FINANCIAL INTERMEDIATION,
MONETARY POLICY,
AND MACROECONOMICS

A Dissertation

Submitted to the Graduate School
of the University of Notre Dame
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for the Degree of

Doctor of Philosophy

by

Ronald Mau

_________________________________________________________________

Eric Sims, Director

Graduate Program in Economics
Notre Dame, Indiana
April 2018
This doctoral dissertation includes three chapters, each with a focus on the interaction of finance and monetary policy in the macroeconomy.

The 2007-2008 Financial Crisis brought about a renewed focus on the role of the financial sector in macroeconomic models. Chapter 1 investigates the role commercial banks play in this relationship by (i) providing business cycle facts for commercial bank balance sheet items (quantities) and balance sheet shares (allocation) along with standard macroeconomic business cycle facts and (ii) characterizing commercial bank responses to monetary policy shocks using local projection methods. A key result is the substitution by commercial banks between liability types in response to monetary policy shocks. This liability substitution limits the effect of monetary policy shocks on the asset side of the balance sheet, thus limiting monetary policy transmission effects on commercial bank balance sheets. This mechanism should be considered in future models of financial intermediation and monetary policy transmission.

Financial shocks have been shown to play a large role in explaining endogenous movements of real variables during the “Great Recession”. Chapter 2 considers a monetary model with an exogenous financial shock. The implications of the presence of financial shocks for optimal monetary policy are explored and the model is esti-
mated via Bayesian techniques. I find inflation targeting accomplishes over 85% of the potential welfare gains of optimal policy and financial shocks explain over 20% of the variation in output in United States data from 1984 to 2008.

Chapter 3 is a joint work prepared with Timothy S. Fuerst. The chapter integrates two traditional explanations for the mean and variability of the term premium into a medium-scale DSGE model: (i) time varying risk premia on long bonds, and (ii) segmented markets between short and long bond markets. We consider two sources of business cycle variability, shocks to total factor productivity (TFP) and the marginal efficiency of investment (MEI). We find market segmentation is required to match empirical moments of the term premium in the model. The market segmentation reflects a real distortion, thus smoothing the term premium is typically welfare-improving, although we discuss difficulties with such a policy.
In memory of Timothy S. Fuerst


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To my mother — thank you for loving Rusty and I well and providing support for each endeavor in my life up to this point. I appreciate the value our family put on education and the continuous atmosphere of learning which was fostered in our home. That learning will continue in my life, even after the submission of this formal dissertation.

A special thanks to Taryn Cooper, Rusty Mau, Adam Ray, and Ryan Whitmore.
CHAPTER 1

COMMERCIAL BANK BALANCE SHEET COMPOSITION AND MONETARY POLICY TRANSMISSION

1.1 Introduction

The 2007-2008 Financial Crisis brought about a renewed focus on the role of the financial sector in macroeconomics. In this chapter I investigate the specific role commercial banks play in this relationship by (i) providing business cycle facts for commercial bank balance sheet items (quantities) and balance sheet shares (allocations) along with standard macroeconomic business cycle facts, and (ii) characterizing commercial bank responses to monetary policy shocks using local projection methods.

I find that banks substitute between liability types in response to macroeconomic movements. Specifically, bank substitute from deposits to wholesale funding and this substitution is procyclical. Wholesale funding is both non-reserved and uninsured so this substitution has implications for the overall stability of the financial sector. As banks substitute to wholesale funding the risk of a run on funding to the financial sector increases. In addition, this substitution limits the immediate impact of macroeconomic movements on the overall size of bank balance sheets. Bank assets and lending adjust by less than retail deposits in response to monetary policy shocks. Finally, I show the dynamic nature of this substitution with banks continuing to increase reliance on wholesale funding multiple years after a contractionary monetary policy shock.

Using the Reports of Condition and Income, or call reports, I generate a panel dataset of commercial banks in the United States from the first quarter of 1984 to the
fourth quarter of 2011. A commercial bank is defined as any domestic, insured, state member bank. Each commercial bank manages a balance sheet made up of assets, liabilities, and equity. I first look at the aggregate commercial bank balance sheet for each period to generate time series for commercial bank asset holdings, lending activity, deposit taking, and leverage, as well as other balance sheet items of interest. In addition, I define a liability type called wholesale funding to analyze commercial bank reliance on safe deposits vs. non-insured, non-reserved wholesale funding.

I am interested in how banks utilize wholesale funding because the Financial Crisis has been characterized as a run on wholesale funding, specifically repurchase agreements\(^1\). I seek to better understand the function of wholesale funding on bank balance sheets leading up to the crisis. For example, in the Post-Volcker era, prior to the crisis, I find retail deposits and wholesale funding are substitutes, with retail deposits moving countercyclically to output and wholesale funding appearing procyclical. Banks substitute between liability types to limit the effects of deposit movements on the asset side of the balance sheet. Banks increase (decrease) wholesale funding in response to deposit reduction (growth) in order to avoid reducing (increasing) assets. Thus, as macroeconomic factors affect economy-wide savings decisions, and therefore deposit supply, banks respond by changing the financial structure of their balance sheet.

Subsequently, this substitution affects how banks respond to monetary policy, potentially impacting the effectiveness of monetary policy decisions on the macroeconomy, or monetary policy transmission. The role of banks in monetary policy transmission has long been a question of interest\(^2\). Two recent papers have highlighted the specific role of deposits and wholesale funding in monetary policy transmission. \[\text{Drechsler et al. (2017)}\] characterize a “deposit channel” of monetary policy. \[\text{Drechsler}\]

\(^1\)See Gorton and Metrick (2012) for example.

\(^2\)see the seminal works of Kashyap and Stein (2000) or Romer et al. (1990)
et al. find that as the policy rate increases, the spread between the deposit rate and policy rate, widens due to imperfectly competitive deposit taking, and deposits flow out of the banking system.

Choi and Choi (2017) show the immediate effect of monetary policy changes on wholesale funding reliance. Choi and Choi find wholesale funding reliance increases in response to federal funds rate tightening. This is consistent with my results in this chapter. In addition to the findings of Choi and Choi I am able to characterize the dynamic response of banks to a monetary policy shock. I find that the liability substitution is dynamic and increases over time. Wholesale funding reliance, defined as the ratio of wholesale funding to retail deposits, continues to increase at least 2 years after the contractionary monetary policy shock.

Figure 1.1 shows how aggregate commercial bank wholesale funding reliance moves with the federal funds rate. In general, during periods of monetary tightening (loosening), wholesale funding reliance increases (decreases). This implies two things. One, federal funds rate increases may be less effective at reducing lending, and thus investment, in the economy as banks use wholesale funding to replace deposit financing on the right hand side of the balance sheet. Secondly, federal funds rate movements influence the level of wholesale funding reliance in the commercial banking system. Point one is important to recognize when attempting to measure the effectiveness of monetary policy decisions on the economy. Point two alludes to the fact that central bank decisions may lead banks to rely more on run prone liabilities to finance lending activities.
Figure 1.1. Bank wholesale funding reliance vs. the federal funds rate

Source: Effective Federal Funds Rate, FEDFUNDS, retrieved from FRED, Federal Reserve Bank of St. Louis.

Note: Wholesale funding reliance is the ratio of aggregate wholesale funding to aggregate retail deposits of commercial banks in the U.S. economy. Data is taken from the Reports of Condition and Income, FFIEC 031/041. Aggregate series are constructed by summing all commercial bank balance sheets for each period.
I use the local projection technique of Jordà (2005) to estimate the effect of monetary policy shocks on balance sheet quantities and shares to further investigate how monetary policy affects bank balance sheets. A key result is the confirmed substitution by commercial banks between wholesale funding and retail deposits in response to monetary policy shocks. Wholesale funding reliance in the banking sector increases in response to contractionary monetary policy shocks. This liability substitution limits the effect of monetary policy movements on the asset side of the balance sheet, both bank assets and lending fall by less than retail deposits in response to the monetary policy shock. Thus, I conclude liability substitution between retail deposits and wholesale funding limits monetary policy transmission in the economy. Considering this liability substitution could be a fruitful avenue of future research when modeling financial intermediation and monetary policy transmission.

The remainder of the chapter is outlined as follows: I conclude the introduction with a literature review. Section 2 provides details about the data and methodology for my analysis. Section 3 summarizes both sets of empirical results. Section 4 provides an explanation of how bank liability substitution limits the bank lending channel of monetary policy transmission using simple bank balance sheet analysis. Section 5 concludes.

1.1.1 Literature Review

This chapter is most closely related to the works of Choi and Choi (2017), and Drechsler et al. (2017). These two papers seek to understand the role of the federal funds rate in driving bank financing. Choi and Choi use a bank-quarter dataset similar to this paper with the addition of FR Y-9C holding company data to address how wholesale funding reliance responds to changes to the federal funds rate. Unlike my paper they do not address the overall effect of monetary policy changes on bank balance sheet size or composition. Their focus is on the liabilities portion of the
balance sheet. Choi and Choi utilize an autoregressive distributed lag model and find that as the federal funds rate tightens, wholesale funding reliance at large banks increases. This result is consistent with my paper. I build on their work by utilizing the local projection technique of Jordà (2005) to show the effects of monetary policy shocks on bank balance sheets over time. In addition I extend my analysis to many balance sheet items including bank assets.

Drechsler et al. use a more disaggregated dataset with branch-quarter observations compared to my bank-quarter observations. They show how deposits in the banking sector are affected by monetary policy changes. They find retail deposits fall in response to monetary tightening, a result consistent with my results, and show how monopsony power in deposit-taking drives this fact. Drechsler et al. take advantage of variation in pricing power within the bank, between branches, in their identification. Drechsler et al. do not include wholesale funding data in their analysis as wholesale funding reliance is a decision made at the bank level, rather than the branch level. DSS note that banks would substitute to wholesale funding in response to deposit outflows due to monetary tightening, which is what I find. I build on their work by showing this substitution occurs by estimating the effect of previously identified monetary policy shocks on the entire bank balance sheet, including wholesale funding.

The role of the banking sector in monetary policy transmission has long been an area of focus in economic research. Kashyap and Stein (2000), Romer et al. (1990), and Romer and Romer (2004), are seminal works which address this question. I use the same dataset as Kashyap and Stein with the data extended through 2016. In addition, I utilize the shock series from Romer and Romer updated to 2007 by Wieland and Yang (2016), in my estimation. More recent papers have attempted to empirically identify various channels for monetary policy transmission and how they have changed over time. These works include Boivin et al. (2010) who use a FAVAR

Since the financial crisis multiple papers have attempted to show the business cycle properties of bank balance sheets. Adrian and Shin (2010) document how using book-value versus market-value of equity affects bank leverage cyclicality measures. Mimir (2016) shows the cyclicality of bank balance sheet levels over the last 30 years and attempts to match these statistics in a DSGE model with financial intermediaries. In addition to the balance sheet items in Mimir, I include wholesale funding, a subset of bank liabilities.

1.2 Data and Methodology

In this section I describe the two types of data I use, macroeconomic time series and commercial bank data, as well as the estimation technique I employ.

1.2.1 Macroeconomic Data

All macroeconomic data is collected from FRED3. Table 1.1 describes the selected series. I deflate all consumption and investment series by the implicit price deflator, GDPDEF. Hours is defined as the product of nonfarm employees and nonfarm average weekly hours, PAYEMS*PRS85006023. Consumption is defined as the sum of personal consumption expenditures on services and personal consumption expenditures on nondurable goods, PCESV + PCND. Investment is the sum of personal consumption expenditures on nondurables and private domestic investment, PCDG + GPDI. Output is the sum of consumption and investment. The federal funds rate

3FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org
is simply the \textit{FEDFUNDS} series.

1.2.2 Reports of Condition and Income

I use Reports of Condition and Income, FFIEC 031/041, data retrieved from the Federal Reserve Bank of Chicago and the FFIEC Central Data Repository to build a panel dataset of commercial bank financial statements. The Reports of Condition and Income, or call reports, are used to assess and monitor the financial condition of banking organizations. All state member banks are required to fill out a call report quarterly, requiring the completion of a balance sheet, income statement, and supporting schedules. Banks fill out either FFIEC 031 or FFIEC 041 based on whether they have foreign branches or only operate domestically, respectively. The call reports are available in a fairly functional format since 1976, although the structure of the report changes over time with financial regulation. The dynamic nature of reporting requirements causes financial variables to be available for varying time periods. I will return to this point below when discussing variable selection.

The raw call reports provide a panel dataset of the U.S. commercial banking universe. The data includes five types of variables in general: identifiers, consolidated foreign and domestic balance sheet items, domestic balance sheet items, foreign balance sheet items, and income statement items. These variables are distinguished by the mnemonics \textit{rssd}, \textit{rcfd}, \textit{rcon}, \textit{rcfn}, and \textit{riad}, respectively. One thing to note is the three types of balance sheet items: domestic (\textit{rcon}), foreign (\textit{rcfn}), and consolidated (\textit{rcfd}). In the most recent data releases, since 2011, banks which file the FFIEC 041 form have both foreign and consolidated balance sheet measures reported as missing. In order to ensure I have all balance sheet data I first pull the consolidated measure for a balance sheet item, i.e. for assets \textit{rcfd2170}, and then, if the consolidated measure is missing, I pull the domestic only measure, \textit{rcon2170}. I am interested in all bank operations so include consolidated variables when available.
<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAYEMS</td>
<td>All Employees: Total Nonfarm Payrolls, Thousands of Persons, Quarterly, Seasonally Adjusted</td>
</tr>
<tr>
<td>PRS85006023</td>
<td>Nonfarm Business Sector: Average Weekly Hours, Index 2009=100, Quarterly, Seasonally Adjusted</td>
</tr>
<tr>
<td>PCESV</td>
<td>Personal Consumption Expenditures: Services, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate</td>
</tr>
<tr>
<td>PCND</td>
<td>Personal Consumption Expenditures: Nondurable Goods, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate</td>
</tr>
<tr>
<td>PCDG</td>
<td>Personal Consumption Expenditures: Durable Goods, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate</td>
</tr>
<tr>
<td>GPDI</td>
<td>Gross Private Domestic Investment, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate</td>
</tr>
<tr>
<td>GDPDEF</td>
<td>Gross Domestic Product: Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted</td>
</tr>
<tr>
<td>FEDFUNDS</td>
<td>Effective Federal Funds Rate, Percent, Quarterly, Not Seasonally Adjusted</td>
</tr>
</tbody>
</table>

Source: FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org
I seek to study domestic, insured banks and filter the data by period based on a few criteria. First, I keep domestic, \(0 < \text{rssd9210} < 57\), commercial, \(\text{rssd9048} = 200\), insured, \(\text{rssd9424} \in \{1, 2, 6, 7\}\), banks. I require that each bank has positive asset holdings, \(\text{rcfd2170} > 0\) or \(\text{rcon2170} > 0\). I limit my sample to the period after 1984 due to data limitations in the call reports and prior to the enactment of the Dodd-Frank Act.

Table 1.2 lists my variable selection and definitions. The majority of variables are available as a single series throughout the sample. Federal funds purchased and repurchase agreements splits into two measures in 2001. This is also true for federal funds and reverse repos on the asset side of the balance sheet. Securities are defined as the sum of total investment securities and total assets held in trading accounts prior to 1994. After 1994 securities are measured as the sum of total held-to-maturity securities and securities available-for-sale. Other borrowed money changes item numbers in 1994. Liquid assets are defined as the sum of federal funds sold and reverse repurchase agreements and securities. Retail deposits are total deposits net foreign deposits. Wholesale funding is the sum of foreign deposits, federal funds purchased and repurchase agreements, and other borrowed money. Total liabilities are calculated as the difference between assets and equity.

Table 1.3 provides summary statistics the balance sheet items of interest for my dataset. There is significant consolidation and exit in my sample with 14,383 individual institutions in the dataset in 1984 and only 6,227 by the fourth quarter of 2011. This is consistent with other studies of the banking sector such as Corbae and D’Erasmo (2014). The average bank operates at a reasonable level of equity, around 10%, similar to current capital requirements. The level of wholesale funding on the balance sheet was increasing until the Financial Crisis with the average bank financing 6% of their balance sheet via wholesale funding in the fourth quarter of 2007.
<table>
<thead>
<tr>
<th>Item Name</th>
<th>Item Number</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets</td>
<td>rcfd2170</td>
<td>1984q1-</td>
</tr>
<tr>
<td>Loans</td>
<td>rcfd2122</td>
<td>1984q1-</td>
</tr>
<tr>
<td>Cash/Reserves</td>
<td>rcfd0010</td>
<td>1984q1-</td>
</tr>
<tr>
<td>Federal Funds Sold</td>
<td>rcfd1350</td>
<td>1984q1-2001q4</td>
</tr>
<tr>
<td>and Reverse Repos</td>
<td>rconb987 + rconb989</td>
<td>2002q1-</td>
</tr>
<tr>
<td>Securities</td>
<td>rcfd0390 + rcfd2146</td>
<td>1984q1-1993q4</td>
</tr>
<tr>
<td></td>
<td>rcfd1754 + rcfd1773</td>
<td>1994q1-</td>
</tr>
<tr>
<td>Liquid Assets</td>
<td>FFS&amp;RR + Securities</td>
<td></td>
</tr>
<tr>
<td>Deposits</td>
<td>rcfd2200</td>
<td>1984q1-</td>
</tr>
<tr>
<td>Foreign Deposits</td>
<td>rcfn2200</td>
<td>1984q1-</td>
</tr>
<tr>
<td>Other Borrowed Money</td>
<td>rcfd2850</td>
<td>1984q1-1993q4</td>
</tr>
<tr>
<td></td>
<td>rcfd3190</td>
<td>1994q1-</td>
</tr>
<tr>
<td>Federal Funds Purchased</td>
<td>rcfd2800</td>
<td>1984q1-2001q4</td>
</tr>
<tr>
<td>and Repos</td>
<td>rconb993 + rconb995</td>
<td>2002q1-</td>
</tr>
<tr>
<td>Equity</td>
<td>rcfd3210</td>
<td>1984q1-</td>
</tr>
<tr>
<td>Retail Deposits</td>
<td>Deposits - Foreign Deposits</td>
<td></td>
</tr>
<tr>
<td>Wholesale Funding</td>
<td>FD + FFP&amp;R + OBM</td>
<td></td>
</tr>
<tr>
<td>Liabilities</td>
<td>Assets - Equity</td>
<td></td>
</tr>
<tr>
<td>Wholesale Funding Reliance</td>
<td>WSF/RD</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 1.3

BANK BALANCE SHEET SIZE AND COMPOSITION

<table>
<thead>
<tr>
<th></th>
<th>1984q1</th>
<th>1999q1</th>
<th>2007q4</th>
<th>2011q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets (mm)</td>
<td>163</td>
<td>618</td>
<td>1,500</td>
<td>1,995</td>
</tr>
<tr>
<td>Loans</td>
<td>51.8</td>
<td>57.9</td>
<td>65.8</td>
<td>60.0</td>
</tr>
<tr>
<td>Liquid Assets</td>
<td>35.9</td>
<td>33.6</td>
<td>25.0</td>
<td>25.2</td>
</tr>
<tr>
<td>Cash</td>
<td>8.3</td>
<td>5.1</td>
<td>4.5</td>
<td>10.1</td>
</tr>
<tr>
<td>Other Assets</td>
<td>4.0</td>
<td>3.4</td>
<td>4.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Retail Deposits</td>
<td>87.4</td>
<td>83.6</td>
<td>80.5</td>
<td>84.2</td>
</tr>
<tr>
<td>Wholesale Funding</td>
<td>1.8</td>
<td>4.0</td>
<td>6.1</td>
<td>4.0</td>
</tr>
<tr>
<td>Other Liabilities</td>
<td>1.6</td>
<td>1.1</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Equity</td>
<td>9.2</td>
<td>11.3</td>
<td>12.4</td>
<td>11.1</td>
</tr>
<tr>
<td># of Banks</td>
<td>14,383</td>
<td>8,644</td>
<td>7,203</td>
<td>6,227</td>
</tr>
</tbody>
</table>

Note: Assets are nominal and in millions of dollars. All other balance sheet items are in percentage shares of the balance sheet, or percentage share of total assets.
Note from Table 1.3, the average bank in my dataset only has $2.7 billion assets in 2016. For comparison, the largest bank has over $2 trillion in total assets. For this reason Table 1.4 provides the same summary statistics for the top 1% of banks by asset holdings for the same periods. The average large bank has $206 billion in assets in 2016 and has significant differences from the average bank in terms of balance sheet composition. The average large bank utilized wholesale funding to finance around 25% of their balance sheet prior to the Financial Crisis. Due to this difference I will distinguish banks by size in my estimations below.

1.2.3 Methodology

My results utilize derived aggregate time series of the banking sector variables. I aggregate all banks each period to generate a time series for each banking variable of interest. I also perform aggregation by bank size, splitting the banks into large, medium, and small categories each period then aggregating within the category. The bank categories are determined by asset percentiles with large banks representing the top 1% of banks by size each period, medium are defined as banks in the 95th to 99th percentile, and small banks are the remaining banks. This categorization follows [Kashyap and Stein (2000)].

I provide business cycle facts for both bank balance sheet quantities and bank balance sheet composition by looking at the share of assets each balance sheet item represents. All macroeconomic series and bank quantities are in logs and all time series are HP filtered.
## TABLE 1.4

**BANK BALANCE SHEET SIZE AND COMPOSITION: BIG BANKS**

<table>
<thead>
<tr>
<th></th>
<th>1984q1</th>
<th>1999q1</th>
<th>2007q4</th>
<th>2011q4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assets (mm)</strong></td>
<td>9,218</td>
<td>42,242</td>
<td>118,245</td>
<td>161,621</td>
</tr>
<tr>
<td>Loans</td>
<td>57.7</td>
<td>65.7</td>
<td>65.0</td>
<td>60.4</td>
</tr>
<tr>
<td>Liquid Assets</td>
<td>18.6</td>
<td>20.1</td>
<td>18.5</td>
<td>20.8</td>
</tr>
<tr>
<td>Cash</td>
<td>17.7</td>
<td>6.1</td>
<td>4.4</td>
<td>8.6</td>
</tr>
<tr>
<td>Other Assets</td>
<td>6.0</td>
<td>8.2</td>
<td>12.1</td>
<td>10.2</td>
</tr>
<tr>
<td>Retail Deposits</td>
<td>62.1</td>
<td>56.1</td>
<td>55.3</td>
<td>66.5</td>
</tr>
<tr>
<td>Wholesale Funding</td>
<td>26.4</td>
<td>28.7</td>
<td>28.2</td>
<td>16.9</td>
</tr>
<tr>
<td>Other Liabilities</td>
<td>6.0</td>
<td>6.5</td>
<td>4.9</td>
<td>4.6</td>
</tr>
<tr>
<td>Equity</td>
<td>5.5</td>
<td>8.7</td>
<td>11.6</td>
<td>12.0</td>
</tr>
<tr>
<td><strong># of Banks</strong></td>
<td>143</td>
<td>86</td>
<td>72</td>
<td>62</td>
</tr>
</tbody>
</table>

Note: Big banks are defined as the top 1% of banks by asset holdings for the given period. Assets are nominal and in millions of dollars. All other balance sheet items are in percentage shares of the balance sheet, or percentage share of total assets.
I then use local projection techniques, Jordà (2005), to estimate the response of bank balance sheet items to monetary policy shocks. Local projection allows me to use an identified shock series, Romer and Romer (2004) Greenbook shocks, and estimate the response of any outcome variable to the shock without defining an underlying structural model. The Romer and Romer shock series has been updated by Wieland and Yang through 2007, prior to entering the ZLB regime. I run my estimations through 2007 due to the availability of the shock series. The estimation specification I use is similar to Ramey (2016),

\[
y_{t+h} = \alpha + \gamma_h \xi_t + x_t \beta + \rho y_{t-1} + \varepsilon_{t+h} \tag{1.1}
\]

where \( y \) is the outcome variable of interest, \( \xi \) is the shock series, \( x \) is a set of controls including the lagged federal funds rate. I include a lag of the outcome variable in the estimation equation. I use industrial production, the price level, unemployment, and the federal funds rate as controls with two lags of each included. I estimate (1.1) using the Newey-West estimator. By performing the estimation at future horizons up to \( H \) of the outcome variable, I generate a series of estimates, \( \{ \hat{\gamma}_h \}_{h=0}^H \), which is the estimated impulse response of \( y \) to \( \xi \). I generate impulse response functions in this way for both the aggregate balance sheet series and series by size categories.

1.3 Empirical Results

In this section I highlight 2 sets of results: (1) business cycle facts summarizing the relationship between bank balance sheet items and real outcomes, (2) impulse responses of bank balance sheet items to monetary policy shocks.
1.3.1 Business Cycle Facts

Table 1.5 provides the standard deviation of macroeconomic time series, bank balance sheet quantities, and bank balance sheet shares, as well as correlations between all variables with output. I report the standard deviation of output with all other standard deviations reported relative to output. The largest current/future correlation in magnitude in each row is in bold. Table 1.5 has three different sets of variables. The first set is macroeconomic items, followed by bank balance sheet quantities, and lastly balance sheet shares, or balance sheet items as a percentage of total assets. All macroeconomic items and balance sheet quantities are in logs. All data is HP filtered.

The balance sheet quantity results are consistent with the results from Mimir (2016). In addition to the measures in Mimir I include wholesale funding. Retail deposits behave somewhat countercyclically whereas wholesale funding is procyclical. This is evidence of the substitution between the two liability types over the cycle. The composition of the balance sheet is consistently more correlated with the cycle than the quantity measures. Wholesale funding reliance, the ratio of wholesale funding to retail deposits, moves procyclically. Figure 1.2 further shows how wholesale funding reliance varies with macroeconomic variables plotting wholesale funding reliance versus the federal funds rate and output.
### TABLE 1.5

**BUSINESS CYCLE STATISTICS**

<table>
<thead>
<tr>
<th></th>
<th>SD</th>
<th>$x_{t-4}$</th>
<th>$x_{t-3}$</th>
<th>$x_{t-2}$</th>
<th>$x_{t-1}$</th>
<th>$x_t$</th>
<th>$x_{t+1}$</th>
<th>$x_{t+2}$</th>
<th>$x_{t+3}$</th>
<th>$x_{t+4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td>1.73</td>
<td>0.22</td>
<td>0.45</td>
<td>0.69</td>
<td>0.90</td>
<td>1.00</td>
<td>0.90</td>
<td>0.69</td>
<td>0.45</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td>0.46</td>
<td>-0.11</td>
<td>0.12</td>
<td>0.41</td>
<td>0.68</td>
<td><strong>0.84</strong></td>
<td>0.83</td>
<td>0.71</td>
<td>0.56</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td>2.55</td>
<td>0.32</td>
<td>0.52</td>
<td>0.74</td>
<td>0.90</td>
<td><strong>0.97</strong></td>
<td>0.85</td>
<td>0.63</td>
<td>0.36</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Hours</strong></td>
<td>0.82</td>
<td>0.01</td>
<td>0.24</td>
<td>0.49</td>
<td>0.71</td>
<td>0.87</td>
<td><strong>0.91</strong></td>
<td>0.84</td>
<td>0.69</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>Assets</strong></td>
<td>1.04</td>
<td>-0.12</td>
<td>-0.03</td>
<td>0.08</td>
<td>0.18</td>
<td>0.29</td>
<td><strong>0.38</strong></td>
<td>0.38</td>
<td>0.36</td>
<td>0.37</td>
</tr>
<tr>
<td><strong>Loans</strong></td>
<td>1.41</td>
<td>-0.18</td>
<td>-0.04</td>
<td>0.12</td>
<td>0.28</td>
<td>0.44</td>
<td>0.58</td>
<td>0.65</td>
<td><strong>0.67</strong></td>
<td>0.66</td>
</tr>
<tr>
<td><strong>Liquid Assets</strong></td>
<td>2.35</td>
<td>0.30</td>
<td>0.22</td>
<td>0.11</td>
<td>-0.02</td>
<td>-0.17</td>
<td>-0.29</td>
<td>-0.40</td>
<td>-0.48</td>
<td><strong>-0.52</strong></td>
</tr>
<tr>
<td><strong>Retail Deposits</strong></td>
<td>1.04</td>
<td>0.17</td>
<td>0.03</td>
<td>-0.11</td>
<td>-0.26</td>
<td><strong>-0.27</strong></td>
<td>-0.26</td>
<td>-0.24</td>
<td>-0.21</td>
<td>-0.11</td>
</tr>
<tr>
<td><strong>Wholesale Funding</strong></td>
<td>3.32</td>
<td>-0.16</td>
<td>0.04</td>
<td>0.23</td>
<td>0.42</td>
<td>0.54</td>
<td><strong>0.62</strong></td>
<td>0.61</td>
<td>0.56</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td>1.37</td>
<td>0.27</td>
<td>0.33</td>
<td>0.34</td>
<td>0.30</td>
<td>0.19</td>
<td>0.07</td>
<td>-0.03</td>
<td>-0.06</td>
<td>-0.08</td>
</tr>
<tr>
<td><strong>WFR</strong></td>
<td>1.45</td>
<td>-0.27</td>
<td>-0.04</td>
<td>0.20</td>
<td>0.43</td>
<td>0.55</td>
<td><strong>0.63</strong></td>
<td>0.62</td>
<td>0.57</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Leverage Ratio</strong></td>
<td>0.13</td>
<td>0.36</td>
<td>0.37</td>
<td>0.30</td>
<td>0.19</td>
<td>0.00</td>
<td>-0.19</td>
<td>-0.29</td>
<td><strong>-0.31</strong></td>
<td><strong>-0.31</strong></td>
</tr>
<tr>
<td><strong>L/A</strong></td>
<td>0.58</td>
<td>-0.13</td>
<td>-0.02</td>
<td>0.09</td>
<td>0.21</td>
<td>0.33</td>
<td>0.44</td>
<td>0.54</td>
<td><strong>0.59</strong></td>
<td>0.57</td>
</tr>
<tr>
<td><strong>LA/A</strong></td>
<td>0.60</td>
<td>0.31</td>
<td>0.20</td>
<td>0.07</td>
<td>-0.08</td>
<td>-0.26</td>
<td>-0.40</td>
<td>-0.49</td>
<td>-0.56</td>
<td><strong>-0.60</strong></td>
</tr>
<tr>
<td><strong>RD/A</strong></td>
<td>0.68</td>
<td>0.24</td>
<td>0.03</td>
<td>-0.19</td>
<td>-0.42</td>
<td>-0.53</td>
<td><strong>-0.59</strong></td>
<td>-0.56</td>
<td>-0.51</td>
<td>-0.42</td>
</tr>
<tr>
<td><strong>WSF/A</strong></td>
<td>0.62</td>
<td>-0.19</td>
<td>0.03</td>
<td>0.24</td>
<td>0.45</td>
<td>0.56</td>
<td><strong>0.63</strong></td>
<td>0.62</td>
<td>0.56</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Note: Big banks are defined as the top 1% of banks by asset holdings for the given period. Assets are nominal and in millions of dollars. All other balance sheet items are in percentage shares of the balance sheet, or percentage share of total assets. Reported standard deviations are relative to the standard deviation of output. The largest current/future correlation in magnitude is highlighted.
Figure 1.2. Bank wholesale funding reliance over the business cycle

Source: Effective Federal Funds Rate, *FEDFUNDS*, and Real Gross Domestic Product, *GDPC1*, retrieved from FRED, Federal Reserve Bank of St. Louis.

Note: Wholesale funding reliance is the ratio of aggregate wholesale funding to aggregate retail deposits of commercial banks in the U.S. economy. Data is taken from the Reports of Condition and Income, FFIEC 031/041. Aggregate series are constructed by summing all commercial bank balance sheets for each period. All series are HP-filtered.
As mentioned before, large banks utilize wholesale funding more than small banks. Figure 1.3 shows how wholesale funding reliance at the large banks varies with the federal funds rate, whereas wholesale funding reliance at the small banks is seemingly uncorrelated with the federal funds rate. Large banks control over 50% of the assets held by commercial banks at the start of the sample and around 70% of total assets by the end of the sample. Given this fact the behavior of the aggregate commercial bank balance sheet more closely resembles the behavior of large banks.

1.3.2 Responses to Monetary Policy Shocks

Figure 1.4 plots \( \hat{\gamma}_j \) from the estimation of equation (1.1) with the outcome variables being the macroeconomic series and the bank balance sheet levels. The first key takeaway from this figure is that the monetary policy shock is in fact contractionary in the long run. The second is to look at the behavior of the balance sheet items. The shock reduces retail deposits. This reflects the deposit channel of monetary policy documented by Drechsler et al.. Notice, as in Choi and Choi banks increase wholesale funding in response to the deposit outflow. This explains the limited response of assets and loans to the shock.
Figure 1.3. Bank wholesale funding reliance by size vs. the federal funds rate

Source: Effective Federal Funds Rate, FEDFUNDS, retrieved from FRED, Federal Reserve Bank of St. Louis.

Note: Wholesale funding reliance is the ratio of wholesale funding to retail deposits of commercial banks in the U.S. economy with series aggregated by bank size categories. Data is taken from the Reports of Condition and Income, FFIEC 031/041. All series are HP-filtered.
Figure 1.4. Monetary policy shock effects (levels), local projection

Note: Shading reflects 95% and 70% confidence interval bands of the estimates.
Figure 1.5 shows two things. First, the top panel provides the balance sheet composition response. The responses here have a slightly different meaning than those from Figure 1.4. Responses for loans, retail deposits, and wholesale funding are relative to total assets. Thus, a positive response implies the variable falls by less than total assets, or even increases, and becomes a larger share of the balance sheet. For instance, wholesale funding as a share of the balance sheet increases in response to the monetary policy shock as we saw in Figure 1.4 that wholesale funding increased and assets stayed constant. The fact that retail deposits fall by more than total assets whereas wholesale funding increases is evidence of the substitution between the two funding types limiting the effect of the monetary policy shock on the total size of the balance sheet.

Wholesale funding becomes a larger share of the balance sheet in response to the monetary policy shock. Wholesale funding reliance summarizes the response of wholesale funding to retail deposits and we see banks become more reliant on wholesale funding in response to the shock. Wholesale funding is susceptible to runs and thus a less stable funding source for the commercial banks. This response to monetary policy shocks implies monetary policy surprises have direct implications for the stability of the banking system. The bottom panel of Figure 1.5 proves this point further showing large banks, the most systemically important, increase wholesale funding reliance the most in response to the shock.
Figure 1.5. Monetary policy shock effects (shares), local projection

Note: Shading reflects 95% and 70% confidence interval bands of the estimates.
In this section I highlight one potential role of wholesale funding in mitigating monetary policy transmission.

Consider a textbook explanation of monetary policy transmission through the reserve requirement. The monetary authority adjusts the supply of reserves in the economy via open market operations, selling (buying) securities to (from) the banking sector to reduce (increase) reserves. Reducing reserves in the economy limits the total deposits in the banking sector due to the reserve requirement. Given the fall in deposits is equal to the inverse of the reserve requirement, $|\Delta \text{Deposits}| > |\Delta \text{Reserves}|$, the bank must reduce their lending in response to this policy adjustment as well. The net effect of the open market operation is fewer reserves, deposits, and lending in the economy.

Alternatively, if wholesale funding is available as a substitute to deposits, the banks can increase wholesale funding in response to the open market operation. This substitution limits the effect of the open market operation on loan supply and suppresses monetary policy transmission through bank lending.\(^4\)

Consider a bank which holds reserves, $R$, securities, $S$, and loans, $L$, financed by deposits, $D$, and wholesale funding $W$.

\[ R + S + L = D + W \]

\(^4\)One shortfall of this explanation of monetary policy transmission is the inability to explain monetary transmission in a world with excess reserves. This would be the case for the time period after August 2008. The updated Romer and Romer shock series is available through 2007 and it is appropriate to consider the transmission mechanism described above. For an explanation of monetary policy transmission through deposit rate spreads, alleviating this concern about excess reserves, see [Drechsler et al. (2017)](#). Drechsler et al. note banks will substitute to wholesale funding in response to reduced deposits similar to what I describe.
with the reserve requirement and collateral constraint\footnote{\(\eta\) is calibrated to match an initial level of \textit{wholesale funding reliance}, \(\omega = W/D\).}

\[
D \leq \rho R
\]

\[
W \leq \eta S
\]

where the central bank (Fed) is a monopolistic supplier of reserves. The central bank holds securities to match the reserve liabilities on their balance sheet. The public saves through deposits at the bank and utilizes loans from the bank. Wholesale funding is provided by a 100\% equity financed shadow bank owned by households.

Given an initial level of bank reserves, \(R\), I write the balance sheets for all agents in the economy (bank, shadow bank, central bank, and public) in terms of \(R\) and the parameters above assuming the reserve requirement is initially binding.

\[
\begin{array}{ccc}
\text{Bank} & & \text{Fed} \\
L & (1 - \lambda) \rho (1 + \omega) R & D & \rho R \\
S & \lambda \rho (1 + \omega) - 1 R & W & \omega \rho R \\
R & R & & \\
\hline
\end{array}
\]

\[
\begin{array}{ccc}
\text{Public} & & \text{Shadow} \\
D & \rho R & L & (1 - \lambda) \rho (1 + \omega) R \\
E^f & \omega \rho R & E^p & \lambda \rho (1 + \omega) R \\
W & \omega \rho R & E^p & \omega \rho R \\
\hline
\end{array}
\]

This implies the calibrated collateral requirement parameter, \(\eta\), is given by,

\[
\eta = \frac{W}{S} = \frac{\omega \rho}{\lambda \rho (1 + \omega) - 1}.
\]

Assume the collateral constraint is always binding and consider a monetary tightening, \(\Delta R\), note the bank receives \(\Delta R\) securities from the Fed as part of the open
market operation. This allows the bank to increase the quantity of wholesale funding on the balance sheet until the collateral constraint is binding again.

\[
\begin{align*}
\text{Bank} & \quad \text{Fed} \\
L' & = L - (\rho - \eta) \Delta R & D' & = D - \rho \Delta R \\
S' & = S + \Delta R & W' & = W + \eta \Delta R \\
R' & = R - \Delta R
\end{align*}
\]

Thus, the loan multiplier is given by,

\[
\frac{\Delta L}{\Delta R} = \rho - \eta = \rho - \frac{\omega \rho}{\lambda \rho (1 + \omega) - 1}.
\]

Notice, when there is zero initial wholesale funding reliance, \(\omega = 0\), the loan multiplier is simply the inverse of the reserve requirement, \(\rho\), as described above.

The change in wholesale funding reliance due to the contraction is given by,

\[
\Delta \omega = \omega' - \omega = \frac{\eta + \rho \omega}{\rho (R - \Delta R)} \Delta R.
\]

Looking at the change in wholesale funding reliance it is worth noting: (i) consecutive monetary tightenings compound these effects as wholesale funding reliance continues to increase,

\[
\omega'' - \omega' > \omega' - \omega,
\]

and (ii) the change in wholesale funding reliance is increasing in the size of the open market operation,

\[
\frac{\partial \Delta \omega}{\partial \Delta R} > 0.
\]
This implies the lending multiplier would be decreasing in response to consecutive monetary tightenings and future lending multipliers are affected by the size of the current open market operation.

1.5 Conclusion

This chapter highlights how banks substitute between liability types and how this affects the balance sheet composition of the commercial banking sector over the business cycle. Banks utilize wholesale funding in response to outflows of deposits in order to minimize the impact of changes to deposit funding on the total size of the balance sheet and asset composition.

This substitution can be seen over the business cycle looking at business cycle moments, as well as in response to monetary policy shocks as I show using local projection techniques. The fact that monetary policy drives a portion of this substitution implies monetary policy decisions have a direct effect on the level of financial stability in the banking sector. As monetary policy tightens, banks become more reliant on less stable funding sources. In addition, the effectiveness of monetary policy may be dampened as bank assets do not have to adjust as much when banks substitute between liability types. This substitution mechanism should be considered in future macroeconomic models with financial intermediation.
CHAPTER 2

OPTIMAL MONETARY POLICY IN THE PRESENCE OF FINANCIAL SHOCKS

2.1 Introduction

After the 2007-2008 financial crisis many macroeconomic models focused on the interaction of real and financial variables. Jermann and Quadrini (2012) is one example of such a model as they embed firm financial structure in a macroeconomic model in order to match the cyclicality of both real and financial variables. They use tax-incentives on long-term debt, a working capital loan subject to limited enforcement, and a financial shock to match the data moments of interest. I build on their model by adding nominal rigidities to explore how financial shocks and firm financial structure affect optimal monetary policy. In addition, I perform Bayesian estimation to better understand the role of the financial shock in explaining Post-Volcker United States data.

The presence of the working capital loan affects optimal monetary policy by introducing an additional source of variation in the labor wedge. Define the labor wedge as the difference between the log approximation of the marginal product of labor and the household’s marginal rate of substitution between consumption and labor,

$$Wedge = MPL - MRS.$$  

In the standard New Keynesian model the only source of variation in the labor wedge
is the marginal cost, or inverse mark-up, from the firm problem,

$$Wedge = M\hat{PL} - M\hat{RS} = \hat{mc}.$$ 

Optimal policy in the standard model is inflation targeting which causes zero variation in marginal cost, and thus variation in the labor wedge,

$$Wedge = M\hat{PL} - M\hat{RS} = \hat{mc} = 0.$$ 

With the limited enforcement constraint and working capital loan in the model, the log-deviation of marginal cost is given by,

$$\hat{mc} = \hat{R}_l - \hat{MPL} + \hat{MRS}.$$ 

Under inflation targeting, there is still no variation in marginal cost, but note the labor wedge is given by,

$$Wedge = M\hat{PL} - M\hat{RS} = \hat{R}_l,$$

where $R_l$ is the interest rate on the working capital loan. Even under inflation targeting there is still observed variation in the labor wedge. Thus, optimal policy varies from the standard result in the New Keynesian literature of inflation targeting. One caveat to the point above is the case of fixed capital. When capital is fixed optimal policy and inflation targeting are nearly identical. Variable capital in the model is a key feature driving this result, although, even with fully flexible capital, optimal policy is at most a 15% improvement in terms of welfare over inflation targeting.

I also explore the dynamics of the model in response to both technology and
financial shocks. Financial shocks are defined as shocks to the probability of enforce-
ment in the case of default on working capital loans. Working capital loans are used
to circumvent a timing problem in which firms must pay for wages and investment
throughout the period whereas revenues arrive at the end of the period. In response
to financial shocks I observe substitution from investment to consumption when fi-
nancial conditions tighten. Also, responses to the financial shock exhibit similar
behavior to aggregate demand shocks as inflation and output both fall in response
to the shock. Under a simple interest rate rule the policy rate falls in response to
the shock. This is consistent with the fact that the federal funds rate fell to the zero
lower bound a year after the financial crisis began.

In addition to analyzing the calibrated model I perform Bayesian estimation on
an expanded version of the baseline model. The model I estimate is similar to the
models of Smets and Wouters (2007) or Christiano et al. (2005). In addition to
the technology and financial shocks in the calibrated model I include shocks to the
share of government spending, price mark-ups, wage mark-ups, the policy rate, the
discount factor, and the marginal efficiency of investment. Variance decomposition
of the estimated model shows financial shocks are the leading driver of variation of
output in the immediate short-run and unconditionally.

One additional result from estimation is the role of the financial shock in driving
the labor wedge and labor. The labor wedge responds counter-cyclically in response
to financial shocks which is consistent with the data. Over 45% of the immediate
variation in labor and the labor wedge is driven by the financial shock. Garin (2015)
explores the role of a similar type financial shock in explaining variation in unem-
ployment. A policy model with unemployment and nominal rigidities would be a
potentially fruitful avenue of future research, building on the work presented here
and Garin.

The remainder of the chapter is outlined as follows: I conclude the introduction
with a literature review. Section 2 presents a baseline model which features working
capital loans, a limited enforcement financial constraint on these loans, and nominal
rigidities. The capital structure features of the intermediate goods firms are laid out
and an equilibrium for the model is defined. Section 3 characterizes the steady state
of the model, dynamics of the model, and optimal policy. Section 4 explains addi-
tional extensions to the model from Section 2 necessary for estimation, the Bayesian
maximum likelihood estimation technique used, and the data used in estimation.
Section 5 presents empirical results from the estimation including posterior distribu-
tions of parameters and conditional variance decompositions of endogenous variables
in response to the eight shocks. Section 6 concludes.

2.1.1 Literature Review

This paper adds to three literatures. First, this paper builds on the work of
Jermann and Quadrini which focuses on shocks originating in the financial sector
and how these shocks affect real economic outcomes. This work is closely related to
models of financial frictions and the financial accelerator such as the seminal works
of Bernanke et al. (1999) and Kiyotaki and Moore (1997). I add nominal rigidities
to a model of financial frictions and financial shocks to understand how monetary
policy interacts with financial features.

Second, I estimate an extended version of the model using Bayesian techniques.
The estimation procedure I use is in the same vein as Smets and Wouters (2007) or
Christiano et al. (2005). I include shocks to the marginal efficiency of investment as
in Justiniano et al. (2011). The model I estimate is most closely related to Gilchrist
et al. (2009) who estimate a model with a financial accelerator and document the role
of the financial accelerator in the United States economy in the Post-Volcker era.

Lastly, I build on the existing work on optimal monetary policy in New Keynes-
ian models. Including variable capital in a New Keynesian model and analyzing
optimal policy was first addressed by Lopez-Salido et al. (2004). My work adds to the optimal policy problem with endogenous capital by adding a financial friction in the model. The financial friction generates an endogenous cost channel. This cost channel affects the variability of the labor wedge, even in an inflation targeting monetary policy regime. This fact is very similar to the findings of Ravenna and Walsh (2006). Carlstrom et al. (2010) is an example of another paper which analyzes optimal monetary policy in a model with financial frictions. Carlstrom et al. use a model with agency costs rather than a Kiyotaki and Moore type financial friction as in my model.

2.2 Calibrated Model

I embed the financial friction of Jermann and Quadrini (2012) into a New Keynesian model with capital accumulation. Consumers maximize lifetime utility over consumption and labor while also providing labor to the intermediate firms, holding inter-temporal debt, and are the residual claimant to the intermediate goods firms’ profits. A final good producer bundles differentiated goods of the intermediate goods producers using a CES aggregator. Intermediate producers use capital and labor to produce intermediate goods, face nominal rigidities in price adjustment, investment adjustment costs, and dividend adjustment costs. There is a tax-benefit to the interest paid on debt which generates a pecking-order in capital structure. The effective nominal rate on debt paid by the firm is,

$$R_t = 1 + r_t(1 - \tau),$$  \hspace{1cm} (2.1)

\footnotesize{\[\text{Lintner (1956)}\]}
with the benefit funded by a lump-sum tax to consumers, expressed in real terms,

\[ T_t = b_{t+1} \frac{E_t \pi_{t+1}}{R_t} - b_{t+1} \frac{E_t \pi_{t+1}}{1 + r_t}. \]  

(2.2)

The monetary authority uses the nominal interest rate as an instrument and follows the following monetary policy rule,

\[ 1 + r_t = (1 + r) \left( \frac{\pi_t}{\bar{\pi}} \right)^{\psi} \left( \frac{y_t}{y_{t'}} \right)^{\eta}. \]  

(2.3)

2.2.1 Household Sector

A representative household maximizes lifetime utility by choosing consumption, \( c_t \), labor, \( h_t \), and real bond holdings, \( b_t \), taking the wage rate, \( w_t \), as given. They are also the claimant of firm dividend payments, \( d_t \), and face a lump-sum tax, \( T_t \). The household has utility over consumption, \( c_t \), and disutility in labor, \( h_t \). The household maximizes lifetime utility given by,

\[
\max \sum_{t=0}^{\infty} \beta^t \left\{ \frac{c_t^{1-\sigma}}{1 - \sigma} - \psi \frac{h_t^{1+\eta}}{1 + \eta} \right\},
\]

subject to their budget constraint,

\[
b_{t+1} \frac{E_t \pi_{t+1}}{1 + r_t} + c_t + T_t = w_t h_t + d_t + b_t.
\]

(2.4)

Household optimality is characterized by a labor supply equation and an Euler equation for debt holdings, or Fisher equation, and their stochastic discount factor (SDF), \( S_{t,t+1} \).

\[
\psi h_t^\eta = w_t c_t^{-\sigma}
\]

(2.5)

\[
1 = E_t S_{t,t+1} \frac{1 + r_t}{\pi_{t+1}}
\]

(2.6)
\[ S_{t,t+1} = \beta \left( \frac{c_{t+1}}{c_t} \right)^{-\sigma} \]  

(2.7)

2.2.2 Final Good Firm

The final good producer “bundles” intermediate goods using constant elasticity of substitution technology,

\[ y_t = \left( \int_0^1 y_t(j) \left( \frac{p_t(j)}{p_t} \right)^{\epsilon_p - 1} \, dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}, \]

choosing each \( y_t(j) \) to maximize profits. The final good producer’s maximization condition determines the following demand constraint for the intermediate goods producers,

\[ y_t(j) = \left( \frac{p_t(j)}{P_t} \right)^{-\epsilon_p} Y_t. \]

2.2.3 Intermediate Goods Firms

Intermediate goods firms are monopolistically competitive, borrow intra-temporally to finance operations, and face convex price adjustment costs à la Rotemberg (1982),

\[ \phi_{\pi} \left( \frac{p_t(j)}{p_{t-1}(j)} - 1 \right)^2 y_t. \]

Real equity payouts which differ from the target payout are subject to a convex cost\(^2\)

\[ \varphi(d_t(j)) = d_t(j) + \frac{\phi_d}{2} (d_t(j) - d^*)^2, \]

where \( d^* \) is the steady-state level of real equity payouts. These convex adjustment costs to equity govern the speed with which firms change capital structure, either by de-leveraging or increasing inter-temporal debt levels.

\(^2\)Lintner (1956)
2.2.3.1 Limited Enforcement Constraint

Intermediate goods firms take out a working capital loan, \( l_t \), which is used to pay for the wage bill and new investment in the period due to a timing mismatch, \( w_t h_t(j) + i_t(j) \). If firms default on this loan, the bank will fully liquidate the firm’s capital, \( k_{t+1} \), with probability \( \varepsilon^f_t \). In the case of liquidation, firms promise to make a payment equal to their outstanding intertemporal debt at the beginning of next period, meaning the bank liquidates only excess capital holdings at the firm. With probability \( \varepsilon^f_t \) the value of defaulting (in real terms) is,

\[
l_t + E_t S_{t,t+1} V_{t+1} - \left( k_{t+1} - b_{t+1} \frac{E_t \pi_{t+1}}{1 + r_t} \right),
\]

and with probability \( 1 - \varepsilon_f^t \) the bank does not liquidate the capital and the value of default is,

\[
l_t + E_t S_{t,t+1} V_{t+1}.
\]

In order to rule out potential default, the value of repayment must be greater than or equal to the expected value of default, or,

\[
E_t S_{t,t+1} V_{t+1} \geq l_t + E_t S_{t,t+1} V_{t+1} - \varepsilon^f_t \left( k_{t+1} - b_{t+1} \frac{E_t \pi_{t+1}}{1 + r_t} \right),
\]

simplifying,

\[
\varepsilon^f_t \left( k_{t+1} - b_{t+1} \frac{E_t \pi_{t+1}}{1 + r_t} \right) \geq l_t.
\]

This constraint binds due to the tax incentive on inter-temporal debt financing.

2.2.3.2 Intermediate Firm Value Maximization

Intermediate goods producers maximize firm value, or the discounted value of cash flows (dividends/excess profits), using Cobb-Douglas production technology while
facing multiple constraints, investment adjustment costs, Rotemberg price adjustment costs, and dividend adjustment costs.

Budget constraint:

\[
\frac{p_t(j)}{p_t} \varepsilon^a i k_t(j)^{\alpha} h_t(j)^{1-\alpha} + b_{t+1}(j) \frac{E_t \pi_{t+1}}{R_t} = w_t h_t(j) + b_t(j) + \frac{\phi}{2} \left( \frac{p_t(j)}{p_{t-1}(j)} - 1 \right)^2 y_t + \varphi(d_t(j)) + i_t(j)
\]

Capital accumulation:

\[
k_{t+1}(j) = (1 - \delta) k_t(j) + \left[ 1 - \frac{\phi}{2} \left( \frac{i_t(j)}{i_{t-1}(j)} - 1 \right)^2 \right] i_t(j)
\]

Working capital financial constraint:

\[
\varepsilon^f_t \left( k_{t+1}(j) - b_{t+1}(j) \frac{E_t \pi_{t+1}}{1 + r_t} \right) \geq w_t h_t(j) + i_t(j)
\]

Demand constraint:

\[
\varepsilon^a_t k_t(j)^{\alpha} h_t(j)^{1-\alpha} \geq \left( \frac{p_t(j)}{p_t} \right)^{-\varepsilon^p} y_t
\]

\(\varepsilon^a_t\) is an exogenous TFP shock and \(\varepsilon^f_t\) is an exogenous shock to the probability of enforcement. Both shocks are aggregate shocks.

Intermediate goods producers solve the following maximization problem, subject to the budget, investment, lending, and demand constraints above,

\[
V_t(j) = \max d_t(j) + ES_{t,t+1} V_{t+1}(j),
\]

by choosing sequences of equity payouts, labor, prices, future capital, investment, and inter-temporal debt carried into the next period. A symmetric equilibrium exists as all firms face the same constraints and aggregate shocks. The symmetric first order
conditions for firm value maximization are given below. The Lagrange multipliers for the budget constraint, capital accumulation equation, enforcement constraint, and demand condition are \(\lambda_t, \kappa_t, \mu_t, \nu_t\), respectively.

\[
1 = \lambda_t \varphi'(d_t)
\]

\[
w_t = \frac{\lambda_t + \nu_t (1 - \alpha)}{\lambda_t + \mu_t} \frac{y_t}{h_t}
\]

\[
\frac{\kappa_t}{\lambda_t} \left[ 1 - \phi_i \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 - \phi_i \left( \frac{i_t}{i_{t-1}} - 1 \right) \frac{i_t}{i_{t-1}} \right] = 1 + \frac{\mu_t}{\lambda_t} - E_t S_{t,t+1} \frac{\lambda_{t+1}}{\lambda_t} \frac{\kappa_{t+1}}{\lambda_t} \phi_i \left( \frac{i_{t+1}}{i_t} - 1 \right) \left( \frac{i_{t+1}}{i_t} \right)^2
\]

\[
\frac{\kappa_t}{\lambda_t} = \varepsilon_i \frac{\mu_t}{\lambda_t} + E_t S_{t,t+1} \frac{\lambda_{t+1}}{\lambda_t} \left( \left( 1 + \frac{\nu_{t+1}}{\lambda_{t+1}} \right) \alpha \frac{y_{t+1}}{k_{t+1}} + (1 - \delta) \frac{\kappa_{t+1}}{\lambda_{t+1}} \right)
\]

To simplify these conditions I define three transformations of the Lagrange multipliers, 

\[
R^l_t = 1 + \frac{\mu_t}{\lambda_t}, \quad mc_t = 1 + \frac{\nu_t}{\lambda_t}, \quad P^k_t = \frac{\kappa_t}{\lambda_t},
\]

which I call the shadow lending rate, marginal cost, and price of capital, respectively. I rewrite the optimality conditions in terms of these variables.

\[
w_t = \frac{mc_t}{R^l_t} (1 - \alpha) \frac{y_t}{h_t}
\]

\[
P^k_t \left[ 1 - \phi_i \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 - \phi_i \left( \frac{i_t}{i_{t-1}} - 1 \right) \frac{i_t}{i_{t-1}} \right] = R^l_t - E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} P^k_t \phi_i \left( \frac{i_{t+1}}{i_t} - 1 \right) \left( \frac{i_{t+1}}{i_t} \right)^2
\]

\[
P^k_t = \varepsilon_i (R^l_t - 1) + E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \left( mc_t \alpha \frac{y_{t+1}}{k_{t+1}} + (1 - \delta) P^k_{t+1} \right)
\]
\[ 1 = \varepsilon_f (P_t^l - 1) \frac{R_t}{1 + r_t} + E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \frac{R_t}{\pi_t+1} \]

\[ \phi(\pi_t - 1)\pi_t = 1 - \varepsilon^p + \varepsilon^p mc_t + E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \phi(\pi_{t+1} - 1)\pi_{t+1} \frac{y_{t+1}}{y_t} \]  

Equation (2.8) is the standard New Keynesian labor demand curve, divided by the shadow lending rate. Thus, the limited enforcement constraint generates a cost channel in the model which is discussed below. The SDF in each Euler equation is augmented by the ratio of marginal costs of dividend adjustments, \( S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \).

Equations (2.9) and (2.12) are the standard investment adjustment and price adjustment equations with the altered SDF.

The constraints facing the intermediate firms in a symmetric equilibrium are given by,

\[ y_t + b_{t+1} \frac{E_t \pi_{t+1}}{R_t} = w_t h_t + b + \frac{\phi_i}{2} (\pi_t - 1)^2 y_t + \varphi(d_t) + i_t \]  

\[ k_{t+1} = (1 - \delta)k_t + \left[ 1 - \frac{\phi_i}{2} \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 \right] i_t \]  

\[ \varepsilon_f \left( k_{t+1} - b_{t+1} \frac{E_t \pi_{t+1}}{1 + r_t} \right) \geq w_t h_t + i_t \]

with production given by,

\[ y_t = \varepsilon^a_t k_t^\alpha h_t^{1-\alpha} \]  

2.2.4 Equilibrium

An equilibrium is characterized by a sequence of allocations, \( \{y_t, c_t, k_t, i_t, h_t, b_t, d_t, T_t\}_{t=0}^\infty \), prices, \( \{S_{t,t+1}, w_t, mc_t, R_t^L, P_t^K, r_t, R_t, \pi_t\}_{t=0}^\infty \), and exogenous sequences of technology, \( \varepsilon^a_t \), and financial shocks, \( \varepsilon_f^t \), such that: production and capital accumulation are given by (2.16) and (2.14); the enforcement constraint, (2.15), binds; household optimality conditions hold, (2.5)-(2.7); firm optimality conditions hold, (2.8)-(2.12); household, firm, and government budget constraints are satisfied, (2.4), (2.13), and
(2.2); the nominal rate and effective nominal rate follow (2.3) and (2.1). \[^{3}\]

2.2.4.1 Exogenous Processes

The exogenous processes are given below.

Technology: $\ln(\varepsilon^a_t) = \rho_a \ln(\varepsilon^a_{t-1}) - \eta^a_t$

Enforcement: $\ln(\varepsilon^f_t / \bar{\varepsilon}^f_t) = \rho_a \ln(\varepsilon^f_{t-1} / \bar{\varepsilon}^f_{t-1}) - \eta^f_t$

$\eta^x_t \sim N(0, \sigma_x)$

2.2.4.2 The Cost Channel

Ravenna and Walsh (2006) show how working capital requirements cause an additional channel for monetary policy to transfer into the economy. In their model, working capital (intra-period) loans require an interest payment equal to the nominal interest rate at the end of the period. This causes the labor demand condition to take the form,

$$w_t = \frac{mc_t}{R_t} MPL_t \Rightarrow mc_t = R_t \frac{w_t}{MPL_t} = R_t s_t.$$  

The NKPC takes on the standard form under log-linearization,

$$\tilde{\pi}_t = \gamma \tilde{mc}_t + \beta E_t \tilde{\pi}_{t+1},$$

and substituting in the log-linearized marginal cost,

$$\tilde{\pi}_t = \gamma (\tilde{R}_t + \tilde{s}_t) + \beta E_t \tilde{\pi}_{t+1}.$$

\[^{3}\]Section A.1 in the appendix provides the full set of equilibrium equations for the model.
Here, \( \hat{s}_t \) can be thought of as the log-linearized marginal cost without the working capital condition and \( \hat{R}_t \) is the non-trivial addition to the Phillip's curve.

Much like the above model, the labor supply condition in my model is given by,

\[
\hat{w}_t = \frac{mc_t}{R^L_t} \Rightarrow mc_t = R^L_t \frac{\hat{w}_t}{\text{MPL}_t} = R^L_t \hat{s}_t,
\]

where,

\[
\text{MPL}_t = (1 - \alpha) \frac{y_t}{h_t}.
\]

And the log-linearized NKPC under Rotemberg pricing,

\[
\hat{\pi}_t = \frac{\varepsilon - 1}{\phi} \hat{mc}_t + \beta E_t \hat{\pi}_{t+1}.
\]

Divine coincidence holds here in the sense that under strict inflation targeting, the sticky and flexible economy are subject to the same wedges so the output gap is closed, but deviations in the labor wedge still exist.

\[
0 = \frac{\varepsilon - 1}{\phi} \hat{mc}_t = \frac{\varepsilon - 1}{\phi} (\hat{R}^L_t + \hat{w}_t - \text{MPL}_t)
\]

\[
\hat{w}_t = \text{MRS}_t
\]

\[
\text{MPL}_t - \text{MRS}_t = \hat{R}^L_t
\]

Note,

\[
\text{MRS}_t = \psi h_t c_t^\sigma.
\]
2.3 Steady State Inefficiency and Dynamics

The model, as written, has an inefficient steady state due to monopolistic competition and the enforcement constraint \[^3\] An efficient steady state can be obtained using subsidies to wages and the marginal product of capital, funded by lump sum transfers. Steady-state wage subsidies are determined by,

\[
w^* = (1 + s_w)w = (1 + s_w)\frac{mc}{R^L}MPL \equiv MPL \Rightarrow (1 + s_w) = \frac{R^L}{mc}.
\]

Steady-state subsidies for the rental rate to capital are determined by solving the following two equation system for \(s_q\),

\[
P^k = (R^l - 1)\varepsilon^f + \beta ((1 + s_q)mcMPK + (1 - \delta)P^k)
\]

\[1 = \beta(MPK + (1 - \delta))
\]

Table 2.1 presents the parameterization for calibrated model. I target a 2% annual nominal policy rate and zero inflation in steady-state. Depreciation is calibrated to 10% per year. The mark-up in the economy is calibrated to 25%, \(\varepsilon^p = 5\). Labor is calibrated to 1. The price adjustment and investment adjustment costs are standard to the literature. The dividend adjustment cost is taken from Jermann and Quadrini (2012). Policy response coefficients are standard.

\[^4\]Section A.2 in the appendix provides the full set of steady-state conditions for the model.
TABLE 2.1

CALIBRATION

<table>
<thead>
<tr>
<th>Calibrated Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor, $\beta$</td>
<td>0.995</td>
</tr>
<tr>
<td>Depreciation rate, $\delta$</td>
<td>0.026</td>
</tr>
<tr>
<td>Tax advantage, $\tau$</td>
<td>0.35</td>
</tr>
<tr>
<td>Curvature (price), $\varepsilon^p$</td>
<td>5</td>
</tr>
<tr>
<td>Capital share, $\alpha$</td>
<td>0.33</td>
</tr>
<tr>
<td>Price adjustment, $\phi$</td>
<td>100</td>
</tr>
<tr>
<td>Investment adjustment, $\phi_i$</td>
<td>4</td>
</tr>
<tr>
<td>Dividend adjustment, $\phi_d$</td>
<td>0.29</td>
</tr>
<tr>
<td>Inflation response, $\nu_\pi$</td>
<td>1.5</td>
</tr>
<tr>
<td>Output gap response, $\nu_y$</td>
<td>0.5</td>
</tr>
</tbody>
</table>
2.3.1 Responses to Productivity and Financial Shocks

Figures 2.1 and 2.2 show the responses of various endogenous variables to the technology, $\varepsilon^a$, and financial, $\varepsilon^f$, shocks respectively. In response to the financial shock we see households substitute from investment to consumption, causing countercyclical consumption which is counterfactual to the data. This is a common problem in models which include financial shocks. Note, the financial shock behaves similarly to an aggregate demand shock with inflation moving procyclically in response to the financial shock. The policy rate thus falls in response to the financial shock.

2.3.2 Optimal Policy

Ramsey optimal policy is obtained using the methods of Lopez-Salido et al. (2004). Ramsey optimal policy is computed by taking a second-order approximation of the entire model. Ramsey optimal policy is characterized as the household welfare maximizing policy choosing the nominal rate subject to the equilibrium conditions of the competitive equilibrium. Figures 2.3 and 2.4 show the impulse response functions in response to technology, $\varepsilon^a$, and financial, $\varepsilon^f$, shocks respectively. Optimal policy is almost identical to inflation targeting, outside of slightly variable inflation in response to both shocks.

From Figure 2.3 we can see the policy rate over responds to the technology shock when following a simple monetary policy rule. An interesting result is found in the shadow rate response. Variability in the shadow rate is essentially variability in the limited enforcement constraint multiplier. Through monetary policy the central bank is able to essentially remove all variation in the enforcement constraint multiplier in response to the technology shock.
Figure 2.1. Responses to technology shocks

Note: Output, consumption, labor, labor wedge, and investment are percent deviations from steady state. The policy rate, inflation, and shadow rate are deviations from steady state in annualized percentages. The IRFs are computed using a second-order approximation. The solid line is the model presented above. The dashed line is the model above with no investment adjustment costs. The dash-dot line is the model above with no investment adjustment costs and no nominal rigidities.
Figure 2.2. Responses to financial shocks

Note: Output, consumption, labor, labor wedge, and investment are percent deviations from steady state. The policy rate, inflation, and shadow rate are deviations from steady state in annualized percentages. The IRFs are computed using a second-order approximation. The solid line is the model presented above. The dashed line is the model above with no investment adjustment costs. The dash-dot line is the model above with no investment adjustment costs and no nominal rigidities.
Figure 2.3. Optimal policy responses to technology shocks

Note: Output, consumption, labor, labor wedge, and investment are percent deviations from steady state. The policy rate, inflation, and shadow rate are deviations from steady state in annualized percentages. The IRFs are computed using a second-order approximation. The solid line is the model presented above. The dashed line is the responses under Ramsey optimal policy. The dotted line is the response under inflation targeting.
Figure 2.4. Optimal policy responses to financial shocks

Note: Output, consumption, labor, labor wedge, and investment are percent deviations from steady state. The policy rate, inflation, and shadow rate are deviations from steady state in annualized percentages. The IRFs are computed using a second-order approximation. The solid line is the model presented above. The dashed line is the responses under Ramsey optimal policy. The dotted line is the response under inflation targeting.
Figure 2.4 shows how monetary policy can overcome the natural trade-off between consumption and investment that occurs in response to the financial shock. Under either Ramsey or inflation targeting policy the policy rate rises in response to the financial shock. This increases the relative cost of consumption today to tomorrow, and investment, and households decrease consumption, rather than increase, in response to the financial shock. This causes investment to fall by less on impact under inflation targeting or Ramsey optimal policy relative to the the simple monetary policy rule.

Table 2.2 shows the welfare improvement of Ramsey optimal policy and an inflation target with varying degrees of investment adjustment costs. Notice as the investment adjustment cost increases the policy benefit relative to the simple monetary policy rule grows. In addition, as the adjustment cost increases, the relative benefit of Ramsey optimal policy to inflation targeting declines. For the limiting case of fixed capital Ramsey optimal policy is nearly identical to inflation targeting.

Figure 2.5 shows the sensitivity of the welfare measures to the relative importance of the financial shock in the model. The welfare gains when there are no investment adjustment costs, blue lines, and costly investment adjustment, black lines are shown. The dashed line in each set is the welfare gains to inflation targeting. As I increase the variance of the financial shock the welfare gains from either policy increase. The relative gains in percentage terms of inflation targeting to Ramsey optimal policy remain fairly constant.

---

5 As I vary the investment adjustment cost, $\phi_i$, I recalibrate the model such that the financial shock is responsible for 10% of the unconditional variance in output when monetary policy follows the simple rule.
Figure 2.5. Welfare

Note: Welfare gains are normalized to consumption units so that, for example, 0.05 means a perpetual increase in steady state consumption of 0.05%. The blue lines are for the case when there are no investment adjustment costs, $\phi_i = 0$. The black lines are for the case when $\phi_i = 4$. The dashed line is the welfare gain from an inflation targeting policy and the black line is Ramsey optimal policy.
TABLE 2.2

WELFARE

<table>
<thead>
<tr>
<th>Targeting</th>
<th>Ramsey</th>
<th>Targ./Ram. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_i = 0$</td>
<td>0.1565</td>
<td>0.1765</td>
</tr>
<tr>
<td>$\phi_i = 1$</td>
<td>0.2560</td>
<td>0.2700</td>
</tr>
<tr>
<td>$\phi_i = 2$</td>
<td>0.3063</td>
<td>0.3174</td>
</tr>
<tr>
<td>$\phi_i = 4$</td>
<td>0.4000</td>
<td>0.4076</td>
</tr>
<tr>
<td>$\phi_i \to \infty$</td>
<td>0.6387</td>
<td>0.6401</td>
</tr>
</tbody>
</table>

Note: Welfare gains are normalized to consumption units so that, for example, 0.05 means a perpetual increase in steady state consumption of 0.05%.

2.4 Medium Scale Model

The medium scale model used for estimation includes six additional exogenous shocks to the above model. Shocks to the discount factor, marginal efficiency of investment, government spending, price mark-ups, wage mark-ups, and monetary policy are included. In addition to these shocks there is differentiated labor between workers which gives wage-setting power to workers. There are nominal rigidities to wage setting à la Calvo (1983). Household preferences exhibit habit formation in consumption. In addition to the capital and investment structure in the simple model, intermediate firms make capital utilization decisions subject to convex costs to variation from full utilization. Appendix A.3 summarizes the equilibrium of the medium scale model.
2.4.1 Household

The household problem is the same as above with three additional features: habit formation in consumption, differentiated labor with time-varying wage mark-ups, time-varying discount factor shocks, \( \varepsilon^d \). The household solves the following maximization problem choosing consumption, labor, wages, and debt-holdings.

\[
\max E_t \sum_{s=0}^{\infty} \beta^s \varepsilon^d_{t+s} \left\{ \left( \frac{c_{t+s} - \zeta c_{t+s-1}}{1 - \sigma} \right)^{1-\sigma} - \psi \frac{h_{t+s}(l)^{1+\eta}}{1 + \eta} \right\}
\]

s.t. \[
\begin{align*}
bt+1 & = \frac{E_t \pi_{t+1}}{1 + r_t} + c_t + T_t = w_t(l)h_t(l) + d_t + b_t \\
h_t(l) & = \left( \frac{w_t(l)}{w_t} \right)^{-\varepsilon^w_t} h_t
\end{align*}
\]

The first-order conditions unrelated to labor and wage choices are given by,

\[
\lambda_t = \varepsilon^d_t (c_t - \zeta c_{t-1})^{-\sigma} - \beta \zeta E_t \varepsilon^d_{t+1} (c_{t+1} - \zeta c_t)^{-\sigma} \\
1 = E_t S_{t,t+1} \frac{1 + r_t}{\pi_{t+1}} \\
S_{t,t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t}
\]

2.4.1.1 Labor Packer and Wage Setting

Differentiated labor is bundled and sold to the firm using a Dixit-Stiglitz aggregator,

\[
h_t = \left( \int_0^1 h_t(l) \frac{\varepsilon^w_{t-1}}{\varepsilon^w_t} dl \right)^{\frac{\varepsilon^w_{t-1}}{\varepsilon^w_t}},
\]

where \( \varepsilon^w_t \) is the stochastic wage mark-up shock. Profit maximization of the bundler yields a demand condition for labor of each type,

\[
h_t(l) = \left( \frac{w_t(l)}{w_t} \right)^{-\varepsilon^w_t} h_t.
\]
This demand condition is substituted into the household’s problem above. The household now optimally chooses their wage rather than labor. There are nominal rigidities to wage updating and wages are updated with probability \(1 - \phi_w\). Utility maximization yields the optimal reset wage,

\[
w^*_t = \frac{\varepsilon^{w}_t h_{1,t}}{\varepsilon^{w}_t - 1 h_{2,t}}.
\]

Where,

\[
h_{1,t} = \varepsilon^{d}_t \psi w^{\varepsilon^{w}_t(1+\eta)} h_{t}^{1+\eta} + \phi_w \beta E_t (1 + \pi_{t+1})^{\varepsilon^{w}_{t+1}(1+\eta)} h_{1,t+1}
\]

\[
h_{2,t} = \lambda_t w^{\varepsilon^{w}_t} h_t + \phi_w \beta E_t (1 + \pi_{t+1})^{\varepsilon^{w}_{t+1}} h_{2,t+1}
\]

and the aggregate wage is given by,

\[
w^{1-\varepsilon^{w}_t} = \phi_w w^{1-\varepsilon^{w}_t}_{t-1} + (1 - \phi_w) w^{*}_{t-1}^{1-\varepsilon^{w}_t}
\]

2.4.2 Intermediate Firm Value Maximization

The intermediate good producer problem is the same as above with three additional features: variable capital utilization, shocks to the marginal efficiency of investment, \(\varepsilon^i_t\), and time-varying price mark-ups. The constraints faced by the firm are given below.

Production:

\[
y_t(j) = \varepsilon^{a}_t (u_t(j) k_t(j))^{\alpha} h_t(j)^{1-\alpha}
\]

Budget constraint:

\[
\frac{p_t(j)}{p_t} y_t(j) + b_{t+1}(j) \frac{E_t \pi_{t+1}}{R_t} = w_t h_t(j) + \frac{\phi}{2} \left( \frac{p_t(j)}{p_{t-1}(j)} - 1 \right)^2 y_t
\]
\[ + b_t(j) + d_t(j) + \frac{\kappa}{2} (d_t(j) - d^*)^2 + i_t(j) \]

Working capital financial constraint:
\[ \varepsilon^f_t \left( k_{t+1}(j) - b_{t+1}(j) \frac{E_t \pi_{t+1}}{1 + r_t} \right) \geq I_t \]

Demand constraint:
\[ y_t(j) \geq \left( \frac{p_t(j)}{P_t} \right)^{-\varepsilon_t^p} Y_t \]

Investment:
\[ \varepsilon^i_t \left[ 1 - \phi_k \frac{i_t(j)}{2} \left( \frac{i_t(j)}{i_{t-1}(j)} - 1 \right) - \phi \left( \frac{i_t(j)}{i_{t-1}(j)} - 1 \right) \right] i_t(j) = k_{t+1}(j) - (1 - \delta(u_t(j)))k_t(j) \]

Intermediate goods solve the following maximization problem, subject to the constraints above,
\[ V_t(j) = \max d_t(j) + E m_{t+1} V_{t+1}(j), \]

by choosing sequences of equity payouts, labor, prices, future capital, investment, utilization, and future inter-temporal debt. Variable capital utilization affects the level of depreciation in the period, \( \delta(u_t) \). The functional form for depreciation is given by \( \delta(u_t) = \delta_0 + \delta_1 (u_t - 1) + \frac{\delta_2}{2} (u_t - 1)^2 \). All firms face the same optimization problem and a symmetric equilibrium exists. The optimization conditions for the firm are given below.

\[ w_t = \frac{mc_t}{R_t} (1 - \alpha) \frac{y_t}{L_t} \]
\[ P_t^k \varepsilon_t^i \left[ 1 - \phi_i \frac{i_t}{2} \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 - \phi \left( \frac{i_t}{i_{t-1}} - 1 \right) \right] \]
\[ = R_t - E_t S_{t+1} \varphi'(d_t) P_{t+1}^k \varepsilon_{t+1}^i \phi_i \left( \frac{i_{t+1}}{i_t} - 1 \right) \left( \frac{i_{t+1}}{i_t} \right)^2 \]
\[ P_t^k = \varepsilon_t^f (R_t^l - 1) + E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \left( mc_{t+1} \frac{y_{t+1}}{k_{t+1}} + (1 - \delta(u_{t+1})) P_{t+1}^k \right) \]

\[ P_t^k \delta'(u_t) k_t = mc_t \frac{y_t}{u_t} \]

\[ \phi(\pi_t - 1) \pi_t = 1 - \varepsilon_p^p + \varepsilon_t^p mc_t + E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \phi(\pi_{t+1} - 1) \pi_{t+1} \frac{y_{t+1}}{y_t} \]

### 2.4.3 Monetary Policy and Government Spending

Monetary policy is the same as above with the addition of a monetary policy shock, \( \varepsilon_t^r \),

\[ 1 + r_t = (1 + r) \left( \frac{\pi_t}{\pi} \right)^{v_x} \left( \frac{y_t}{y_{t-1}} \right)^{v_y} \varepsilon_t^r. \]

There is exogenous government spending, \( g_t \), financed by the lump-sum tax on households,

\[ T_t = b_{t+1} E_t \pi_{t+1} - b_{t+1} E_t \pi_{t+1} - 1 + r_t + g_t. \]

Government spending is defined as,

\[ g_t = \varepsilon_t^g y_t, \]

where,

\[ \ln \varepsilon_t^g = (1 - \rho_g) \ln s^g + \rho_g \ln \varepsilon_{t-1}^g + \eta_t^g. \]

### 2.5 Estimation

The model is estimated using Bayesian maximum likelihood techniques. The observables I use are output, consumption, investment, and wage growth, inflation, the federal funds rate, government spending as a share of GDP, and the debt repurchases series as constructed in Jermann and Quadrini. Each observable series is demeaned. Table 2.3 lists the data series used for the estimation. The measurement equation for
the model is given by a system of eight equations presented in vector notation below:

\[
\begin{bmatrix}
    dy_t - dy \\
    dc_t - dc \\
    dinve_t - dinve \\
    dw_t - dw \\
    G/Y_t - G/Y \\
    pinfobs_t - pinfobs \\
    FedFunds_t - FedFunds
\end{bmatrix}
= \begin{bmatrix}
    y_t - y_{t-1} \\
    c_t - c_{t-1} \\
    i_t - i_{t-1} \\
    w_t - w_{t-1} \\
    g_t/y_t \\
    \pi_t \\
    r_t
\end{bmatrix}
- \begin{bmatrix}
    0 \\
    0 \\
    0 \\
    0 \\
    s^g \\
    1 \\
    r
\end{bmatrix}
\]

The share of government spending to output is defined as the ratio of "Real Government Consumption Expenditures and Gross Investment" to "Real Gross Domestic Product". Debt repurchases is defined as in Jermann and Quadrini as the negative of the net increase in credit markets instruments of non-financial business. Tables 2.4 and 2.5 show the prior and posterior distributions of the estimated parameters. The mean probability of enforcement is recalculated to hit the target debt to GDP ratio throughout the estimation process as well as the labor preference parameter, $\psi$, is re-calibrated such that $h = 1$. 
## TABLE 2.3

### DATA SERIES

<table>
<thead>
<tr>
<th>Series</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDPC1</td>
<td>Real Gross Domestic Product, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate</td>
</tr>
<tr>
<td>PCECC96</td>
<td>Real Personal Consumption Expenditures, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate</td>
</tr>
<tr>
<td>GPDIC1</td>
<td>Real Gross Private Domestic Investment, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate</td>
</tr>
<tr>
<td>GCEC1</td>
<td>Real Government Consumption Expenditures and Gross Investment, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate</td>
</tr>
<tr>
<td>RCPHBS</td>
<td>Business Sector: Real Compensation Per Hour, Index 2009=100, Quarterly, Seasonally Adjusted</td>
</tr>
<tr>
<td>GDPDEF</td>
<td>Gross Domestic Product: Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted</td>
</tr>
<tr>
<td>FEDFUNDS</td>
<td>Effective Federal Funds Rate, Percent, Quarterly, Not Seasonally Adjusted</td>
</tr>
<tr>
<td>BCNSDODNS</td>
<td>Nonfinancial Corporate Business: Credit Market Instruments – Liability, Quarterly, Seasonally Adjusted</td>
</tr>
</tbody>
</table>

Note: Data was collected from FRED, a publically available database managed by the Federal Reserve Bank of St. Louis.
## Table 2.4

**Parameterization: Structural Parameters**

<table>
<thead>
<tr>
<th>Calibrated Parameters</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Discount factor, $\beta$</td>
<td>0.9951</td>
</tr>
<tr>
<td>Depreciation rate, $\delta$</td>
<td>0.026</td>
</tr>
<tr>
<td>Tax advantage, $\tau$</td>
<td>0.35</td>
</tr>
<tr>
<td>Curvature (wage), $\bar{\varepsilon}_w$</td>
<td>6</td>
</tr>
<tr>
<td>Curvature (price), $\bar{\varepsilon}_p$</td>
<td>6</td>
</tr>
<tr>
<td>Avg. gov’t spending, $s_g$</td>
<td>0.18</td>
</tr>
<tr>
<td>Capital share, $\alpha$</td>
<td>0.33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Est. Parameters</th>
<th>Posterior Mean</th>
<th>Mode</th>
<th>5%</th>
<th>95%</th>
<th>Shape</th>
<th>Prior Mean</th>
<th>Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habit, $\zeta$</td>
<td>0.831</td>
<td>0.819</td>
<td>0.820</td>
<td>0.850</td>
<td>Beta</td>
<td>0.7</td>
<td>0.1</td>
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<tr>
<td>Risk aversion, $\sigma$</td>
<td>0.117</td>
<td>0.171</td>
<td>0.086</td>
<td>0.137</td>
<td>Beta</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Equity payout cost, $\phi_d$</td>
<td>1.075</td>
<td>0.989</td>
<td>1.051</td>
<td>1.101</td>
<td>IGamma</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Capital util. cost, $\gamma$</td>
<td>0.002</td>
<td>0.002</td>
<td>0.001</td>
<td>0.002</td>
<td>Beta</td>
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<td>0.1</td>
</tr>
<tr>
<td>Investment adj. cost, $\phi_i$</td>
<td>3.449</td>
<td>3.612</td>
<td>3.283</td>
<td>3.616</td>
<td>Normal</td>
<td>4</td>
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<td>1.335</td>
<td>1.237</td>
<td>1.297</td>
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<td>0.943</td>
<td>0.953</td>
<td>0.959</td>
<td>Beta</td>
<td>0.7</td>
<td>0.1</td>
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<td>Price adj. cost, $\phi$</td>
<td>235.4</td>
<td>223.6</td>
<td>230.2</td>
<td>242.3</td>
<td>Normal</td>
<td>100</td>
<td>25</td>
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<td>1.225</td>
<td>1.420</td>
<td>1.155</td>
<td>1.328</td>
<td>Normal</td>
<td>2</td>
<td>0.2</td>
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<tr>
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<td>0.327</td>
<td>0.372</td>
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<td>0.5</td>
<td>0.25</td>
</tr>
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<td>Parameter</td>
<td>Posterior Mean</td>
<td>Posterior Mode</td>
<td>Posterior 5%</td>
<td>Posterior 95%</td>
<td>Prior Shape</td>
<td>Prior Mean</td>
<td>Prior Std.</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------</td>
<td>----------------</td>
<td>--------------</td>
<td>--------------</td>
<td>-------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>0.861</td>
<td>0.814</td>
<td>0.825</td>
<td>0.891</td>
<td>Beta</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>$\rho_d$</td>
<td>0.275</td>
<td>0.405</td>
<td>0.158</td>
<td>0.378</td>
<td>Beta</td>
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<td>0.2</td>
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<tr>
<td>$\rho_i$</td>
<td>0.141</td>
<td>0.127</td>
<td>0.058</td>
<td>0.268</td>
<td>Beta</td>
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<td>0.2</td>
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<tr>
<td>$\rho_g$</td>
<td>0.938</td>
<td>0.956</td>
<td>0.932</td>
<td>0.954</td>
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<td>0.2</td>
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<tr>
<td>$\rho_w$</td>
<td>0.714</td>
<td>0.600</td>
<td>0.661</td>
<td>0.744</td>
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<td>0.2</td>
</tr>
<tr>
<td>$\rho_p$</td>
<td>0.541</td>
<td>0.593</td>
<td>0.492</td>
<td>0.588</td>
<td>Beta</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>$\rho_r$</td>
<td>0.531</td>
<td>0.569</td>
<td>0.492</td>
<td>0.586</td>
<td>Beta</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>$\rho_f$</td>
<td>0.869</td>
<td>0.913</td>
<td>0.861</td>
<td>0.873</td>
<td>Beta</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>0.017</td>
<td>0.018</td>
<td>0.016</td>
<td>0.018</td>
<td>IGamma</td>
<td>0.001</td>
<td>0.05</td>
</tr>
<tr>
<td>$\sigma_d$</td>
<td>0.004</td>
<td>0.005</td>
<td>0.003</td>
<td>0.005</td>
<td>IGamma</td>
<td>0.001</td>
<td>0.05</td>
</tr>
<tr>
<td>$\sigma_i$</td>
<td>0.124</td>
<td>0.122</td>
<td>0.109</td>
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<tr>
<td>$\sigma_g$</td>
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<td>0.037</td>
<td>0.032</td>
<td>0.041</td>
<td>IGamma</td>
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<td>$\sigma_w$</td>
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<td>$\sigma_p$</td>
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<td>0.244</td>
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<td>0.280</td>
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<td>0.05</td>
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<tr>
<td>$\sigma_r$</td>
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<td>0.05</td>
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<td>$\sigma_f$</td>
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<td>0.019</td>
<td>0.022</td>
<td>IGamma</td>
<td>0.001</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Table 2.6 shows the conditional variance decomposition of output, consumption, labor, investment, and the labor wedge upon impact, a year later, and two years later, as well as the unconditional variance decomposition. The financial shock is responsible for 22% of the unconditional variance in output and 30% of the variance in output on impact. The investment shock is a large driver of all variables presented, excluding consumption, on impact. Unconditionally, the financial shock is responsible for 10% or more of the variation of all variable presented. The role of the financial shock in driving the labor wedge on impact non-trivial. Garin (2015) explores the role of this financial shock in a model with unemployment building from the simple model presented above. Combining unemployment, nominal rigidities, and the financial shock from Jermann and Quadrini is an important area of future research.

2.6 Conclusion

This paper adds financial features to a New Keynesian model including the financial shock from Jermann and Quadrini. I find inflation targeting generates similar welfare gains to Ramsey optimal policy when capital is fixed. As capital becomes more variable the difference in welfare gains between inflation targeting and Ramsey optimal policy widens, albeit the gap is less than 15% with fully flexible capital. This result implies that although financial features may be added to a model to better explain co-movements of endogenous variables and financial flows, it is still optimal for the central bank pin down inflation in response to both technological and financial shocks.
<table>
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<tr>
<th>Variable</th>
<th>$\varepsilon_t^a$</th>
<th>$\varepsilon_t^d$</th>
<th>$\varepsilon_t^l$</th>
<th>$\varepsilon_t^g$</th>
<th>$\varepsilon_t^u$</th>
<th>$\varepsilon_t^p$</th>
<th>$\varepsilon_t^r$</th>
<th>$\varepsilon_t^f$</th>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output, $y$</td>
<td>21.02</td>
<td>3.40</td>
<td>22.15</td>
<td>12.00</td>
<td>11.35</td>
<td>0.24</td>
<td>0.00</td>
<td>29.84</td>
</tr>
<tr>
<td>Consumption, $c$</td>
<td>2.13</td>
<td>59.94</td>
<td>4.23</td>
<td>21.96</td>
<td>0.35</td>
<td>2.89</td>
<td>5.17</td>
<td>3.34</td>
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<tr>
<td>Labor, $h$</td>
<td>25.36</td>
<td>0.31</td>
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<td>0.39</td>
<td>14.18</td>
<td>0.01</td>
<td>0.48</td>
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</tr>
<tr>
<td>Investment, $i$</td>
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<td>1.84</td>
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<td>10.76</td>
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<td>0.89</td>
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</tr>
<tr>
<td>Labor Wedge</td>
<td>40.57</td>
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<td>Output, $y$</td>
<td>11.10</td>
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<tr>
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<td>6.97</td>
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<td>40.91</td>
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<td>Labor Wedge</td>
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<tr>
<td>Output, $y$</td>
<td>16.18</td>
<td>1.36</td>
<td>5.09</td>
<td>15.02</td>
<td>43.97</td>
<td>0.33</td>
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<td>14.78</td>
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<tr>
<td>Consumption, $c$</td>
<td>4.44</td>
<td>20.45</td>
<td>1.63</td>
<td>55.14</td>
<td>11.25</td>
<td>0.78</td>
<td>1.30</td>
<td>5.01</td>
</tr>
<tr>
<td>Labor, $h$</td>
<td>53.68</td>
<td>0.21</td>
<td>1.96</td>
<td>6.62</td>
<td>25.45</td>
<td>0.15</td>
<td>2.11</td>
<td>9.83</td>
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<td>46.09</td>
<td>0.09</td>
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<td>0.10</td>
<td>2.48</td>
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<td>16.85</td>
<td>0.11</td>
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</tr>
<tr>
<td>Output, $y$</td>
<td>17.49</td>
<td>1.42</td>
<td>4.68</td>
<td>22.91</td>
<td>27.32</td>
<td>0.58</td>
<td>3.34</td>
<td>22.28</td>
</tr>
<tr>
<td>Consumption, $c$</td>
<td>5.43</td>
<td>5.24</td>
<td>5.75</td>
<td>52.76</td>
<td>12.60</td>
<td>0.26</td>
<td>1.32</td>
<td>16.64</td>
</tr>
<tr>
<td>Labor, $h$</td>
<td>49.56</td>
<td>0.35</td>
<td>2.61</td>
<td>9.57</td>
<td>20.80</td>
<td>0.35</td>
<td>2.24</td>
<td>14.52</td>
</tr>
<tr>
<td>Investment, $i$</td>
<td>19.12</td>
<td>3.56</td>
<td>6.24</td>
<td>19.97</td>
<td>37.24</td>
<td>0.32</td>
<td>3.57</td>
<td>9.98</td>
</tr>
<tr>
<td>Labor Wedge</td>
<td>59.35</td>
<td>0.20</td>
<td>2.89</td>
<td>8.29</td>
<td>15.39</td>
<td>0.26</td>
<td>1.61</td>
<td>12.01</td>
</tr>
</tbody>
</table>

Note: Theoretical variance decompositions computed at the posterior mode.
By adding these financial features to a medium scale model similar to Smets and Wouters or Christiano, Eichenbaum, and Evans, I further explore the relative role of financial shocks in Post-Volcker United States data prior to the period in which the zero lower bound binds. I find the financial shock explains more than 10% of the unconditional variance in output, consumption, labor, investment, and the labor wedge with 25% of output variation being attributed to this shock. The financial shock is especially important in explaining the immediate variability in output, investment, and the labor wedge. Understanding the role of this shock in driving labor market movements is the principal goal of Garin (2015). Exploring this relationship further and attempting to understand the role of this shock in driving labor market slack, especially during the zero lower bound regime, is policy relevant and an important direction of future research.
CHAPTER 3
TERM PREMIUM VARIABILITY AND MONETARY POLICY

3.1 Introduction

This chapter was prepared with Timothy S. Fuerst for the Oxford Handbook of the Economics of Central Banking edited by David Mayes, Pierre Siklos, and Jan-Egbert Sturm.

In the aftermath of the 2008 financial crisis many central banks have adopted unconventional policies, including outright purchases of long term government debt. These bond purchases were an attempt to alter the yield curve for a given path of the federal funds rate. That is, they were meant to alter the term premium. In a monetary policy environment with a large Fed balance sheet, an important policy question going forward is whether the term premium (in addition to the funds rate) should be a regular input into the policy-making process. That is, should the Feds bond portfolio be used to smooth fluctuations in the term premium?

In this paper we integrate two distinct approaches to modeling the term premium in a medium-scale dynamic stochastic general equilibrium (DSGE) model and characterize the ability of each approach to generate a variable term premium as observed in the data. We then address how a policymaker should respond to term premium variability within the context of each modeling approach. Finally, we highlight two concerns which should be considered with the use of this new policy instrument and comment on the implications of each on the benefits to policy which smooths fluctuations in the term premium.
The first approach we implement to model the term premium alters preferences as in Epstein-Zin (1989), hereafter EZ. EZ preferences separate risk aversion from intertemporal substitution elasticities and are a common feature in the finance literature. Rudebusch and Swanson (2012) is a prominent example of using EZ preferences in a DSGE framework to model the term premium. The second approach deviates from an economy with frictionless asset trade by segmenting the asset market so that short and long bonds are priced by different agents, and the ability of agents to arbitrage the spread between long and short bonds is constrained by the net worth of the financial sector. In this environment a bond purchase policy will alter the term premium and have real affects. Carlstrom et al. (2017) is a recent example of this approach.

The two approaches have wildly different implications for monetary policy so that the modeling choice matters for the central bank. If the term premium is simply another asset price in a world with frictionless asset trade, then fluctuations in the term premium reflect changes in real activity but are otherwise irrelevant for central bankers (unless it helps forecast variables of interest to the policymaker). That is, in a frictionless model with EZ preferences the term premium should not directly concern policy makers. In contrast, if the term premium reflects an economic distortion arising from market segmentation, then there is a first-order role for smoothing fluctuations in the term premium.

Our principle results include the following. First, with a standard calibration of the DSGE model, and assuming that the business cycle is driven by TFP shocks, the EZ approach can produce an average term premium comparable to that found in the data, but a trivial and counterfactually small level of variability in the premium. These results are sensitive to the exogenous shocks. A recurring theme in the estimated DSGE literature is the importance of MEI (marginal efficiency of investment) shocks which perturb the link between investment spending and final capital goods.
If the business cycle is instead driven by these shocks, then the average term premium is negative with again trivial variability. We conclude that the EZ approach by itself has difficulty in both hitting the mean and the variability in the term premium.

Our second set of results concerns the segmentation model of Carlstrom et al. (2017). This model features two parameters that define the degree of segmentation in the financial sector: (i) the degree of impatience of financial intermediaries, and (ii) the level of adjustment costs in changes in portfolios. These parameters can be chosen to hit exactly the empirical mean and variability in the term premium. Given such a calibration, there are significant welfare gains to a central bank smoothing variations in the term premium by actively using its portfolio of long bonds.

We consider two practical difficulties with implementing a policy that eliminates all variability in the term premium, what we will call a term premium peg. First, the economic distortion of the peg depends upon the steady-state term premium which is different from the mean term premium if the yield on the long bond includes adjustments for risk. This implies that by implementing a term premium peg the policymaker is suppressing fluctuations in the term premium that come from the risk-adjustment but which are not representative of the segmentation distortion. Second, the term premium is subject to serially correlated measurement error. Thus, under a term premium peg the policymaker is inadvertently introducing exogenous variation into the model economy. This paper explores both of these effects and concludes that their quantitative significance is modest.

The paper proceeds as follows. Section 2 lays out the basic segmented markets model with EZ preferences. Section 3 provides a quantitative analysis of the model with segmentation effects turned off. Section 4 provides the complementary analysis for the model with active segmentation effects. Policy issues are discussed in Section 5. Section 6 concludes.
3.2 The Model

The model economy consists of households, employment agencies, firms, and financial intermediaries (FI). We will discuss each in turn.

3.2.1 Households

Each household has recursive preferences over consumption and labor given by

\[ V_t = U(c_t, h_t) + \beta \left[ E_t V_{t+1}^{1-\theta} \right]^{1/(1-\theta)} \]  (3.1)

Using the terminology of Rudebusch and Swanson (2012), the Epstein-Zin (EZ) preferences twist the value function. Risk aversion is increasing in \( \theta \). If we set \( \theta = 0 \), we have the standard preferences. The intra-period utility functional is given by:

\[ U(c_t, h_t) \equiv \frac{c_t^{1-\nu}}{1-\nu} - b \frac{h_t^{1+\eta}}{1+\eta} + k \]  (3.2)

where \( c_t \) and \( h_t \) denote consumption and labor, respectively. We choose the constant \( k > 0 \) so that steady state utility is positive which ensures that the value function always takes on positive values.

The household has two means of intertemporal smoothing: short term deposits, \( D_t \), in the financial intermediary (FI) and accumulation of physical capital, \( K_t \). Households also have access to the market in short term government bonds (T-bills). But since T-bills are perfect substitutes with deposits, and the supply of T-bills moves endogenously to hit the central banks short-term interest rate target, we treat \( D_t \) as the households net resource flow into the FIs. To introduce a need for intermediation, we assume that all investment purchases must be financed by issuing new investment bonds that are ultimately purchased by the FI. We find it convenient to use perpetual bonds with cash flows of 1, \( \kappa \), \( \kappa^2 \), etc. Let \( Q_t \) denote the time-t price of a new issue.
Given the time pattern of the perpetuity payment, the new issue price $Q_t$ summarizes the prices at all maturities, eg., $\kappa Q_t$ is the time-$t$ price of the perpetuity issued in period $t-1$. The duration and (gross) yield to maturity on these bonds are defined as: duration $= (1-\kappa)^{-1}$, gross yield to maturity $= Q_t^{-1} + \kappa$. Let $CI_t$ denote the number of new perpetuities issued in time-$t$ to finance investment. In time-$t$, the households nominal liability on past issues is given by:

$$F_{t-1} = CI_{t-1} + \kappa CI_{t-2} + \kappa^2 CI_{t-3} + \cdots$$ \hspace{1cm} (3.3)

We can use this recursion to write the new issue as

$$CI_t = F_t - \kappa F_{t-1}$$ \hspace{1cm} (3.4)

The representative household’s constraints are thus given by:

$$c_t + \frac{D_t}{P_t} + P_t^k I_t + \frac{F_{t-1}}{P_t} \leq M_t h_t + R_t^k K_t - T_t + \frac{D_{t-1}}{P_t} R_{t-1} + \frac{Q_t (F_t - \kappa F_{t-1})}{P_t} + div_t$$ \hspace{1cm} (3.5)

$$K_{t+1} \leq (1-\delta) K_t + I_t$$ \hspace{1cm} (3.6)

$$P_t^k I_t \leq \frac{Q_t (F_t - \kappa F_{t-1})}{P_t} = \frac{Q_t CI_t}{P_t}$$ \hspace{1cm} (3.7)

where $P_t$ is the price level, $P_t^k$ is the real price of capital, $R_{t-1}$ is the gross nominal interest rate on deposits, $R_t^k$ is the real rental rate, $M_t$ is the real wage paid to households, $T_t$ are lump-sum taxes, and $div_t$ denotes the dividend flow from the FIs. The household also receives a profit flow from the intermediate goods producers and the new capital producers, but this is entirely standard so we dispense from this added notation for simplicity. The loan-in-advance constraint (3.7) will increase the private
cost of purchasing investment goods. The first order conditions to the household problem include:

$$- \frac{U_h(h_t)}{U_c(c_t)} = M_t$$  \hspace{1cm} (3.8)$$

$$1 = E_t S_{t+1} \frac{R_t}{\Pi_{t+1}}$$  \hspace{1cm} (3.9)$$

$$P^k_t M_t = E_t S_{t+1} \left[ R^k_{t+1} + (1 - \delta) P^k_{t+1} M_{t+1} \right]$$ \hspace{1cm} (3.10)$$

$$Q_t M_t = E_t \frac{S_{t+1}}{\Pi_{t+1}} \left[ 1 + \kappa Q_{t+1} M_{t+1} \right]$$ \hspace{1cm} (3.11)$$

where the real stochastic discount factor (SDF) is given by

$$S_{t+1} = \left[ \left( \frac{V_{t+1}}{[E_t V_{t+1}^{1-\theta}]^{(1-\theta)/(1-\theta)}} \right)^{-\theta} \right] \beta \frac{U_c(c_{t+1})}{U_c(c_t)}$$ \hspace{1cm} (3.12)$$

and $\Pi_t \equiv P_t/P_{t-1}$ is gross inflation. Expressions (3.8) and (3.9) are the familiar labor supply equation and Fisher equation, respectively. The capital accumulation expression (3.10) is distorted relative to the familiar by the time-varying distortion $M_t$, where $M_t \equiv 1 + \vartheta_t/\Lambda_t$, $\vartheta_t$ and $\Lambda_t$ are the multipliers on the loan-in-advance constraint and budget constraint, respectively. The endogenous behavior of this distortion is fundamental to the real effects arising from market segmentation. Other things equal, there is a welfare advantage to stabilizing this distortion.

3.2.2 Labor Unions and Employment Agencies

There are a continuum of labor unions that purchase raw labor from households at price $M_t$ and transform it into a unique labor skill that is then sold to competitive
employment agencies. Union $i$ faces a labor demand curve given by:

$$H^i_t = H_t \left( \frac{W^*_t}{W_t} \right)^{-\epsilon_w} \quad (3.13)$$

where $W_t$ is the aggregate real wage and $W^*_t$ is the real wage set by union $i$. With probability $(1 - \theta_w)$, the union can re-set its nominal wage in the current period, while with probability $\theta_w$ its nominal wage simply grows by $\Pi^w_t$, where $\epsilon_w$ is the degree of nominal wage indexation to the inflation rate. If union $i$ can re-set its wage in time-$t$, its maximization problem is given by:

$$\max_{W^*_t} \; W^*_t H^i_t - H^i_t \mathcal{M}_t + \theta_w S_{t+1} \{ W^*_t \Psi^1_{t+1} - H^i_t \Psi^{-\epsilon_w}_{t+1} \mathcal{M}_{t+1} \}$$

$$+ \theta^2_w S_{t+1} S_{t+2} \{ W^*_t \Psi^1_{t+1} \Psi^1_{t+2} - H^i_t \Psi^{-\epsilon_w}_{t+2} \Psi^{-\epsilon_w}_{t+1} \mathcal{M}_{t+2} \} + \cdots \quad (3.14)$$

where $\Psi^1_{t+1} \equiv \Pi^w_t / \Pi_{t+1}$ denotes the automatic adjustment of the real wage to inflation. The optimal real wage choice for a typical union that can re-set its wage is given by the following:

$$W^*_t = \frac{G_{1,t}}{G_{2,t}} \quad (3.15)$$

$$G_{1,t} = W^*_t H_t \mathcal{M}_t + \theta_w S_{t+1} \left( \frac{\Pi_{t+1}}{\Pi^w_t} \right)^{\epsilon_w} G_{1,t+1} \quad (3.16)$$

$$G_{2,t} = \frac{\epsilon_w - 1}{\epsilon_w} W^*_t H_t + \theta_w S_{t+1} \left( \frac{\Pi_{t+1}}{\Pi^w_t} \right)^{\epsilon_w-1} G_{2,t+1} \quad (3.17)$$

The aggregate real wage then evolves as follows:

$$W^1_{t+1} = (1 - \theta_w) W^*_{t+1} + \theta_w \left( \frac{\Pi^w_{t+1}}{\Pi_t} \right)^{1-\epsilon_w} W^1_{t-1} \quad (3.18)$$
The nominal wage rigidity implies a time-varying dispersion, $d^w_t$, of real wages that is given by:

$$d^w_t = (1 - \theta_w) \left( \frac{W^*_t}{W_t} \right)^{-\epsilon_w} + \theta_w \left( \frac{W_{t-1}}{W_t} \right)^{-\epsilon_w} \frac{\Pi_t}{\Pi_{t-1}} \epsilon_w d^w_{t-1} \quad (3.19)$$

Each union sells its specific employment variety to a competitive employment agency. These agencies aggregate up these varieties into a labor service that is sold to firms at real wage $W_t$. These agencies solve the following maximization problem:

$$W_t \left[ \int_0^1 H_t(i)^{1-1/\epsilon_w} di \right]^{1/(1-1/\epsilon_w)} - \int_0^1 W_t(i) H_t(i) di \quad (3.20)$$

The optimization conditions are given by:

$$H_t(i) = \left( \frac{W_t(i)}{W_t} \right)^{-\epsilon_w} H_t \quad (3.21)$$

$$H_t \equiv \left[ \int_0^1 H_t(i)^{1-1/\epsilon_w} di \right]^{1/(1-1/\epsilon_w)} \quad (3.22)$$

### 3.2.3 Firms and Production

The production side of the model is standard and symmetric with the provision of labor input. There are a continuum of intermediate good producers, each with monopoly power over the input variety they produce. A monopolist produces intermediate good $i$ according to the production function

$$Y_t(i) = A_t K_t(i)^\alpha H_t(i)^{1-\alpha} \quad (3.23)$$
where \( K_t(i) \) and \( H_t(i) \) denote the amounts of capital and labor employed by firm \( i \).

The variable \( \ln A_t \) is the exogenous level of TFP and evolves according to:

\[
\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_{a,t} \quad (3.24)
\]

Every period a fraction \( \theta_p \) of intermediate firms cannot choose its price optimally, but resets it according to the indexation rule:

\[
P_t(i) = P_{t-1}(i)\Pi_{t-1}^{\theta_p} \quad (3.25)
\]

where \( \Pi_t = P_t/P_{t-1} \) is gross inflation. The firms who can re-set their prices, choose their relative price \( x_t \equiv P_t(i)/P_t \), optimally to maximize the present discounted value of profits:

\[
\max_{x_t} x_t Y_t(i) - Y_t(i)MC_t + \theta_pS_{t+w}\{x_tY_{t+1}(i)\Psi_{t+1}^{1-\varepsilon_p} - Y_{t+1}(i)\Psi_{t+1}^{-\varepsilon_p}MC_{t+1}\} \\
+ \theta_p^2S_{t+1}S_{t+2}\{x_t\Psi_{t+1}^{1-\varepsilon_p}\Psi_{t+2}^{1-\varepsilon_p}Y_{t+2}(i) - Y_{t+2}(i)\Psi_{t+2}^{-\varepsilon_p}\Psi_{t+2}^{-\varepsilon_p}MC_{t+2}\} \cdots \quad (3.26)
\]

where \( MC_t \) denotes real marginal cost, \( \Psi(t + 1) \equiv \Pi_t^{\theta_p}/\Pi_{t+1} \) is the automatic movement in the relative price, and the firm faces a demand curve given by:

\[
Y_t(i) = Y_t x_t^{-\varepsilon_p} \quad (3.27)
\]

The firms optimization conditions include:

\[
R^k_t = MC_tMPK_t \quad (3.28)
\]

\[
W_t = MC_tMPL_t \quad (3.29)
\]
\[ \Pi_t^* = \frac{\epsilon_p}{\epsilon_p - 1} X_{1,t} \Pi_t \] (3.30)

\[ X_{1,t} = MC_t Y_t + S_{t+1} \theta_p \Pi_t^{-\epsilon_p} \Pi_{t+1}^\epsilon X_{1,t+1} \] (3.31)

\[ X_{2,t} = Y_t + S_{t+1} \theta_p \Pi_t^{-\epsilon_p(1-\epsilon_p)} \Pi_{t+1}^{\epsilon_p-1} X_{2,t+1} \] (3.32)

The aggregate inflation rate and price dispersion, respectively, then evolve as:

\[ \Pi_t^{1-\epsilon_p} = (1 - \theta_p) \Pi_t^{1-\epsilon_p} + \theta_p \Pi_{t-1}^{\epsilon_p(1-\epsilon_p)} \] (3.33)

\[ d_t = \Pi_t^{\epsilon_p} \left[ (1 - \theta_p) \Pi_t^{1-\epsilon_p} + \theta_p \Pi_{t-1}^{-\epsilon_p} d_{t-1} \right] \] (3.34)

These monopolists sell their intermediate goods to perfectly competitive firms that produce the final consumption good \( Y_t \) combining a continuum of intermediate goods according to the CES technology:

\[ Y_t = \left[ \int_0^1 Y_t(i)^{1-\epsilon_p} di \right]^{1/(1-\epsilon_p)} \] (3.35)

Profit maximization and the zero profit condition imply that the price of the final good, \( P_t \), is the familiar CES aggregate of the prices of the intermediate goods.

3.2.4 New Capital Producers

New capital is produced according to the production technology that takes \( I_t \) investment goods and transforms them into \( \mu_t [1 - S (I_t/I_{t-1})] I_t \) new capital goods.
The time-$t$ profit flow is thus given by

$$P_t^k \mu_t \left[ 1 - S \left( \frac{I_t}{I_{t-1}} \right) \right] I_t - I_t \quad (3.36)$$

where the function $S(\cdot)$ captures the presence of adjustment costs in investment, and is given by $S(I_t/I_{t-1}) \equiv \frac{\psi_i}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2$. These firms are owned by households and discount future cash flows using the households SDF. The investment shock follows the stochastic process

$$\ln \mu_t = \rho \ln \mu_{t-1} + \varepsilon_{\mu,t} \quad (3.37)$$

where $\varepsilon_{\mu,t}$ is i.i.d. $N(0, \sigma^2_{\mu})$. Using the terminology of Justiniano et al. (2011), we will refer to these shocks as marginal efficiency of investment (MEI) shocks.

3.2.5 Financial Intermediaries

The FIs in the model are a stand-in for the entire financial nexus that uses accumulated net worth, $N_t$, and short term liabilities, $D_t$, to finance investment bonds, $F_t$, and the long-term government bonds, $B_t$. The FIs are the sole buyers of the investment bonds and long term government bonds. We again assume that government debt takes the form of perpetuities that provide payments of 1, $\kappa$, $\kappa^2$, etc. Let $Q_t$ denote the price of a new-debt issue at time-$t$. The time-$t$ asset value of the current and past issues of investment bonds is:

$$Q_t CI_t + \kappa Q_t \left[ CI_{t-1} + \kappa CI_{t-2} + \kappa^2 CI_{t-3} + \cdots \right] = Q_t F_t \quad (3.38)$$

The FIs balance sheet is thus given by:

$$\frac{B_t}{P_t} Q_t + \frac{F_t}{P_t} Q_t = \frac{D_t}{P_t} + N_t = L_t N_t \quad (3.39)$$
where $L_t$ denotes leverage. Note that on the asset side, investment lending and long term bond purchases are perfect substitutes to the FI. Let $R_{t+1}^L \equiv (1 + Q_{t+1})/Q_t$, denote the realized nominal holding period return on the long bond. The FIs time-$t$ profits are then given by:

$$.prof_t \equiv \frac{P_{t-1}}{P_t} \left[ (R_t^L - R_{t-1}^d) L_{t-1} + R_{t-1} ight] N_{t-1}$$

(3.40)

The FI will pay out some of these profits as dividends $div_t$ to the household, and retain the rest as net worth for subsequent activity. In making this choice the FI discounts dividend flows using the households pricing kernel augmented with additional impatience. The FI accumulates net worth because it is subject to a financial constraint: the FIs ability to attract deposits will be limited by its net worth. We will use a simple hold-up problem to generate this leverage constraint, but a wide variety of informational restrictions will generate the same constraint. We assume that leverage is taken as given by the FI. We will return to this below. The FI chooses dividends and net worth to solve:

$$V_t \equiv \max_{N_t, div_t} E_t \sum_{j=0}^{\infty} \left( \beta \zeta \right)^j \Lambda_{t+j} div_{t+j}$$

(3.41)

subject to the financing constraint developed below and the following budget constraint:

$$div_t + N_t [1 + f(N_t)] \leq \frac{P_{t-1}}{P_t} \left[ (R_t^L - R_{t-1}^d) L_{t-1} + R_{t-1} \right] N_{t-1}$$

(3.42)

The function $f(N_t) \equiv \frac{\psi_n}{2} \left( \frac{N_t - N_{ss}}{N_{ss}} \right)^2$, denotes an adjustment cost function that dampens the ability of the FI to adjust the size of its portfolio in response to shocks.
The FIs optimal accumulation decision is then given by:

$$\Lambda_t \left[ 1 + N_t f'(N_t) + f(N_t) \right] = E_t \beta \zeta \Lambda_{t+1} \frac{P_t}{P_{t+1}} \left[ (R_{t+1}^L - R_t^d)L_t + R_t^d \right]$$  \hspace{1cm} (3.43)

The hold-up problem works as follows. At the beginning of period \(t+1\), but before aggregate shocks are realized, the FI can choose to default on its planned repayment to depositors. In this event, depositors can seize at most fraction \((1 - \Phi)\) of the FIs assets. If the FI defaults, the FI is left with \(\Phi R_t^LL_t N_t\), which it carries into the subsequent period. To ensure that the FI will always re-pay the depositor, the time-\(t\) incentive compatibility constraint is thus given by:

$$E_t S_{t+1} \frac{P_t}{P_{t+1}} \left\{ R_{t+1}^L L_t N_t - R_t^d (L_t - 1) N_t \right\} \geq \Phi L_t N_t E_t S_{t+1} \frac{P_t}{P_{t+1}} R_{t+1}^L$$  \hspace{1cm} (3.44)

It is useful to think of (44) as determining leverage. Since net worth scales both sides of the inequality, leverage is a function of aggregate variables but is independent of each FIs net worth. We will calibrate the model so that this constraint is binding in the steady state (and thus binding for small shocks around the steady state).

Equations (43) and (44) are fundamental to the model as they summarize the limits to arbitrage between the return on long term bonds and the rate paid on short term deposits. The leverage constraint (44) limits the FIs ability to attract deposits and eliminate the arbitrage opportunity between the deposit and lending rate. Increases in net worth allow for greater arbitrage and thus can eliminate this market segmentation. Equation (43) limits this arbitrage in the steady-state by additional impatience \((\zeta < 1)\) and dynamically by portfolio adjustment costs \((\psi_n > 0)\). Since the FI is the sole means of investment finance, this market segmentation means that central bank purchases that alter the supply of long term debt will have repercussions for investment loans because net worth and deposits cannot quickly sterilize the purchases.
3.2.6 Central Bank Policy

We assume that the central bank follows a familiar Taylor rule over the short rate (T-bills and deposits):

\[
\ln(R_t) = (1 - \rho) \ln(R_{ss}) + \rho \ln(R_{t-1}) + (1 - \rho) (\tau_\pi \pi_t + \tau_y y_{gap}^t) \tag{3.45}
\]

where \( y_{gap}^t \equiv \ln(Y_t/Y_{ft}) \) denotes the deviation of output from its flexible price counterpart. We will think of this as the Federal Funds Rate (FFR). The supply of short term bonds (T-bills) is endogenous, varying as needed to support the FFR target. As for the long term bond policy, the central bank will choose between: (i) an exogenous path for the quantity of long term debt availables to FIs, or (ii) a policy rule that pegs the term premium and thus makes the level of debt endogenous. We will return to this below.

Fiscal policy is entirely passive. Government expenditures are set to zero. Lump sum taxes move endogenously to support the interest payments on the short and long debt.

3.2.7 Debt Market Policies

To close the model, we need one more restriction that will pin down the behavior in the long debt market. We will consider two different policy regimes for this market: (i) exogenous debt, and (ii) endogenous debt. We will discuss each in turn.

**Exogenous debt.** The variable \( b_t \equiv Q_t \frac{B_t}{P_t} \) denotes the real value of long term government debt on the balance sheet of FIs. There are two distinct reasons why this variable could fluctuate. First, the central bank could engage in long bond purchases (quantitative easing, or QE). Second, the fiscal authority could alter the mix of short debt to long debt in its maturity structure. Further research could model both of these scenarios as exogenous movements in long debt and the quantitative effect of
each. Our benchmark experiments will hold long debt fixed at steady state. Under this exogenous debt scenario, the long yield and term premium will be endogenous.

**Endogenous debt.** The polar opposite scenario is a policy under which the central bank pegs the term-premium at its steady state value. Under this policy regime the level of long debt will be endogenous. Under a term premium peg the asset value of the intermediary will remain fixed, while composition of assets will vary. That is, any increase of FI holdings of investment debt is achieved via the central bank purchasing an equal magnitude of government bonds. The proceeds from this sale effectively finances loans for investment.

### 3.2.8 Yields and Term Premia

The (gross) yield on the long term bond is defined by $R_{t}^{long}$:

$$
R_{t}^{long} = \frac{1}{Q_{t}} + \kappa
$$

(3.46)

The term premium is defined to be the difference between this yield and the corresponding yield implied by the expectations hypothesis, EH, of the term structure. This hypothetical bond price and corresponding yield are defined as:

$$
Q_{t}^{EH} = \frac{1 + \kappa E_{t}Q_{t+1}^{EH}}{R_{t}}
$$

(3.47)

$$
R_{t}^{EH,long} = \frac{1}{Q_{t}^{EH}} + \kappa
$$

The term premium is then given by:

$$
TP_{t} \equiv \frac{1}{Q_{t}} - \frac{1}{Q_{t}^{EH}} = R_{t}^{long} - R_{t}^{EH,long}
$$

(3.48)
We also define two other popular measures of the term structure: the slope of the term structure which is defined as the spread between the long rate and the short rate, and the excess return which is defined as the spread between the holding period returns on the long bond and the short rate:

\[ \text{Slope}_t \equiv R_{t}^{\text{long}} - R_t \]  

\[ \text{ER}_t \equiv (1 + \kappa Q_t) - R_{t-1} = R_l^t - R_{t-1} \]  

3.3 The Term Premium with Frictionless Financial Markets

We begin our quantitative analysis by abstracting from market segmentation effects. Segmentation is toggled off by setting \( \zeta = 1 \), and \( \psi_n = 0 \). This implies \( M_t \equiv 1 \).

Expanding the definition of the bond price we have:

\[ Q_t = E_t \frac{S_{t+1}}{\Pi_{t+1}} + \kappa E_t \frac{S_{t+1}}{\Pi_{t+1}} \frac{S_{t+2}}{\Pi_{t+2}} + \kappa^2 E_t \frac{S_{t+1}}{\Pi_{t+1}} \frac{S_{t+2}}{\Pi_{t+2}} \frac{S_{t+3}}{\Pi_{t+3}} + \cdots \]  

(3.51)

Similarly we have:

\[ Q_t^{EH} = E_t \frac{S_{t+1}}{\Pi_{t+1}} + \kappa E_t \frac{S_{t+1}}{\Pi_{t+1}} E_t \frac{S_{t+2}}{\Pi_{t+2}} + \kappa^2 E_t \frac{S_{t+1}}{\Pi_{t+1}} E_t \frac{S_{t+2}}{\Pi_{t+2}} E_t \frac{S_{t+3}}{\Pi_{t+3}} + \cdots \]  

(3.52)

This implies that the bond price can be expressed as

\[ Q_t = Q_t^{EH} + \kappa \text{cov}_t \left( \frac{S_{t+1}}{\Pi_{t+1}}, \frac{S_{t+2}}{\Pi_{t+2}} \right) + \cdots \]  

(3.53)

Since \( \kappa < 1 \), the early covariances are quantitatively the most important. Hence, there is a positive term premium if and only if the nominal SDF, \( S_{t+1}/\Pi_{t+1} \), is negatively autocorrelated at short horizons.
As emphasized by Fuerst (2015), it is impossible to generate a significantly positive term premium with standard preferences ($\theta = 0$). There are two reasons for this result. First, with $\theta = 0$, and for plausible values of $\nu$ in (2), the real SDF has trivial variability (this is just a manifestation of the equity premium puzzle). Second, inflation is positively autocorrelated at short horizons, an autocorrelation that is inherited by the nominal SDF. This positive autocorrelation in the nominal SDF kills any chance of generating a positive term premium.

But the EZ effect ($\theta > 0$) can easily deliver a positive term premium. Recall that the real SDF is given by:

$$S_{t+1} = \left[ \left( \frac{V_{t+1}}{E_t V_{t+1}^{1-\theta} \cdot (1-\theta)} \right)^{-\theta} \beta \frac{U_c(t+1)}{U_c(t)} \right]^{1/1-\theta}$$

(3.54)

The SDF is a product of an EZ term and the traditional inter-temporal marginal rate of substitution. The EZ term is, essentially, a forecast error, an innovation in lifetime utility. If $\theta$ is large enough, then a positive innovation in lifetime utility will lead to a sharp one-time decline in the real SDF. To generate a term premium we need a persistent movement inflation that is of the opposite sign as this innovation in lifetime utility. The model has two exogenous shocks: TFP shocks and MEI shocks. Positive innovations in either of these shocks will lead to positive innovations in lifetime utility. The implications for the term premium then depend upon the response of inflation to these shocks. We will look at each shock in turn.
To capture the mean and variability of the term premium, we use a third-order approximation to the model. The baseline parameter values are displayed in Table 3.1. The financial parameters are chosen to imply a bond duration of 40 quarters, a steady state term premium of 100 b.p., and FI leverage of 6. In this section we abstract from segmentation issues and set \( \zeta = 1 \) (implying no steady state term premium), and \( \psi_n = 0 \). The remaining parameter values are broadly consistent with the literature that estimates medium-scale DSGE models, with two important caveats. The estimation literature typically includes habit in consumption (from which we abstract), but excludes EZ effects (which we include). Consistent with the evidence in Justiniano, Primiceri, and Tambalotti (2011), output and investment variability are largely driven by MEI shocks. At the 8-quarter horizon, MEI shocks account for 62% of the variability of output, and 87% of the variability of investment.

Measurement of the term premium is easy in theory, but difficult in practice. For the period 1961-2007, Rudebusch and Swanson (2012) report a mean term premium of 106 bp, and a standard deviation of 54 bp. For the period 1962:1-2008:4, Adrian, Crump, and Moench (2013) report a mean of 169 bp, and a standard deviation of 154 bp. For our benchmark data target we will use a mean of 130 bp, and a standard deviation of 100 bp.
TABLE 3.1

PARAMETER VALUES FOR BASELINE CALIBRATION

<table>
<thead>
<tr>
<th>Preference parameters</th>
<th>Production parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
</tr>
<tr>
<td>$\nu$</td>
<td>2</td>
</tr>
<tr>
<td>$\eta$</td>
<td>1</td>
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<tr>
<td>$U_{ss}$</td>
<td>1</td>
</tr>
<tr>
<td>$h_{ss}$</td>
<td>1</td>
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<table>
<thead>
<tr>
<th>Nominal stickiness</th>
<th>Financial parameters</th>
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<tr>
<td>$\theta_p = \theta_w$</td>
<td>0.75</td>
</tr>
<tr>
<td>$\iota_p = \iota_w$</td>
<td>0.5</td>
</tr>
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<td></td>
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<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Exogenous Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_A, \sigma_A$</td>
</tr>
<tr>
<td>$\rho_\mu, \sigma_\mu$</td>
</tr>
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</table>
Table 3.2 reports some business cycle statistics for the model under a variety of scenarios. For present purposes, the focus is on Cases I and II which look at the model without segmentation effects, and with no EZ effects ($\theta = 0$) and substantial EZ effects ($\theta = 200$). A key takeaway from Table 3.2 is that adding EZ effects has essentially no effect on macro aggregates such as output, consumption, and investment. But there can be important effects on some financial variables. This phenomenon has been dubbed macro finance separation, in that EZ preferences can alter the behavior of asset prices without altering the behavior of macro aggregates. See Lopez-Salido et al. (2015) for a recent contribution. In the present case, a key change in financial variables is the cyclical behavior of the term premium which goes from mildly procyclical without EZ effects, to strongly countercyclical with the EZ effects. This is the only significant change the financial business cycle statistics. In both cases, no EZ effects and large EZ effects, a significant disappointment is the trivial variability in the term premium. We will return to this below.

Figures 1 and 2 examine the models implications for TFP shocks. With no EZ effects ($\theta = 0$), the model generates a trivial average term premium. But with sufficient EZ risk aversion, it is quite easy to hit a fairly large mean premium: with $\theta = 200$, the mean term premium is nearly 100 b.p. The reason for this is quite evident in the impulse response function in Figure 2 (which assumes $\theta = 200$). A positive TFP shock leads to a sharp increase in lifetime utility which implies a large negative innovation in the real SDF. The persistent TFP shock implies a persistent decline in inflation. Hence, the nominal SDF is significantly negatively correlated at short horizons thus implying a positive term premium. Without the EZ effect, the movement in the real SDF is trivial so that there is only a tiny term premium.
### TABLE 3.2

**BUSINESS CYCLE STATISTICS**

<table>
<thead>
<tr>
<th>Case</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
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<tr>
<td></td>
<td>$\sigma_Y$</td>
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<td>$\sigma_Y$</td>
<td>$\rho_{Y,Y}$</td>
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<tr>
<td>ln $Y$</td>
<td>5.14</td>
<td>1.00</td>
<td>5.17</td>
<td>1.00</td>
<td>4.06</td>
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<tr>
<td>ln $c$</td>
<td>0.67</td>
<td>0.47</td>
<td>0.66</td>
<td>0.44</td>
<td>0.94</td>
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<tr>
<td>ln $I$</td>
<td>3.90</td>
<td>0.85</td>
<td>3.82</td>
<td>0.86</td>
<td>5.31</td>
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<tr>
<td>ln $h$</td>
<td>0.69</td>
<td>0.39</td>
<td>0.70</td>
<td>0.41</td>
<td>1.09</td>
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<tr>
<td>ln $w$</td>
<td>0.95</td>
<td>0.79</td>
<td>0.94</td>
<td>0.78</td>
<td>1.00</td>
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</table>

<table>
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<th>$\sigma_x$</th>
<th>$\rho_{x,Y}$</th>
<th>$\sigma_x$</th>
<th>$\rho_{x,Y}$</th>
<th>$\sigma_x$</th>
<th>$\rho_{x,Y}$</th>
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</thead>
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<tr>
<td>r</td>
<td>407.36</td>
<td>0.30</td>
<td>400.38</td>
<td>0.37</td>
<td>548.33</td>
<td>0.59</td>
<td>419.89</td>
<td>0.37</td>
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<td>$r^\text{long}$</td>
<td>127.90</td>
<td>-0.33</td>
<td>99.84</td>
<td>-0.24</td>
<td>113.21</td>
<td>0.18</td>
<td>110.62</td>
<td>-0.25</td>
</tr>
<tr>
<td>$r^{EH,\text{long}}$</td>
<td>127.17</td>
<td>-0.33</td>
<td>97.06</td>
<td>-0.22</td>
<td>160.05</td>
<td>0.07</td>
<td>110.62</td>
<td>-0.25</td>
</tr>
<tr>
<td>$r^L$</td>
<td>964.41</td>
<td>0.06</td>
<td>959.97</td>
<td>0.07</td>
<td>952.52</td>
<td>0.15</td>
<td>926.88</td>
<td>0.08</td>
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<tr>
<td>$\pi$</td>
<td>228.02</td>
<td>0.16</td>
<td>214.79</td>
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<td>328.33</td>
<td>0.51</td>
<td>227.56</td>
<td>0.26</td>
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<tr>
<td>$TP$</td>
<td>0.78</td>
<td>0.44</td>
<td>3.72</td>
<td>-0.72</td>
<td>85.53</td>
<td>0.11</td>
<td>0.00</td>
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</tr>
<tr>
<td>Slope</td>
<td>351.57</td>
<td>-0.47</td>
<td>357.83</td>
<td>-0.49</td>
<td>488.45</td>
<td>-0.63</td>
<td>373.69</td>
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<td>ER</td>
<td>924.04</td>
<td>-0.04</td>
<td>925.99</td>
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<td>943.39</td>
<td>-0.15</td>
<td>890.29</td>
<td>-0.11</td>
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</table>

Note: We consider five cases when computing business cycle statistics. (I) No Epstein-Zin effects and no segmentation costs, $\theta = 0$ and $\psi_n = 0$ (II) Epstein-Zin effects only, $\theta = 200$ and $\psi_n = 0$ (III) Epstein-Zin effects and segmentation costs, $\theta = 50$ and $\psi_n = 1$ (IV) Pegged Term Premium (V) Pegged segmentation multiplier. For each case we show the standard deviation of output, the relative standard deviation of consumption, investment, labor, and real wages to output, the standard deviation of net interest rates, inflation, and spreads in basis points, and the correlation of quantities and prices with output. $Slope_t = R^\text{long}_t - R_t$, $ER_t = R^L_t - R_{t-1}$, $r_t = R_t - 1$.
Figure 3.1. Term premium (TFP shocks)
Figure 3.2. IRF to a TFP shock (no segmentation effects)

Note: Output, investment, consumption, output gap, and real SDF are percent deviations from steady state. Inflation, the funds rate, the 10-year yield, and the term premium are deviations from steady state in annualized basis points. The IRFs are computed using a third-order approximation.
But there is a problem with TFP shocks. The variability of the term premium is counterfactually small. Even with $\theta = 200$, the standard deviation is less than 5 b.p. (!). This result is distinct from the results reported by Rudebusch and Swanson (2012) who report much larger variability in the premium. For example, their best fit in their Table 3.2 reports a term premium standard deviation of 47 b.p. The reason for this different result is the form of the Taylor rule used. Rudebusch and Swanson (2012) assume that the central bank responds to the level of output relative to steady state (or trend in a model with exogenous growth). Let us call this an output rule in contrast to the gap rule in (45). It is useful to rewrite the gap as,

$$y_t^{gap} = \ln \left( \frac{Y_t}{Y_{ss}} \right) = \ln \left( \frac{Y_{t}}{Y_{ss}} \right) - \ln \left( \frac{Y_{t}}{Y_{ss}} \right) = y_t - y_t^{flex}$$  \hspace{1cm} (3.55)$$

Since output is the sum of flexible price output and the gap, we can write an output rule as:

$$\ln(R_t) = (1 - \rho) \ln(R_{ss}) + \rho \ln(R_{t-1}) + (1 - \rho) \left( \tau \pi_t^{\pi} + \tau \pi_t^{y} + \tau y_t^{gap} + \tau y_t^{flex} \right)$$  \hspace{1cm} (3.56)$$

For the case of TFP shocks, an output rule is akin to adding serially correlated exogenous policy shocks to a gap-based Taylor rule. Consider a positive TFP shock. An output based rule implies that the central bank commits to a persistent series of contractionary policy shocks. This then implies that the decline of inflation is much more substantial, and thus generates more term premium variability. Under a gap rule, the initial decline in inflation is 45 b.p. and the (negative) innovation in the real SDF is under 10%. Under an output rule, the initial inflation decline is 275 b.p. and the SDF innovation is over 15%. Further, under an output rule the persistent sequence of contractionary policy shocks keeps inflation persistently below steady state. Even after 20 quarters, inflation is over 200 b.p. below steady state (compared to 10 b.p. for the gap rule). We thus conclude that the model is
able to generate substantial term premium variability only if the central bank uses a non-typical policy rule.

Figures 3 and 4 provide the corresponding analysis for MEI shocks. In this case, the EZ preferences actually hurt the models ability to generate a positive term premium: the mean term premium is monotonically decreasing in $\theta$. The reason for this is clear in the impulse response function in Figure 4 (which assumes $\theta = 200$). A positive MEI shock increases lifetime utility and thus generates a negative innovation in the real SDF. But by increasing the demand for final output which can now more easily be transformed into capital, the MEI shock increases total demand and thus persistently increases the inflation rate. Hence, the nominal SDF has positive serial correlation and thus delivers a negative term premium. For demand shocks long term bonds are a hedge, and thus have a negative term premium. As with TFP shocks, the variability of the term premium is again trivial.

Figure 5 reports the mean and standard deviation of the term premium when both shocks are active. The results are as anticipated. The mean term premium is increasing in the EZ parameter, but the effect is much more modest than in Figure 1. The variability of the term premium is again trivial.

As emphasized by Bansal and Yaron (2004), long run risk is helpful in matching the equity premium with EZ preferences. The basic logic is that more persistence in the shock process implies larger variability in the real SDF. For the case of the term premium, greater persistence in either the TFP or MEI shocks is not helpful. As TFP shocks become more persistent, the wealth effect on labor supply tends to increase marginal cost and inflation, an effect that mitigates the EZ effects. For example, if we set $\rho_A = 0.999$, and $\theta = 200$, the mean term premium is 34 b.p., with a standard deviation of 8 b.p. For MEI shocks, greater persistence simply amplifies the hedging properties of the long bond. With $\rho_\mu = 0.95$, and $\theta = 200$, the mean term premium is -416 b.p., with a standard deviation of 78 b.p.
Figure 3.3. Term premium (MEI shocks)
Figure 3.4. IRF to a MEI shock (no segmentation effects)

Note: Output, investment, consumption, output gap, and real SDF are percent deviations from steady state. Inflation, the funds rate, the 10-year yield, and the term premium are deviations from steady state in annualized basis points. The IRFs are computed using a third-order approximation.
Figure 3.5. Term premium (TFP and MEI shocks)
We thus conclude that the EZ approach to the term premium has difficulty in matching either the mean or standard deviation of the term premium. One significant caveat to this is if the cycle is driven by TFP shocks and the central bank follows an output Taylor rule. Since the gap represents departure from the flexible price benchmark, optimal Taylor rules will typically include responses to the measured gap. In contrast, there is never a welfare-based argument for responding to measured output. One could thus suggest that to match the mean and variability of the term premium requires EZ effects and a suboptimal policy rule of a particular form.

3.4 Adding Segmented Markets

Given the difficulty of generating significant variability in the term premium solely from EZ effects, here we investigate the model with the segmentation effects turned on. As noted in Table 3.1, we use $\psi_n = 1$, and $\zeta = 0.9852$. The portfolio adjustment elasticity is comparable to the estimate of Carlstrom et al. (2017). The extra-level of discounting generates a steady-state term premium of 100 b.p., and a steady state segmentation distortion of $M_{ss} = 1.072$. The mean term premium will be the sum of the steady-state premium and the EZ risk adjustment that comes from the higher order approximation of the model.

Figure 6 reports the mean and standard deviation of the models term premium for the case in which both shocks are active. The results with the segmentation effects turned off are also reported for comparison. Several comments are in order. First, the model with segmentation effects make long bonds much riskier. Compared to the model without segmentation effects, the mean term premium is more sharply increasing in $\theta$. These effects are quantitatively important. With $\theta = 200$, the segmentation effects increase the mean risk adjustment for long bonds by over 200 b.p. It is thus quite easy to match the empirical mean of the term premium by choosing some combination of EZ effects ($\theta$) and extra discounting ($\zeta$). Second,
and more importantly, the segmentation effects can easily generate significant term premium variability. Again, the segmentation effects are quantitatively important: the SD of the term premium is an order of magnitude larger in the model with active segmentation effects. A EZ term of, say, $\theta = 50$, allows the model to closely mirror both the mean and SD of the term premium in the data. We will use this value going forward.

Figures 7 and 8 report the impulse response functions to the two exogenous shocks (for $\theta = 50$). The TFP shock causes a significant decline in the inflation rate. Since long bonds are nominal, this leads to a surge in the FIs real holdings of long bonds. The portfolio adjustment costs imply that the FI is willing to hold this abundance of long bonds only if term premia rise in compensation. This premia movement is substantial (roughly 20 b.p. on impact), and because of the loan-in-advance constraint on investment, leads to a decline in investment and a corresponding surge in consumption.

For the MEI shock there are contrasting effects on the term premium. The surge in inflation lowers the FIs holding of long bonds implying a decline in term premia. But the MEI shock increases the demand for investment and a consequent rise in term premia. The net effect is quite small: the term premium falls by 7 b.p. on impact. This is an important observation. Although the MEI shocks are an important driver of the business cycle, they contribute only a modest portion of variability in the term premium.
Figure 3.6. Term premium with segmentation (TFP and MEI shocks)
Figure 3.7. IRF to a TFP shock (with segmentation effects)

Note: Output, investment, consumption, output gap, and real SDF are percent deviations from steady state. Inflation, the funds rate, the 10-year yield, and the term premium are deviations from steady state in annualized basis points. The IRFs are computed using a third-order approximation.
Note: Output, investment, consumption, output gap, and real SDF are percent deviations from steady state. Inflation, the funds rate, the 10-year yield, and the term premium are deviations from steady state in annualized basis points. The IRFs are computed using a third-order approximation.
These endogenous movements in the term premium reflect changes in the risk adjustment on long bonds and changes in the segmentation distortion. From our earlier results we know that there are trivial movements in the premium arising from risk effects. Instead, almost all of the variability in the term premium reflects changes in the segmentation distortion. The central bank could use purchases (sales) of long debt to mitigate these increases (decreases) in the term premium and their consequent effect on real activity. We will investigate these issues below.

Table 3.2 also reports the business cycle statistics for the model with segmentation effects (Case III in the Table). Segmentation is a real distortion so there is no macro-finance separation here. Output is now less variable because the distortion dampens real behavior. But it also alters the mix of variability so that investment becomes a much more important driver of the business cycle, the relative SD rises from 3.8 to 5.3. As for the finance variables, a key difference is in the variability of the term premium. As discussed above, it increases by an order of magnitude from Case II to Case III. Curiously, this increase in the volatility of the term premium is due to the increased variability of the EH bond yield. The observed long term bond return exhibits no additional volatility. But the cyclicality of the term premium does change, with it switching from countercyclical under Case II to mildly procyclical in Case III. Thus, although the model with segmented markets generates empirically valid levels of variability in the term premium, the model may fail to generate observed cyclicality of risk premia. The robustness of this result is to the inclusion of other shocks, etc., is a subject for further research. However, observed measures of bond risk such as the term structure slope and excess return remain countercyclical in the presence of segmentation effects.

3.5 Segmented Markets and Monetary Policy

Carlstrom et al. (2017) demonstrate that up to a first-order approximation the
term premium moves one-for-one with the market segmentation distortion, $M_t$. This segmentation distortion has real effects by altering the efficient allocation of output between consumption and investment. Hence, a policy that stabilizes the term premium is likely to be welfare increasing. But things are more complicated with EZ effects and higher order approximations. Now the term premium will reflect both the segmentation distortion (Carlstrom et al. (2017)), and the time-varying risk effects arising from the EZ preferences.

Our focus is on policy across the business cycle, so we introduce steady-state subsidies on factor prices (to counter the monopoly mark-ups) and the cost of capital goods (to counter the loan-in-advance constraint) so that the steady-state of the model is efficient. Using a third-order approximation, we compute the welfare gain of a policy that varies the central banks holdings of long bonds to stabilize the term premium at its steady state level of 100 b.p. The baseline comparison policy is one in which the central bank holds its nominal bond portfolio fixed. Welfare is measured by expected lifetime utility of the household evaluated at the non-stochastic steady state.

Before turning to the welfare analysis, it is instructive to return to Table 3.2 and business cycle statistics. Cases IV and V consider the case of a term premium peg and segmentation peg, respectively. An important observation is that under either peg, the business cycle statistics closely mirror the model with EZ effects but no segmentation effects. This is not surprising. If, for example, the segmentation distortion is held fixed as it is under a peg, then the real model becomes isomorphic to the model with no such distortion. This is a powerful example of how the nature of monetary policy will drive financial variables such as the term premium. That is, in a world with segmentation effects, optimal monetary policy will eliminate the real and financial implications of segmentation.

Figure 9 reports the welfare gain of a term premium peg as a function of $\theta$. The
welfare gain is normalized to consumption units so that for example, 0.05, means a perpetual increase in steady state consumption of 0.05%. Figure 9 also reports the welfare gain of a long debt policy in which the central bank pegs the market segmentation distortion at steady-state ($M_t = M_{ss}$). Absent any interactions with the mark-up distortions, a segmentation peg will be optimal as it eliminates a time-varying distortion from the model. We do not view a segmentation peg as a reasonable policy alternative, but it helps demonstrate the advantages and disadvantages of a term premium peg. Recall that up to a first-order approximation, these two pegs are identical. But there are differences with higher order effects.

For the case of both shocks and $\theta = 0$, there is a welfare gain of the term premium peg of nearly 0.2%. This is close to the gain of a segmentation peg. But as we increase the EZ coefficient $\theta$, these two welfare gains diverge. The gain of a segmentation peg is modestly increasing in $\theta$, an implication of the households preference for distortion-stabilization as risk aversion increases. But the gain of a term premium peg diminishes in $\theta$. This decline arises because of the growing gap between the steady-state and mean term premium. The steady state premium comes from the additional FI discounting and thus reflects the segmentation distortion. The mean term premium is the steady-state premium plus the risk adjustment (either positive or negative) that comes from the EZ effect. As we increase the EZ coefficient, the mean term premium under the baseline policy becomes further separated from the steady-state term premium. A central bank that pegs the mean term premium at 100 b.p. will therefore exacerbate the average segmentation distortion by pegging the premium at the wrong level. This mismeasurement problem is increasing in $\theta$, so that the welfare gain of the premium peg is decreasing in $\theta$. 
Figure 3.9. Welfare gain of a term premium peg

Note: Welfare gains are normalized to consumption units so that for example, 0.05, means a perpetual increase in steady state consumption of 0.05%. 
This mismeasurement problem is similar but distinct for the two shocks. Consider first the case of TFP shocks in Figure 9. As we increase $\theta$, the mean term premium under an exogenous debt policy increases because of risk aversion effects (see Figure 1). If the central bank pegs the mean term premium at 100 b.p., it is then using its portfolio to overcompensate for segmentation effects, thus driving the average segmentation distortion below steady state. These effects are illustrated in Figure 10 which graphs the average segmentation wedge (relative to steady-state) as a function of $\theta$. Under a term premium peg this mean distortion is decreasing in $\theta$ as the overcompensation effect increases. This then implies that the gain to a term premium peg is diminishing in $\theta$. The story is symmetric for the case of MEI shocks. The risk effect on the average term premium is now decreasing in $\theta$ (see Figure 2). If the central bank pegs the mean term premium at 100 b.p., it will drive the average segmentation distortion above steady state (see Figure 10). The average segmentation distortion is thus increasing in $\theta$, so that the welfare gain of a term premium peg is again decreasing in $\theta$.

In summary, in a world with EZ risk effects on bond prices, the mean term premium is not the same as the mean segmentation distortion. By pegging the mean term premium, the central bank will typically exacerbate the mean segmentation distortion, pushing it above or below its non-stochastic steady state. There is thus a trade-off between minimizing variability in the segmentation distortion and achieving a desired mean. But these mismeasurement effects are modest. Even with $\theta=200$, the welfare gain of the peg is still substantial at 0.14%.
Figure 3.10. Mean segmentation wedge

Note: Mean segmentation wedge under a term premium peg of 100 basis points.
All of these effects are magnified if we abstract from subsidies that make the non-stochastic steady state efficient. With TFP shocks, the mean segmentation distortion is decreasing in $\theta$, so that the welfare gain of the term premium peg is increasing in $\theta$. Just the converse is true for MEI shocks. With $\theta = 200$, the welfare gain of the term premium peg is nearly 1.2% for TFP shocks, -0.5% for MEI shocks, and 0.68% for both shocks.

Another pitfall to responding to the term premium is that it is likely measured with significant error. We thus introduce serially correlated measurement error to the model’s observed term premium. By pegging the measured term premium at a mean of 100 b.p., measurement error implies that the central bank is inadvertently introducing exogenous fluctuations in the term premium into the model economy. We set the serial correlation of measurement error to 0.50. Figure 11 sets $\theta = 50$, and plots the welfare gain of the term premium peg as a function of the SD of measurement error. Since the SD of the term premium in the data is no more than 130 b.p., a reasonable upper bound on the measurement error is 100 b.p. But even with this large degree of noise, the gain to a term premium peg remains substantial.

Table 3.3 provides some sensitivity analysis by combining these two forms of measurement error. As discussed, the gain to a segmentation peg is modestly increasing in risk aversion $\theta$. The gain of the term premium peg is decreasing in both $\theta$, and the level of measurement error in the central bank’s observation of the term premium. But even with very high risk aversion, and a large level of measurement error, the welfare gain of the term premium peg is still significant: 0.07%.
Figure 3.11. Welfare gain of a term premium peg (measurement error)

Note: Mean welfare gains are normalized to consumption units so that for example, 0.05, means a perpetual increase in steady state consumption of 0.05%
TABLE 3.3

WELFARE GAIN OF TERM PREMIUM PEG AND SEGMENTATION PEG (BOTH SHOCKS)

<table>
<thead>
<tr>
<th>θ = 0</th>
<th>Term Peg</th>
<th>Segmentation Peg</th>
</tr>
</thead>
<tbody>
<tr>
<td>σₘₑ = 0</td>
<td>0.1869</td>
<td>0.1974</td>
</tr>
<tr>
<td>σₘₑ = 100</td>
<td>0.1185</td>
<td>0.1974</td>
</tr>
<tr>
<td>θ = 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>σₘₑ = 0</td>
<td>0.1759</td>
<td>0.2000</td>
</tr>
<tr>
<td>σₘₑ = 100</td>
<td>0.1076</td>
<td>0.2000</td>
</tr>
<tr>
<td>θ = 200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>σₘₑ = 0</td>
<td>0.1431</td>
<td>0.2079</td>
</tr>
<tr>
<td>σₘₑ = 100</td>
<td>0.0748</td>
<td>0.2079</td>
</tr>
</tbody>
</table>

Note: welfare gains are normalized to consumption units so that, for example, 0.05 means a perpetual increase in steady state consumption of 0.05%.
3.6 Conclusion

The last decade has demonstrated the creativity of central banks in creating new policy tools to deal with an evolving financial crisis and tepid recovery. A natural question going forward is which of these tools should become part of the regular toolbox of policymakers. One justification for the large scale asset purchases was to alter the term structure for a given path of the short term policy rate. That is, the policies were (in part) designed to alter the term premium. In analyzing such policies in a DSGE environment, one needs an economic rationale for both the mean and variability in the term premium. This paper has investigated two natural choices: (i) a time-varying risk premium for long bonds, and (ii) a time-varying market segmentation effect.

The paper suggests that the risk approach has difficulty in explaining the observed variability in the premium, whereas the segmentation approach can easily match the variability in the data. Further, according to the segmentation approach this variability is welfare-reducing so that there is a natural argument for a central bank to use its balance sheet to smooth fluctuations in the term premium. There are at least two concerns to consider when smoothing these fluctuations. The first is that a term premium peg prohibits fluctuations due to real economic activity, i.e. time varying risk effects. The second is that the term premium could be mismeasured and pegging the observed term premium introduces the measurement error into the economy. This paper shows that the effect of both of these concerns is modest and there are considerable welfare gains to smoothing term premium fluctuations.
A.1 Equilibrium

An equilibrium for the model in section 2.2 is characterized by a sequence of allocations, \( \{y_t, c_t, k_t, i_t, h_t, b_t, d_t, T_t\}_{t=0}^{\infty} \), prices, \( \{S_{t,t+1}, w_t, mc_t, R_t^L, P_t^k, r_t, R_t, \pi_t\}_{t=0}^{\infty} \), and exogenous sequences of technology, \( \varepsilon_t^a \), and financial shocks, \( \varepsilon_t^f \), such that: production and capital accumulation are given by (2.16) and (2.14); the enforcement constraint, (2.15), binds; household optimality conditions hold, (2.5)-(2.7); firm optimality conditions hold, (2.8)-(2.12); household, firm, and government budget constraints are satisfied, (2.4), (2.13), and (2.2); the nominal rate and effective nominal rate follow (2.3) and (2.1). The equilibrium conditions are summarized below.

\[
\begin{align*}
 b_{t+1} &+ \frac{E_t \pi_{t+1}}{1+r_t} + c_t + T_t = w_t h_t + d_t + b_{t-1} \\
\left(1 - \frac{\phi}{2}(\pi_t - 1)^2\right) y_t &+ b_{t+1} \frac{E_t \pi_{t+1}}{R_t} - b_t = w_t h_t + d_t + \frac{\phi d}{2}(d_t - d)^2 + i_t \\
 T_t & = b_{t+1} E_t \pi_{t+1}\left(\frac{1}{R_t} - \frac{1}{1+r_t}\right) \\
y_t & = \varepsilon_t^a k_t^{\alpha} h_t^{1-\alpha} \\
\Gamma \left(\frac{i_t}{t-1}\right) i_t & = k_{t+1} - (1-\delta)k_t \\
w_t h_t + i_t & = \varepsilon_t^f \left(k_{t+1} - b_{t+1} \frac{E_t \pi_{t+1}}{1+r_t}\right) \\
\psi h_t^\eta & = w_t c_t^{-\sigma} \\
1 & = E_t S_{t,t+1} \frac{1+r_t}{\pi_{t+1}}
\end{align*}
\]
\[ S_{t+1} = \beta \left( \frac{c_{t+1}}{c_t} \right)^{-\sigma} \]  
\[ w_t = (1 + s_w) \frac{mc_t}{R_{t}^f} (1 - \alpha) \frac{y_t}{h_t} \]  
\[ P_t^k \left( \Gamma \left( \frac{i_t}{i_{t-1}} \right) - \Gamma' \left( \frac{i_t}{i_{t-1}} \right) \left( \frac{i_t}{i_{t-1}} \right) \right) = R_t^f - E_t S_{t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} P_t^{k+1} \Gamma' \left( \frac{i_{t+1}}{i_t} \right) \left( \frac{i_{t+1}}{i_t} \right)^2 \]  
\[ P_t^k = \varepsilon_t^f (R_t^f - 1) + E_t S_{t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \left( (1 + s_q) mc_{t+1} \alpha \frac{y_{t+1}}{k_{t+1}} + (1 - \delta) P_{t+1}^k \right) \]  
\[ 1 = \varepsilon_t^f (R_t^f - 1) \frac{R_t}{1 + r_t} + E_t S_{t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \frac{R_t}{1 + \pi_{t+1}} \]  
\[ \phi(\pi_t - 1) \pi_t = 1 - \varepsilon^p + \varepsilon^p mc_t + E_t S_{t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \phi(\pi_{t+1} - 1) \frac{y_{t+1}}{y_t} \]  
\[ 1 + r_t = (1 + r) \pi_t^v \left( \frac{y_t}{y_t} \right)^{\nu_y} \]  
\[ R_t = 1 + r_t (1 - \tau) \]  
\[ \varepsilon_t^a = \rho_a \varepsilon_t^a - \sigma_a \eta_t^a \]  
\[ \varepsilon_t^f = \rho_f \varepsilon_t^f - \sigma_f \eta_t^f \]  

The flexible price economy is given by the same equations with \( \phi = 0 \) and the policy rule,

\[ 1 + r_t^f = (1 + r) \pi_t^{f,v} \left( 1 \right)^{\nu_y} . \]
A.2 Steady-State

Steady-state for the model from section 2.2 is characterized by the following equations. Note: $h = 1$, $\pi = 1$, and the steady-state level of inter-temporal debt is set to $\chi = 3.36$ as in Jermann and Quadrini (2012).

\begin{align*}
1 &= \beta (1 + r) \quad (A.21) \\
R &= 1 + r * (1 - \tau) \quad (A.22) \\
m_c &= \frac{\varepsilon_p - 1}{\varepsilon_p} \quad (A.23) \\
1 &= \beta \left(\frac{\alpha y}{k} + (1 - \delta)\right) \quad (A.24) \\
i &= \delta k \quad (A.25) \\
y &= k^\alpha h^{1 - \alpha} \quad (A.26) \\
c + i &= y \quad (A.27) \\
b &= \chi y \quad (A.28) \\
T &= b \left(\frac{1}{R} - \frac{1}{1 + r}\right) \quad (A.29) \\
w &= (1 - \alpha) \frac{y}{n} \quad (A.30) \\
\psi h^\eta &= wc^{-\sigma} \quad (A.31) \\
wh + i &= \varepsilon^f \left(k - b \frac{1}{1 + r}\right) \quad (A.32) \\
1 &= \varepsilon^f (R^l - 1) \frac{R}{1 + r} + \beta R \quad (A.33) \\
1 &= (1 + s_w) mc \frac{mc}{R^l} \quad (A.34) \\
P^k &= R^l \quad (A.35) \\
P^k &= \varepsilon^f (R^l - 1) + \beta \left((1 + s_q) mc \frac{y}{k} + (1 - \delta) P^k\right) \quad (A.36) \\
d &= b \left(\frac{1}{1 + r} - 1\right) + c + T - wh \quad (A.37)
\end{align*}
A.3 Medium Scale Model

\[ b_{t+1} + \frac{E_t \pi_{t+1}}{1 + r_t} + c_t + T_t = w_t h_t + d_t + b_{t-1} \]  
(A.38)

\[ \left(1 - \frac{\phi}{2}(\pi_t - 1)^2\right) y_t + b_{t+1} \frac{E_t \pi_{t+1}}{R_t} - b_t = w_t h_t + d_t + \frac{\phi_d}{2}(d_t - d)^2 + i_t \]  
(A.39)

\[ T_t = b_{t+1} E_t \pi_{t+1} \left(\frac{1}{R_t} - \frac{1}{1 + r_t}\right) + g_t \]  
(A.40)

\[ g_t = \varepsilon_t^g y_t \]  
(A.41)

\[ y_t = \varepsilon_t^a (u_t k_t)^a h_t^{1-a} \]  
(A.42)

\[ \varepsilon_t^0 \Gamma \left(\frac{i_t}{i_{t-1}}\right) i_t = k_{t+1} - (1 - \delta(u_t)) k_t \]  
(A.43)

\[ w_t h_t + i_t = \varepsilon_t^f \left(k_{t+1} - b_{t+1} \frac{E_t \pi_{t+1}}{1 + r_t}\right) \]  
(A.44)

\[ \lambda_t = \varepsilon_t^d (c_t - \zeta c_{t-1})^{-\sigma} - \beta \zeta E_t \varepsilon_t^{d+1}(c_{t+1} - \zeta c_t)^{-\sigma} \]  
(A.45)

\[ 1 = E_t S_{t,t+1} \frac{1 + r_t}{\pi_{t+1}} \]  
(A.46)

\[ S_{t,t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t} \]  
(A.47)

\[ w_t^* = \frac{\varepsilon_t^\psi}{\varepsilon_t^{\psi-1} h_{2,t} h_{1,t}} \]  
(A.48)

\[ h_{1,t} = \varepsilon_t^d \psi w_t^{\psi} \left(1 + \eta\right) h_{1,t+1}^{1+\eta} + \phi_w \beta E_t \varepsilon_t^{\psi+1}(1+\eta) h_{1,t+1} \]  
(A.49)

\[ h_{2,t} = \lambda_t w_t^\varepsilon h_t + \phi_w \beta E_t \pi_{t+1}^{\pi_{t+1}-1} h_{2,t+1} \]  
(A.50)

\[ w_t^{1-\varepsilon^{\psi}} = \phi_w w_{t-1}^{1-\varepsilon^{\psi}} + (1 - \phi_w) w_t^{1-\varepsilon^{\psi}} \]  
(A.51)

\[ w_t = (1 + s_w) \frac{mc_t}{R_t} \left(1 - \alpha\right) \frac{y_t}{h_t} \]  
(A.52)

\[ P_t^{k,i} \varepsilon_t^i \left(\Gamma \left(\frac{i_t}{i_{t-1}}\right) - \Gamma' \left(\frac{i_t}{i_{t-1}}\right) \left(\frac{i_t}{i_{t-1}}\right)\right) \]  
\[ = R_t^l - E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} P_{t+1}^k \varepsilon_{t+1}^i \Gamma' \left(\frac{i_{t+1}}{i_t}\right) \left(\frac{i_{t+1}}{i_{t-1}}\right)^2 \]  
(A.53)

\[ P_t^k = \varepsilon_t^f (R_t^l - 1) \]  
(A.54)

\[ + E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \left(1 + s_q \right) mc_{t+1} \frac{y_{t+1}}{k_{t+1}} + (1 - \delta(u_{t+1})) P_{t+1}^k \]
\[ P_t^k \delta'(u_t) k_t = mc_t \alpha \frac{y_t}{k_t} \]  \hspace{1cm} (A.55)

\[ 1 = \varepsilon'_t \left( R'_t - 1 \right) \frac{R_t}{1 + r_t} + E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \frac{R_t}{1 + \pi_{t+1}} \]  \hspace{1cm} (A.56)

\[ \phi(\pi_t - 1) \pi_t = 1 - \varepsilon'_t + \varepsilon'_t mc_t + E_t S_{t,t+1} \frac{\varphi'(d_t)}{\varphi'(d_{t+1})} \phi(\pi_{t+1} - 1) \pi_{t+1} \frac{y_{t+1}}{y_t} \]  \hspace{1cm} (A.57)

\[ 1 + r_t = (1 + r) \pi_t^{y_{t+1}} \left( \frac{y_t}{y_{t-1}} \right)^{v_y} \varepsilon'_t \]  \hspace{1cm} (A.58)

\[ R_t = 1 + r_t(1 - \tau) \]  \hspace{1cm} (A.59)

\[ \hat{\varepsilon}_t^a = \rho_a \hat{\varepsilon}_t^a - \sigma_a \eta_t^a \]  \hspace{1cm} (A.60)

\[ \hat{\varepsilon}_t^d = \rho_d \hat{\varepsilon}_t^d - \sigma_d \eta_t^d \]  \hspace{1cm} (A.61)

\[ \hat{\varepsilon}_t^i = \rho_i \hat{\varepsilon}_t^i - \sigma_i \eta_t^i \]  \hspace{1cm} (A.62)

\[ \hat{\varepsilon}_t^g = \rho_g \hat{\varepsilon}_t^g - \sigma_g \eta_t^g \]  \hspace{1cm} (A.63)

\[ \hat{\varepsilon}_t^w = \rho_w \hat{\varepsilon}_t^w - \sigma_w \eta_t^w \]  \hspace{1cm} (A.64)

\[ \hat{\varepsilon}_t^p = \rho_p \hat{\varepsilon}_t^p - \sigma_p \eta_t^p \]  \hspace{1cm} (A.65)

\[ \hat{\varepsilon}_t^r = \rho_r \hat{\varepsilon}_t^r - \sigma_r \eta_t^r \]  \hspace{1cm} (A.66)

\[ \hat{\varepsilon}_t^f = \rho_f \hat{\varepsilon}_t^f - \sigma_f \eta_t^f \]  \hspace{1cm} (A.67)

\[ \hat{\varepsilon}_t = \rho_e \hat{\varepsilon}_t^e - \sigma_e \eta_t^e \]  \hspace{1cm} (A.68)


