

Essays on Monetary Policy and Asset Prices

by

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Business Administration
Duke University

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Brian Weller

Dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in Business Administration
in the Graduate School of Duke University
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ABSTRACT

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Abstract

My Ph.D. dissertation is composed of two chapters studying how monetary policy influences asset prices.

The first chapter empirically explores the effects of the Federal Reserve (Fed)'s large-scale asset purchasing (LSAP) program on the cross-section of equity returns through financial intermediaries' funding liquidity. Using the LSAP shock by Swanson (2017) as a policy measure and the Liquidity Mismatch Index by Bai et al. (2018) as a funding liquidity measure of intermediaries, I show that an expansionary policy shock increases the stock return of banks with low liquidity more than those with high liquidity. In addition, the liquidity of lenders also influences their borrowers' equity prices through their sticky loan contracts. Firms borrowing from low liquidity banks, and of high loan-to-asset ratio earn relatively higher returns under the same expansionary shock. The response of borrowers is weaker, more delayed, and more

persistent than that of lenders. These findings collectively provide supportive evidence of the bank lending channel as a policy transmission mechanism in the quantitative easing period.

The second chapter theoretically analyzes how monetary policy feedback rule can influence the risk premium of financial assets in a New Keynesian general equilibrium model where a firm's default is endogenously determined from the limited liability of stockholders, and nominal price and wage rigidity exist. A productivity (monetary policy) shock shifts supply (demand) curve, causing output comove positively (negatively) with inflation. A policy rule to output and inflation determines the magnitude of output response to those shocks, determining the price of risk and the procyclicality of dividend. Higher (lower) inflation and lower (higher) output feedback lead to higher equity premium driven by a productivity (policy) risk. This trend is robust to the source of nominal rigidity. Under a baseline calibration, the model generates 1.76% (1.87%) of the annual levered (unlevered) equity risk premium, indicating an endogenous leverage does not amplify the equity return. The countercyclicality of the default rate in the model generates a credit risk premium, but does not amplify the overall credit spread. Producing reasonable asset pricing dynamics based on New Keynesian production-based models remains challenge.

To my family and the Lord Jesus Christ

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List of Abbreviations and Symbols

Abbreviations

BHC	Bank Holding Company
BRP	Bond Risk Premium
BLMI	Borrower-averaged Liquidity Mismatch Index
CES	Constant Elasticity of Substitution
CRRA	Constant Relative Risk Aversion
DSGE	Dynamic Stochastic General Equilibrium
ERP	Equity Risk Premium
FOMC	Federal Open Market Committee
IES	Intertemporal Elasticity of Substitution
IS	Investment-Saving
LSAP	Large-Scale Asset Purchases
LMI	Liquidity Mismatch Index
MP	Monetary Policy
OIS	Overnight Index Swap
PC	Phillips Curve
QE	Quantitative Easing
SDF	Stochastic Discount Factor

TFP Total Factor Productivity
WRDS Wharton Research Data Services

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Introduction

Monetary policy is one of the most controversial research areas in modern economics because scholarly disagreements are still prevalent across a wide spectrum; including the choice of the policy instrument and its identification strategy, policy goals, optimal policy rules or discretions to reach such objectives, and its transmission mechanisms in both descriptive and normative manner. The economic implications of a given monetary policy is not static and has varied significantly over time due to the evolving economic state and the change in policy implementations. In addition, the interaction between monetary policy and the economy has further perplexed our understanding surrounding such issues.

Unfortunately, there exists a chasm in our understanding regarding economic consequences stemming from new economic states and policy responses. Not surprisingly, many historical episodes have required economists to revisit firmly grounded theories

and propose remedies to address this gap. The most notable example in the recent period is the global financial crisis, driven primarily by the liquidity and the credit worsening of financial intermediaries. As a result, the Federal Reserve has been criticized heavily for overlooking critical signals arising from those intermediaries and asset prices in the financial market. The question of how the central bank should monitor the financial market has garnered substantial public attention following the former Fed chairman Greenspan's 'Irrational Exuberance' public speech in 1996; consequently spurring more academic research focusing on how monetary policies can reversely affect asset prices. Therefore, monetary policy research should include a thorough examination of financial market conditions including asset prices in order to further our understanding of policy transmission mechanisms and its optimal execution strategy.

My dissertation addresses this question by highlighting the relationship between monetary policies and asset prices. While interest rate dynamics mainly govern the pricing of safe bonds, for high-risk assets, stock prices are subject to dividend dynamics whereas corporate bond prices are to the default probability in addition to interest rates. Thus, I specifically focus on relatively underexplored high-risk assets given their indirect effect on monetary policy such as equities or corporate bonds.

My dissertation is composed of two chapters. The first chapter empirically investigates how unexpected news from the Federal Reserve affects the U.S. stock prices in the recent quantitative easing period. In particular, I focus on the funding liquidity of financial intermediaries as the source of cross-sectional dispersion of those responses. The second chapter discusses how a monetary policy rule influences the price of stocks and defaultable bonds through the lens of New Keynesian general equilibrium model in which a firm's default is endogenously determined. Together, chapters one and two juxtapose seemingly unrelated but complementary effect of the monetary policy empirical vs. theoretical, monetary quantity vs. interest rate, unconventional vs. conventional regime, and discretion vs. rule-based implementation policy, respectively.

Monetary Liquidity Provision and Stock Returns: the Role of Intermediaries' Funding Liquidity

1.1 Introduction

With the advent of the financial crisis, the U.S economy entered a period where the short-term nominal interest is virtually bound to zero. During that period from December 2008 to December 2015, the policy tool of the Federal Reserve (Fed) was not the target fed funds rate, but the amount of assets it purchases. The efficiency of this quantitative easing (QE) program to spur economic activity is still hotly debated. With the cost of increasing debt, the annual real GDP grew steadily by 2%, and the unemployment rate fell from 10% to 4%.¹ At the same time, the stock market ex-

¹ The unemployment rate reached 10% in October 2009.

perienced a huge boom, earning 20% of returns annually on average. However, these seemingly good signs of economic recovery do not uncover the effect of this unconventional policy and how it was transmitted to the economy and financial markets. Understanding the channel through which it operated is essential for evaluating the policy and forecasting the economic state in the post-QE era that entails tapering and reselling of the securities the Fed once purchased.

This paper explores the effect of injecting monetary liquidity through the Fed's large-scale asset purchasing (LSAP) program on the cross-section of equity returns through the lens of financial intermediaries' funding liquidity and its bank lending channel. To clearly differentiate, I use the term monetary liquidity as the availability of money, or equivalently cash or very liquid assets in the economy, while funding liquidity refers to an ability of a bank borrowing money from other entities. The bank lending channel indicates that expansionary monetary policy increases loan supply and accordingly the credit availability of borrowers, causing real effects by inducing more financing and investments.

Focusing on the heterogeneous exposure of individual stocks to the common policy shock can allow to trace an underlying source of heterogeneity that is affected by the policy, thus hinting at its transmission mechanism. The funding liquidity of financial

intermediaries is a natural candidate to explore, because liquidity dryup and credit contagion were key elements in amplifying the financial crisis (e.g. Brunnermeier and Pedersen (2008), Gertler and Kiyotaki (2015), and Calvo (2012)). Accordingly, bank funding liquidity might be potentially one of the main factors the Fed can closely pay attention to. It is not coincidental that many regulations and bank stress tests developed after the crisis impose more strict requirements in a liquidity management.

Highlighting on the role of bank funding liquidity, the monetary liquidity injected through the LSAP program can influence both intermediaries themselves and other corporate entities to a different degree depending on their balance sheet structure. As a primary effect, it can enhance the funding liquidity of intermediaries who suffer from liquidity dryup relatively more than those with good liquidity maintenance. Secondly, given this strong primary effect, it could also enhance firms who borrow from such intermediaries if the policy is effectively transmitted through bank lending channel. The stock market reflects all these anticipated changes which are triggered by the policy in a forward-looking manner. While the real change of funding conditions can be only tracked with a considerable lag due to quarterly observations, the response of stock prices is immediately observable, allowing to isolate the policy impact more cleanly without the impact of other policy-free information.

This study requires well-identified measures for the monetary liquidity by the Fed and the funding liquidity of intermediaries. For the monetary liquidity, I use the LSAP shock of Swanson (2017), which is one component of monetary policy risk extracted from the prices of interest rate futures of various maturities.² This measure characterizes the unanticipated scale of the Fed's asset purchases, thus capturing another dimension of the policy news conventionally represented by the rate change. For the funding liquidity, I construct the Liquidity Mismatch Index (LMI) of bank holding companies (BHCs) developed by Bai et al. (2018). LMI is based on the notion that a bank can fail to repay short-term liabilities if its assets are mostly illiquid (e.g. long-term loans or real estates). To capture this, different dynamic weights are assigned to each asset and liability class based on their own liquidity profile and macroeconomic conditions. LMI is the difference between the weighted sum of assets and liabilities, and is higher for the better funding liquidity condition.

Utilizing these liquidity measures, I investigate the impact of policy on stock prices step by step in two layers: lenders (intermediaries) and borrowers (firms). On the lender side, I show that the stock return of low-LMI bank rises relatively more than that of high-LMI analogues when the Fed's LSAP scale exceeds market expectations.

² Swanson (2017) decomposes the policy risk into the target rate, forward guidance, and LSAP shocks.

This observation is supported by the real effect that the LMI of low-LMI banks surges more than the high-LMI counterpart after the arrival of the hugest expansionary LSAP shock on March 18, 2009. Based on this strong pattern on the loan-supplier side, I also observe the demand side and find that i) firms who borrow from low-LMI banks, and ii) firms that are more dependent on lenders experience higher stock returns upon the realization of the same policy shock. As a joint version of these two findings, I also observe, after controlling for the lender-borrower connection, that the borrowers linked to low-LMI banks exhibit higher returns, although the power of the test is weak. Generally, these borrowers' stock response is weaker and more delayed than the lenders' stocks. These empirical results collectively provide supportive evidence that the policy risk is transmitted through the bank lending channel and gradually impacts the stock market starting with intermediaries and followed by firms.

This paper is related to the several branches of literature. The first line examines the real effects of monetary policy on bank lending behavior. Numerous papers state that banks with weak balance sheets reduce their loan supply following a monetary contraction. (e.g. Bernanke and Gertler (1995), Kashyap and Stein (2000), and Cingano et al. (2016)). Related to QE, Rodnyansky and Darmouni (2017) report that

banks with higher MBS-to-asset ratio increased their lending more only when MBSs are largely purchased by the Fed potentially due to their better liquidity condition.³ Despite the abundance of literature, the study of its ramification on the stock prices are relatively scarce in both lender and borrower side.

On the lender side, there has been paid relatively less attention to financial stocks. One contribution is Gandhi and Lustig (2015) who show that larger banks demand lower returns despite higher leverage due to a too-big-to-fail subsidy. More closely, Boualam and Cororaton (2017) study how bank liquidity affects its own stock returns. Their liquidity measure is conceptually similar to the LMI I use. However, These studies only deal with the lender side and do not directly address how those bank-specific factors create heterogeneous equity responses to the policy risk.

On the side of borrowers or non-financial firms, broad literature examines how monetary policy affects the stock market. In these studies, monetary policy risk is mostly characterized by interest rate changes (see Bernanke and Kuttner (2005), Gurkaynak et al. (2005)). A common finding is an unexpected easing by 25 bps leads to a 1-2% stock return increase. Cross-sectionally, Ozdagli and Velikov (2016) summarize the past findings about firm-specific factors that affect the stock return

³ Among three stages of the LSAP program (*a.k.a.* QE1-QE3), MBSs were only involved in QE1 and QE3.

exposure to policy, and propose a comprehensive exposure measure. Those factors include cash holdings, firm size, cash-flow duration and volatility, financial constraints, and profitability. However, none of these studies explore the stock market responses to LSAP shocks as opposed to target rate shocks. Moreover, I try to explain the cross-section of equity returns as a function of their lenders' liquidity.

This paper also belongs to a stream of literature examining how QE influences asset prices. In this area, most studies have focused on the class of assets that are purchased by the LSAP program such as Treasuries, agency mortgage-backed securities (MBS), other agency debts, and corporate bonds (i.e. Bauer and Rudebusch (2014), DAmico and King (2013), and Joyce et al. (2011)). These studies generally root to the monetary policy transmission mechanism through signaling channel (the Fed's forward guidance for long-term interest rates), or portfolio balance channel (the price change by supply shifts induced by the Fed).⁴ However, none of these are directly applicable to the equities. My paper tries to fill this gap through the lens of a bank lending channel.

This paper is organized as follows. Section 1.2 presents the construction of monetary and funding liquidity measures. Section 1.3 introduces the data structure and

⁴ Krishnamurthy and Vissing-Jorgensen (2011) summarize the transmission channels particularly operable in the QE period.

building the borrower-lender relationship through loan contracts. In Section 1.4, I study the role of lender liquidity in the response of lender stocks to policy shocks. Section 1.5 investigates the analogous version for borrower stocks. In Section 1.6, I test a trading strategy that exploits the return differentials originating from the cross-sectional dispersion of lender liquidity. Finally, Section 1.7 concludes.

1.2 Construction of Liquidity Measures

In the finance and economics literature, the term ‘liquidity’ has been used broadly in three different concepts despite their potential interdependence. The first is *monetary* liquidity meaning the availability of money, or equivalently, cash or very liquid assets in the economy. It is controlled by the monetary authority mainly through open market operations. Particularly in the QE regime, the policy indicator is the scale of money supply, not the interest rate target. In this sense, the monetary policy objective here is identical to the *monetary* liquidity control. The second meaning is *funding* liquidity which captures an ability of a bank borrowing money from other entities. Lastly, it refers to *market* liquidity, the ability to purchase or sell an asset without causing drastic change in the asset’s price in the market, usually expressed by bid-ask spreads, but this is out of scope in this study.

In this section, I construct *monetary* liquidity as a policy variable and *funding* liquidity of bank holding companies as a source of the intermediaries' heterogeneity.

1.2.1 *The Federal Reserve's Monetary Liquidity News*

To construct the measure of monetary liquidity provision by the Fed's LSAP program, I use the method proposed by Swanson (2017),⁵ who decomposed monetary policy shocks into target rate, forward guidance, and LSAP factors. The monetary policy shock is defined as *unanticipated* information released in the Federal Open Market Committee (FOMC) meeting scheduled regularly eight times a year. Extracting this *unanticipated* component is important because all the expected information is already reflected in asset prices by forward-looking investors. The period of my interest is from 2009 to 2014, so that I obtain 48 shocks as a result. Following his approach, I use daily price changes of n assets composed of 1-month federal funds futures (contracts expiring the current month and each of the next six months), 3-month eurodollar futures (contracts expiring the current quarter and each of the next eight quarters), Treasury bond yields (for the 3-month, 6-month and 2-, 5-, 10-, and 30-year maturities), the stock market (S&P 500), and exchange rates (yen/dollar and

⁵ Swanson (2017) extends the method originally proposed by Gurkaynak et al. (2005) who decomposed the policy risk into only target rate and forward guidance factors.

euro/dollar) measured each FOMC announcement from July 1991 to October 2015.

This system is described by a factor model,

$$X = F\Lambda + \varepsilon \tag{1.1}$$

where X is a $T \times n$ matrix of price changes, F is a $T \times k$ matrix with $k < n$ latent factors, Λ is a $k \times n$ matrix of loadings of the price responses on the k factors, and ε is a $T \times n$ matrix of white noise residuals. Cragg and Donald (1997)'s rank test shows that the minimum k that does not reject the white noise structure of ε is three, thus extracting three principal components represented by the $T \times 3$ matrix F . To provide a structural interpretation at this statistical decomposition, F is rotated by a 3×3 orthogonal transition matrix M and is transformed into the new factor $\tilde{F} \equiv FM$ and new loadings $\tilde{\Lambda} \equiv M'\Lambda$ that meet the following criteria.

- i) Changes in LSAP factor do not affect the current target rate.
- ii) Changes in forward guidance factor do not affect the current target rate.
- iii) LSAP factor is as small as possible before 2009.

Combined with the orthogonality condition, these three criteria limit the free parameters in the matrix M to three, and allow to exact identification. After the

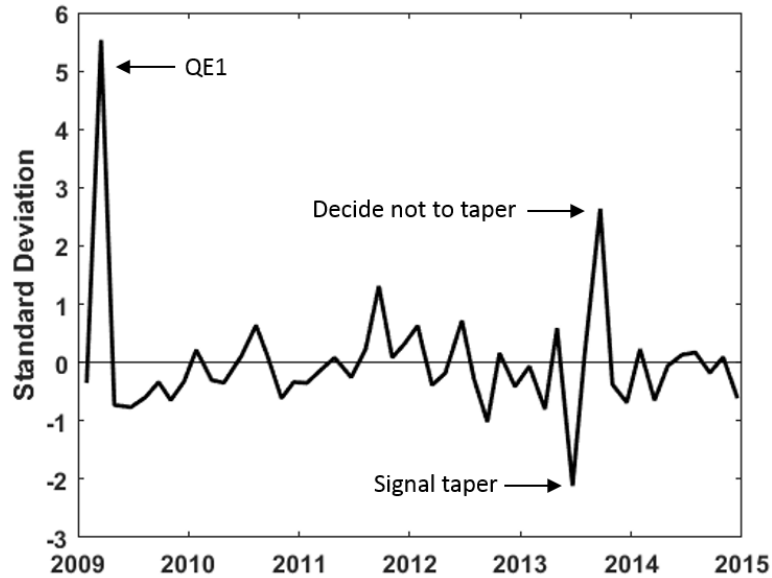


FIGURE 1.1: The LSAP Shock in the QE period

The horizontal axis indicates the beginning of year. The shocks are normalized to have zero mean and unit standard error.

estimation, the new factors are rescaled to have zero mean and unit standard deviation from the time series of 48 FOMC announcements.

Figure 1.1 illustrates the resulting LSAP shocks in the ZLB period from 2009 to 2014. I set the positive (negative) LSAP shock indicates the quantitative easing (tapering). As noted by Swanson (2017), the resulting LSAP shock captures some major events. For example, the positive 5.5-standard-deviation (SD) LSAP shock on 18 March 2009 reflects the unprecedented scale of monetary expansion by an additional purchase of \$1 trillion of debt in the first LSAP program (QE1). Other noticeable shocks are the negative 2.12-SD and the positive 2.63-SD in the mid of

2013. This huge oscillation coincides with news about tapering. In June 2013, the Fed released optimistic views about the economic growth, which led to the signal of early tapering. However, on 18 September 2013, the Fed announced not to taper early. Accordingly, the sign and magnitude of the LSAP shocks are consistent with these major episodes.

For the later analysis, converting the magnitude of LSAP shocks to the dollar amount of monetary liquidity provision would be helpful. I rescale the 5.5-SD LSAP shocks to \$1 trillion monetary base increases, following the initial QE1 announcement for the Fed's asset-purchasing scale. Although the estimate based on this single event can be inaccurate, using the later LSAP shocks can mislead the link between shocks and the actual liquidity injection as the market can better anticipate the Fed's actions in the later period.

1.2.2 Funding Liquidity of Bank Holding Companies: Liquidity Mismatch Index

As a proxy for intermediaries' funding liquidity, I construct the modified version of a Liquidity Mismatch Index (LMI) developed by Bai et al. (2018). LMI is based on the notion that a bank is more prone to the liquidity risk when it faces the obligation to repay short-term liabilities (e.g. overnight debts or commercial papers) when holding

mostly illiquid assets (e.g. mortgage loans or real estates). Oppositely, an immediate shortage in cash does not necessarily cause a severe problem if most liabilities have long-term maturities. To capture this into consideration, different dynamic weights are assigned to each asset and liability class based on their own liquidity profile and macroeconomic conditions. LMI is the difference between the weighted sum of assets and liabilities.⁶ Formally, the LMI of firm i at quarter t

$$LMI_t^i = \sum_k \lambda_{t,a_k} a_{t,k}^i - \sum_{k'} \lambda_{t,l'_k} l_{t,k'}^i \quad (1.2)$$

where the λ_{t,a_k} and λ_{t,l'_k} denote the weights of asset- and liability-side, and $a_{t,k}$ and $l_{t,k'}$ are the dollar amount of asset k , and liability k' , respectively. The key part is the determination of the weight. On the asset side,

$$\lambda_{t,a_k} = 1 - m_{t,k} \quad (1.3)$$

where m_k is the haircut on a term repurchase contract for the asset class k , so that $(1 - m_{t,k})a_{t,k}$ is the cash-equivalent amount of cash the bank can immediately raise using $a_{t,k}$ as collateral. Note that the haircut $m_{t,k}$ is a function of both time and asset class. First, the haircut is usually so counter-cyclical that the cash-equivalence

⁶ Berger and Bouwman (2009) initially use this idea but with static weights.

of an asset drops and thus dropping the overall LMI in bad times. Second, it varies by asset class as well. For example, the weight assigned to cash and overnight fed funds purchased is one as they are not discounted in liquidation. On the other hand, the cash-equivalent value of fixed assets is severely penalized upon repurchase, thus its weight is close to zero.

On the liability side, the weight

$$\lambda_{t,l'_k} = e^{-\mu_t T_{k'}} \quad (1.4)$$

where μ_t is the log of OIS-Tbill spread. Here, the weight is determined by the maturity of a liability and the OIS-Tbill spread. First, the longer-term maturity imposes less weight to a liability and thus less penalizes the LMI. Second, the OIS-Tbill spread is considered to be a measure of risk and liquidity in the money market. At the end of 2007, the OIS-Tbill spread rose to 0.85%, indicating a decreased willingness to lend by major banks due to bad creditworthiness of other financial institutions. In this case, even the long-term liabilities are highly weighted and contribute to the reduction of overall LMI.

Table 1.1 summarizes the direction of LMIs caused by time-varying macroeco-

conomic states and the nature of each balance sheet category. In bad times, an increased haircut margin (OIS-Tbill) spread respectively reduces (increases) the asset (liability) weight, contributing to a reduction of LMI.

Table 1.1: Determinants of Liquidity Mismatch Index

	variable	x	$\frac{\partial LMI}{\partial x}$	Low x	High x
Asset	Haircut	m	-	cash, fed funds sold good times	loan, real estate bad times
Liability	OIS-TBill	μ	-	good times	bad times
	Maturity	T'	+	overnight debt	equity, collaterals

To complete the implementation of LMI, the assignments of the haircut m for each asset, and the maturity T' for each liability class are required. For the detailed description of these steps, I refer to the Appendix of Bai et al. (2018).

Who serve as financial intermediaries in this study? I choose bank holding companies (BHCs) instead of national banks, state banks, or savings association. A BHC is a corporation that controls one or more banks.⁷ Large banking organizations in the United States such as Citigroup, JP Morgan Chase, and Bank of America are organized according to a BHC structure. At every quarter, a BHC whose asset size is more than \$500 million should file FR Y-9C report that serves as a monitoring tool of the BHC's financial condition by the Fed. The report describes its balance sheet

⁷ One BHC can also control other BHCs.

structure in more than 3,000 items,⁸ and is utilized as a source of constructing LMI.⁹

The reason BHCs are the main focus in my study is two-fold. First, BHCs generally issue their own equities, thus allowing to study intermediaries' stocks. Second, BHCs are the primary counterpart when the Fed trades through open market operations. For example, most Treasuries and MBSs that the Fed purchased during the LSAP program are sold by several major BHCs.¹⁰

Figure 1.2 illustrates the dispersion of BHCs' LMIs scaled by their own total asset from 2002Q2 to 2014Q1. Before the crisis, the average LMI is near 0.5, and the mid-80% of LMIs lie between 0.2 and 0.8. Beginning around the crisis in early 2007, the average LMI drops to -2.7 with significantly wider cross-sectional dispersion. After initiating the LSAP program in 2008Q4, the LMI recovers to the similar level and dispersion with the pre-crisis period.

The characteristics of BHCs of high- and low-LMIs are different in several aspects.

⁸ For the detailed information of the report structure, see <https://www.federalreserve.gov/apps/reportforms/reportdetail.aspx>.

⁹ The minimum asset threshold for FR Y-9C filing increased to \$1 billion from March 2015. Instead, every national banks, state bank, and savings association is required to file Consolidated Reports of Condition and Income (a "Call Report"). The overall structure between FR Y-9C and Call Report is slightly different.

¹⁰ The detail transaction records through open market operations are found in the website https://www.newyorkfed.org/markets/omo_transaction_data.html. For example, the BHCs that sold Treasuries to the Fed in 2010Q3 include Citigroup, Credit Suisse, Deutsche Bank, Goldman Sachs, and Morgan Stanley.

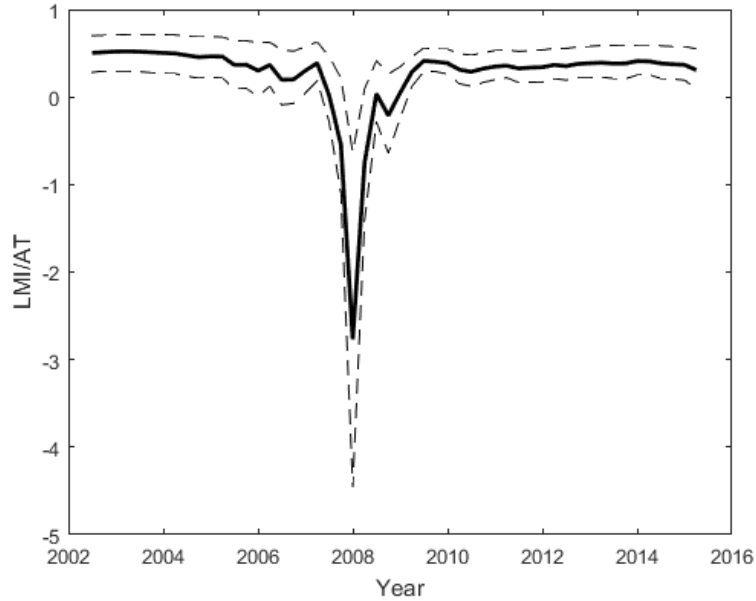


FIGURE 1.2: The Time Series of Liquidity Mismatch Index (LMI) to Total Assets

The bold line is the cross-sectional average of LMI. The upper (lower)-dashed line indicates the upper (lower) 10% of the cross-sectional distribution. The horizontal axis indicates the first day of the year.

Table 1.2 presents the time-series averages of the various LMI elements and other characteristics for the five BHC groups sorted by their LMI-to-asset ratio. The BHCs with higher LMI banks generally hold more cash, Treasuries and MBSs but less loans. They also sell more and buy less fed funds, implying their higher liquidity capacity. The only deviations from this trend are found in the higher cash holding (6.23%) in the lowest LMIs, and higher fed fund purchases (0.19%) of the highest LMIs. Potentially associated with this liquidity condition, the BHCs of higher LMIs are less levered and financially constrained, but closer to value firms. This pattern in the BHCs is

Table 1.2: LMI and the characteristics of BHCs

The numbers indicate the time-series average of 5 equally-sorted LMI bins divided at each quarter. Net fed funds sold-to-asset indicates the dollar fed funds sold minus fed funds purchased, scaled by total assets. The non-LMI characteristics in the lowest five rows are constructed based on the procedure in Section 1.3.1

LMI Bin	Low	2	3	4	High
LMI-to-asset	-0.177	0.278	0.353	0.417	0.510
$\sum w_k a_k / \sum a_k$	0.542	0.597	0.610	0.622	0.654
$\sum w_{k'} l_{k'} / \sum l_{k'}$	0.719	0.319	0.257	0.206	0.144
Cash-to-asset (%)	6.23	4.44	4.78	5.57	7.89
Loan-to-asset (%)	56.76	67.07	66.62	65.67	62.32
Treasury-to-asset (%)	2.65	3.28	3.60	3.99	5.03
MBS-to-asset (%)	11.24	11.93	11.62	12.93	13.95
Fed Funds sold-to-asset (%)	0.11	0.26	0.33	0.35	0.73
Fed Funds purchased-to-liability (%)	0.71	0.39	0.15	0.11	0.19
Net Fed Funds sold-to-asset (%)	-0.53	-0.08	0.20	0.26	0.56
log(Asset)	16.77	14.99	14.56	14.24	14.03
Quasi-leverage	0.548	0.524	0.495	0.476	0.387
Tobin's Q	1.084	1.136	1.193	1.284	1.345
Tangibility-to-asset (%)	1.88	1.63	1.76	1.84	1.59
Whited-Wu	-0.482	-0.410	-0.392	-0.378	-0.370

interesting in that value firms are usually highly levered typically in non-financial firms. Overall, the strong correlation of these characteristics with respect to LMI requires controlling for them in the following analysis.

1.3 Data and the Sample Construction

In this study, the whole sample universe is constructed mainly from five data sets:

- (1) daily interest rate futures downloaded from Datastream for the monetary liquidity measure,
- (2) quarterly FR Y-9C reports from the Fed to construct the LMI,
- (3) daily

equity prices from the Intraday Indicators in WRDS (Wharton Research Data Services), (4) quarterly accounting information of both intermediaries and non-financial firms from COMPUSTAT, and (5) loan issuance and its lender and borrower entities from LPC-Reuter’s DealScan syndicated loan database. As the policy and funding liquidity measures constructed from (1) and (2) are introduced in Section 1.2, respectively, I describe the remaining parts in this section. On the lender side, I link the LMI of intermediaries to their own stock returns calculated based on the FOMC announcement dates. On the borrower side, I connect the LMI of intermediaries to their borrowers’ stock returns through their loan relationships. Each step involves matching different form of identifiers and merging datasets available at different frequencies. I describe how the sample is constructed regarding these concerns.

1.3.1 Firm-Specific Variables and Linkage to Monetary Liquidity

As a first step, I merge monetary policy shocks, stock prices, and LMIs. LSAP shocks are available eight times a year, stock prices are daily, and LMIs are quarterly. At each FOMC announcement date t , I construct equity returns of firm i as

$$r_{i,t \rightarrow t+d} \equiv \frac{P_{i,t+d(4pm)}}{P_{i,t(1pm)}} - 1 \quad (1.5)$$

where d is the return horizon expressed in day, and 1pm (4pm) denotes the time of price measurement in day t ($t + d$). This availability of price measured at different times in the same day is particularly useful in capturing the immediate response of stock prices on the announcement day t , as new information in a FOMC meeting is usually released in 2:15pm. I vary d from 0 to 21 trading days that correspond to one calendar month. This process yields 22 returns series per each firm and announcement date which matches with a single LSAP shock, leading to eight observations per year and firm. I only track the return horizon to a month ahead from the announcement because the average duration between two adjacent FOMC announcements corresponds to only six weeks. Therefore, the 6-week return can be an outcome from the responses to two LSAP shocks.

As a second step, I construct control variables necessary in estimating the model specifications in Section 1.4 and 1.5, from the following accounting variables. In terms of COMPUSTAT items, size is log of total assets (ATQ) Quasi-leverage ratio is the book debt (BD) divided by sum of BD and market equity (ME), where BD is the sum of debt in current liabilities (DLCQ) and long-term debt (DLTTQ), and ME is price (PRCC) times shares outstanding (CSHO*PRCC). Tobin's Q is the common equity (CEQQ) divided by ME. Tangibility ratio is property plant and equipment

(PPENTQ) divided by ATQ. Finally as a proxy for financial constraints, I use the Whited and Wu (2006) measure defined as

$$WW = -0.091 \cdot CF - 0.062 \cdot DIVPOS + 0.021 \cdot TLTD - 0.044 \cdot Size + 0.102 \cdot ISG - 0.035 \cdot SG \quad (1.6)$$

where CF is the ratio of cash flow to total assets, DIVPOS is the cash dividend indicator variable, TLTD is the long term debt ratio to assets (DLCQ/ATQ), ISG is the firm's three-digit industry growth, and SG is sales growth. Firms with higher WW is more financially constrained. Whited and Wu (2006) measure indicates that such firms tend to be small, have low or even negative cash flows and high debt-to-asset ratio, cannot distribute dividends, and suffer from low sales growth particularly when the sales growth of competitors in the same industry is high.

Thirdly, I match the quarterly LMI contemporaneously with the control variables using CRSP-FRB Link provided by the Federal Reserve Bank of New York. In the link data, 1,412 BHCs expressed by RSSD identifiers in the FR Y-9C report are matched with their PERMCO counterpart.

Finally, I relate two FOMC events to the sample of the previous calendar quarter. For example, the shocks of 28th January 2009 and 18th March 2009 are matched

identically to its LMI calculated in the fourth quarter of 2008. Matching them contemporaneously (i.e. to the first quarter of 2009) does not substantially alter the main result, possibly due to very persistent patterns of the accounting variables. This procedure yields 11,923 BHC-FOMC observations from 436 BHCs in the lender sample.

1.3.2 Linking Lender and Borrower Relations

The previous steps allow to link monetary policy variables to lenders' LMI and stock prices. The remaining step is to connect borrowers' stock prices to their lenders' LMI. This requires three additional linkages. At the center, a borrower and lenders are linked by loan contracts. I match their relationship based on the identifiers in LPC-Reuter's Dealscan database. The dataset includes the loan amount, contract terms, the loan nature (e.g. type, seniority, and purpose), and the borrower and lender identifiers for each loan facility from 1981 to 2016. At the borrower end, I use Dealscan-COMPUSTAT link data offered by Chava and Roberts (2008). This link connects a Dealscan identifier of a borrower to its GVKEY identifier. At the lender end, I manually match a Dealscan identifier to the corresponding RSSD identifier based on its company name and location. Each linking step involves a significant loss

of data. Finally, 44,204 borrower-FOMC observations composed of 1,437 borrowers and 123 lenders survives in the period from 2009 to 2014.¹¹

A firm is generally financed by multiple loan facilities, each of which also involves by multiple banks. This one-to-many borrower-lender relationships require two further steps: averaging and handling missing data. First, LMIs of different banks should be merged into a single number for each firm-FOMC observation. Denote \overline{BLMI}_i the facility-weighted average of lenders' LMIs for a given borrower i . Formally, it is expressed by

$$\overline{BLMI}_i = \sum_{f \in f_i} \left[\frac{A_f}{\sum_{f' \in f_i} A_{f'}} \cdot \sum_{l \in l_f} LMI_l \right] \quad (1.7)$$

where f_i is the facility of i , l_f is the lender bank l involved in f , LMI_l is the lender l 's LMI, and A_f is the initial facility amount of f divided by its own maturity. For example, \$60 million of facility contract with a 60-month term loan is considered \$3 million of financing every quarter.

I do not consider the lender-weighting in a given facility here due to the sparsity of bank allocation information in the original Dealscan Lenders data.¹² Dropping this missing data further truncates the sample size and decreases the power of tests.

¹¹ That matches with 30,709 borrower-quarter observations from 2008Q4 to 2014Q3.

¹² In the original Dealscan Lenders database, only 31.8% of bank allocation is non-missing.

Therefore, the above measure simply assumes that all participants are equal contributors in a facility.

Second, I omit the lenders with missing LMI values in a facility. These lenders might not be a part of BHCs. This treatment overweighs the role of lenders with LMI availability.¹³ One possible approach that does not drop LMI-missing lenders is to impose an arbitrary LMI based on propensity score matching. However, its inaccurate approximation can rather obfuscate the lender effect on borrowers. After omitting the missing sample, the BLMI-assigned facilities cover all on-the-run facilities in 67% of the sample observations.

1.4 The Equity Response of Financial Intermediaries

Utilizing LSAP shocks and the LMI as measures of monetary policy and funding liquidity of financial intermediaries, respectively, I explore how monetary policy is transmitted to the real economy through the eyes of stock prices. Although such real changes can be often directly measured by accounting variables, they are usually updated in a quarterly frequency. In contrast, stock prices incorporate all the anticipated future changes and boil them down to a single present value relatively

¹³ For example, one BHC whose LMI only exists among ten lenders in the same facility represent the LMI of that facility.

immediately. This facilitates the isolation of policy impacts on the economy relatively in a short horizon without disturbance of other policy-free information.

Based on this rationale, I investigate how the funding liquidity of intermediaries influence the response of stock prices of not only the intermediaries or lenders themselves, but also their borrower firms, when the Fed injects monetary liquidity. This section focuses on the intermediaries first.

I naturally begin with a conjecture that banks who suffer from poorer funding conditions will enjoy greater benefits when the central bank provides liquidity to the economy through the LSAP program. Before tracking the stock prices, however, it is instructive to check that whether such policy leads to a *de facto* real change in intermediaries' LMIs after the realization of a policy news. Choosing 18 March 2009, the date with the largest expansionary LSAP shock, as the event date, I estimate the LMI growth of BHC i as a function of its original LMIs using the specification

$$\frac{\Delta LMI_{i,t+q}}{AT_{i,t}} = \alpha + \beta \cdot \frac{LMI_{i,t}}{AT_{i,t}} + Controls_{i,t} + \varepsilon_{i,t+q} \quad (1.8)$$

where the denominator AT is total asset, baseline quarter t is 2008Q4, q is the quarterly horizon, and controls include quasi-leverage ratio, Tobin's Q, tangibility, and the

WW measure constructed in Section 1.3.1. In Table 1.3 that presents the estimates of Equation (1.8), the negative β indicates that the relative funding liquidity enhanced more in BHCs that were more liquidity-constrained in 2008Q4. In particular, the coefficient for the increment to 2009Q1 is -0.59, while that beginning from 2009Q2 is flattened near -0.80. This indicates that the effect of the biggest LSAP shock on the 18th of March 2009 is not fully absorbed at the end of 2009Q1. This observation supports the conjecture that a policy shock can trigger a real change in the economy, and motivates the following hypothesis,

Hypothesis L1 (HL1): Upon the arrival of positive LSAP shock, the equity of a BHC with a smaller LMI exhibits higher price increases than that with a greater LMI.

To test this, I estimate the following pooled difference-in-difference regression model

$$r_{i,t \rightarrow t+d} = \alpha + \beta \cdot LSAP_t + \gamma \cdot LMI_{i,t} + \delta \cdot LSAP_t \cdot LMI_{i,t} + Controls_{i,t} + \varepsilon_{i,t} \quad (1.9)$$

by varying the return horizon d . For control variables, I use the same variables as

Equation (1.8) and their interaction terms with LSAP shocks. *HL1* predicts that the conditional response on the LMI, δ , is negative while the unconditional response β to a LSAP shock is positive.

Table 1.3: LMI Increments upon the Expansionary Policy

LMI is the dollar value. The baseline quarter t is 2008Q4. The OLS standard deviation is in the parenthesis.

q	2009Q1	2009Q2	2009Q3	2009Q4
LMI_t/AT_t	-0.589 (0.009)	-0.856 (0.008)	-0.833 (0.007)	-0.838 (0.008)
$\ln(AT_t)$	-0.053 (0.007)	-0.034 (0.006)	-0.021 (0.005)	-0.024 (0.006)
<i>const</i>	0.888 (0.102)	0.797 (0.086)	0.774 (0.074)	0.809 (0.085)
BHCs	287	283	287	283
R^2	0.949	0.984	0.987	0.984

Table 1.4: Test of *HL1*

The unit of return horizon d indicates D(daily), W(weekly), and M(monthly). The regression coefficients for controls and the intercept are omitted for brevity. p -values from the standard errors clustered by both borrowers and 48 FOMC announcements is in the parenthesis. Dependent variables are winsorized at 1% level.

d	D0	D1	D2	D3	W1	W2	W3	M1
LSAP	-0.040 (0.968)	2.023*** (0.007)	2.485*** (0.000)	2.864*** (0.002)	3.953*** (0.003)	5.143*** (0.000)	4.616*** (0.001)	0.714 (0.749)
LMI	-0.184* (0.078)	-0.062 (0.650)	-0.034 (0.873)	-0.080 (0.737)	-0.067 (0.860)	-0.036 (0.920)	0.623 (0.515)	0.819 (0.504)
Size	0.054 (0.627)	0.152 (0.182)	0.206 (0.120)	0.327** (0.036)	0.581*** (0.008)	0.738** (0.020)	0.642** (0.044)	1.103*** (0.005)
LSAP · LMI	-0.308** (0.017)	-0.386** (0.019)	-0.309** (0.047)	-0.478** (0.016)	-0.629** (0.015)	-0.739** (0.021)	-1.045** (0.045)	-1.183* (0.097)
LSAP · Size	0.003 (0.965)	-0.157** (0.012)	-0.192*** (0.002)	-0.222*** (0.007)	-0.296** (0.010)	-0.410*** (0.000)	-0.360** (0.018)	-0.135 (0.554)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BHCs	436	435	436	436	436	431	432	432
Obs	11,923	11,602	11,352	11,141	10,918	10,624	10,587	10,528
R^2	0.031	0.027	0.027	0.034	0.034	0.033	0.029	0.056

Table 1.4 presents the result from estimating Equation (1.9), and the upper panels in Figure 1.3 supplements illustrations of confidence interval of δ and β over the return horizon. As predicted in *HL1*, the negative coefficients of the LMI interacting with the LSAP shock indicate that an expansionary policy is more beneficial to more liquidity-constrained banks. This LMI effect is significant and persistent over the month since the shock realization. As a result, the return differential between the low- and the high-LMI stocks widens at longer horizons. On the other hand, the unconditional response is hump-shaped and loses the statistical significance in a month ahead. Back-of-the-envelope calculations demonstrated in Section 1.2.1 suggest that the unanticipated expansion of the Fed’s asset purchases by \$100 billion increases the average weekly stock return of lowest- and highest-decile BHCs by 2.38% and 2.01%, and the monthly of 0.75% and 0.04%, respectively.¹⁴

In addition to LMI-to-asset as a key variable in the analysis, I also present the coefficients related to bank size in Table 1.5. The negative coefficients of size interacted with policy shocks indicate that small banks respond more to policy shocks. This size effect can be potentially related to the *too big to fail* mechanism of Gandhi and

¹⁴ This calculation is based the following steps. One standard deviation of LSAP shock corresponds to \$180 billion following Section 1.2.1. The average of LMI in the lowest- and highest decile is -0.538 and 0.546, respectively. Plugging these into β and δ for the corresponding horizon provides the result.

Lustig (2015), suggesting that larger banks demand lower returns despite elevated leverage, consistent with government guarantees for such banks. However, this size effect also decays after two weeks from the news release. Overall, the LMI effect is robust to controlling for other variables and has a long memory in stock returns.

Is this LMI effect triggered by a subset of intermediaries? If the stock price responds to a policy news in a non-linear manner, the relationship between the bank's LMI and its stock return can potentially hold only in a specific range of LMIs. To check this possibility, I separately estimate Equation (1.9) for each of the five LMI-sorted portfolios and present the result in Table 1.5. If the relationship is perfectly linear, the interaction coefficients δ are identical across the portfolios. Table 1.5 shows that the coefficient is all negative in any portfolio for both weekly and monthly returns, but that for the lowest-LMI bin exhibits close to zero compared to any other portfolios.¹⁵ This abnormality can be potentially related to the deviating pattern of this portfolio demonstrated in Table 1.2, but I leave this conjecture for future research. Overall, *HL1* is supported in most ranges of LMI levels. This demonstrates that monetary policy impacts stock prices of financial intermediaries to a different degree depending on their own funding liquidity condition.

¹⁵ Under 10 LMI-sorted bin, only the lowest-bin again shows the moderate negativity of δ , implying that this abnormality comes from the BHCs in the very left tail.

Table 1.5: Test of *HL1* - Subsample by LMI levels

The unit of return horizon d indicates D(daily), W(weekly), and M(monthly). The regression coefficients for controls and the intercept are omitted for brevity. p -values from the standard errors clustered by both borrowers and 48 FOMC announcements is in the parenthesis. Dependent variables are winsorized at 1% level.

d	Weekly (W1)					Monthly (M1)				
LMI	Low	2	3	4	High	Low	2	3	4	High
LSAP	3.789* (0.094)	5.504 (0.388)	4.670 (0.110)	11.154*** (0.000)	3.710 (0.395)	1.136 (0.826)	7.580 (0.285)	-2.915 (0.682)	6.364 (0.337)	6.776 (0.472)
LMI	0.000 (0.999)	3.848 (0.531)	5.869 (0.229)	6.315 (0.326)	0.208 (0.958)	0.649 (0.368)	19.787 (0.107)	32.668** (0.011)	22.173 (0.119)	17.476 (0.235)
Size	1.252*** (0.002)	0.585 (0.198)	1.292*** (0.001)	0.153 (0.652)	0.714** (0.049)	1.967*** (0.001)	0.123 (0.876)	2.340*** (0.003)	0.248 (0.630)	1.397 (0.241)
LSAP · LMI	-0.773*** (0.000)	-4.371*** (0.005)	-3.955*** (0.006)	-6.867*** (0.000)	-3.276*** (0.008)	-1.090* (0.092)	-11.955*** (0.000)	-9.895*** (0.003)	-14.555*** (0.001)	-10.458*** (0.003)
LSAP · Size	-0.378 (0.157)	-0.485 (0.444)	-0.604*** (0.005)	-0.541*** (0.003)	-0.357 (0.414)	-0.269 (0.683)	-1.626 (0.129)	-0.361 (0.611)	0.041 (0.923)	-1.331 (0.264)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BHCs	142	199	226	241	180	139	194	225	238	179
Obs	2,344	2,416	2,253	2,227	2,300	2,271	2,344	2,185	2,153	2,217
R^2	0.069	0.075	0.087	0.064	0.030	0.111	0.153	0.160	0.080	0.060

1.5 The Equity Response of Borrower Firms

After observing the heterogeneous reaction of bank stocks sorted by their own LMIs, I next explore whether bank lending channel served as one of the serious policy transmission mechanism in the QE period. The bank lending channel states that expansionary policy eases the funding constraints of intermediaries, provides more room for their loan supply, thereby causes real effects not only to themselves, but also to their borrowers. Therefore, the asset price response of lenders can spill over to that of borrowers if the bank lending channel strongly operates.

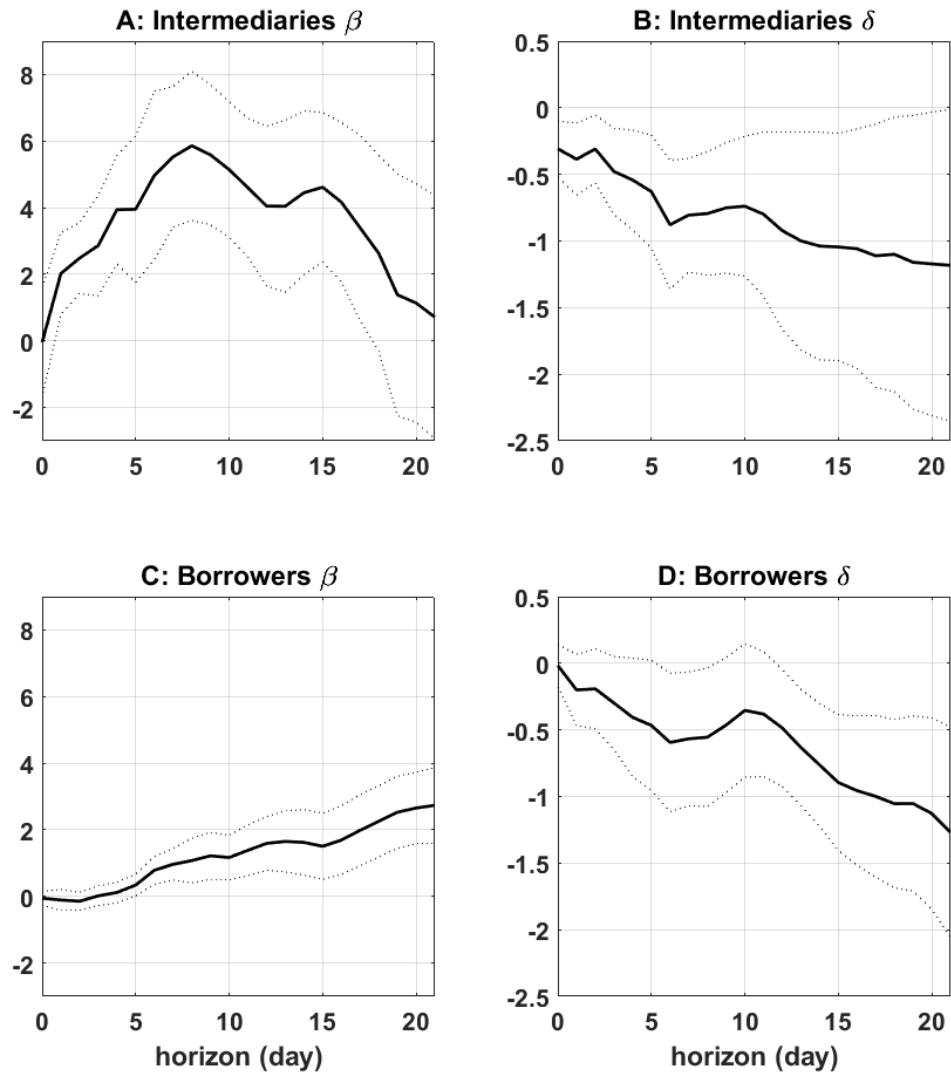


FIGURE 1.3: Selected Coefficients over the Return Horizon

Results in the upper panel indicate the estimate for $HL1$ from Equation (1.9), the lower panel for $HB1$ from Equation (1.12). The dashed lines indicate 90% confidence interval.

Despite the abundance of literature that highlights on bank lending behavior upon monetary policy, however, viewing this in the perspective of stock prices is surprisingly underexplored possibly due to two main reasons. First, equity does not belong to an asset class that the Fed traded in the LSAP program. Accordingly, most studies the asset pricing implication on monetary policy focus on Treasuries or MBSs. Second, a potential difficulty arises from linking the datasets from the intermediaries balance sheet to the borrower stock prices through their loan relationships. Each step requires matching different forms of identifiers and involves losing significant portion of data. Partially overcoming this problem by hand-matching, I focus on the cross-section of stock returns in terms of their lender-specific factors.

Applying the potential ramification of bank lending to asset pricing, investors of a firm financed by low-liquidity banks can demand a higher equity risk premium due to the carryover of liquidity risk of those lender banks. On top of that, borrowing more from such lenders can intensify this relationship. However, it is also possible that the borrower can dilute the liquidity shock originating from a lender by loan-smoothing over multiple lenders. In this case, the influence of lender-specific shocks on borrowers would be moderate.

To address these issues, I first investigate the degree of loan smoothing in the

sample and show that the lender-side risk spills over to borrowers without too much mitigation due to stickiness in their loan relationships. Based on this observation, I next explore how lenders' funding condition influences stock returns of borrowers, and how the degree of linkage proxied by the number of lenders and the loan weight to the total asset strengthens that pattern.

1.5.1 The Possibility of Loan Smoothing

Exploring the bank lending channel by observing the reaction of borrowing firms upon shocks to their lenders assumes that the loan supply shock and demand shock are closely correlated. However, such a tight relationship does not necessarily hold in many cases. For example, Khwaja and Mian (2008) report, from unexpected nuclear tests in Pakistan, that a firm borrowing from a bank which faces more severe liquidity dryup experiences a higher reduction in loans from that bank compared to the loans from less-affected banks. However, large firms compensate this loss by additional borrowing through the credit market. If the similar effect is found in the loan market in the United States, the policy impact through the bank lending channel will be crucially mitigated by the smoothing ability of borrowers. Therefore, it is prerequisite to investigate the loan rigidity between lenders and borrowers. If their loan contracts

are highly sticky, the borrowers are unable to hedge their lender-specific risk.

In the spirit of Khwaja and Mian (2008), I examine this loan rigidity step by step in loan-level and firm-level outcome. In the loan-level analysis, I test whether the *same* firm borrowing from two different banks experience a larger decline in lending from the bank facing a relatively greater fall in its liquidity supply. Accordingly, I estimate the following model with the borrower fixed-effect

$$\Delta L_{ij} = \beta_j + \beta_1 \Delta D_i + \varepsilon_{ij} \quad (1.10)$$

where ΔD_i is the total loan growth rate of lender i , ΔL_{ij} is the growth rate of the loan between lender i and borrower j , and β_j absorbs all the firm-specific credit demand shocks. If the aforementioned conjecture holds, β_1 is positive. The result in the upper panel of Table 1.6 supports this argument by showing that the 1% reduction of lender loans leads to 0.63% of the loan reduction from that lender. In particular, this relationship is significant and robust to the size of the borrowing firms.

In the firm-level analysis, I examine whether firms can borrow from other banks when the adverse shock occurs to existing banks, directly related to the degree of loan smoothing. In this case, the reduction in the loan supply from existing banks

Table 1.6: Test of Loan Rigidity

In the right three columns, the sample is three size-sorted bins. The annual sample begins in 2008 and ends in 2014. Panel A and B estimate Equation (1.10) and (1.11), respectively. The standard errors are in parenthesis. In Panel B, the standard errors are clustered by firm and year. Both dependent and independent variables are winsorized at 1% level.

			Full	Small	Mid	Big
A	Loan-level	ΔD_i	0.630*** (0.034)	0.635*** (0.119)	0.490*** (0.127)	0.450*** (0.115)
		Firm FE	Yes	Yes	Yes	Yes
		Loans	27,317	2,558	3,263	3,644
		Obs	42,820	3,659	4,882	6,092
		R^2	0.037	0.030	0.019	0.015
	<hr/>					
B	Firm-level	$\Delta \bar{D}_j$	0.241*** (0.018)	0.306*** (0.057)	0.319*** (0.057)	0.331*** (0.038)
		const	0.064*** (0.006)	0.123*** (0.016)	0.128*** (0.024)	0.123*** (0.031)
		Firms	13,393	838	803	699
		Obs	44,871	2,526	2,532	2,535
		R^2	0.053	0.043	0.086	0.097

does not crucially exacerbate the loan amount of borrowers. To test this, I estimate

$$\Delta Y_j = \beta_0 + \beta_1 \Delta \bar{D}_j + \eta_j \quad (1.11)$$

where ΔY_j is the total loan growth rate of borrower j and $\Delta \bar{D}_j$ is a weighted average

of the loan supply growth of banks lending to j . If firms can fully smooth, β_1 is zero.

On the other hand, if the loan relationship is fully rigid, β_1 is significantly positive.

In the lower panel of Table 1.6, a 1% loan reduction of average lenders significantly

reduces 0.24% of loan availability of borrowers. This indicates that firms absorb

liquidity shocks originating from lenders without sufficient loan-smoothing ability.

Also, this effect is robust to the size of borrower firms. To summarize, these findings collectively suggest that loan relationships are rigid.

1.5.2 The Effect of Lenders' Funding Liquidity

The results in the previous subsection suggest that the lender risk can be potentially transferred to its borrowers through their sticky loan relationships. Based on this observation, I test the following hypothesis.

Hypothesis B1 (HB1): Upon the realization of a positive LSAP shock, stock prices of firms who borrow from smaller-LMI banks rise relatively more than those from larger-LMI banks.

This is the borrower version of *Hypothesis L1*, which can be evident only if policy is strongly transmitted through bank lending. In this case, a macroeconomic liquidity injection by the Fed can potentially enhance not only constrained banks, but also their borrowers. As a result, the stocks of firms associated with smaller LMI banks will earn a higher risk premium. To see this, the corresponding pooled regression

model is estimated:

$$r_{i,t \rightarrow t+d} = \alpha + \beta \cdot LSAP_t + \gamma \cdot \overline{BLMI}_{i,t} + \delta \cdot LSAP_t \cdot \overline{BLMI}_{i,t} + Controls_{i,t} + \varepsilon_{i,t} \quad (1.12)$$

As the link between borrowers and lenders is not one-to-one, I calculate the lenders' average LMI (*a.k.a.* \overline{BLMI}) for a given borrower by the procedure introduced in Section 1.3.2. I also construct borrower-specific characteristics and their interaction terms with the policy shock as controls. Similarly to lender's Equation (1.9), the controls include log of total assets, quasi-leverage ratio, book-to-market ratio, asset tangibility, and the Whited and Wu measure of borrowers.

The key parameter of interest is δ as it captures the difference in borrowers' price responses conditional on the lenders' LMI. Consistent with *HL1*, *HB1* implies that δ is negative. Also, an unconditional increase of stock prices upon a positive LSAP shock implies that β is positive.

The corresponding estimates are presented in Table 1.7. Consistent with the prediction, the table shows that the response conditional on the lender-average LMI, δ , is negative and statistically significant, particularly at longer horizons. Upon the virtual FOMC announcement with the unexpected policy expansion by \$100 billion,

Table 1.7: Test of *HB1*

Controls include the borrower firms' quasi-leverage ratio, book-to-market ratio, tangibility, and Whited-Wu measure and their interaction terms with the policy shock. The regression coefficients for controls and the intercept are omitted for brevity. *p*-values from the standard errors clustered by both borrowers and 48 FOMC announcements is in the parenthesis. Dependent variables are winsorized at 1% level.

d	D0	D1	D2	D3	W1	W2	W3	M1
<i>LSAP</i>	-0.053 (0.671)	-0.109 (0.574)	-0.145 (0.374)	0.016 (0.930)	0.340* (0.086)	1.168*** (0.004)	1.504** (0.013)	2.735*** (0.000)
\overline{BLMI}	-0.091 (0.207)	0.101 (0.405)	0.145 (0.433)	0.182 (0.419)	0.320 (0.347)	0.383 (0.196)	0.980* (0.076)	1.585* (0.073)
<i>Size</i>	0.012 (0.464)	-0.001 (0.980)	-0.019 (0.486)	-0.038 (0.215)	-0.066 (0.177)	-0.051 (0.484)	-0.045 (0.675)	-0.108 (0.504)
<i>LSAP</i> · \overline{BLMI}	-0.017 (0.859)	-0.200 (0.218)	-0.192 (0.294)	-0.298 (0.161)	-0.466 (0.119)	-0.354 (0.247)	-0.895*** (0.004)	-1.269*** (0.008)
<i>LSAP</i> · <i>Size</i>	0.021 (0.336)	-0.003 (0.924)	-0.000 (0.988)	-0.010 (0.735)	-0.031 (0.362)	-0.100* (0.077)	-0.118** (0.037)	-0.190*** (0.000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Borrowers	1,298	1,298	1,297	1,297	1,296	1,296	1,295	1,295
Obs	37,373	37,344	37,322	37,281	37,240	36,567	36,548	36,531
<i>R</i> ²	0.046	0.020	0.009	0.017	0.018	0.013	0.032	0.058

a firm in the lowest BLMI-quintile earns 0.92% of higher returns than one in the highest BLMI-quintile after a month. Also, the unconditional response β is positive as predicted.

However, Figure 1.3 illustrates that the response at lenders and borrowers upon the same policy shock exhibit different patterns. The unconditional response of borrowers are weaker, slower, but more persistent than that of lenders, and does not exhibit mean-reversion at least within a monthly window. The conditional response δ also shows that the stock price of borrowers begins to differentiate the lender's funding condition significantly after two weeks. In overall, this comparison highlights the

delayed but longer-lasting response of borrowers compared to lenders.

Are these patterns robust to borrower-specific characteristics? I particularly focus on firm size for two reasons. First, previous studies argue that firm size can influence interest rate exposure of equity. Perez-Quiros and Timmermann (2000) find that stock prices of smaller firms are more responsive to monetary policy changes measured by money supply, because they are usually more financially constrained. Ozdagli and Velikov (2016) reinforce these findings by showing that more financially constrained stocks respond more to the policy. In my experiment, the negative coefficients on the interaction terms with size shown in Table 1.8 are consistent with these findings. Small firms experience higher returns upon expansionary policy shocks, and this effect survives together with the lender-LMI effect when controlling for other variables.

Table 1.8: Test of *HB1*: Robustness to Size Factor

The borrowers' stock prices sorted into five portfolios by their size at each FOMC announcement. The coefficients indicate δ of Equation (1.12). p -values from the standard errors clustered by both borrowers and 48 FOMC announcements is in the parenthesis. Dependent variables are winsorized at 1% level.

Return	Small	2	3	4	Big
Daily	-0.305 (0.035)	-3.569 (0.000)	-2.565 (0.021)	-3.857 (0.006)	-2.118 (0.059)
Weekly	-0.773 (0.000)	-4.371 (0.005)	-3.955 (0.006)	-6.867 (0.000)	-3.276 (0.008)
Monthly	-1.090 (0.092)	-11.955 (0.000)	-9.895 (0.003)	-14.555 (0.001)	-10.458 (0.003)

Second, and more importantly, big firms can be in a better position to smooth out loans and dilute lender-driven liquidity shocks as pointed out by Khwaja and Mian (2008). However, the analysis in Section 1.5.1 shows that the loan market of the United States in the QE period rules out such frequent smoothing of borrowers regardless of their firm size. To further verify this, I estimate Equation (1.12) separately for five bins sorted by firm size. If smoothing is more prevalent in big firms, δ of Equation (1.12) for big firms will not be significantly negative anymore. Table 1.8 shows that the differential response of stock returns with respect to BLMI also strongly appears in big firms. Collectively, these findings support that borrowers' equity prices their lenders' funding liquidity.

1.5.3 The Effect of Lender-Borrower Linkage

Under the assumption that financial intermediaries are assumed to be the primary entities that disperse the policy shock into the rest of the economy, the monetary policy transmission of the bank lending channel can be further supported if a closer borrower-lender relationship influences more on borrowers' asset price response upon a monetary shock. This rationale can even operate independently of banks' funding condition. Accordingly, I test the following hypothesis.

Hypothesis B2 (HB2): Firms that are more dependent on lenders experience relatively higher stock price increases when a LSAP shock is expansionary

For the ease of notation, let the term *Link* is the measure for borrowers' lender-dependence. Using the log of the number of lenders and the log loan-to-asset ratio as the proxy for lender-dependence, I estimate the following pooled equation as a model for *HB2*.

$$r_{i,t \rightarrow t+d} = \alpha + \beta \cdot LSAP_t + \gamma \cdot Link_{i,t} + \delta \cdot LSAP_t \cdot Link_{i,t} + Controls_{i,t} + \varepsilon_{i,t} \quad (1.13)$$

If a higher linkage facilitates the transmission of policy shocks to borrowers, their stock prices would further increase upon a macro liquidity injection. This implies that δ is positive.

The results presented in Table 1.9 supports *HB2* particularly at longer horizons in using any of two lender-dependence proxies. The degree of connection to lenders proxied by the number of lenders and the loan proportion both lead to elevated price responses upon a liquidity shock.

Table 1.9: Test of *HB2*

Lender denotes number of lenders. *L/A* is loan-to-asset ratio. The same controls with Equation (1.13) are used. The regression coefficients for controls and the intercept are omitted for brevity. *p*-values from the standard errors clustered by both borrowers and 48 FOMC announcements is in the parenthesis. Dependent variables are winsorized at 1% level.

d	D0	D1	D2	D3	W1	W2	W3	M1
LSAP	-0.057 (0.707)	-0.162 (0.494)	-0.188 (0.376)	-0.067 (0.779)	0.180 (0.521)	1.008** (0.030)	1.100 (0.128)	2.168*** (0.009)
LSAP · ln(Lender)	0.001 (0.949)	-0.027 (0.510)	-0.045 (0.328)	-0.032 (0.485)	0.001 (0.983)	0.062 (0.266)	0.180*** (0.010)	0.214** (0.023)
ln(Lender)	-0.023 (0.185)	-0.034 (0.250)	-0.054 (0.179)	-0.039 (0.414)	0.016 (0.821)	0.029 (0.700)	0.085 (0.396)	0.160 (0.295)
ln(Size)	0.023 (0.137)	-0.010 (0.531)	-0.033* (0.096)	-0.057** (0.015)	-0.104** (0.015)	-0.096 (0.170)	-0.163* (0.055)	-0.299** (0.012)
LSAP · ln(Size)	0.024* (0.089)	0.024 (0.187)	0.027 (0.127)	0.029* (0.067)	0.027 (0.234)	-0.062 (0.108)	-0.025 (0.558)	-0.054 (0.293)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firms	1,298	1,298	1,297	1,297	1,296	1,296	1,295	1,295
Observations	37,373	37,344	37,322	37,281	37,240	36,567	36,548	36,531
<i>R</i> ²	0.045	0.017	0.007	0.013	0.013	0.011	0.026	0.049
LSAP	-0.066 (0.675)	-0.154 (0.483)	-0.171 (0.383)	-0.048 (0.829)	0.177 (0.511)	0.867** (0.049)	0.820 (0.281)	1.865* (0.052)
LSAP · ln(L/A)	0.004 (0.675)	-0.010 (0.668)	-0.019 (0.527)	-0.017 (0.542)	0.001 (0.966)	0.078** (0.022)	0.169*** (0.000)	0.189** (0.020)
ln(L/A)	-0.025 (0.141)	-0.036 (0.209)	-0.054 (0.146)	-0.041 (0.355)	0.007 (0.924)	0.008 (0.908)	0.051 (0.567)	0.199 (0.105)
ln(Size)	0.011 (0.501)	-0.028* (0.093)	-0.060*** (0.006)	-0.078*** (0.003)	-0.100** (0.039)	-0.091 (0.169)	-0.135 (0.136)	-0.201* (0.058)
LSAP · ln(Size)	0.026** (0.031)	0.017* (0.091)	0.015 (0.251)	0.019 (0.192)	0.028 (0.345)	-0.023 (0.593)	0.064 (0.157)	0.046 (0.491)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firms	1,298	1,298	1,297	1,297	1,296	1,296	1,295	1,295
Observations	37,373	37,344	37,322	37,281	37,240	36,567	36,548	36,531
<i>R</i> ²	0.045	0.017	0.007	0.013	0.013	0.011	0.026	0.049

1.5.4 The Effect of Lenders' Liquidity conditional on the Linkage

Under the sticky loan relationships between borrowers and lenders, the previous results show that stock prices of firms borrowing from liquidity-constrained banks

or that are heavily dependent on lenders more sensitively reacts to a policy shock. These findings allows to jointly test their interactive effects. For example, lenders' funding condition might not be important to a firm that issues only minimal amount of loans. In contrast, such lender factors can crucially influence the future cash-flow of borrowers if their source of funding mainly relies on loans. This naturally leads to the hypothesis and the corresponding model:

Hypothesis B3 (HB3): Conditional on the BLM I, the stock return of firms that are more heavily linked to lenders is higher when the Fed injects the liquidity shock.

$$\begin{aligned}
r_{i,t \rightarrow t+d} &= \alpha + \beta \cdot LSAP_t + \gamma_1 \cdot \overline{BLMI}_{i,t} + \gamma_2 \cdot Link_{i,t} \\
&+ \delta_1 \cdot LSAP_t \cdot \overline{BLMI}_{i,t} + \delta_2 \cdot LSAP_t \cdot Link_{i,t} \\
&+ \phi \cdot LSAP_t \cdot \overline{BLMI}_{i,t} \cdot Link_{i,t} + Controls_{i,t} + \varepsilon_{i,t} \quad (1.14)
\end{aligned}$$

In Equation (1.14), the relevant part of the interaction between \overline{BLMI} and $Link$ can be rewritten to

$$\beta \cdot LSAP \left[1 + \frac{\delta_1}{\beta} \overline{BLMI} \left(1 + \frac{\phi}{\delta_1} Link \right) \right]$$

The stronger effect of \overline{BLMI} upon more lending relationships implies that the sign of

ϕ and δ_1 are same. Combined with the evidence on *HB1* where $\delta_1 < 0$, *HB3* implies $\phi < 0$.

However, testing the triple interaction term ϕ requires a sufficiently high power of the test. Unfortunately, the borrower sample clustered by only 48 observation lacks this property. Therefore, I use this test as a suggestive experiment.

Table 1.10 presents estimates of Equation (1.14). As predicted by *HB3*, the interaction-of-interaction term ϕ is negative with sporadic statistical significance over the horizon. A one-SD policy shock increases the monthly stock return of borrowers financed from a single zero-LMI bank by 3.3%, from a single one-LMI bank by 2.4%, and from five one-LMI banks by 1.7%. Overall, the tests of *HB1*, *HB2*, and *HB3* collectively provide supportive evidence that funding liquidity of lenders influences the exposure of borrowers' stock returns to the LSAP shock in the QE period.

1.6 Investment Perspective

The results in the previous sections show that the funding liquidity of financial intermediaries influence the response of stock returns upon the monetary policy shock, generating return differentials across the stocks. Upon the realization of an expansionary policy shock, the stocks of banks with low funding liquidity as well as their

Table 1.10: Test of $HB\beta$

Link is log of the number of lenders. Controls include the borrower firms' quasi-leverage ratio, book-to-market ratio, tangibility, and Whited-Wu measure and their interaction terms with the policy shock. The regression coefficients for controls and the intercept are omitted for brevity. *p*-values from the standard errors clustered by both borrowers and 48 FOMC announcements is in the parenthesis. Dependent variables are winsorized at 1% level.

	D0	D1	D2	D3	W1	W2	W3	M1
LSAP	-0.159 (0.380)	-0.469 (0.279)	-0.415 (0.222)	0.597 (0.174)	0.801* (0.095)	1.336** (0.032)	2.094** (0.010)	3.317*** (0.000)
BLMI	0.019 (0.898)	0.072 (0.822)	0.039 (0.931)	-0.267 (0.576)	0.095 (0.868)	0.388 (0.579)	0.760 (0.441)	0.749 (0.613)
Link	-0.037* (0.055)	-0.033 (0.505)	-0.076 (0.176)	0.031 (0.689)	0.108 (0.165)	0.023 (0.825)	0.206* (0.090)	0.367** (0.012)
BLMI · Link	-0.055** (0.028)	0.125 (0.198)	0.122 (0.505)	0.170 (0.384)	0.214 (0.215)	0.129 (0.511)	0.520 (0.131)	0.793 (0.112)
Size	0.012 (0.549)	0.002 (0.954)	-0.039 (0.408)	-0.071 (0.191)	-0.048 (0.477)	-0.052 (0.518)	-0.035 (0.788)	-0.184 (0.302)
LSAP · BLMI	-0.162 (0.262)	-0.739* (0.053)	-0.433 (0.194)	-0.411 (0.311)	-0.343 (0.474)	-0.101 (0.829)	-0.323 (0.513)	-0.885 (0.189)
LSAP · Link	0.015 (0.622)	-0.135 (0.256)	-0.160* (0.057)	-0.085 (0.483)	-0.033 (0.795)	-0.092 (0.258)	0.127 (0.142)	0.038 (0.809)
LSAP · BLMI · Link	0.025 (0.210)	-0.130 (0.134)	-0.122** (0.050)	-0.180 (0.177)	-0.199 (0.149)	-0.233*** (0.005)	-0.265 (0.169)	-0.481* (0.082)
LSAP · Size	0.033 (0.218)	0.032 (0.657)	0.055 (0.379)	-0.038 (0.566)	-0.069 (0.243)	-0.105 (0.218)	-0.258*** (0.002)	-0.252*** (0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firms	1,298	1,298	1,297	1,297	1,296	1,296	1,295	1,295
Obs	37,373	37,344	37,346	37,323	37,317	36,645	36,620	36,605
R2	0.047	0.016	0.008	0.035	0.021	0.018	0.028	0.067

borrowers tend to earn relatively higher positive returns. In contrast, a contractionary shock causes them to rather earn lower negative returns. Generally, stock prices of liquidity-constrained lenders and their borrowers not only respond more sensitively to a policy news, but also move crucially depending on the direction of the news.

Can this pattern be exploited to a profitable trading strategy? The first answer is no, because the above argument is concluded from the return series based on 1pm of an

FOMC announcement day, when the direction of a shock is uncertain. If stock prices persistently respond to a shock, however, trading stocks immediately after observing the shock can serve as a feasible and profitable strategy that can still exploit such pattern. To test this, I define a feasible version of a stock return of firm i as

$$\tilde{r}_{i,t \rightarrow t+d} \equiv \frac{P_{i,t+d(4pm)}}{P_{i,t(4pm)}} - 1 \quad (1.15)$$

where t is an FOMC announcement day, and d is horizon. This close-to-close return is solely acquired after observing a policy shock. Accordingly, one intuitive investment strategy can be buying lowest-LMI stocks and selling highest-LMI ones immediately after an expansionary shock, but doing oppositely after a contractionary shock. Formally, the excess return from the corresponding strategy is represented by

$$\tilde{r}^e = \begin{cases} \tilde{r}^L - \tilde{r}^H, & \text{if } LSAP > 0. \\ \tilde{r}^H - \tilde{r}^L, & \text{otherwise.} \end{cases} \quad (1.16)$$

where \tilde{r}^L and \tilde{r}^H is returns of low- and high-LMI bank portfolios, respectively. To empirically test this, I calculate the average monthly return of five portfolios sorted by LMI-to-asset ratio from intermediaries' stocks and use the highest- and the lowest-

LMI ones to construct the hedged portfolio represented by 48 excess returns.¹⁶ The correlation between the LSAP shocks and returns of low-minus-high-LMI portfolio is 0.16, which indicates that an expansionary (contractionary) shock causes higher returns for bank stocks with lower (higher) LMI. Also, the correlation between the absolute magnitude of LSAP shocks and the excess return from the strategy, \hat{r}^e , is 0.10, implying that such return differential is greater when the realized shock is greater in either direction. These observations are consistent with the pattern found in Section 1.4.

Table 1.11: Performance and Factor Exposure of the Strategy

\hat{r}^e is the excess return obtained from the strategy in Equation(1.16). MktRf is the excess market return. SMB is the return difference between small and big stocks. HML is that between value and growth stocks. MOM is a momentum factor proposed by Carhart (1997). These factors are downloaded from Kenneth French website. α is expressed in percent. The OLS standard errors are expressed in the parenthesis. ** and *** denote 1% and 5% significance level, respectively.

\hat{r}^e	α	MktRf	SMB	HML	MOM	R^2
Intermediaries	0.683	-0.133				0.038
	(0.448)	(0.100)				
	0.930**	-0.255**	-0.076	0.316		0.097
	(0.468)	(0.135)	(0.231)	(0.195)		
Borrowers	0.958**	-0.279**	-0.063	0.252	-0.080	0.111
	(0.471)	(0.139)	(0.232)	(0.211)	(0.100)	
	-0.019	-0.095				0.052
	(0.273)	(0.061)				
	-0.017	-0.132	0.140	0.035		0.073
	(0.291)	(0.084)	(0.143)	(0.121)		
	-0.076	-0.080	0.113	0.171	0.171***	0.238
	(0.268)	(0.079)	(0.132)	(0.120)	(0.057)	

¹⁶ To avoid confusion, the monthly return indicates $\hat{r}_{t,t+21}^e$, not the sample frequency.

Does this strategy outperform passive benchmarks? To test this, I incorporate Fama and French (1993) factors and the momentum factor of Carhart (1997) and regress \tilde{r}^e on these factors that are contemporaneously matched with it. The upper panel of Table 1.11 shows that this strategy based on the lenders' stocks, initiating immediately after the announcement and waiting for one month, earns approximately 0.9% at each FOMC announcement when 3- or 4-factor models are applied. In addition, it accompanies the negative exposure to market factor. This is consistent with the *betting-against-beta* story of Frazzini and Pedersen (2014), as negative beta can be associated with positive alpha.

The same strategy to the borrowers' stocks, however, is not profitable as shown in the lower panel of Table 1.11. The alpha is negligible in any factor model. In particular, the significant fraction of the excess return is explained by the momentum factor, which increases the goodness-of-fit to 23.8%. The reason of this high momentum exposure is obscure at this stage. I leave it to a future research. To summarize, an active portfolio strategy to exploit the different exposure of stock prices to a policy risk according to an intermediaries' funding liquidity is profitable when it is constructed from their own lenders' stocks. However, the same effect does not carry over to the borrowers' side.

1.7 Concluding Remarks

In this paper, I explore the effects of the Federal Reserve (Fed)'s large-scale asset purchasing (LSAP) program on the cross-section of equity returns through financial intermediaries' funding liquidity. Using the LSAP shock by Swanson (2017) as a policy measure and the Liquidity Mismatch Index by Bai et al. (2018) as a funding liquidity measure of intermediaries, I show that an expansionary policy shock increases the stock return of banks with low liquidity more than those with high liquidity. In addition, the liquidity of lenders also influences their borrowers' equity prices through the rigid loan relationship. Firms borrowing from low liquidity banks, and of high loan-to-asset ratio earn relatively higher returns under the same expansionary shock. The response of borrowers is weaker, more delayed, and more persistent than that of lenders. Based on these observations, I also test a portfolio strategy that exploits such return differential, and find that it is particularly profitable on the lender side. Collectively, these findings provide supportive evidence of the bank lending channel as a policy transmission mechanism in the quantitative easing period.

Levered Equity and Credit Risk Premia: the Role of Monetary Policy Rule

2.1 Introduction

New Keynesian models have been widely served as a useful lens investigating how monetary policy can influence the real economy, as these models can reproduce key macroeconomic observations linked to the policy implementation such as the delayed and persistent response of output, inflation, and marginal cost (e.g. Christiano et al. (2005)). Recently, more considerable attention has been paid for the role of monetary policy on stabilizing asset prices. For example, the recent global financial crisis originating from the liquidity draught of the U.S. sub-prime mortgage market raised the

criticism that the Federal Reserve ignored or too slowly reacted to very important signals in the financial markets.

Accordingly, these concerns necessitate a model that can reasonably predict not only macroeconomic dynamics, but also asset pricing dynamics. However, most production-based models still suffer from reasonably generating empirical asset pricing moments such as an equity risk premium or a credit spread. In the case of models that do not design corporate debt, one conventional approach to acquire a sizeable equity premium is doubling or tripling the unlevered equity return in the model. However, this approach is mechanical and can miss an economic mechanism how levered equity and defaultable debt prices correlate.

In this paper, I explore how monetary policy rule can influence equity and defaultable bond prices using a medium-scale dynamic stochastic general equilibrium (DSGE) model. The model has two important features. To design both equity and corporate bond, my model closely follows Gomes et al. (2016) where each firm faces an idiosyncratic operating profit shock and its default barrier is endogenously determined by the limited liability of firm values. To impose nominal non-neutrality, I incorporate a sticky price of firms proposed by Calvo (1983), and a sticky wage of households, which are latter augmented by Erceg et al. (2000). Two additional

model ingredients are convex capital adjustment cost and the Epstein and Zin (1991) preference. The former allows a continuous transition from a fully flexible capital to a fixed capital. The latter serves a role in exclusively amplifying the equity premium driven by productivity risks.

Prior to its analysis, I use a simplified reduced-form New Keynesian model to capture how monetary policy feedback to the economic state can influence the equity premium under the economy where the source of uncertainty is total factor productivity (TFP) and monetary policy risk. The TFP shock shifts the supply curve, driving the movement of output and inflation oppositely. Therefore, the more (less) inflationary (output) policy inertia causes the more variation of the equilibrium output if the nominal rate does not significantly deviate from its steady state. On the other hand, the discretionary policy shock shifts the demand curve, driving their movements in the same direction. In this case, the policy inertia of both output and inflation leads to the decline of the output variation. In this simplified framework, the more output variation contributes to both the higher market price of risk and the more procyclicality of dividends, leading to the higher equity risk premium. The observations in the full model are also consistent with this economic intuition.

Under the reasonable range of model parameters, the model does not produce a

realistic equity risk premium. Under the endogenous default barrier without nominal rigidities, the unlevered and levered equity premium are 1.86% and 1.75% per annum, respectively. This result shows the sharp contrast to the conventional approach tripling the unlevered return to obtain a sizeable risk premium. When nominal rigidities are included, monetary policy influences the real economy, but the magnitude of risk premia further declines, showing their trade-off in a modeling perspective. Also in the baseline calibration, the credit spread and the annual default rate is 0.35% and 3.78%, respectively, which exhibit the credit spread puzzle reported in many previous studies based on production-based models.¹ To resolve this puzzle, I augment the model by incorporating a countercyclical restructuring cost upon default to induce a sizeable credit risk premium. However, this approach sacrifices the magnitude of the risk-neutral component of the spread, resulting in the overall credit spread almost unaltered.

This paper is related mainly to two branches of literature. The first branch examines the implication of monetary policy on the stock price through nominal rigidities.² Weber (2015) empirically show that more price-staggered firms earn higher

¹ Empirically, both the average credit spread (Baa-Aaa) and the annual default rate are roughly 1%.

² Most New Keynesian literature focus on macroeconomic equilibrium and the yield of government bonds.

equity premium. Lopez et al. (2015) uses nominal price rigidity to explain the downward term structure of expected equity returns. Campbell et al. (2014) and Li and Palomino (2014) more directly investigate the role of monetary policy in stock prices through a reduced-form and a DSGE New Keynesian model, respectively. The second branch contains the design of defaultable bond in equilibrium models. Following the endogenous default literature pioneered by Leland and Toft (1996), Bhamra et al. (2009) jointly explains levered equity premium and credit spreads. Bhamra et al. (2011) studies how monetary policy influences corporate default due to the change of real debt value through inflation control. Related to these streams, two of the most relevant papers to my research are Gomes et al. (2016) and Corhay (2017), who incorporate both endogenous bankruptcy and nominal rigidity in their models to allow joint pricing of both equity and corporate bonds. My model closely follows their model specification, but more focuses on how asset pricing dynamics are influenced by monetary policy depending on the source of exogenous risks.

This paper is organized as follows. Section 2.2 illustrates the relationship of monetary policy and an equity risk premium in a simplified New Keynesian framework. Section 2.3 introduces a full DSGE model. Section 2.4 solves the model. Section 2.5 lists the calibration of model parameters. Section 2.6 discusses how nominal rigidities

and monetary policy influence the levered equity and the credit risk premia. Finally, Section 2.7 concludes.

2.2 Monetary Policy and an Equity Risk Premium: Analytical Approach from a Simplified Framework

In this section, I investigate how monetary policy rule can influence the equity risk premium from a simplified New Keynesian framework where the only nominal friction is a staggered price by Calvo (1983). The log-linearization of any New Keynesian DSGE model can be reduced to the following three building blocks

$$\hat{r}_{ft}^{\$} = E_t \hat{\pi}_{t+1} - \psi^{-1}(\hat{y}_t - \hat{y}_{t+1}) \quad (\text{IS})$$

$$\hat{r}_{ft}^{\$} = \phi_{\pi} \hat{\pi}_t + \phi_y (\hat{y}_t - \hat{y}_t^n) - z_t \quad (\text{MP})$$

$$\hat{\pi}_t = \kappa(\hat{y}_t - \hat{y}_t^n) + \beta E_t \hat{\pi}_{t+1} \quad (\text{PC})$$

where $r_f^{\$}$ is a nominal interest rate, π is inflation, y is output, and y^n is the natural level of output under the fully flexible economy. The hat-notation at each variable indicates the deviation from its steady state. The IS curve is derived from a Fisher equation and the assumption of CRRA preference of a household where ψ is an intertemporal elasticity of substitution. The monetary policy (MP) equation has the

inflation and output coefficient ϕ_π and ϕ_y determined by the monetary authority, and a discretionary rate shock z where $z > 0$ means expansionary. Finally, the Phillips curve (PC) is derived from an optimal price-resetting of firms under the existence of a price rigidity. The slope of a Phillips curve $\kappa > 0$ depends on the degree of nominal rigidity. Under a fully flexible economy, the slope is vertical and the equilibrium output is the natural level of output itself in any inflation level. On the other hand, under a full nominal rigidity, κ is zero and the output deviates from its natural level in a certain fixed inflation. In overall, IS and MP jointly determine the aggregate demand, and PC serves as the aggregate supply of output.

Under the log-linearization, the deviation of any economic variable x from its steady state can be represented as

$$\hat{x}_t = \sum_{s \in S} \frac{\partial x}{\partial s} s_t = \sum_{s \in S} \xi_{xs} s_t \quad (2.1)$$

where the term ξ_{xs} captures its response to a state variable s . I assume the economy has two exogenous state variables: a TFP shock a and a monetary policy shock z . Both shocks are assumed to follow AR(1) process where their persistence is ρ_a and ρ_z , and volatility σ_a and σ_z , respectively.

2.2.1 Macroeconomic Equilibrium

Prior to derive the equity premium, I first solve a macroeconomic equilibrium. Combining the log-linearized IS, MP, and PC equation, solving output and inflation in terms of state variables by the method of undetermined coefficients gives

$$\begin{bmatrix} \xi_{ya} \\ \xi_{\pi a} \end{bmatrix} = \frac{\xi_{y^na}}{D_a} \begin{bmatrix} \phi_y(1 - \beta\rho_a) + \kappa(\phi_\pi - \rho_a) \\ -\kappa\psi^{-1}(1 - \rho_a) \end{bmatrix} \quad \begin{bmatrix} \xi_{yz} \\ \xi_{\pi z} \end{bmatrix} = \frac{1}{D_z} \begin{bmatrix} 1 - \beta\rho_z \\ \kappa \end{bmatrix} \quad (2.2)$$

where $\xi_{y^na} > 0$ and

$$D_s = \kappa(\phi_\pi - \rho_x) + (1 - \beta\rho_x)[\psi^{-1}(1 - \rho_x) + \phi_y] > 0. \quad (2.3)$$

where the set of state variables $S = \{a, z\}$. The natural level of output y_n is independent of the monetary policy risk z due to the nominal neutrality without the price stickiness.

Table 2.1 summarizes the sign of responses to state variables and monetary policy coefficients, which are consistent with the following intuitions.

A positive productivity shock lowers a marginal cost of firms and shifts the supply curve PC to right, leading to a rise of output and a decline in inflation. The relative

Table 2.1: The Direction of Responses

Shock	Productivity			Monetary Policy		
Shift	Supply			Demand		
	$\frac{\partial}{\partial a}$	$\frac{\partial^2}{\partial a \partial \phi_\pi}$	$\frac{\partial^2}{\partial a \partial \phi_y}$	$\frac{\partial}{\partial z}$	$\frac{\partial^2}{\partial z \partial \phi_\pi}$	$\frac{\partial^2}{\partial z \partial \phi_y}$
y	+	+	-	+	-	-
π	-	+	+	+	-	-

magnitude of their opposite movement, however, depends on their policy coefficient in Equation MP. As the policy is more anti-inflationary (higher ϕ_π) or loosely reacting to output growth (smaller ϕ_y), it leads to a relatively less deflation and more output increase assuming that the nominal interest rate is preserved after the shock arrival.

An expansionary nominal rate shock, jointly by the IS and MP curve, indirectly shifts a demand curve upward by contracting the output demand. This causes both output and inflation to increase, but the relative degree of such decline depends on the slope of the PC curve. In this case, any of either output or inflation policy inertia (higher ϕ_π or ϕ_y) causes both of them moderately to increase.

2.2.2 Equity Risk Premium

To obtain a non-zero risk premium, the model at least requires the second-order approximation of equilibrium conditions. However, this adds huge complexity on the derivation and make it almost intractable. Instead, I plugged the above log-linearized

solution to the following log-normal form of the asset pricing equation

$$E_t[\exp(m_{t+1} + r_{t+1}^X)] = 1 \quad (2.4)$$

where m_t and r_t^X denote the real stochastic discount factor (SDF) and the real return of asset X , respectively, expressed in log terms. With assuming that the exogenous shocks have normal distributions, this equation results in the equity risk premium

$$ERP_t = E_t r_{t+1}^E - r_{ft} = -cov_t(m_{t+1}, r_{t+1}^E) - \frac{1}{2} var_t r_{t+1}^E \quad (2.5)$$

where r^E is the equity return.

This approach gives an identical result with that using the 2nd-order approximation, because the equity premium is solely expressed in terms of the conditional covariances that only depend on the coefficients for the innovation terms in the equilibrium solution. In the model without a time-varying volatility, all the 2nd-order coefficients, or the convexity adjustment terms are captured by coefficient on constant terms, thus cannot affect the risk premium.³

To link the macroeconomic equilibrium to the asset price, I additionally use the

³ In this sense, solving the whole system using the log-normal approximation also generate the same equity premium.

following lemma,

Lemma 1. Suppose i) $\beta \rightarrow 1$, ii) the logarithm of the real SDF m_t has the form⁴

$$m_{t,t+1} - \bar{m} = - \sum_{f \in F} \tilde{\lambda}_f (f_{t+1} - f_t)$$

where the factor

$$f_t = \bar{f} + \sum_{s \in S} \xi_{fs} s_t$$

for the state variable s_t , and iii) $E_t s_{t+1} = \rho_s s_t$ for $\forall s_t$. Then the log-normal form of the asset pricing equation 2.4 and the log-linearized return from 2.5 give that the equity return innovation

$$\begin{aligned} r_{t+1}^E - E_t r_{t+1}^E &= \sum_{s \in S} \beta_s s_{t+1} \\ &= -(m_{t+1} - E_t m_{t+1}) = \sum_{s \in S} \sum_{f \in F} \tilde{\lambda}_f \xi_{fs} s_{t+1} = \sum_{s \in S} \lambda_s s_{t+1} \end{aligned}$$

where β_s is the risk exposure to s and the market price of risk $\lambda_s = \sum_{f \in F} \tilde{\lambda}_f \xi_{fs}$. Then the equity risk premium

$$ERP_t \equiv E_t r_{t+1}^E - r_{ft} \simeq \frac{1}{2} \text{var}_t m_{t+1}$$

⁴ A notable exception is Epstein and Zin (1991) preference.

Lemma 1 implies that the market price of risk and the equity beta are identical each other when the SDF can be expressed solely in the growth rate of endogenous variables, and the all the state variables follow the AR(1) process. Accordingly, the equity beta, identical to the market price of risk, can be represented as

$$\beta_a = \lambda_a = \psi^{-1}\xi_{ya} > 0 \quad \beta_z = \lambda_z = \psi^{-1}\xi_{yz} > 0,$$

This representation indicates that the output response both governs market price of risk and dividend dynamics and suffices to approximate the premium. Combined with the result in 2.1, the equity premium under Lemma 1

$$ERP_t \simeq \frac{1}{2}[(\lambda_a\beta_a\sigma_a)^2 + (\lambda_z\beta_z\sigma_z)^2] = \frac{1}{2}(\psi^{-1})^2[\sigma_a^2\xi_{ya}^2 + \sigma_z^2\xi_{yz}^2]$$

where its derivative with respect to the policy in inflation

$$\frac{\partial ERP_t}{\partial \phi_\pi} = \underbrace{\frac{\partial ERP_t}{\partial \xi_{ya}}}_{(+)} \cdot \underbrace{\frac{\partial \xi_{ya}}{\partial \phi_\pi}}_{(+)} + \underbrace{\frac{\partial ERP_t}{\partial \xi_{yz}}}_{(+)} \cdot \underbrace{\frac{\partial \xi_{yz}}{\partial \phi_\pi}}_{(-)}$$

and with respect to the policy in output

$$\frac{\partial ERP_t}{\partial \phi_y} = \underbrace{\frac{\partial ERP_t}{\partial \xi_{ya}}}_{(+)} \cdot \underbrace{\frac{\partial \xi_{ya}}{\partial \phi_y}}_{(-)} + \underbrace{\frac{\partial ERP_t}{\partial \xi_{yz}}}_{(+)} \cdot \underbrace{\frac{\partial \xi_{yz}}{\partial \phi_y}}_{(-)}$$

As the market price of both risks are positive, a policy parameter that induces more procyclical output variation leads to the higher premium.

2.3 A Full Model

In this section, I stretch the reduced-form model in Section 2.2 to a full New Keynesian DSGE model where the economy is composed of continuum of firms, the representative household, and the monetary authority. The model is further augmented by time-varying capital and additional real and nominal frictions. The real friction is a convex capital adjustment cost, and the nominal friction is a wage stickiness and a debt repayment. The monetary authority adjusts the nominal short interest rate to affect the real economy through the nominal friction.

2.3.1 Firms

Individual firms are exposed to idiosyncratic shocks on their operating profits and can fund by issuing both equity and defaultable corporate bond, closely following the

setup in Gomes et al. (2016). Under the existence of tax shields, the firm chooses the optimal capital structure from the tradeoff between tax benefit and default cost of the corporate debt.

Technology

Firm j produces output from its own labor demand and capital by the Cobb-Douglas function,

$$y_{jt} = A_t F(k_{jt}, n_{jt}) = e^{a_t} k_{jt}^\alpha n_{jt}^{1-\alpha} \quad (2.6)$$

where $A_t = \exp(a_t)$ is aggregate productivity and contains the long-run productivity risk as

$$\Delta a_{t+1} = x_t + \sigma_a \varepsilon_{a,t+1} \quad (2.7)$$

$$x_{t+1} = \rho_x x_t + \sigma_x \varepsilon_{x,t+1} \quad (2.8)$$

The short-run and the long-run productivity shock, $\varepsilon_{a,t}$ and $\varepsilon_{x,t}$ is *i.i.d* cross-sectionally and over time.

The optimal choice of the labor demand gives the operating profit

$$r_t k_{jt} = \max_{n_{jt}^d} A_t F(k_{jt}, n_{jt}) - w_t n_{jt} \quad (2.9)$$

where r_t is the rental rate of capital and w_t is the real wage.

This firm-level operating profit is further subject to additive firm-specific risks, $z_{jt}k_{jt}$, so that the operating profit is

$$(r_t - z_{jt})k_{jt} \tag{2.10}$$

Here, I assume that the idiosyncratic shock z_{jt} is *i.i.d* across firms and time, and has the mean-zero symmetric probability distribution function and the corresponding cumulative distribution function

$$\phi(z_{jt}) = \eta_1 + \eta_2 z_{jt}^2 \tag{2.11}$$

$$\Phi(z_{jt}) = \eta_0 + \eta_1 z_{jt} + \frac{\eta_2}{3} z_{jt}^3 \tag{2.12}$$

where η_0 , η_1 , and η_2 meet the required condition of distribution functions in the interval $[\underline{z}, \bar{z}]$ where $\bar{z} = -\underline{z}$.

The firm also accumulates capital by

$$k_{j,t+1} = (1 - \delta + \Psi(i_{jt}))k_{jt} = g(i_{jt})k_{jt} \tag{2.13}$$

where i_{jt} denotes the investment to capital ratio for firm j and

$$\Psi(i_{jt}) = \frac{\alpha_1}{1 - \frac{1}{\xi_k}} i_{jt}^{1 - \frac{1}{\xi_k}} + \alpha_2 \quad (2.14)$$

$\Psi(i_{jt})$ captures the real friction of the capital adjustment which is symmetric on investment and disinvestment, and distorts the real price of equity claims.

Price Setting

To induce the real effect by monetary policy, I further assume that firms face monopolistic competition by producing differentiated goods and nominal price rigidity following New Keynesian literature. For such device, I use Dixit and Stiglitz (1977)

CES aggregator

$$Y_t^d \equiv \left(\int_0^1 y_{it}^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}}$$

where Y_t^d and P_t are the aggregate index of output demand and price, and η is the elasticity of substitution among goods that determines the degree of market power.

It follows that each firm faces the demand curve

$$y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} Y_t^d$$

I assume that the nominal rigidity follows Calvo (1983) in that only a fraction of suppliers θ_p can optimize their prices. From the Dixit-Stiglitz aggregator,

$$P_t^{1-\eta} \equiv (1 - \theta_p)P_t^{*\$1-\eta} + \theta_p P_{t-1}^{1-\eta} \quad (2.15)$$

respectively, where $P_t^{*\$}$ denotes the reoptimized nominal price.

Valuation of Levered Equity and Defaultable Bond

Firms can fund themselves by issuing both equity and defaultable nominal bond. I assume that corporate bonds have equal seniority and single-period of maturity. When the firm does not default, it is required to pay a coupon c in addition to the principal per unit of debt at maturity. In default, the creditors collect the current operating profit and equity claims from shareholders, but are required to pay the restructuring cost $(1 - \tau)\xi$ per unit of capital, given the effective tax rate τ . Due to tax shields, the firm chooses the optimal level of bond issuance to maximize the firm valuation given the price of equities and bonds determined from the equilibrium.

Denoting B_t^j is the stock of outstanding defaultable nominal debt of the firm j issued at the beginning of period t , and q_t^j the *real* market price of a unit of debt in terms of consumption goods during period t , the real market value of new debt issues

during period t is $q_t^j \frac{B_{t+1}}{P_t} = q_t^j b_{t+1}^j$, where P_t is the nominal price level in the economy.

In the equity claim, the *real* dividend d_{jt} is

$$d_{jt} = (1 - \tau)(r_t - z_{jt})k_{jt} + q_t b_{jt+1} - ((1 - \tau)c + 1) \frac{b_t^j}{\pi_t} - (i - \tau\delta)k_{jt} \quad (2.16)$$

where π_t denotes the inflation between the period $t - 1$ and t . The dividend is composed of the current after-tax operating profit and the new debt issuance, deducted by the debt repayment and the capital expenditure considering tax-shields and depreciation. Accordingly, the equity value

$$V(k_{jt}, b_{jt}, z_{jt}, \pi_t) = \max \left[0, \max_{k_{jt+1}, b_{jt+1}} \left(d_{jt} + E_t M_{t+1} \int_{\underline{z}}^{z^*} V(k_{jt+1}, b_{jt+1}, z_{jt+1}, \pi_{t+1}) \right) \right] \quad (2.17)$$

where z^* is the default threshold. Due to the limited liability constraint inherent in Equation (2.17), the firm defaults when the equity value reaches zero from above.

This constraint implicitly determines the boundary of default

$$z_{jt}^* = r_t k_{jt} - \left(c + \frac{1}{1 - \tau} \right) \frac{b_{jt}}{\pi_t} + \frac{V(k_{jt}, b_{jt}, z_{jt}, \pi_t)}{1 - \tau} \quad (2.18)$$

such that the firm facing $z_j \in [z^*, \bar{z}]$ defaults.

The valuation of corporate bond at the end of period t is,

$$q_{jt}b_{jt+1} = E_t M_{t+1}(\Omega_{jt+1}^{nd} + \Omega_{jt+1}^d) = E_t M_{t+1} \Omega_{jt+1} \quad (2.19)$$

where

$$\Omega_{jt}^{nd} = \Phi(z_{jt+1}^*)(c+1) \frac{b_{jt+1}}{\pi_{t+1}} \quad (2.20)$$

$$\Omega_{jt}^d = \int_{z_{jt+1}^*}^{\bar{z}} ((1-\tau)(r_{t+1} - z_{jt+1} - \xi_{t+1})k_{jt+1} + V_{jt+1}) d\Phi(z_{jt+1}) \quad (2.21)$$

and the restructuring cost upon default

$$\xi_t = \xi_0 - \xi_1 \Delta a_t \quad (2.22)$$

with $\xi_0 > 0$ and $\xi_1 > 0$ indicating its countercyclicality. I allow this restructuring cost to vary over time to induce a sizeable credit risk premium. In overall, the payoff of corporate bond is composed of two elements: i) the principal and coupon payment when the firm does not default (Ω^{nd}), and ii) the equity claim and restructuring expense in default (Ω^d).

2.3.2 Household

The representative household chooses the consumption bundle \hat{C}_t to maximize the Epstein and Zin (1991) recursive utility function.

$$U_t = \left[(1 - \beta)\hat{C}_t^{1-\psi} + \beta E_t[U_{t+1}^{1-\gamma}]^{\frac{1-\psi}{1-\gamma}} \right]^{\frac{1}{1-\psi}} \quad (2.23)$$

where β is the time discount factor, $\gamma > 0$ is the risk aversion parameter, and $\psi > 0$ is the intertemporal elasticity of substitution (IES). By disentangling the inverse relationship between risk aversion from the IES, the Epstein-Zin preference can contribute to resolve both equity premium puzzle and risk-free rate puzzle in a uniform setting. If $\gamma = \frac{1}{\psi}$, it is reduced to the CRRA preference.

The consumption bundle \hat{C}_t is expressed by the Dixit and Stiglitz (1977) CES aggregator between consumption and leisure

$$\hat{C}(C_t, L_t) = \left[oC_t^{1-\frac{1}{f}} + (1 - o)(e^{at}L_t)^{1-\frac{1}{f}} \right]^{\frac{1}{1-\frac{1}{f}}} \quad (2.24)$$

which converges to the Cobb-Douglas function when the elasticity of the CES aggregator f is equal to 1.

The one-period real stochastic discount factor (SDF) is

$$M_{t+1} = \beta \left(\frac{U_t}{Q_t} \right)^{\frac{1}{\psi}} \left(\frac{Q_t}{U_{t+1}} \right)^{\gamma} \frac{\partial U_{t+1} / \partial C_{t+1}}{\partial U_t / \partial C_t} \quad (2.25)$$

In addition, households are wage-setters and face monopolistic competition in the labor market. Each household k is aggregated by the following Dixit and Stiglitz (1977) CES aggregator

$$N_t^d \equiv \left(\int_0^1 n_{kt}^{\frac{\nu-1}{\nu}} di \right)^{\frac{\nu}{\nu-1}}$$

where N_t^d and W_t are the aggregate index of labor demand and nominal wage, and ν is the elasticity of substitution among labor that determines the degree of market power. It follows that each household faces the labor demand curve

$$n_{kt} = \left(\frac{W_{kt}}{W_t} \right)^{-\nu} N_t^d$$

The wage rigidity again follows Calvo (1983) that only a fraction of households θ_w can optimize their wages as the following:

$$W_t^{1-\nu} \equiv (1 - \theta_w) W_t^{*1-\nu} + \theta_w W_{t-1}^{1-\nu} \quad (2.26)$$

respectively, where W_t^* denotes the reoptimized nominal wage. Second, I assume a

single economy-wide labor market that provides a single labor to a representative firm⁵

2.3.3 Central Bank

The monetary authority reacts to the policy function:

$$\frac{R_{ft}^{\$}}{R_{f,ss}^{\$}} = \left(\frac{R_{f,t-1}^{\$}}{R_{f,ss}^{\$}} \right)^{\rho_R} \left(\left(\frac{\pi_t}{\pi_{ss}} \right)^{\nu_m} \left(\frac{Y_t^d/Y_{t-1}^d}{\mu} \right)^{\nu_y} \right)^{1-\rho_R} \exp(-\zeta_t) \quad (2.27)$$

where $R_{f,ss}^{\$}$ and π_{ss} are the steady-state value of nominal one-period interest rate and inflation, respectively, which are determined in the general equilibrium.

The monetary authority can impose a discretionary *i.i.d.* shock ζ to alter the market expectation, in addition to the commitment to responses on inflation and output. For the ease of analytical tractability, the policy rule reacts to the gap of output growth instead of the output gap which is more prevalent in the New Keynesian literature (e.g. Diercks (2015)).

⁵ Or equivalently, to firms that use same kinds of labor in the same wage.

2.3.4 Aggregate Constraint

In the good market, I assume that default causes the deadweight loss of output.

Therefore, the aggregate resource constraint is

$$C_t + I_t = Y_t^d + (1 - \Phi(z_t^*)) (1 - \tau) \xi_t K_t \quad (2.28)$$

The aggregate capital evolves over time by

$$K_{t+1} = \left(1 - \delta + \Psi \left(\frac{I_t}{K_t} \right) \right) K_t + I_t \quad (2.29)$$

The labor market and hours also clear by

$$1 = N_t^s + L_t \quad (2.30)$$

2.4 Characterization

To characterize how the monetary policy influences on the risk and return of financial assets, I derive the close-form equation of the asset returns from the optimality condition of firms.

2.4.1 Optimality Conditions

The model is solved from the optimal condition of firms and the representative household, and the aggregate market clearing condition of goods and labor.

Investment and Leverage The firm maximizes the valuation by choosing the optimal investment and debt financing. Following the approach in Gomes et al. (2016), using the leverage ratio defined as $\omega = b/k$ reduces the dimension of the state variables of valuation equations of equity and defaultable bond. Also, given the idiosyncratic shock z_j , all the firms face the identical problem, thus dropping j from the following optimal conditions. More specifically, the equity valuation (2.17) and the default boundary (2.18) can be expressed as

$$v_t = \max_{\omega', i} q_t \omega_{t+1} g(i_t) - i_t + \tau \delta \quad (2.31)$$

$$+ (1 - \tau) g(i_t) E_t M_{t+1} \int_{\underline{z}}^{z_{t+1}^*} (z_{t+1}^* - z_{t+1}) d\Phi(z_{t+1})$$

$$z_t^* = r_t - \left(c + \frac{1}{1 - \tau} \right) \frac{\omega_t}{\pi_t} + \frac{v_t}{1 - \tau} \quad (2.32)$$

The first-order conditions with respect to investment is

$$1 - q_t \omega_{t+1} \frac{\partial \Psi(i_t)}{\partial i_t} = (1 - \tau) \frac{\partial \Psi(i_t)}{\partial i_t} E_t M_{t+1} \int_{\underline{z}}^{z_{t+1}^*} (z_{t+1}^* - z_{t+1}) d\Phi(z_{t+1}) \quad (2.33)$$

The firm also chooses optimal capital structure from the tradeoff between the tax benefit and the default risk of corporate bond. The first-order condition with respect to leverage is

$$\left(q_t + \frac{\partial q_{t+1}}{\partial \omega_{t+1}} \right) \omega_{t+1} = -(1 - \tau) E_t M_{t+1} \Phi(z_{t+1}^*) \frac{\partial z_{t+1}^*}{\partial \omega_{t+1}} \quad (2.34)$$

where

$$\frac{\partial z_t^*}{\partial \omega_t} = - \left(c + \frac{1}{1 - \tau} \right) \frac{1}{\pi_t} \quad (2.35)$$

The bond valuation (2.19) can be re-expressed as

$$q_t \omega_{t+1} = E_t M_{t+1} (\tilde{\Omega}_{t+1}^{nd} + (\tilde{\Omega}_{t+1}^d)) \quad (2.36)$$

where the principal and coupon repayment under non-default $\tilde{\Omega}^{nd}$ and the tax-deducted loss $\tilde{\Omega}^d$ are

$$\tilde{\Omega}_t^{nd} = \frac{c + 1}{\pi_t} \Phi(z_t^*) \quad (2.37)$$

$$\tilde{\Omega}_t^d = \frac{1}{\omega_t} \left[\int_{z_t^*}^{\bar{z}} (z_t^* - z_t) d\Phi(z_t) - (1 - \Phi(z_t^*)) \left(\omega_t \frac{\partial z_t^*}{\partial \omega_t} + \xi \right) \right], \quad (2.38)$$

respectively.

$\tilde{\Omega}_t^d$ is further decomposed into two terms. The first term captures the operating loss transferred from the equity. The second term captures the restructuring cost and the increment driven by the change of default threshold, $\frac{\partial z^*}{\partial \omega}$. $\frac{\partial z^*}{\partial \omega}$ is always negative as shown in (2.35), because the reduced leverage ratio decreases the default probability by raising the default threshold, resulting in the reduction of the loss in the event of default.

From the first-order condition of leverage, the new term $\frac{\partial q_{t+1}}{\partial \omega_{t+1}}$ should meet the internal consistency generated by the derivative of the bond valuation

$$q_t + \frac{\partial q_{t+1}}{\partial \omega_{t+1}} \omega_{t+1} = E_t M_{t+1} \left[\Phi(z_{t+1}^*) (c + 1) \frac{\omega_{t+1}}{\pi_{t+1}} + \Xi_{t+1} \right] \quad (2.39)$$

where

$$\Xi_t = \phi(z_t^*) \frac{\partial z_t^*}{\partial \omega_t} \left(-(1 - \tau)(r_t - z_t^*) + (c + 1) \frac{\omega_t}{\pi_t} + (1 - \tau)\xi_t - v_t \right) \quad (2.40)$$

Nominal Price and Wage Taken P_t , and Y_t^d given, firm i chooses its own output price P_{it} to maximize the present value of the dividend

$$E_t \sum_{T=t}^{\infty} \theta^{T-t} M_{t,T}^{\$} D_{iT}$$

where $M_{t,T}^{\$}$ is the nominal SDF and the nominal dividend $D_{it} = P_{it}y_{it} - W_t n_{it}$. Then its first-order condition with respect to P_{it} yields

$$p_t^* \equiv \frac{P_t^*}{P_t} = \frac{\eta}{\eta - 1} \frac{\sum_{T=t}^{\infty} \theta^{T-t} M_{t,T}^{\$} MC_T \left(\frac{P_T}{P_t}\right)^{\eta+1} Y_T^d}{\sum_{T=t}^{\infty} \theta^{T-t} M_{t,T}^{\$} \left(\frac{P_T}{P_t}\right)^{\eta} Y_T^d} = \frac{\eta}{\eta - 1} \frac{G_t}{H_t}$$

where

$$G_t = Y_t^d \cdot MC_t + \theta_p E_t M_{t+1} \pi_{t+1}^{\eta} G_{t+1}$$

$$H_t = Y_t^d + \theta_p E_t M_{t+1} \pi_{t+1}^{\eta-1} H_{t+1}$$

and MC_t is the marginal production cost at time t . I drop the subscript i as all firms face the identical problem. The aggregate output supply

$$Y_t^s = \int_0^1 y_{it} di = \int_0^1 \left(\frac{P_{it}}{P_t}\right)^{-\eta} di \cdot Y_t^d = F_t Y_t^d$$

where the measure of price dispersion F_t can be recursively expressed as

$$F_t = (1 - \theta_p) \left(\frac{P_t^*}{P_t}\right)^{-\eta} + \theta_p \left(\frac{P_{t-1}}{P_t}\right)^{-\eta} F_{t-1}$$

Taken W_t and H_t given, each household k maximizes her utility U_t by choosing the

optimal wage W_{kt} . Its first-order condition with respect to W_{kt} yields

$$w_t^* \equiv \frac{W_t^*}{P_t} = \frac{\nu}{\nu - 1} \frac{\partial \hat{C}_t / \partial L_t}{\partial \hat{C}_t / \partial C_t} \frac{G_{wt}}{H_{wt}}$$

where

$$G_{w,t} = 1 + \theta_w E_t \frac{\partial \hat{U}_{t+1} / \partial L_{t+1}}{\partial \hat{U}_t / \partial L_t} \frac{N_{t+1}^d}{N_t^d} \left(\frac{w_{t+1}}{w_t} \right)^\nu \pi_{t+1}^\nu G_{w,t+1}$$

$$H_{w,t} = 1 + \theta_w E_t \frac{\partial \hat{U}_{t+1} / \partial C_{t+1}}{\partial \hat{U}_t / \partial C_t} \frac{N_{t+1}^d}{N_t^d} \left(\frac{w_{t+1}}{w_t} \right)^\nu \pi_{t+1}^{\nu-1} H_{w,t+1}$$

The aggregate labor supply

$$N_t^s = \int_0^1 n_{kt} dk = \int_0^1 \left(\frac{W_{kt}}{W_t} \right)^{-\nu} dk \cdot N_t = F_{wt} N_t^d$$

where the measure of price dispersion $F_{w,t}$ can be recursively expressed as

$$F_{wt} = (1 - \theta_w) \left(\frac{W_t^*}{W_t} \right)^{-\nu} + \theta_w \left(\frac{W_{t-1}}{W_t} \right)^{-\nu} F_{w,t-1}$$

2.4.2 Financial Moments

In this subsection, I derive the levered equity returns and credit spreads and decompose them into individual economic constituents using the optimality conditions

derived in the previous subsection.

Levered Equity Return The optimality for investment (2.33) can be restated by

$$p_t^E \equiv \frac{1}{\frac{\partial \Psi(i_t)}{\partial i_t}} = q_t \omega_{t+1} + E_t M_{t+1} \int_{\underline{z}}^{z_{t+1}^*} (z_{t+1}^* - z_{t+1}) d\Phi(z_{t+1}) \quad (2.41)$$

The left hand side and right hand side of the equation captures the real equity price p^E and its expected payoff, respectively. The equity price depends on the real friction of capital adjustment. In the expected payoff, the first term captures the leverage by corporate bond financing, and the second term is unlevered dividend.

Combining Equation (2.36) and (2.41), the realized levered equity return is implicitly defined as

$$p_{t-1}^E \cdot r_t^E = q_{t-1} \omega_t \cdot r_t^B + (1 - \tau) \int_{\underline{z}}^{z_t^*} (z_t^* - z_t) d\Phi(z_t) \quad (2.42)$$

where the defaultable bond return r_B is implied in Equation (2.36).

For the equity and bond risk premium, I use a log-linearized return and SDF to calculate the premium following Equation (2.5).⁶

⁶ Obtaining a non-zero risk premium requires at least a second-order approximation of the model, but this high-order solution often fails to converge. In terms of computation, using log-normal asset pricing equations with a log-linearized macroeconomic solution asymptotically yields an identical

The conditional covariance in Equation (2.5) are acquired by

$$\text{cov}_t(m_{t+1}, r_{t+1}^X) = \text{cov}(m_t, r_t^X) - \text{cov}(E_t m_{t+1}, E_t r_{t+1}^X), \quad X = \{E, B\} \quad (2.43)$$

where these two unconditional moments are easily implemented from the simulation using Dynare++.

Credit Spread From the defaultable bond pricing equation 2.36, a default-free bond price q_t^f at $z^* = \bar{z}$ and $\Phi(z^*) = 1$ is

$$q_t^f = (c + 1)E_t \left[\frac{M_{t+1}}{\pi_{t+1}} \right] = \frac{c + 1}{1 + r_{ft}^s} \quad (2.44)$$

The credit spread

$$cs_t = (c + 1) \left[\frac{1}{q_t} - \frac{1}{q_t^f} \right] \approx q_t^f - q_t = E_t M_{t+1} \Omega_{t+1}^\Delta \quad (2.45)$$

where

$$\omega_t \cdot \Omega_t^\Delta = (1 - \Phi(z_t^*)) \left\{ \tau c \frac{\omega_t}{\pi_t} - (1 - \tau) z_t^* + \xi \right\} + (1 - \tau) \int_{z_t^*}^{\bar{z}} z_t d\Phi(z_t) \quad (2.46)$$

risk premium with one from the second-order approximation.

The credit risk premium

$$\begin{aligned} CRP_t &= cov_t(M_{t+1}, \Omega_{t+1}^\Delta) = E_t M_{t+1} \Omega_{t+1}^\Delta - E_t M_{t+1} \cdot E_t \Omega_{t+1}^\Delta & (2.47) \\ &= cs_t - \frac{E_t \Omega_{t+1}^\Delta}{1 + r_{ft}} \end{aligned}$$

The credit spread is attributed to the risk-neutral component of the default rate and the credit risk premium driven by its cyclicity.

2.5 Calibration

The model parameters are calibrated quarterly and summarized in Table 2.2.

Preferences The preference parameters are consistent with the long-run risk literature. The annualized subjective discount factor is set to 0.98 to match the real rate. The risk aversion coefficient is 10 (Bansal and Yaron (2004)) and the IES is set to 2 (Croce (2014)). These parameter values allow the early resolution of uncertainty in the Epstein and Zin preference. The consumption-leisure elasticity f is set to 1, leading to the Cobb-Douglas consumption bundle. The CES weight o is set to 0.18 to match the 18% of working hours in the steady-state.

Production In the production technology, the capital share is 0.35 and the annualized depreciation rate is set to 3%. In the stochastic process of the aggregate

productivity, the annual persistence of long-run risk is set to 0.85 following Corhay (2016). The long-run risk process is assumed no drift here as this stationarity assumption significantly improves the model convergence and does not alter the asset pricing moments. The annual short-run and long-run volatility is set to 5.8% and 0.63%, respectively. Firms are also exposed to the idiosyncratic shocks in the range $[-0.7, 0.7]$ and the distribution parameter η_1 and η_2 to cause the zero probability on the boundary. This boundary is smaller than Gomes et al. (2016), but helps better targeting the empirical annual default rate of 1%. For the source of the real friction, the capital adjustment cost is set to 5.

Monetary Policy The monetary policy coefficients are set based on the empirical estimate of Diercks (2015) from 1983 to 2002, excluding the recent period of the zero lower-bound of the nominal interest rate. Its quarterly persistence is set to 0.9, inflation coefficient is set to 3, and output coefficient is set to 1. The volatility of a discretionary policy shock is 1%, considering the high inflation era in 1980s and 1990s. The annual steady-state inflation is assumed to be 2%.

Corporate Bond The firm issues corporate bond with a coupon rate 3% under the effective tax rate of 11%. The restructuring cost upon default is set to 0.01.

2.6 Model Implications

In this section, I investigate how different nominal frictions and a monetary policy rule in the model affect the risk premium of equities and defaultable bonds.

2.6.1 The Effect of Nominal Frictions

In order for monetary policy to influence the real economy, I incorporate the staggered price and wage as nominal frictions in the model. Before investigating asset prices affected by the policy parameters, I check how each nominal friction influences the equilibrium and its implication in the economy.

Table 2.3 compares macroeconomic and asset pricing moments of the model by alternatively closing the source of frictions. When no nominal friction and corporate debt exists as shown in column (1), the annualized unlevered equity risk premium is 1.85%, considerably smaller than the empirical observation. Incorporating a firm's default that allows the pricing of a corporate bond does not significantly alter the macroeconomic moments.⁷ In particular, the levered equity premium is 1.76%, rather smaller than the unlevered counterpart. This exhibits a striking difference from con-

⁷ Similarly, Bhamra et al. (2011) study the model where the only source of nominal friction is the repayment of nominal corporate bonds. They show that the expected inflation affects the corporate bond issuing fixed nominal coupon even without other nominal frictions.

ventional approaches to assume the levered return by two or three times its unlevered one (see Bansal and Yaron (2004)). Endogenizing defaultable bond price does not lead to amplifying the premium, thus not resolving the equity premium puzzle.

The additional inclusion of sticky price and wage lowers both equity and bond risk premium, indicating the trade-off between the real effect of monetary policy and the generation of sizeable risk premia. In terms of macroeconomic moments, the sticky wage particularly contributes to match the volatility of output and labor, and the correlation between consumption and equity risk premium.

Finally, nominal frictions do not enhance the credit spread puzzle. The magnitude of default rate and credit spread is inert to the source of nominal friction, and additional calibration shows that matching the level of credit spread to data necessarily leads to higher default rate.

2.6.2 The Effect of Monetary Policy Stance

I study how the central bank's monetary policy stance represented by inflation, output, and rate persistence parameters influences macroeconomic and asset pricing equilibrium. Table 2.4 indicates that any reasonable combination of policy parameters does not considerably affect investment-to-output ratio, leverage ratio, default rate,

and credit spread. On the other hand, low inflation and output coefficients, and high rate persistence parameter lead to unrealistically huge output dynamics and the correlation between consumption growth rate and inflation.

Decomposing the premium by three orthogonal risk sources (short- and long-run TFP risk, and monetary policy risk), provides more detailed economic view how each risk contributes to asset prices. Figure 2.1 illustrates the levered equity risk premium when the policy parameters of output, inflation, and the persistence of interest rate vary. When the economy responds to a positive short-run productivity shock, both the stronger inflation suppression (higher ϕ_π) and the weaker output inertia (lower ϕ_y) contribute to the higher equity premium under the existence of nominal rigidities. This observation is consistent with the intuition in Section 2.2. A reduced marginal cost shifts the supply curve PC downward, causing output to increase and inflation to decrease. When the inflation policy inertia is high, output should increase further to offset the moderate inflation decline if the nominal rate does not significantly respond to the shock. Similarly, the lower output policy coefficient also allows the output increase further from its steady state. Figure 2.2 further supports this interpretation. The initial response of output is higher as the inflation (output) policy coefficient is higher (lower), where this order is preserved in the resultant equity risk premium.

The negative response of inflation also supports that the new equilibrium is caused by the supply shift. Finally, the relative response of nominal interest is smaller than output and inflation, validating the assumption of the rate preservation in the above interpretation. The responses to a long-run productivity shock also exhibits the similar patterns with those to short-run one, but are more persistent and greater in magnitude (see Figure 2.3).

When the monetary authority imposes an expansionary shock, both the higher inflation and output inertia contribute to the smaller equity premium. This rate expansion shifts the demand curve to upward by influencing the IS curve, causing both output and inflation increase. When either output or inflation inertia is high, it suppresses both of their response linked through the PC curve, leading to a smaller premium. This phenomenon is also supported by Figure 2.4. Both output and inflation respond positively and more strongly for smaller policy coefficients. It is noteworthy to mention that the nominal rate rather increases after the easing shock when the policy is less anti-inflationary. This is because the resultant surge of inflation outweighs the decline of a real rate.

In an aggregate manner, Epstein and Zin (1991) preference particularly amplifies the risk premium driven by the long-run risk by disentangling risk aversion from the

elasticity of intertemporal substitution, outweighing the effect caused by monetary policy risk. As a result, both higher anti-inflationary stance and less output inertia lead to the decrease of equity premia in any inclusion of nominal rigidity as shown in Table 2.4. An exceptional case where the effect of a monetary policy risk can outweigh that of a TFP risk is when the persistence of interest rate is closer to unity. This case, however, leads to unrealistically high output volatility.

2.6.3 Credit Risk Premium

Designing a default barrier in the model also allows the calculation of model-implied credit spread and default rate. Table 2.3 and 2.4 show that the model yields 0.31% of the credit spread when the annual default rate is 3.79%. Matching the default rate to the empirical counterpart, 1%, further reduces the spread to 0.10%. The resultant spread and the default rate does not significantly change upon the choice of nominal rigidities and the monetary policy stance. This is well-known dilemma in many macroeconomic models called a credit spread puzzle indicating that the credit spread is too large to be explained by the empirical default rate.

One potential rationalization for this puzzle is that the credit spread contains the risk premium beyond its risk-neutral component. Such premium can be attributed to

the countercyclical default rate. However, the empirical evidence on that credit risk premium is yet scarce. One example is Asvanunt and Richardson (2016) reporting that the credit risk premium exists after adjusting for term risk in both European and the U.S. market.

To create a sizeable credit risk premium and see how it affects the overall credit spread given the default rate in my model, I allow the restructuring cost upon default countercyclical to induce a sizeable credit risk premium. This premium is attributed to the positive covariance between a SDF and a default rate. As a result, one can expect that the overall spread while the risk-neutral component of the spread, which is the function of average default rate, unaltered.

Table 2.5 illustrates the asset pricing moments when the cyclicity of the restructuring cost and the approximation order changes. When ξ_1 changes from 0 to 3, the credit risk premium is amplified from 0.011 to 0.111, contributing 45% of the total spread. However, the overall spread is virtually unchanged. When the model is solved by the second-order approximation, both the default rate and the spread increases with the counterintuitively negative covariance between the SDF and the default rate, and the less likelihood of the stationary solution. In overall, the model provides a room to generate a sizeable credit risk premium, but does not resolve a credit spread

puzzle.

2.7 Concluding Remarks

This paper theoretically analyzes how monetary policy can influence the risk premium of financial assets in a New Keynesian general equilibrium model where a firm's default is endogenously determined from the limited liability of stockholders, and nominal price and wage rigidity exist. A productivity (monetary policy) shock shifts supply (demand) curve, causing output comoves positively (negatively) with inflation. A policy feedback rule to output and inflation determines the magnitude of output response to those shocks, determining the price of risk and the procyclicality of dividend. Higher (lower) inflation and lower (lower) output feedback lead to higher equity premium driven by a productivity (policy) risk. This trend is robust to the source of nominal rigidity. Under a baseline calibration, the model generates 1.76% (1.87%) of the annual levered (unlevered) equity risk premium, indicating an endogenous leverage does not amplify the equity return. The countercyclicality of the default rate in the model generates a credit risk premium, but does not amplify the overall credit spread. Producing reasonable asset pricing dynamics based on New Keynesian DSGE models remains challenge. A potential stretch is to incorporate

informational frictions or different designs of the default to allow more flexibility of the leverage choice and the default barrier based on an economic state. I leave these concerns for future research.

Table 2.2: Quarterly Baseline Calibration

σ_a and σ_x are $\sqrt{3}$ times greater than Croce (2014). o is set to match that the fraction of the steady-state number of hours worked is 0.18, similarly with Croce (2014). τ is set to match the steady-state leverage ratio of 0.4. $\eta_0 = 0.5$ and $\eta_2 = \eta_4 = 0$ for the symmetry of z -distribution.

Preference	β^4	Subjective discount factor	0.98
	γ	Risk aversion	10
	ψ	Elasticity of intertemporal substitution	2
	o	Consumption-leisure CES weight	0.18
	f	Consumption-labor elasticity	1
Production and Capital	α	Production function exponent	0.35
	4δ	Depreciation rate	0.03
	4μ	Growth rate of productivity	0
	ρ^4	Persistence of long-run productivity shock	0.85
	$\sqrt{4}\sigma_a$	Short-run productivity risk	0.047
	$\sqrt{4}\sigma_x$	Long-run productivity risk	0.0051
	ξ_k	Adjustment cost coefficient	5
Nominal Rigidity	η	Elasticity between goods	7
	θ_p	Price stickiness	0.7
	ν	Elasticity between labor	7
	θ_w	Wage stickiness	0.7
Idiosyncratic Shock	η_1	Distribution parameter	1.075
	η_3	Distribution parameter	-2.16
	\bar{z}	Shock upper bound	0.7
Monetary Policy	ρ_R	Persistence of nominal rate	0.9
	ν_m	Inflation coefficient	3
	ν_y	Output coefficient	1
	$\sqrt{4}\sigma_\zeta$	Volatility of policy shock	0.01
	π_{ss}	Target inflation	0.02
Bond	c	Coupon rate	0.03
	τ	Tax rate	0.102
	ξ_0	Restructuring cost level	0.01
	ξ_1	Restructuring cost cyclicalilty	0

Table 2.3: Annualized Macroeconomic and Asset Pricing Moments

Defr denotes the default rate $1-\Phi(z^*)$. SP and SW means sticky price and wage, respectively. All moments are annualized.

	Model					Data
	(1)	(2)	(3)	(4)	(5)	
SP			✓		✓	
SW				✓	✓	
Default		✓	✓	✓	✓	
E(I/Y)	0.19	0.20	0.20	0.20	0.20	0.20
$\sigma(\Delta I)/\sigma(\Delta Y)$	2.48	2.40	2.91	2.80	3.07	4.50
$\sigma(\Delta C)/\sigma(\Delta Y)$	0.80	0.82	0.70	0.80	0.65	0.71
$\sigma(\Delta N)/\sigma(\Delta Y)$	0.31	0.30	1.38	1.31	1.50	1.70
$\sigma(\Delta Y)$ (%)	3.82	3.78	5.11	3.18	5.34	3.56
$E(r_f^n)$ (%)	4.03	4.01	4.00	4.01	4.00	2.25
$\sigma(r_f^n)$ (%)	0.32	0.31	0.42	0.35	0.46	0.69
$E(\omega)$		0.45	0.45	0.45	0.45	0.42
$\sigma(\omega)$		0.13	0.13	0.12	0.13	3.40
<i>ERP</i> (%)	1.85	1.76	1.35	0.98	1.03	7.23
<i>BRP</i> (%)		0.75	0.39	0.17	0.20	3.54
<i>Defr</i> (%)		3.78	3.79	3.78	3.79	1.00
$E(cs)$ (%)		0.31	0.31	0.31	0.31	0.96
$\sigma(cs)$ (%)		0.05	0.05	0.05	0.05	0.42
<i>CRP</i> (%)		0.04	0.04	0.03	0.03	
$\text{corr}(\Delta c, \pi)$	-0.31	-0.30	0.06	0.22	0.10	0.08
$\text{corr}(\Delta c, r^E - r_f)$	0.58	0.59	0.62	0.39	0.66	0.25
$\text{corr}(r^E, r^B)$		0.33	-0.10	-0.35	-0.05	0.13
$\text{corr}(cs, r^E - r_f)$		-0.07	-0.08	-0.05	-0.09	-0.02
$\text{corr}(SDF, Defr)$		0.62	0.33	0.35	0.27	

Table 2.4: The Effect of Monetary Policy Coefficients on the Aggregate Moments

Defr denotes the default rate $1-\Phi(z^*)$. All moments are annualized. Except the policy coefficients, the baseline calibration is used.

	ϕ_π				ϕ_y			ρ_r		
	2	3	4	5	0	1	2	0.9	0.95	0.99
$E(I/Y)$	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.23
$\sigma(\Delta I)/\sigma(\Delta Y)$	3.13	3.07	3.02	2.97	3.09	3.07	3.07	3.07	3.19	4.32
$\sigma(\Delta C)/\sigma(\Delta Y)$	0.62	0.65	0.68	0.70	0.62	0.65	0.68	0.65	0.59	0.54
$\sigma(\Delta N)/\sigma(\Delta Y)$	1.57	1.50	1.44	1.38	1.38	1.50	1.67	1.50	1.54	1.65
$\sigma(\Delta Y)$ (%)	6.71	5.34	4.71	4.35	6.91	5.33	4.43	5.33	9.31	42.77
$E(r_f^n)$ (%)	4.02	4.03	4.00	4.05	4.06	4.03	4.02	4.01	4.00	4.01
$\sigma(r_f^n)$ (%)	0.31	0.39	0.49	0.55	1.01	0.39	0.48	0.39	0.41	0.45
$E(\omega)$	0.45	0.45	0.45	0.46	0.46	0.45	0.45	0.45	0.45	0.47
$\sigma(\omega)$	0.12	0.13	0.13	0.13	0.13	0.12	0.13	0.12	0.13	0.19
<i>ERP</i> (%)	0.64	1.03	1.15	1.20	1.94	1.03	0.43	1.03	1.18	4.64
<i>BRP</i> (%)	0.42	0.20	0.13	0.10	-0.24	0.19	0.62	0.20	0.10	-2.69
<i>Defr</i> (%)	3.78	3.77	3.79	3.77	3.77	3.78	3.78	3.78	3.78	3.81
$E(cs)$	0.31	0.30	0.31	0.30	0.30	0.30	0.31	0.31	0.31	0.31
$\sigma(cs)$	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.07
<i>CRP</i> (%)	0.02	0.03	0.03	0.04	0.06	0.03	0.01	0.03	0.04	0.26
$\text{corr}(\Delta c, \pi)$	0.12	0.09	0.08	0.07	0.41	0.10	-0.18	0.09	0.27	0.36
$\text{corr}(\Delta c, r^E - r_f)$	0.74	0.66	0.61	0.58	0.77	0.66	0.53	0.66	0.82	0.91
$\text{corr}(r^E, r^B)$	-0.16	-0.04	0.04	0.10	-0.05	-0.05	-0.04	-0.05	-0.21	-0.31
$\text{corr}(cs, r^E - r_f)$	-0.11	-0.09	-0.08	-0.07	-0.11	-0.09	-0.07	-0.08	-0.15	-0.50
$\text{corr}(SDF, Defr)$	0.11	0.27	0.36	0.42	0.45	0.27	0.06	0.27	0.19	0.27

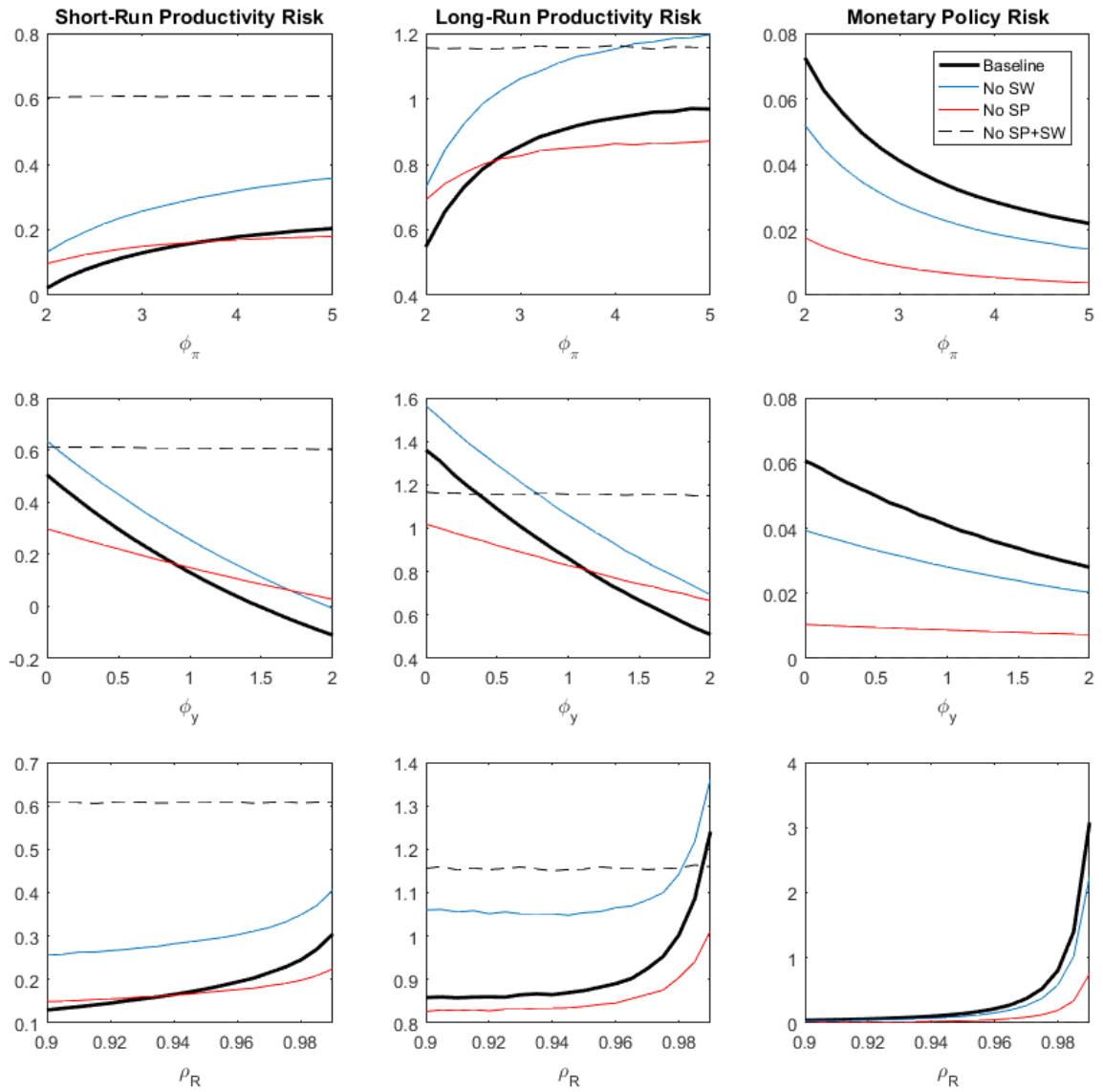


FIGURE 2.1: Levered Equity Risk Premia and Monetary Policy Parameters

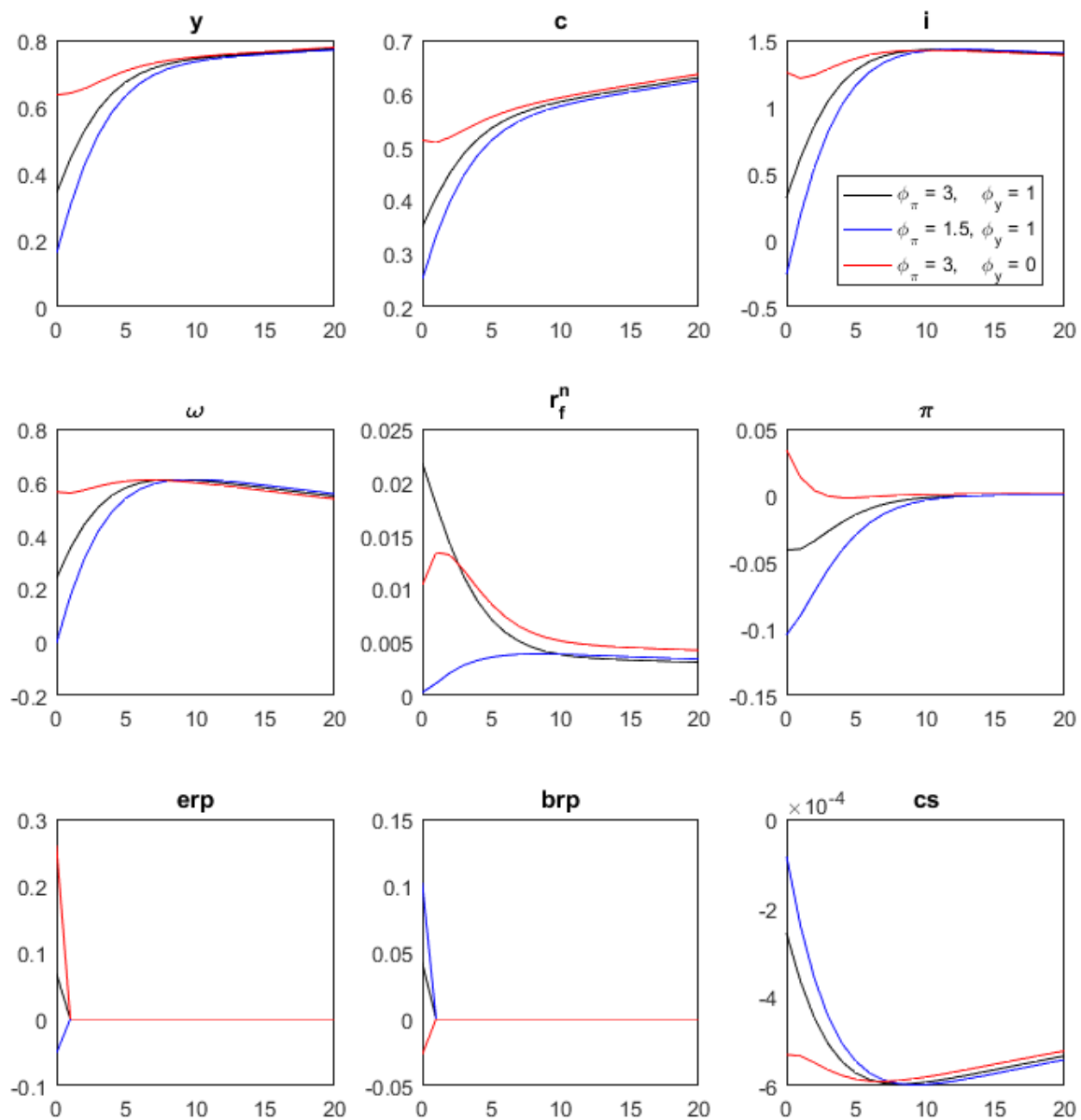


FIGURE 2.2: Impulse-Response of a Positive Short-Run TFP Shock

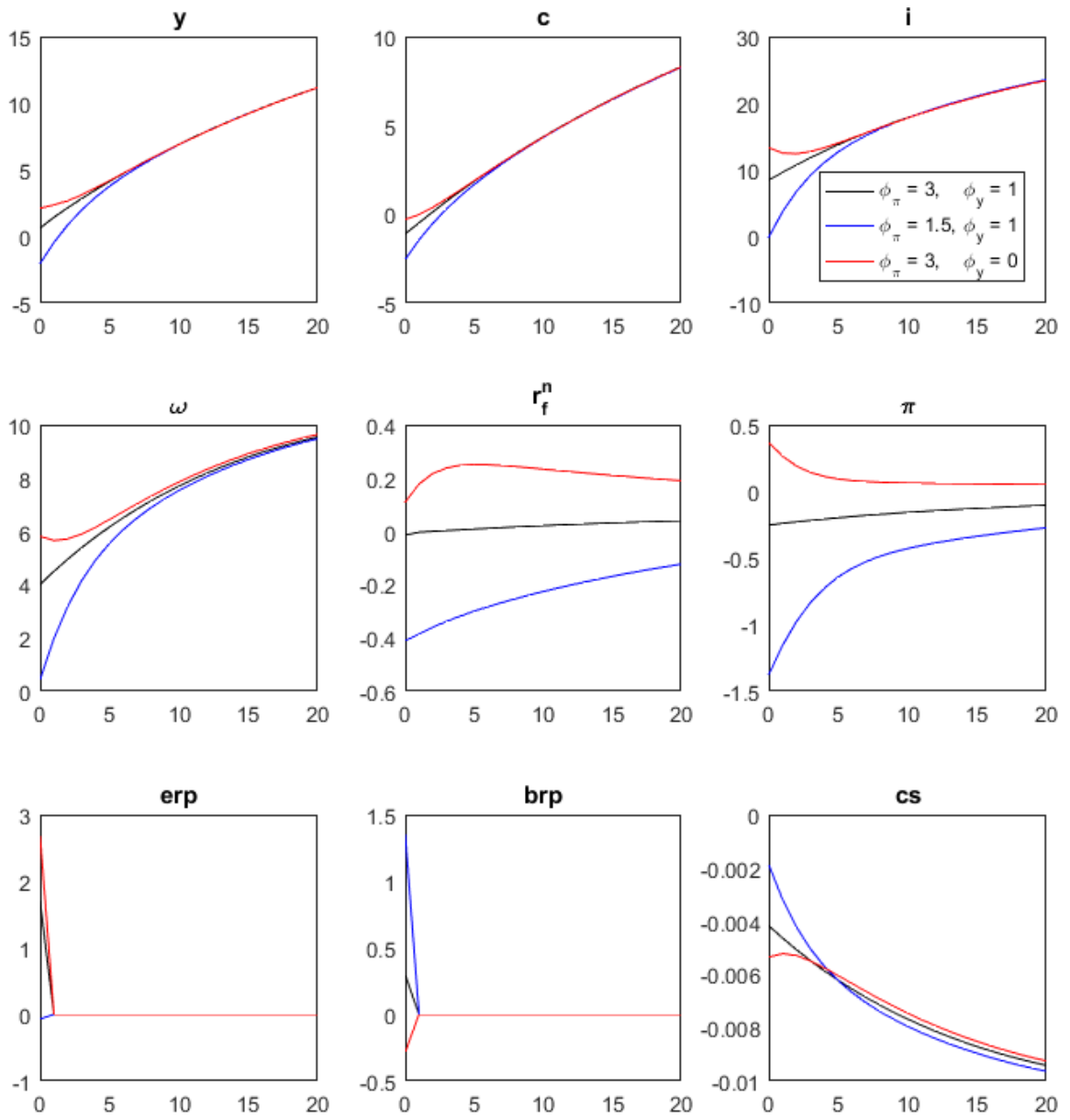


FIGURE 2.3: Impulse-Response of a Positive Long-Run TFP Shock

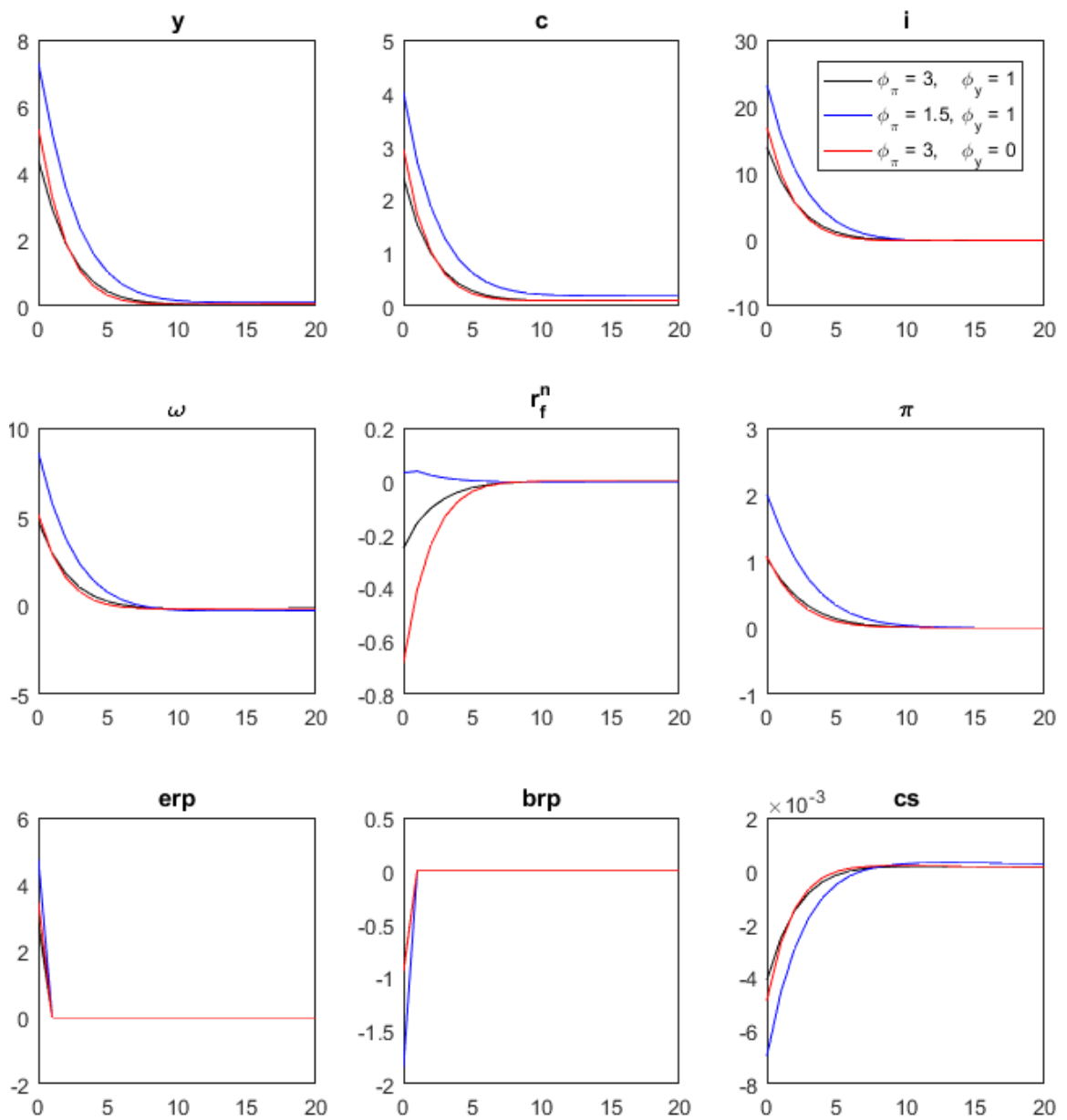


FIGURE 2.4: Impulse-Response of an Expansionary Monetary Policy Shock

Table 2.5: Credit spread and the credit risk premium

$Defr$ is the default rate $1 - \Phi(z^*)$. The standard deviation averaged over 1,000 simulations are in the parenthesis. For each simulation, the length of time series is 12,000. The 2nd-order convergence denotes the rate the resultant equilibrium is stationary. The result is based on the baseline parameters in Table 2.2. All moments are annualized.

order	1	2	1
ξ_1	0	0	3
$Defr$	3.197	3.650	3.177
cs	0.249	0.273	0.248
$E[\sigma(cs)]$	(0.029)	(0.036)	(0.419)
$\sigma[E(cs)]$	(0.027)	(0.033)	(0.172)
CRP	0.011	0.011	0.111
	(0.001)		(0.011)
$corr(SDF, Defr)$	0.664	-0.457	0.036
	(0.018)	(0.166)	(0.035)
ERP	0.468	0.467	0.559
	(0.030)		(0.032)
2^{nd} -order conv		0.786	

Conclusion

I explore how the monetary policy can influence asset prices in two aspects. In the first chapter, I show the funding liquidity of financial intermediaries can significantly affect the price response of not only their own stocks, but also their borrowers' stocks to a monetary policy shock during the quantitative easing period. This observation supports the bank-lending channel as a key policy transmission mechanism during such period. Additional research is warranted to further substantiate this mechanism. In the second chapter, I present a DSGE model where monetary policy can influence the real economy and the default barrier of risky firms through nominal rigidity. The model supports conventional economic intuition that the policy rule determines the equity risk premium, which is driven by demand and supply risk. Other scholars could address the challenge of generating sizeable risk premia that is comparable to the empirical counterparts.

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Biography

Tae-Rog Oh was born in November 10, 1981 in Seoul, Korea. He earned B.S. in Chemistry at Korea Advanced Institute of Science and Technology (KAIST) and M.S. in Chemistry at Seoul National University. During that period, he researched on nanomaterials aiming at energy storage and catalysis. His curiosity about uncertainty and complexity of the world spurred his interest more in social sciences. He earned M.S. in Finance and Economics at London School of Economics (LSE) and Ph.D. in Finance at Duke University. During his Ph.D. study, he mainly focused on how monetary policy influences asset prices.

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