</td>
<td>-0.76***</td>
<td>-0.70***</td>
<td>-0.66***</td>
<td>-0.62***</td>
</tr>
<tr>
<td></td>
<td>(0.60)</td>
<td>(0.19)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>L.Index</td>
<td>-0.72</td>
<td>-0.66***</td>
<td>-0.27***</td>
<td>-0.24***</td>
<td>-0.13***</td>
</tr>
<tr>
<td></td>
<td>(0.51)</td>
<td>(0.17)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>L2.Index</td>
<td>-0.51</td>
<td>-0.21</td>
<td>0.05</td>
<td>0.06</td>
<td>0.10***</td>
</tr>
<tr>
<td></td>
<td>(0.54)</td>
<td>(0.18)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>VIX</td>
<td>0.07</td>
<td>0.09**</td>
<td>0.08***</td>
<td>0.07***</td>
<td>0.04***</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.04)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Financial Stress</td>
<td>0.10</td>
<td>0.02</td>
<td>-0.01***</td>
<td>-0.01***</td>
<td>-0.35***</td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td>(0.07)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>US T-bill</td>
<td>0.04</td>
<td>-0.00</td>
<td>-0.01***</td>
<td>-0.01***</td>
<td>-0.00**</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Crisis Dummy</td>
<td></td>
<td></td>
<td></td>
<td>0.01***</td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Constant</td>
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<td>0.02</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.00***</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Observations</td>
<td>2399</td>
<td>1754</td>
<td>2481</td>
<td>2481</td>
<td>4160</td>
</tr>
<tr>
<td>R(^2)</td>
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<td>0.16</td>
<td>0.20</td>
<td>0.21</td>
<td>0.33</td>
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</tbody>
</table>

***p<0.01, **p<0.05, ***p<0.01

Source: Datastream and Bloomberg

1 Standard errors are reported in parentheses.
2 L and L2 denote the first and second lags, respectively.
Table 4: Determinants of Changes in Bank CDS Spreads in Different Phases of the Crisis

<table>
<thead>
<tr>
<th>VARIABLES²</th>
<th>Pre-Crisis²</th>
<th>Subprime to Lehman</th>
<th>Lehman to Greek bailout</th>
<th>Lehman to Greek bailout with crisis dummy</th>
<th>Post-Greek bailout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank</td>
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<td>-0.04</td>
<td>-0.00</td>
<td>-0.00</td>
<td>-0.02</td>
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<tr>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>L.Bank</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Index</td>
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<td>-0.69***</td>
<td>-0.69***</td>
<td>-0.35***</td>
</tr>
<tr>
<td>(0.87)</td>
<td>(0.19)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>L.Index</td>
<td>0.17</td>
<td>-0.79***</td>
<td>-0.21***</td>
<td>-0.21***</td>
<td>-0.52***</td>
</tr>
<tr>
<td>(0.72)</td>
<td>(0.18)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.05)</td>
</tr>
<tr>
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<td>-0.12**</td>
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<tr>
<td>(0.76)</td>
<td>(0.18)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>VIX</td>
<td>0.05</td>
<td>0.00</td>
<td>0.07***</td>
<td>0.07***</td>
<td>-0.01</td>
</tr>
<tr>
<td>(0.13)</td>
<td>(0.04)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Financial Stress</td>
<td>-0.09</td>
<td>-0.08</td>
<td>-0.01***</td>
<td>-0.01***</td>
<td>-0.53***</td>
</tr>
<tr>
<td>(0.39)</td>
<td>(0.07)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>US T-bill</td>
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<td>0.01</td>
<td>-0.00</td>
<td>-0.00</td>
<td>-0.00***</td>
</tr>
<tr>
<td>(0.03)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Crisis Dummy</td>
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<td></td>
<td></td>
<td>-0.00</td>
</tr>
<tr>
<td>Constant</td>
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<td>-0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.00***</td>
</tr>
<tr>
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<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
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<td>1637</td>
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<td>0.13</td>
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</table>

***p<0.01, **p<0.05, ***p<0.01

Source: Datastream and Bloomberg

¹ Standard errors are reported in parentheses.

² L and L2 denote the first and second lags, respectively.
### Table 5: Johansen Cointegration Test–Full Sample

<table>
<thead>
<tr>
<th>Country</th>
<th># of Lags&lt;sup&gt;1&lt;/sup&gt;</th>
<th>None</th>
<th>At Most 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
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<td>28.06***</td>
<td>5.00*</td>
</tr>
<tr>
<td>Belgium</td>
<td>6</td>
<td>22.28***</td>
<td>3.61</td>
</tr>
<tr>
<td>Denmark</td>
<td>4</td>
<td>21.41***</td>
<td>1.96</td>
</tr>
<tr>
<td>France</td>
<td>4</td>
<td>19.88**</td>
<td>1.94</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
<td>21.54**</td>
<td>2.17</td>
</tr>
<tr>
<td>Greece</td>
<td>5</td>
<td>16.15**</td>
<td>3.46</td>
</tr>
<tr>
<td>Ireland</td>
<td>10</td>
<td>77.13***</td>
<td>1.31</td>
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<tr>
<td>Italy</td>
<td>11</td>
<td>28.73***</td>
<td>1.53</td>
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<td>Netherlands</td>
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<td>2.51</td>
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<td>Portugal</td>
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<td>1.01</td>
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<tr>
<td>Spain</td>
<td>4</td>
<td>26.25***</td>
<td>1.77</td>
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</tbody>
</table>

***p<0.01, **p<0.05, ***p<0.01  
<sup>1</sup> Lags are selected by Akaike Criterion

### Table 6: Vector Error Correction Model Estimation Results

#### a) Pre-crisis

<table>
<thead>
<tr>
<th>Country</th>
<th>$\lambda_1$</th>
<th>t-statistics</th>
<th>$\lambda_2$</th>
<th>t-statistics</th>
<th>$G_{Bank}$ Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>-0.02</td>
<td>-1.50</td>
<td>0.00***</td>
<td>8.18</td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>0.03***</td>
<td>3.94</td>
<td>0.02***</td>
<td>6.85</td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>0.00</td>
<td>1.02</td>
<td>0.08***</td>
<td>11.40</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>0.06***</td>
<td>5.85</td>
<td>0.09***</td>
<td>7.15</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>-0.13***</td>
<td>-4.83</td>
<td>0.00</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>-0.08***</td>
<td>-3.36</td>
<td>0.00</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>Ireland</td>
<td>0.09***</td>
<td>6.32</td>
<td>-0.00</td>
<td>-0.06</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>0.00</td>
<td>0.21</td>
<td>0.01***</td>
<td>3.44</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>-0.00</td>
<td>-0.25</td>
<td>-0.06***</td>
<td>-14.83</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>0.11***</td>
<td>5.31</td>
<td>0.03***</td>
<td>2.70</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>0.00</td>
<td>0.90</td>
<td>0.22***</td>
<td>9.51</td>
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</tr>
</tbody>
</table>

***p<0.01, **p<0.05, ***p<0.01  
Source: Datastream and Bloomberg
### b) Subprime to Lehman

<table>
<thead>
<tr>
<th>Country</th>
<th>$\lambda_1$</th>
<th>t-statistics</th>
<th>$\lambda_2$</th>
<th>t-statistics</th>
<th>$G_{Bank}$ Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td><strong>-0.04</strong>*</td>
<td>-2.86</td>
<td><strong>0.01</strong>*</td>
<td>2.74</td>
<td>0.14</td>
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<tr>
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***p<0.01, **p<0.05, ***p<0.01

**Source:** Datastream and Bloomberg

### c) Lehman to Greece

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***p<0.01, **p<0.05, ***p<0.01

**Source:** Datastream and Bloomberg
### d) Post-Greece

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***p<0.01, **p<0.05, *p<0.01

**Source:** Datastream and Bloomberg
Table 7: Determinants of Changes in Sovereign CDS Spreads in Different Phases of the Crisis

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<th>VARIABLES</th>
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<th>Post-Greek bailout</th>
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***p<0.01, **p<0.05, *p<0.01

Source: Datastream and Bloomberg

1 Standard errors are reported in parentheses.
2 L and L2 denote the first and second lags, respectively.
Appendix

Log-Linearized Model

Let \( \hat{x} \) be the log-deviation of variable \( X \) from steady state value \( \bar{X} \).

Patient households:

\[ \varphi_L \hat{\dot{i}}_{t,s} = \dot{w}_{t,s} - \dot{c}_{t,s} \]  
(A1)

\[ 0 = \dot{c}_{t,s} - E_t(\dot{\hat{c}}_{t+1,s} - \dot{\hat{r}}_{t+1}) \]  
(A2)

\[ \frac{\nu_c}{C_s} (\hat{p}^H_t - \dot{\hat{c}}_{t,s}) = \frac{\nu_h}{H_s} (\hat{\varepsilon}_t - \hat{\dot{h}}_{t,s}) + \beta_s \frac{\nu_c}{C_s} E_t \{ [1 + \dot{\hat{r}}^h (1 - \kappa)] (\dot{\hat{p}}^H_{t+1} - \dot{\hat{c}}_{t+1,s}) + (1 - \kappa) \dot{\hat{r}}^h \} \]  
(A3)

\[ \hat{\lambda}_{t,t+1} = \dot{c}_{t,s} - E_t \dot{\hat{c}}_{t+1,s} \]  
(A4)

Impatient households:

\[ \varphi_L \hat{\dot{i}}_{t,b} = \dot{w}_{t,b} - \dot{c}_{t,b} \]  
(A5)

\[ -\frac{\nu_c}{C_b} \dot{\hat{c}}_{t,b} = \bar{\lambda}_t \hat{R}^L E_t (\hat{\lambda}_t + \hat{\dot{r}}^L_{t+1}) + \beta_b \frac{\nu_c}{C_b} \hat{R}^L E_t (\hat{\dot{r}}^L_{t+1} - \dot{\hat{c}}_{t+1,b}) \]  
(A6)

\[ (\hat{p}^H_t - \dot{\hat{c}}_{t,b}) \frac{\nu_c}{C_b} = \frac{\nu_h}{H_b} (\hat{\varepsilon}_t - \hat{\dot{h}}_{t,b}) + \beta_b \frac{\nu_c}{C_b} E_t (\hat{p}^H_{t+1} - \dot{\hat{c}}_{t+1,b}) + \hat{\lambda} \hat{m} E_t (\hat{p}^H_{t+1} + \hat{\lambda}_t + \hat{m}_t) \]  
(A7)

Financial Intermediaries:

\[ \hat{B} \hat{b}_{t,b} = \hat{\hat{m}} \frac{H_b}{R^L} E_t [\hat{m}_t + \hat{p}^H_{t+1} - \dot{\hat{r}}^L_{t+1} + \hat{\dot{h}}_{t,b}] \]  
(A8)

\[ \hat{b}_{t,e} = \hat{\dot{q}}_t + \hat{\dot{k}}_{t+1} \]  
(A9)

\[ \hat{B} \hat{b}_t = \hat{B}_b \hat{b}_{t,b} + \hat{B}_e \hat{b}_{t,e} \]  
(A10)

\[ \hat{B} \hat{b}_t = \hat{D} \hat{d}_t + \hat{\bar{N}} \hat{n}_t \]  
(A11)
\[\ddot{v}\dot{t} = E_t[(1 - \theta)\beta_s(R^L\hat{r}^L_{t+1} - \hat{R}\hat{r}_{t+1} + \hat{\Lambda}_{t,t+1}R^L - \hat{R})) + \theta\beta_s\dot{v}(\hat{b}_t + \hat{u}_t + \hat{\nu}_t)] \quad (A12)\]

\[\eta_t = \theta\beta_s E_t(\hat{n}_{t+1} + \hat{\Lambda}_{t,t+1} + \hat{\nu}_t - \hat{n}_t) \quad (A13)\]

\[\hat{b}_t = \hat{\phi}_t + \hat{n}_t \quad (A14)\]

\[\hat{\phi}_t = \hat{\eta}_t + \frac{\ddot{v}}{\lambda - \ddot{v}} \quad (A15)\]

\[\hat{n}_t = \theta\hat{\phi}[R^L\hat{r}^L_t - \hat{R}\hat{r}_t] + (\hat{R} - \hat{R})(\hat{\phi}_{t-1} + \hat{n}_{t-1}) + \theta\hat{R}(\hat{r}_t + \hat{n}_{t-1}) + \varpi\hat{\phi}\hat{b}_t \quad (A16)\]

Entrepreneurs:

\[\hat{y}_t = \hat{a}_t + \eta(\hat{u}_t + \hat{\xi}_t + \hat{k}_t) + \nu\hat{h}_{t,s} + (1 - \eta - \nu)(\alpha\hat{h}_{t,s} + (1 - \alpha)\hat{l}_{t,b}) \quad (A17)\]

\[\hat{u}_{t,s} = \hat{p}_m + \hat{y}_t + \hat{l}_{t,s} \quad (A18)\]

\[\hat{u}_{t,b} = \hat{p}_m + \hat{y}_t + \hat{l}_{t,b} \quad (A19)\]

\[(1 + \omega)\hat{u}_t + \hat{\xi}_t + \hat{k}_t = \hat{p}_m + \hat{y}_t \quad (A20)\]

\[\hat{R}^L(\hat{r}^L_{t+1} + \hat{q}_t) = \hat{P}_m\eta\frac{\hat{Y}}{K}(\hat{p}_mt+1 + \hat{y}_{t+1} - \hat{k}_{t+1}) + \hat{q}_{t+1} + (1 - \delta)\hat{\xi}_{t+1} - \delta\hat{u}_{t+1} \quad (A21)\]

\[\hat{r}^h_{t+1} = \hat{p}_mt+1 + \hat{y}_{t+1} - \hat{p}^H_{t+1} - \hat{h}_{t,s} \quad (A22)\]

\[\hat{i}_{nt} = T^\text{invest}_t - \delta K(\hat{u}_t + \hat{\xi}_t + \hat{k}_t) \quad (A23)\]

Capital producers:

\[\hat{K}\hat{k}_{t+1} = \hat{K}(\hat{k}_t + \hat{\xi}_t) + \hat{i}_{nt} \quad (A24)\]

\[q_t = \frac{\phi_I}{I}(\hat{i}_{nt} - \hat{i}_{nt-1}) - \beta_s E_t[\frac{\phi_I}{I}(\hat{i}_{nt+1} - \hat{i}_{nt})] \quad (A25)\]

Retailers:

\[\hat{a}_t^1 = \hat{a}_t^2 \quad (A26)\]
\[a^1_t = Y(\hat{p}_t^* + \hat{y}_t) + \gamma_t \beta_t a^1_t E_t[\hat{p}_t^* - \hat{p}_{t+1} + \hat{a}_{t+1} + (1 - \varepsilon)(\gamma_t \hat{p}_t - \hat{\pi}_{t+1})]\]  
(A27)

\[a^2_t = \tilde{P}_m Y(\hat{p}_m + \hat{y}_t) + \gamma_t \beta_t a^2_t E_t[\hat{p}_t^* - \hat{p}_{t+1} + \hat{a}_{t+2} - \varepsilon(\gamma_t \hat{p}_t - \hat{\pi}_{t+1})]\]  
(A28)

\[0 = (1 - \gamma)(1 - \varepsilon)p_t^* + \gamma_t (1 - \varepsilon)(\gamma_t \pi_{t-1} - \pi_t)\]  
(A29)

Monetary and macroprudential policy:

\[\hat{i}_t = \rho_r(\hat{i}_{t-1}) + (1 - \rho_r)[\gamma_t \hat{\pi}_t + \gamma_t \hat{Y}_t] + \varepsilon^R_t\]  
(A30)

\[\hat{\pi}_t = \hat{\pi}_{t+1} + E_t \hat{\pi}_{t+1}\]  
(A31)

\[\hat{m}_t = \rho_m \hat{m}_{t-1} - \varphi_t \hat{Y}_t - \varphi_t \hat{P}_t^H\]  
(A32)

Market clearing conditions:

\[\bar{H}_s \hat{h}_{t,s} + \bar{H}_b \hat{h}_{t,b} = 0\]  
(A33)

\[\bar{L}_s \hat{h}_{t,s} + \bar{L}_b \hat{h}_{t,b} = 0\]  
(A34)

\[\hat{Y} \hat{y}_t = \bar{C}_s \hat{c}_{t,s} + \bar{C}_b \hat{c}_{t,b} + \bar{I}_{t}^\text{invest}\]  
(A35)

Shock processes:

\[\hat{a}_t = \rho_A \hat{a}_{t-1} + \varepsilon_t^A\]  
(A36)

\[\hat{\varepsilon}_t^H = \rho_H \hat{\varepsilon}_{t-1}^H + \varepsilon_t^H\]  
(A37)

\[\hat{\varepsilon}_t^R = \rho_R \hat{\varepsilon}_{t-1}^R + \varepsilon_t^R\]  
(A38)

\[\hat{\xi}_t = \rho_Q \hat{\xi}_{t-1} + \varepsilon_t^\xi\]  
(A39)
References


Bank.


Political Economy, 27(1), 36-43.


EDUCATION

Ph.D. Economics, Boston University, Boston MA, January 2015 (expected)
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UTAP Scholarship, University of Toronto, 2005-2009
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“Determinants of Sovereign Default--Do Political Factors Matter?”
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“Risk Aversion and Asset Bubbles”

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