Liquidity Premium, Credit Costs, and Optimal Monetary Policy

Sukjoon Lee*

August 2022

Abstract

Contrary to the common belief that all the rates in the economy move in the same direction, raising the nominal policy rate can lower the borrowing cost in the corporate bond market, while increasing that in the bank loan market. This can happen when the corporate bond secondary market is highly liquid. I develop a model of this mechanism and provide empirical evidence of it. In such a case, the Friedman rule is suboptimal, and the optimal policy rate is an increasing function of the degree of the corporate bond secondary market liquidity.

JEL Codes: E44, E52, G12, G30

Keywords: monetary policy, credit cost, corporate finance, bond premium, liquidity premium

*New York University Shanghai, 1555 Century Ave, Pudong, Shanghai, China 200122. sukjoon.lee@nyu.edu.

1 Introduction

Firms finance their investment using multiple sources, and the conventional wisdom is that the borrowing costs of all financing sources move in the same direction in response to changes in monetary policy.[1] However, is this common belief always true? Could it be possible for the real rates at which firms borrow in distinct financial markets to move in different directions following changes in monetary policy? Through what channel could that happen? What does it imply for firms' responses to monetary policy shocks in terms of their investment and borrowing decisions? What would be the optimal monetary policy in such an economy?

To answer these questions, I develop a general equilibrium macroeconomic model where firms have two options for external financing: they can issue corporate bonds or obtain bank loans. An important feature of the model is that corporate bonds are not just stores of value but also serve a liquidity role. The model delivers three predictions. First, an increase in the nominal policy rate can lower the borrowing cost in the corporate bond market, while increasing that in the bank loan market, and I provide empirical evidence that supports the result. Second, a higher nominal policy rate induces firms to substitute corporate bonds for bank loans, and this result is supported by the existing empirical evidence. Third, the Friedman rule is suboptimal so that keeping the cost of holding liquidity at a positive level is socially optimal. The optimal policy rate is an increasing function of the degree of the corporate bond secondary market liquidity.

To provide a concrete concept of liquidity of corporate bonds, I employ the monetary model of Lagos and Wright (2005), extended to incorporate firms externally financing their production. Consumers and firms trade in a decentralized market, where trade is bilateral, credit is imperfect, and thus a

[1] Consider the following quote from Jones (2017)'s Macroeconomics textbook: "The Federal Reserve sets . . . the federal funds rate, . . . effectively setting the rate[s] at which [firms] borrow . . . in financial markets." This quote implies that the Federal Reserve implements monetary policy changes by targeting a single nominal rate but anticipates that these changes will be transmitted (symmetrically) to the rates in all financial markets.

medium of exchange is necessary. Agents allocate their wealth between money and corporate bonds. Both can serve liquidity purposes, but only a fraction of corporate bond holdings can be used towards trades. This assumption is meant to capture the idea that, when in need of extra money, agents liquidate corporate bonds in a secondary market, but due to frictions, trading delays, intermediation fees, etc., only a fraction of these bonds can be sold. Hence, the fraction of bonds that agents can use is meant to capture the degree of liquidity in the secondary market for those assets. Firms need to raise funds to finance production, and they can do so either by issuing corporate bonds or by obtaining a bank loan. Naturally, the liquidity properties of corporate bonds affect their equilibrium price and, consequently, the issuance decision of firms.

In the model, changes in the *nominal* policy rate get transmitted to the *real* cost of issuing corporate bonds and borrowing from a bank through the following mechanism. A higher nominal policy rate increases the opportunity cost of holding money, reduces real money balances, increases the liquidity premium of corporate bonds, and makes issuing corporate bonds less expensive. This pass-through becomes stronger when the corporate bond secondary market is more liquid. The real loan rates are determined in the over-the-counter (OTC) market for loans, where firms and banks are matched and bargain over the size and the interest rate of a loan. With an increase in the nominal policy rate, the cost of holding money increases, agents carry less liquidity, and firms borrow less from a bank since agents can afford less. As a result, the real loan rate increases as it depends positively on the marginal benefit of a loan, and the latter decreases in the loan size.

Having established the mechanism through which the real rates at which firms borrow in distinct financial markets could move in different directions following changes in the nominal interest rate, now the questions are: Is there evidence for this mechanism? Are such movements of the real rates observed empirically? The model focuses on a specific channel, which is through the liquidity premium of corporate bonds, and, of course, there are other channels in action as well in reality. Thus, whether such movements of the real rates can materialize is a quantitative question that depends on whether the channel highlighted in the model can be dominant. Interestingly, the U.S. corporate bond secondary market underwent a structural change in 2002, when the Transaction Reporting and Compliance Engine (TRACE) was introduced to make transactions in the secondary market transparent. Empirical evidence in the literature shows that the corporate bond secondary market liquidity has improved substantially as a result of the increased transparency under the new system, and that liquidity has become a significant component of the corporate bond premium.[2] Based on this observation, I hypothesize that the introduction of the TRACE has strengthened the liquidity premium channel of monetary policy transmission so that it might have become a dominant channel.

To check whether it was indeed the case, I employ the structural vector autoregression (SVAR) and local projections to examine how the excess bond premium and the real loan rates respond to changes in the nominal interest rate, and exploit the high-frequency identified monetary shocks as an instrument, following Gertler and Karadi (2015), to ensure the results are not driven by other macro factors and to limit any potential reverse causality issues. Consistent with the hypothesis, during the post-TRACE period, the real loan rates respond positively to an increase in the nominal interest rate, whereas the excess bond premium responds negatively in medium and long horizons. In contrast, during the pre-TRACE period, the excess bond premium responds positively. Then I provide evidence for the liquidity premium channel by showing that the liquidity premium of corporate bonds, measured using the bid-ask spreads or the trading volume in the secondary market, increases following an increase in the nominal interest rate. The empirical analysis shows that the liquidity premium channel has been strengthened, and become a dominant channel, in monetary policy transmission with the introduction of the TRACE.

Another interesting prediction of the model is that an increase in the

[2]Two remarks are in order. First, Bessembinder, Maxwell, and Venkataraman (2006), Edwards, Harris, and Piwowar (2007), and Goldstein, Hotchkiss, and Sirri (2007) find that the secondary market liquidity increased by 50–84% with the TRACE. Second, Bao, Pan, and Wang (2011) find that liquidity explains 47–60% of the time variation of aggregate bond spreads of high-rated bonds, even larger than the variation that can be explained by credit risk.

nominal policy rate affects the composition of firms' credit by inducing firms to substitute corporate bonds for bank loans. When firms have the option of financing both through issuing corporate bonds and borrowing from a bank, firms with large corporate bond issuance rely less on bank loans and thus can negotiate for a lower real loan rate in the OTC market for loans. A higher nominal policy rate makes issuing corporate bonds less expensive, allowing firms to issue more corporate bonds for the strategic purpose of lowering their financing costs. Becker and Ivashina (2014) provide direct empirical support for such changes in firms' credit composition following changes in monetary policy.

Lastly, I use the model to study optimal monetary policy in an economy where the real rates at which firms borrow in distinct financial markets move in different directions following changes in the nominal interest rate, such as the post-TRACE U.S. economy. A common result in monetary theory is that an increase in the nominal policy rate hurts welfare: a higher nominal policy rate increases the opportunity cost of holding liquidity, induces agents to carry less liquidity, and reduces the quantity of goods they can afford.[3] In my model, however, the Friedman rule—implementing a zero nominal policy rate—is suboptimal. The intuition is as follows. Assume that the current nominal policy rate is low, so that the borrowing cost in the corporate bond market is relatively high, compared to that in the bank loan market. Agents face risk when meeting a firm for trade: they can meet a firm that obtained a bank loan and thus have a large production capacity, or a firm that financed only by issuing corporate bonds and thus have a small production capacity. Increasing the nominal policy rate makes issuing corporate bonds cheaper and borrowing from a bank more expensive, thereby reducing the risk agents face and increasing welfare. The optimal policy rate depends on the corporate bond secondary market liquidity and the corporate finance structure of an economy.

[3]A negative relationship between the nominal policy rate and welfare characterizes a large class of monetary models, including Lagos and Wright (2005) and the majority of models that build upon their framework. However, there are exceptions to this rule. Later, in the literature review, I provide a more detailed discussion of those exceptions to this result and claim that the channel through which my model can deliver a positive relationship between the nominal policy rate and welfare has not been highlighted before.

The more liquid the corporate bond secondary market, or the more firms financing through issuing corporate bonds, the higher the optimal policy rate.

Related literature. On the theory side, this paper employs the New Monetarist framework, surveyed in Lagos, Rocheteau, and Wright (2017) and Nosal and Rocheteau (2017), that highlights the importance of liquidity in the determination of asset prices. The consumer side of the model in this paper builds on Lagos and Wright (2005) and is related to a series of papers, where corporate bonds have a liquidity premium due to the liquidity service they provide, such as Geromichalos, Licari, and Suárez-Lledó (2007), Lagos (2011), Nosal and Rocheteau (2012), Andolfatto, Berentsen, and Waller (2013), and Hu and Rocheteau (2015).[4] The firm side of the model is related to Rocheteau, Wright, and Zhang (2018). While in their paper firms finance using internal financing or bank loans, in this paper I focus on external financing, in particular corporate bond issues and bank loans.

On the empirical side, this paper is mainly related to Gertler and Karadi (2015). They find that a higher nominal policy rate increases the corporate bond premium during the whole period that encompasses both before and after the TRACE was introduced. In this paper, I show that the positive relationship is observed in the pre-TRACE period (more prominently) but overturned in the post-TRACE period, and attribute the reversal to the structural change in the corporate bond secondary market that strengthened the liquidity premium channel of monetary policy transmission.

This paper is thus also related to the literature that examines the relationship between monetary policy and the liquidity premium of liquid assets. Nagel (2016) and Drechsler, Savov, and Schnabl (2018) provide empirical evidence that the liquidity premium of Treasuries is positively associated with the short-term

[4]While in this paper the liquidity property of assets is direct in the sense that they serve as a medium of exchange and thus help to facilitate trade in frictional decentralized markets for goods, it can be microfounded by introducing secondary markets where agents can liquidate assets for money. See for example Berentsen, Huber, and Marchesiani (2014, 2016), Geromichalos and Herrenbrueck (2016, 2022), Geromichalos, Herrenbrueck, and Salyer (2016), Mattesini and Nosal (2016), Herrenbrueck and Geromichalos (2017), Geromichalos, Herrenbrueck, and Lee (2018, 2022), Herrenbrueck (2019a), and Madison (2019).

interest rates.[5] The rationale is the exact same as the one described in this paper: the short-term interest rates imply a higher opportunity cost of holding money and hence a higher premium for the liquidity service benefits of assets that can be substitutes for money. This paper complements the literature by providing evidence that a similar relationship between monetary policy and the liquidity premium holds also for corporate bonds. On a similar note, Lagos and Zhang (2020) provide an empirical study on the equity market.

This paper is also related to the empirical literature that investigates the impact of the implementation of the TRACE on the liquidity of the corporate bond secondary market, such as Bessembinder, Maxwell, and Venkataraman (2006), Edwards, Harris, and Piwowar (2007), and Goldstein, Hotchkiss, and Sirri (2007). This paper contributes to the literature by connecting the discussion to monetary policy, examining how the introduction of the TRACE reshaped the way the corporate bond premium responds to changes in monetary policy.

Also related is the literature that studies firms' financing choices and credit composition, which includes for instance Denis and Mihov (2003), Adrian, Colla, and Shin (2012), Becker and Ivashina (2014), Schwert (2018), and Grosse-Rueschkamp, Steffen, and Streitz (2019). This paper is especially relevant to Becker and Ivashina (2014), as they provide direct empirical support for one of the predictions of the model in this paper that firms switch from loans to bonds following an increase in the nominal policy rate. Grosse-Rueschkamp, Steffen, and Streitz (2019) provide empirical evidence of a similar change in firms' credit composition following large-scale corporate bond purchases.

From a broader perspective, this paper is related to the strand of literature that examines firms' heterogeneous responses in their investment to monetary policy. The heterogeneity that has been looked into depends on the firms'

[5]One should be careful when comparing the results in Nagel (2016) or Drechsler, Savov, and Schnabl (2018) with the results in this paper, as the definition of the liquidity premium in those papers is different from how it is defined in this paper. In those papers, the liquidity premium is defined in terms of the yield, whereas this paper defines it in terms of the price. Hence, the former definition is essentially a reciprocal of the latter, and they moves in the opposite directions. For consistency, I rephrase the results of those papers using the definition of this paper.

various characteristics such as cash flows (Oliner and Rudebusch, 1992), size (Gertler and Gilchrist, 1994; Bernanke, Gertler, and Gilchrist, 1996), liquid asset holdings (Kashyap, Lamont, and Stein, 1994; Jeenas, 2019), default risk (Ottonello and Winberry, 2020), and age and dividend payouts (Cloyne, Ferreira, Froemel, and Surico, 2019). This paper contributes to the literature by providing empirical evidence that the borrowing costs in distinct financial markets can move asymmetrically, thereby suggesting the access to the corporate bond market as another source for firms' heterogeneous responses to monetary policy.

As for the suboptimality of the Friedman rule, there exist generally two classes of models where a positive cost of holding money can be welfare improving.[6] One is the models where monetary policy has distributive effects (Molico, 2006; Rocheteau, Weill, and Wong, 2019), and the other is the models with search externality, where increasing the cost of carrying money can fix this inefficiency (Rocheteau and Wright, 2005; Berentsen, Rocheteau, and Shi, 2007; Geromichalos and Jung, 2019). Another related is Berentsen, Camera, and Waller (2007), who shows that a higher nominal policy rate can improve welfare by relaxing an endogenous borrowing constraint in a banking sector. My paper provides a new rationale for why the Friedman rule can be suboptimal: monetary policy has an asymmetric effect on credit costs across various financing sources, and raising the nominal policy rate can lower the risk that agents face in their trading with firms by reducing the variance of the distribution of firms' production capacity. This implies that the corporate finance structure of an economy matters for monetary policy, and Holm-Hadulla and Thürwächter (2021) provide empirical evidence for this implication.

Definitions of premiums. It is important to clarify how in this paper the premiums are defined. Following the New Monetarist literature, in this paper the liquidity premium of corporate bonds is the additional price that agents are willing to pay over their fundamental value for the liquidity service that the assets provide. On the contrary, the bond premium is defined in terms

[6]For an exhaustive list of the papers in which a deviation from the Friedman rule can be optimal, see Section 6.9 of Nosal and Rocheteau (2017).

of the yield, not the price, following Gilchrist and Zakrajšek (2012); that is, it is the yield of a bond minus the yield associated with a price that equals the net present value of the cash flows, or the fundamental value, of the bond. Thus, under these definitions, the liquidity premium and the bond premium are negatively correlated.

Structure of the paper. Section 2 describes the model, and Section 3 characterizes the equilibrium of the model and examines monetary policy transmission to credit costs. Section 4 contains empirical analysis that provides evidence for the predictions of the model. Section 5 analyzes how monetary policy affects firms' credit composition. Section 6 studies optimal monetary policy. Section 7 concludes.

2 The Model

Time is discrete and continues forever. Each period is divided into two subperiods. In the first subperiod, agents visit a decentralized goods market à la Kiyotaki and Wright (1993), where frictions, such as anonymity and imperfect commitment, make a medium of exchange necessary. In the second subperiod, three markets open in order: a Walrasian or centralized market (CM), which is the frictionless, competitive settlement market of Lagos and Wright (2005); an over-the-counter (OTC) market for bank loans, as in Rocheteau, Wright, and Zhang (2018); and a competitive market for intermediate goods, which are used as inputs for production in the DM. Agents discount across periods, but not subperiods, at rate $\beta \in (0, 1)$.

There are four distinct types of agents—consumers, firms, banks, and intermediate good suppliers (hereafter, suppliers)—and two types of assets—fiat money and corporate bonds—in this economy. Consumers live forever and their measure is normalized to the unit. They consume (or produce) a general good (which is taken as the numeraire) in the CM and consume a special good in the DM. They have a linear preference c over c units of the numeraire, where $c > 0$ is interpreted as consumption of the numeraire and $c < 0$ as production, and derive utility $u(q)$ from consuming q units of the special good, where u is twice continuously differentiable, $u(0) = 0$, $u' > 0$, $u'(0) = \infty$, $u'(\infty) = 0$, and $u'' < 0$. In the CM, consumers can choose to hold any amount of money and purchase any amount of corporate bonds at the ongoing price. The corporate bonds are one-period real, that is, each unit of the bond purchased in this period's CM will deliver one unit of the numeraire in the next period's CM. In the DM, they purchase the special good from firms, and both money and corporate bonds can serve as media of exchange.

Firms live for one period and their measure is normalized to the unit. They are born in the second subperiod and die next period in the second subperiod after settlement. They produce the special good in the DM and consume (and produce) the general good in the CM during the second period of their life. As is the case with consumers, firms have a linear preference over the numeraire. To produce the special good, firms need intermediate goods, which can be purchased from suppliers using the general good in the intermediate goods market. However, it is assumed that firms, when they are just born, do not have access to the technology to produce the general CM good. There are two ways of acquiring the general good: one is to issue corporate bonds and the other is to obtain a loan from a bank. For the moment, it is assumed that the measure $\lambda \in (0, 1)$ of firms issue corporate bonds, and the measure $1 - \lambda$ of firms borrow from a bank.[7] Once firms acquire the general CM good using either way of external financing, they purchase the intermediate goods from suppliers in exchange for those CM good. Then, using those intermediate goods, in the DM they produce the special good with linear technology and sell it to consumers. Any leftover intermediate goods can be brought to the CM and turned into the general good with linear technology. In the CM in the second period of their life, after repaying the debt (from issuing corporate bonds or borrowing from a bank) they consume the general good and die.

Banks live forever and they consume (and produce) the general good in

[7] Section 5 endogenizes the ways of firms' external financing. In that extended version of the model, some firms will (endogenously) finance through both corporate bond issuance and a bank loan, while others finance in either of the two ways.

the CM, over which they also have a linear preference. They provide one-period loans to firms in terms of the general CM good in the OTC market for loans, where banks and firms negotiate over the size and the interest rate of loans. The measure of banks is assumed to be λ (for the reason explained below). Suppliers also live forever, consume (and produce) the general good in the CM, and have a linear preference over the numeraire. They produce the intermediate good with linear technology and sell it to firms in the intermediate goods market. Due to constant returns to scale in their production, the measure of suppliers is irrelevant.

As was mentioned, bank loans are made, realistically, in the OTC market, which is characterized by search and bargaining. To keep the analysis simple, it is assumed that all firms match with a bank, and, accordingly, that the measure of banks is λ. The terms of a loan contract are determined through the proportional bargaining solution of Kalai (1997) between a firm and a bank, and the bank's bargaining power is denoted $\eta \in (0, 1)$. The DM is also characterized by search and bargaining, and all consumers are, for simplicity, assumed to match with a firm. The surplus generated within a match is split according to Kalai's proportional bargaining, and the consumer's bargaining power is denoted $\theta \in (0, 1)$. As was mentioned, both money and corporate bonds can serve as media of exchange. However, corporate bonds are partially liquid, and only a fraction $\chi \in (0, 1]$ of them can be used as payment. This assumption is meant to capture the idea that, when in need of extra money, consumers liquidate corporate bonds in a secondary market, but due to frictions, trading delays, intermediation fees, etc., only a fraction of these bonds can be sold. Hence, the fraction of bonds that consumers can use is meant to capture the degree of liquidity in the secondary market for those assets. Naturally, the liquidity properties of corporate bonds affect their equilibrium price and, consequently, the issuance decision of firms.

The supply of corporate bonds is endogenously determined by the issuance decision of firms. The supply of money is controlled by the monetary authority, and evolves according to $M_{t+1} = (1 + \pi)M_t$, where π is the rate of monetary expansion (or contraction if $\pi < 0$) implemented by lump-sum transfers to (or taxes on) consumers at the beginning of the second subperiod. Money has no intrinsic value, but it is portable, storable, and recognizable, making it an appropriate medium of exchange in the DM. The cost of holding money is represented by $i \equiv (1+\pi)/\beta - 1$, which is the nominal interest rate on an illiquid bond (if such a bond were introduced). An equilibrium exists for $i > 0$, or $\pi > \beta - 1$, and the Friedman rule is considered as $i \to 0$, or $\pi \to \beta - 1$. The first-best level of trade in the DM is denoted q^*, which satisfies $u'(q^*) = 1$.

3 Analysis of the Model

In order to streamline the analysis, the details for the analysis of the model are relegated to Online Appendix A.1. Here I provide a summary and intuitions.

Terms of Trade. First consider a meeting in the DM between a consumer who carries m amount of real balances and a amount of corporate bonds and a firm that brings k amount of intermediate goods. The two parties bargain over the quantity of the DM goods to trade, q, and the amount of financial wealth for the consumer to transfer to the firm, p. Recall that corporate bonds are partially liquid, and that only a fraction χ can be used as a medium of exchange. Hence, the maximum amount of financial wealth that the consumer can use towards trade is $m + \chi a$. The firm can produce the DM goods with linear technology up to k units. Trade is therefore subject to both the consumer's liquidity constraint, $p \leq m + \chi a$, and the firm's production capacity constraint, $q \leq k$. The bargaining solution is given by

$$p = v(q) \equiv (1-\theta)u(q) + \theta q, \quad v'(q) > 0, \tag{1}$$

$$q = \min\{v^{-1}(m + \chi a), k\}, \tag{2}$$

where θ is the consumer's bargaining power. The total surplus is $u(q) - q$, and, as a result of bargaining, the consumer takes θ share of it, and the firm takes $1 - \theta$ share. A consumer must transfer $v(q)$ amount of financial wealth to a firm to get q amount of the DM goods, and a larger amount of financial wealth is needed for a larger amount of the DM goods. The amount of the DM goods traded is the smaller one between what the consumer can afford at most and what the firm can produce at most.

Loan Contract. Consider a meeting in the OTC market for loans between a firm and a bank with w amount of financial wealth that can be lent as a loan. The two parties bargain over the amount of numeraire that the bank lends to the firm, k_ℓ, and the amount of numeraire that the firm needs to repay to the bank in the next period's CM, $(1+r_\ell)k_\ell$, where r_ℓ is the real lending rate. The bargaining solution is given by

$$k_\ell = v^{-1}(m+\chi a), \tag{3}$$

$$r_\ell = \frac{\eta(1-\theta)(u(k_\ell)-k_\ell)}{k_\ell}, \tag{4}$$

where η is the bank's bargaining power. The firm borrows as much as (and no more than) what it needs to satisfy the consumer's demand in the DM. The total surplus is $(1-\theta)(u(k_\ell)-k_\ell)$, which equals the firm's surplus in the DM when bringing k_ℓ amount of intermediate goods, and, as a result of bargaining, the bank takes η share of it, and the firm takes $1-\eta$ share. The terms of DM trade for this firm are denoted (p_L, q_L).

Bond Supply. A firm, which finances by issuing corporate bonds, chooses how many corporate bonds to issue, A, to maximize the profit $(1-\theta)(u(\psi A) - \psi A) - (1-\psi)A$, where the first term is the firm's surplus in the DM and the second is the net cost of issuing bonds. The bond supply, A, is given by

$$A = (u')^{-1}\left(\frac{1/\psi - 1}{1-\theta} + 1\right) \Big/ \psi, \tag{5}$$

or $v^{-1}(m+\chi a)/\psi$ if A exceeds it since the firm will not want to borrow more than it needs to produce what a consumer can afford. Here I restrict attention to the case where $A \leq v^{-1}(m+\chi a)/\psi$.[8] The terms of DM trade for this firm are denoted (p_B, q_B).

[8]This essentially means that i is not too high (Assumption 1). Online Appendix A.3 provides the characterization of the equilibrium outside this parameter space.

Consumer Behavior. In equilibrium, as discussed above, $q_B = \psi A < v^{-1}(m + \chi a)$ and $q_L = v^{-1}(m + \chi a)$, and the consumer's money and bond demand are given by

$$i = (1 - \lambda)L(m + \chi a), \tag{6}$$

$$\psi = \beta(1 + \chi i), \tag{7}$$

where $L(\cdot) \equiv u'(v^{-1}(\cdot))/v'(v^{-1}(\cdot)) - 1$ with $L'(\cdot) < 0$. The $1 - \lambda$ term in the money demand indicates that what matters for consumers at the margin is the meetings with firms financing using loans.

3.1 Monetary Policy Transmission to Credit Costs

This section describes the pass-through from the *nominal* policy rate to the *real* borrowing costs in the corporate bond market and the bank loan market. The equilibrium price of corporate bonds is given by (7): $\psi = \beta(1 + \chi i)$. The liquidity premium of corporate bonds is defined as $LP \equiv \chi i$, the percentage difference between the price of corporate bonds and their fundamental value, that is, the additional price that agents are willing to pay over their fundamental value for the liquidity service that the assets provide. A higher nominal policy rate increases the price of corporate bonds by increasing their liquidity premium: $\partial\psi/\partial i > 0$ and $\partial LP/\partial i > 0$. The intuition is as follows. A higher nominal policy rate implies the opportunity cost of holding money, suppresses the demand for money, and reduces real money balances. Due to less prevalent liquidity in the economy, the corporate bonds are more valued for their liquidity role. This increases their liquidity premium and consequently their equilibrium price, which means issuing corporate bonds becomes less expensive. This is the channel that the model highlights, and it is labeled this the liquidity premium channel of monetary policy transmission.

Later in the empirical analysis, when studying how the borrowing cost in the corporate bond market responds to changes in the nominal policy rate, I use the corporate bond premium data constructed by Gilchrist and Zakrajšek (2012), who define the premium as the (nominal) yield of a bond minus the (nominal) yield associated with a price that equals the net present value of the cash flows, or the fundamental value, of the bond. Following this definition, the corporate bond premium equals $j - i$, where j denotes the nominal yield of corporate bonds, i.e., $j = (1+\pi)/\psi - 1$, and i denotes the nominal yield associated with their fundamental value (which is β), i.e., $i = (1+\pi)/\beta - 1$:

$$BP \equiv j - i \approx \log\left(\frac{1+\pi}{\psi}\right) - \log\left(\frac{1+\pi}{\beta}\right) \approx -\chi i.$$

Thus, under these definitions, the liquidity premium and the corporate bond premium are negatively correlated. The pass-through from the nominal policy rate to the corporate bond premium, in this model, is negative, $\partial BP/\partial i < 0$, which comes from the positive effect of the nominal policy rate on the liquidity premium. The pass-through becomes stronger as χ increases, i.e., as the liquidity in the corporate bond secondary market improves: $\partial|\partial LP/\partial i|/\partial\chi > 0$ and $\partial|\partial BP/\partial i|/\partial\chi > 0$.

The real yield of corporate bonds equals

$$j^{real} = \frac{1}{\psi} - 1 \approx \log\left(\frac{1}{\psi}\right) \approx -\log\beta + BP.$$

As β represents how much the agents discount the future, which is not affected by the nominal policy rate, changes in the corporate bond premium are translated into changes in the real yield of corporate bonds. Thus, in the following discussion, changes in the corporate bond premium and changes in the borrowing cost in the corporate bond market are used interchangeably.

Next consider the borrowing cost in the bank loan market. A higher nominal policy rate leads to a higher real loan rate: $\partial r_\ell/\partial i > 0$. This can be seen from observing $\partial r_\ell/\partial k < 0$ from (4), $\partial k/\partial(m+\chi a) > 0$ from (3) and $v'(\cdot) > 0$, and $\partial(m+\chi a)/\partial i < 0$ from (6) and $L'(\cdot) < 0$. The intuition is as follows. Recall that the real loan rates are determined in the OTC market for loans, where firms and banks are matched and bargain over the size and the interest rate of a loan. From (3), with an increase in the nominal policy rate, the cost of holding money increases, agents carry less liquidity, and firms borrow less from a bank since agents can afford less. As a result, from (4), the real loan rate increases as it depends positively on the marginal benefit of a loan, and the latter decreases in the loan size. This means that borrowing from a bank becomes more expensive.

The following proposition summarizes the discussion.

Proposition 1. *As the nominal policy rate increases, the liquidity premium of corporate bonds increases, the corporate bond premium decreases, and the real borrowing cost in the corporate bond market decreases. The strength of this pass-through depends positively on the liquidity in the corporate bond secondary market. As the nominal policy rate increases, the real loan rate increases, that is, the real borrowing cost in the bank loan market increases:*

$$\frac{\partial LP}{\partial i} > 0, \quad \frac{\partial BP}{\partial i} < 0, \quad \left|\frac{\partial^2 LP}{\partial i\, \partial \chi}\right| > 0, \quad \left|\frac{\partial^2 BP}{\partial i\, \partial \chi}\right| > 0, \quad \frac{\partial j^{real}}{\partial i} < 0, \quad \frac{\partial r_\ell}{\partial i} > 0.$$

3.2 Nominal Policy Rate

In the next section, when studying empirically the monetary policy transmission, I use the Treasury rate as the nominal policy rate. In the discussion so far, i has been considered as the nominal policy rate, and, to be precise, this is the nominal interest rate on a perfectly illiquid bond (if such a bond were in the model). Treasuries are of course liquid and thus their rate is a different object than i. This section is to provide the connection between i and a nominal interest rate on a liquid government bond, such as Treasuries.

Assume that there are government bonds supplied at a fixed amount. Denote their nominal interest rate i_g. Also, assume that those bonds are partially liquid, and that a fraction $\chi_g \in (0, 1]$ can be used for liquidity purposes. In this case, in equilibrium, i_g is given by

$$i_g = \frac{(1-\chi_g)i}{1+\chi_g i}, \quad \frac{\partial i_g}{\partial i} > 0.$$

That is, there is a one-to-one positive relationship between i and i_g. Hence, in the following empirical exercises, I adopt the Treasury rate as the policy rate.[9]

4 Empirical Analysis

4.1 The Introduction of the TRACE and the Structural Change in the Corporate Bond Secondary Market

The trading environment in the U.S. corporate bond secondary market, which is a dealer-oriented OTC market, had been highly opaque for decades. All transaction-related information, such as prices and volumes at which the assets were traded, was available only to the parties involved in the transactions. Such nontransparency led to information asymmetry between dealers and potential traders, and dealers took advantage of it by extracting rents from less-informed customers. The rent-seeking behaviors of dealers incurred investors a huge amount of trading costs and hindered the secondary market from being liquid.[10]

To enhance the transparency and integrity of the corporate bond secondary market, with the approval of the Securities and Exchange Commission (SEC), beginning on July 1, 2002, the National Association of Security Dealers (NASD), a predecessor of the Financial Industry Regulatory Authority (FINRA), required dealers to report all transaction-related information of every trade for publicly traded corporate bonds, including the identification of traded bonds, the date and the time of execution, trade size and price, and whether dealers were a buyer or a seller in transactions.[11] The Transaction Reporting and Compliance

[9]Although theoretically it is possible to generate a negative relationship between i and i_g (see for instance Geromichalos and Herrenbrueck (2022) who study an economy with a microfounded asset secondary market), in a companion paper Herrenbrueck (2019b) empirically shows that, except for Volcker's disinflation period in his first term (1981–1982), the estimated i and the nominal interest rate on the public debt have been positively correlated. This provides another justification for using the Treasury rate as the policy rate, as the sample period in the empirical analysis starts from 1990.

[10]See Biais and Green (2019) for a more detailed discussion on how the opaque transaction environment deteriorated the liquidity of the corporate bond secondary market.

[11]The TRACE was phased in over the period from July 1, 2002, to January 9, 2006. Phase I, effective on July 1, 2002, was limited to the large and generally high-credit quality issues (approximately 520 bonds); Phase II, initially on March 3, 2003, and fully effective on April 14, 2003, was expanded to smaller investment-grade issues (first AAA, AA, A, then

Engine (TRACE) was the platform that the NASD developed to facilitate this mandatory reporting. Under this new system, investors have access to accurate and timely corporate bond transaction information and are able to better gauge the quality of the execution they are receiving from their dealers.

Several studies evaluate the impact of the TRACE on the liquidity of the U.S. corporate bond secondary market, providing empirical evidence that the transaction transparency under the new system reduced the information asymmetry problem between dealers and investors, led to a significant drop in trading costs, and substantially improved the market liquidity. For example, Bessembinder, Maxwell, and Venkataraman (2006), Edwards, Harris, and Piwowar (2007), and Goldstein, Hotchkiss, and Sirri (2007) find that the market liquidity increased by 50–84% as a result of the mandatory transaction reporting system, documenting this dramatic improvement in the market liquidity as a structural change in the U.S. corporate bond secondary market.

4.1.1 Hypotheses

In the model, as summarized in Proposition 1, the real rate at which firms borrow in the corporate bond market and that in the bank loan market move in the different directions following changes in the nominal interest rate. Now the questions are: Is there evidence for the mechanism for this? Are such movements of the real rates observed empirically? The model focuses on a specific channel, which is through the liquidity premium of corporate bonds, and, of course, there are other channels in action as well in reality.[12] Thus, whether such movements of the real rates can materialize is a quantitative

BBB rated bonds, a total of approximately 4,650 bonds); Phase III, intially on October 1, 2004, and fully effective on February 7, 2005, was expanded to approximately 99% of all public transactions; and finally on January 9, 2006, it applied to all public transactions. See FINRA (2005) and Bessembinder and Maxwell (2008) for more detailed information on the TRACE history and timeline.

[12] The credit channel is an example of the other channels, which could offset the liquidity premium channel. According to the credit channel, when financial market imperfections are present, a higher nominal policy rate increases the corporate bond premium by tightening credit constraints and subsequently affecting firms' ability to borrow. See for instance Bernanke and Gertler (1989), Kiyotaki and Moore (1997), and Bernanke, Gertler, and Gilchrist (1999).

question that depends on whether the channel highlighted in the model can be dominant.

The improvement in the corporate bond secondary market liquidity in consequence of introducing the TRACE can be interpreted as an increase in χ in the model—the fraction of corporate bond holdings that can be used towards trades for liquidity purposes—as this parameter represents the degree of the secondary market liquidity: it captures the idea that, when in need of extra money, agents liquidate corporate bonds in a secondary market, but due to frictions, trading delays, intermediation fees, etc., only a fraction of these bonds can be sold. This in turn implies that, as stated in Proposition 1, the liquidity premium channel of monetary policy transmission must be stronger during the period after the TRACE was implemented.

Empirical evidence in the literature shows that, as a result of the improved corporate bond secondary market liquidity with the introduction of the TRACE, liquidity has become a significant component of the corporate bond premium. For example, Bao, Pan, and Wang (2011) find that liquidity explains 47–60% of the time variation of aggregate bond spreads of high-rated bonds, even larger than the variation that can be explained by credit risk.

Based on all these observations, I hypothesize that the introduction of the TRACE has strengthened the liquidity premium channel in monetary policy transmission so that it might have become a dominant channel. Closely related to this question is Gertler and Karadi (2015), who find that, on average, a higher nominal policy rate increases the corporate bond premium during the whole period 1979–2012 that encompasses both before and after the TRACE was introduced. If the hypothesis is true, then the positive relationship between the nominal policy rate and the corporate bond premium should appear more prominently in the pre-TRACE period when the liquidity premium channel is relatively weak, whereas the positive relationship should be overturned in the post-TRACE period.

In the following sections, I provide empirical evidence that it is indeed the case. Section 4.2 compares the effect of monetary policy on the corporate bond premium across the two periods before and after the introduction of the

TRACE, Section 4.3 provides evidence for the liquidity premium channel, and Section 4.4 examines the response of real loan rates to monetary policy shocks.

4.2 Corporate Bond Premium and Monetary Policy Shocks

4.2.1 Empirical Framework

This section examines the dynamic response of the corporate bond premium to an increase in the nominal policy rate. I employ the structural vector autoregression with external instruments (SVAR-IV), introduced by Stock (2008) and Mertens and Ravn (2013) and applied to monetary policy by Gertler and Karadi (2015), and the local projection instrumental variable (LP-IV) approach, introduced by Jordà (2005) and Jordà, Schularick, and Taylor (2020). For the corporate bond premium, I use the excess bond premium measured by Gilchrist and Zakrajšek (2012), which is calculated by the yield of a bond minus the yield associated with a price that equals the net present value of the cash flows, or the fundamental value, of the bond. The SVAR-IV system also includes the following three variables: the 1-year Treasury constant maturity rate (as the policy rate), industrial production (100 times log of it), and the consumer price index (100 times log of it). The same three variables are used as control variables in LP-IV. To ensure the results are not driven by other macro factors and to limit any potential reverse causality issues, I exploit the high-frequency identified monetary shocks as an instrument. Specifically, I use the three-month-ahead financial market surprises from Federal Funds futures in a 30-minute window around the Federal Open Market Committee policy announcements, constructed by Gertler and Karadi (2015), as exogenous variations in the policy rate. The sample period spans 1990:2–2016:12 with monthly frequency. To examine the potentially different effect of a monetary policy shock on the corporate bond premium across the two periods before and after the introduction of the TRACE, I divide the sample period into two: 1990:2–2003:2 for the pre-TRACE period and 2003:3–2016:12 for the post-TRACE period.[13] For both the SVAR-IV and LP-IV specifications, 12-month lags of the four main variables and 4-month lags of the instrument are included. I do the unit effect normalization following Stock and Watson (2018) for direct estimation of the dynamic causal effect in the native unit relevant to policy analysis. The standard errors are calculated using the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap for SVAR-IV, and using the Newey-West heteroskedastic and autocorrelation consistent standard errors for LP-IV. For each point estimate along the horizons, the 95% confidence interval is shown.

4.2.2 Results

The response of the excess bond premium to a one-percent increase in the nominal policy rate (the 1-year Treasury rate) estimated using SVAR-IV is shown in Figure 1, and the response estimated using LP-IV is shown in Figure 2. In both figures, the left panel is for the entire period (that covers both the pre- and the post-TRACE periods), the middle panel is for the pre-TRACE period, and the right panel is for the post-TRACE period. To ensure that the instrument is valid, I check the heteroscedasticity-robust F-statistics from the first-stage regression, and all are safely above the threshold suggested by Stock, Wright, and Yogo (2002) to rule out a reasonable likelihood of a weak instruments problem. When estimated using the entire sample, consistent with the results of Gertler and Karadi (2015), the excess bond premium increases following a one-percent increase in the nominal policy rate.[14] However, the response of the excess bond premium is not the same across the two periods: the pre- and the post-TRACE periods. During the pre-TRACE period, the positive response of the excess bond premium to a one-percent increase in the nominal policy rate appears more persistent and significant. On the other hand, during the post-TRACE period, the response of the excess bond premium is

[13] The breakpoint 2003:3 is when the mandatory reporting to the TRACE started to be imposed on a significant portion of corporate bonds (see footnote 11). In Online Appendix B.2.1, I check the results are robust to alternative breakpoints.

[14] The left panel for the entire period in Figure 1 is basically the result in Gertler and Karadi (2015).

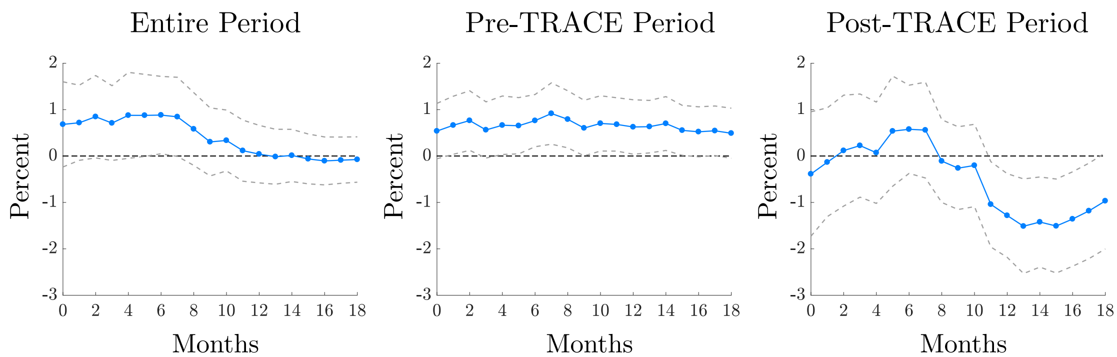

Figure 1: The response of the excess bond premium to a one-percent increase in the nominal policy rate for different sample periods, estimated using SVAR-IV with unit effect normalization. Entire period: 1990:2–2016:12; pre-TRACE period: 1990:2–2003:2; post-TRACE period: 2003:3–2016:12. The dashed lines are the 95% confidence interval.

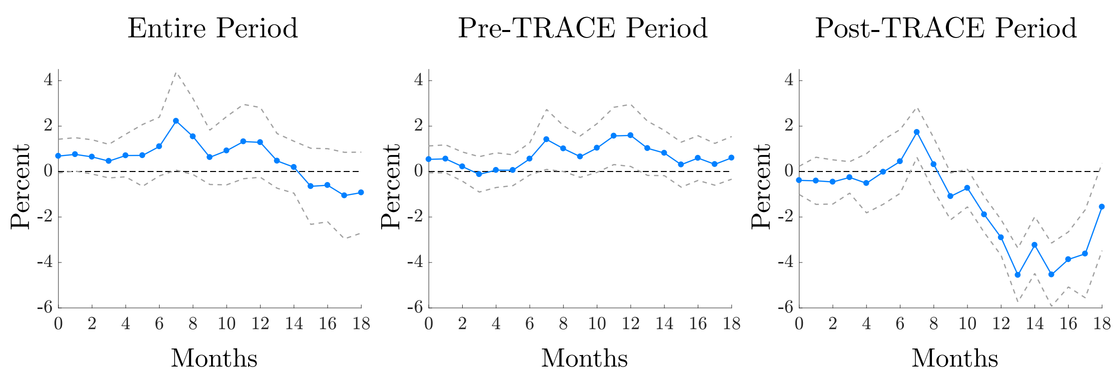

Figure 2: The response of the excess bond premium to a one-percent increase in the nominal policy rate for different sample periods, estimated using LP-IV with unit effect normalization. Entire period: 1990:2–2016:12; pre-TRACE period: 1990:2–2003:2; post-TRACE period: 2003:3–2016:12. The dashed lines are the 95% confidence interval.

not just less strong but it becomes negative (in medium and long horizons). These results are consistent with the hypotheses, based on the predictions of the model, in Section 4.1.1. As a consequence of the introduction of the TRACE and the improved liquidity in the corporate bond secondary market, the liquidity premium channel has been strengthened, and become a dominant channel, in monetary policy transmission. The overall positive relationship between the nominal policy rate and the corporate bond premium during the whole period, which encompasses both before and after the TRACE was implemented, appears more prominently during the pre-TRACE period when the liquidity premium channel is relatively weak, whereas it is overturned during the post-TRACE period when the liquidity premium channel is strong and dominant. Online Appendix B.2.1 contains the sensitivity check to the results.

4.3 Liquidity Premium and Monetary Policy Shocks

4.3.1 Empirical Framework

This section provides evidence for the liquidity premium channel of monetary policy transmission: a positive effect of the nominal policy rate on the liquidity premium of corporate bonds. The two common liquidity measures are bid-ask spreads and trading volume. The more liquid the corporate bonds, the bid-ask spreads should be narrower, and the trading volume should be larger. That is, the liquidity premium and the bid-ask spreads are negatively correlated, while the liquidity premium and the trading volume are positively correlated. Both measures are calculated using the corporate bond transaction data from the TRACE database, following Adrian, Fleming, Shachar, and Vogt (2017): the bid-ask spreads compute the average daily bid-ask spreads by month across bonds,[15] and the trading volume computes the average daily trading volume by month across bonds. The liquidity measure (100 times log of it) is added to the SVAR-IV and LP-IV specifications of Section 4.2. Since the liquidity measures are based on the TRACE database, which obviously starts only after the TRACE was introduced, this section examines solely the post-TRACE period.

4.3.2 Results

The response of the bid-ask spreads in the corporate bond secondary market to a one-percent increase in the nominal policy rate (the 1-year Treasury rate) is

[15] Specifically, first, spreads are calculated daily for each bond as the difference between the average (volume-weighted) dealer-to-client buy price (the price at which dealers are willing to buy, or bid) and the average (volume-weighted) dealer-to-client sell price (the price at which dealers are willing to sell, or ask). Then, the spreads are averaged across bonds using equal weighting and across days for each month.

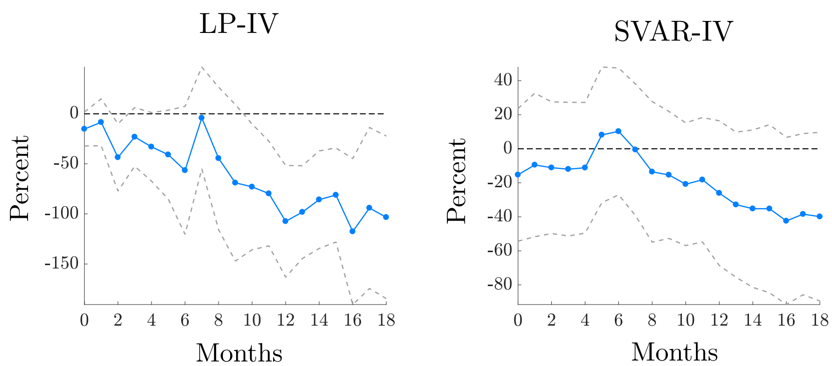

Figure 3: The response of the bid-ask spreads of corporate bonds to a one-percent increase in the nominal policy rate during the post-TRACE period, estimated using LP-IV and SVAR-IV with unit effect normalization. Sample period: 2003:3–2016:12. The dashed lines are the 95% confidence interval.

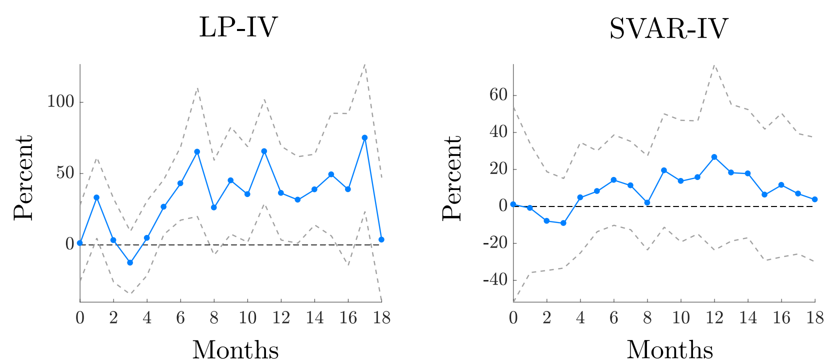

Figure 4: The response of the trading volume of corporate bonds to a one-percent increase in the nominal policy rate during the post-TRACE period, estimated using LP-IV and SVAR-IV with unit effect normalization. Sample period: 2003:3–2016:12. The dashed lines are the 95% confidence interval.

shown in Figure 3, and the response of the trading volume is shown in Figure 4. Both figures consider the post-TRACE period, and, in both figures, the left panel is the estimation using LP-IV, and the right panel is the estimation using SVAR-IV. For all results, I check the heteroscedasticity-robust F-statistics from the first-stage regression to ensure that the results are not subject to a weak instruments problem, and all are safely above the threshold suggested by Stock, Wright, and Yogo (2002). Figure 3 shows that the bid-ask spreads respond negatively to a one-percent increase in the nominal policy rate, and

Figure 4 shows that the trading volume responds positively to a one-percent increase in the nominal policy rate. Both results indicate the liquidity premium channel of monetary policy transmission is in action: the liquidity premium of corporate bonds becomes larger following an increase in the nominal policy rate. The response of the liquidity premium become more noticeable in medium and long horizons, and this timing coincides with the timing of the response of the excess bond premium being negative during the post-TRACE period.[16] Online Appendix B.2.2 contains the sensitivity check to the results.

4.4 Bank Loan Rates and Monetary Policy Shocks

4.4.1 Empirical Framework

This section examines the dynamic response of the real bank loan rates to changes in monetary policy and provide evidence for the post-TRACE period that an increase in the nominal policy rate raises the real bank loan rates, as opposed to the case of corporate bonds. The real bank loan rate is calculated as the nominal bank loan rate minus the expected inflation rate. The real loan rate is added to the SVAR-IV and LP-IV specifications of Section 4.2. The expected inflation rate is the 5-year forward inflation expectation rate from the Federal Reserve Economic Data (FRED), and the data starts from 2003, so this section considers solely the post-TRACE period.

4.4.2 Results

The response of the real bank loan rate to a one-percent increase in the nominal policy rate (the 1-year Treasury rate) during the post-TRACE period is shown in Figure 5. The left panel is the estimation using LP-IV, and the right panel is the estimation using SVAR-IV. The heteroscedasticity-robust F-statistics from the first-stage regressions ensure that the results are not subject to a weak instrument problem, and all are safely above the threshold suggested by Stock, Wright, and Yogo (2002). The results show that, consistent with the

[16]For example, compare the right panel of Figure 1 or 2 with the right panel of Figure 3 or 4.

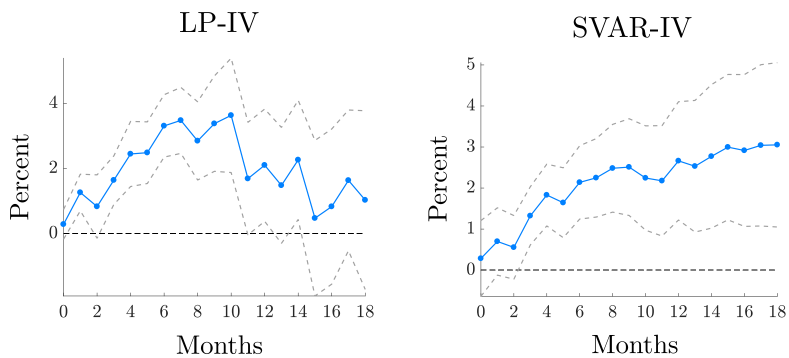

Figure 5: The response of the real loan rate to a one-percent increase in the nominal policy rate during the post-TRACE period, estimated using LP-IV and SVAR-IV with unit effect normalization. Sample period: 2003:3–2016:12. The dashed lines are the 95% confidence interval.

hypotheses, based on the predictions of the model, in Section 4.1.1, during the post-TRACE period, an increase in the nominal policy rate raises the real bank loan rates, as opposed to the case of corporate bonds. Online Appendix B.2.3 contains the sensitivity check to the results.

5 The Effect of Monetary Policy on Firms' Credit Composition

This section examines how changes in monetary policy affect the composition of firms' credit. Previously, it was assumed that some firms finance solely through issuing corporate bonds and the others solely through borrowing from a bank. In this section, I allow some firms to use both ways of external financing. The specific setups are as follows. Consistent with the reality, some firms are assumed to not have access to the corporate bond market, and their measure is $1 - \lambda \in (0, 1)$. On the other hand, all firms have access to the bank loan market. However, as in Rocheteau, Wright, and Zhang (2018), firms should look for a bank that is willing to provide a loan to them, and the chance to be successful in finding one is $\alpha \in (0, 1)$. As a result, among the measure λ of firms with access to the corporate bond market, $\alpha\lambda$ will be able to finance through both corporate bond issuance and a bank loan. When a firm has both options, it first decides how many corporate bonds to issue, then negotiates with a bank the terms of a loan contract.[17] In order to streamline the analysis, the details for the analysis of the model are relegated to Online Appendix A.2. Here I provide a summary and intuitions.

Loan Contract. Now there are two types of meetings in the OTC market for loans: one between a bank and a firm with no access to the corporate bond market, and the other between a bank and a firm with access to the corporate bond market and thus has issued corporate bonds before entering the OTC market for loans. The bargaining problem in the former meeting is the same as in Section 3, and the solution is given by (3) and (4). In the latter meeting, a bank and a firm, which has already raised ψA amount of funds by issuing A amount of corporate bonds at price ψ, bargain over the terms of a loan contract, (k^B, r_ℓ^B). The bargaining solution is given by

$$k_\ell^B = v^{-1}(m + \chi a) - \psi A, \tag{8}$$

$$r_\ell^B = \eta(1-\theta)\left[\frac{u(\psi A + k_\ell^B) - u(\psi A)}{k_\ell^B} - 1\right]. \tag{9}$$

The $-\psi A$ term appears in (8) since the firm now has already raised funds through corporate bond issuance. Here the total surplus is $(1-\theta)[u(\psi A + k_\ell^B) - u(\psi A) - k_\ell^B]$. Its difference from that in Section 3 arises from the fact that now the firm has an outside option, that is, it can still produce a positive amount even without a loan.

Bond Supply. A firm chooses how many corporate bonds to issue, A, to maximize the profit $(1-\theta)[u(\psi A + k_\ell^B) - (\psi A + k_\ell^B)] - (1-\psi)A - r_\ell^B k_\ell^B$, where the first term is the firm's surplus in the DM and the rest is the net cost of

[17] The measure $(1-\alpha)\lambda$ of firms, among λ with access to the corporate bond market, will have to finance only through issuing corporate bonds. Among $1-\lambda$ with no access to the corporate bond market, $\alpha(1-\lambda)$ will finance only through a bank loan, while $(1-\alpha)(1-\lambda)$ will not be able to raise funds and is not productive in that period. To simplify the exposition, the measure of consumers is normalized to $\alpha(1-\lambda)+\lambda$ so that all consumers match with a firm in bilateral meetings in the DM.

issuing bonds and borrowing from a bank. The bond supply, A, is given by

$$A = (u')^{-1}\left(\frac{1/\psi - 1}{\eta(1-\theta)} + 1\right) \Big/ \psi. \tag{10}$$

5.1 Credit Composition

Now I examine the composition of firms' credit between corporate bonds and bank loans. (10) shows that a firm wants to issue some amount of corporate bonds before entering the OTC market for loans. The intuition is as follows. From (9), r_ℓ^B is an increasing function of ψA. It is because firms with large corporate bond issuance rely less on bank loans (as can be seen from (8) that k_ℓ^B is decreasing in ψA) and thus can negotiate for a lower real loan rate (as can be seen from (9) substituting k_ℓ^B with (8)). The optimal credit composition balances this benefit against the cost (the liabilities to the bond holders).

Monetary policy changes affect the composition of firms' credit between corporate bonds and bank loans. A higher nominal policy rate, i, decreases the total size of credit as the consumer's demand declines due to the higher cost of holding liquidity, as can be seen from (8) that $\psi A + k_\ell^B$ equals $v^{-1}(m + \chi a)$, which in turn is a decreasing function of i from (6). On the other hand, at the same time, as is explained in Section 3.1 and Proposition 1, a higher nominal policy rate makes issuing corporate bonds less expensive, allowing firms to issue more corporate bonds for the strategic purpose of lowering their financing costs, as can be seen from (10) that ψA is an increasing function of ψ, which in turn is an increasing function of i. As a result, as the nominal policy rate increases, firms borrow less from a bank, the portion of corporate bonds among the total credit becomes larger, and the portion of bank loans becomes smaller. The following proposition summarizes the discussion.

Proposition 2. *As the nominal policy rate increases, the size of total credit decreases. Among the total credit that becomes smaller, firms increase the* *portion of credit from issuing corporate bonds and decrease that from bank loans:*

$$\frac{\partial(\psi A + k_\ell^B)}{\partial i} < 0, \quad \frac{\partial\left(\dfrac{\psi A}{\psi A + k_\ell^B}\right)}{\partial i} > 0, \quad \frac{\partial\left(\dfrac{k_\ell^B}{\psi A + k_\ell^B}\right)}{\partial i} < 0.$$

Direct empirical support for this theoretical finding is provided by Becker and Ivashina (2014), who show that firms switch from bank loans to corporate bonds following an increase in the nominal policy rate.

6 Optimal Monetary Policy

In this section, I use the model to study optimal monetary policy in an economy, such as the post-TRACE U.S. economy, where the liquidity premium channel of monetary policy transmission is dominant, and the real rates at which firms borrow in distinct financial markets move in different directions following changes in the nominal interest rate. I consider the environment described in Section 2.[18] With the settlement market at the end of each period, maximizing welfare is equivalent to maximizing per-period welfare, which equals the sum of per-period utility of each agent. Per-period utility of suppliers is 0 due to the CRS technology. Per-period utility of firms that finance through borrowing from a bank is $p_L - q_L - r_\ell k_\ell$ and their total measure is $1-\lambda$. Per-period utility of firms that finance through issuing corporate bonds is $p_B - q_B - (1-\psi)A$ and their total measure is λ. Per-period utility of banks that lend to a firm is $r_\ell k_\ell$ and their total measure is $1-\lambda$. Per-period utility of consumers is $(1-\psi)a + (1-\lambda)[u(q_L) - p_L] + \lambda[u(q_B) - p_B]$. All these sum up to

$$\mathcal{W} = (1-\lambda)[u(q_L) - q_L] + \lambda[u(q_B) - q_B]. \tag{11}$$

A common result in monetary theory is that an increase in the nominal

[18]Analysis in the alternative environment in Section 5 needs just a simple relabeling. Notice from (3) and (8) that when a firm has the option of financing through both corporate bond issuance and bank loans, the total credit of such a firm is the same as that of the firm that finances only through bank loans. Relabel $1-\lambda$ in this section as $1-\bar{\lambda} \equiv \alpha$ and λ in this section as $\bar{\lambda} \equiv (1-\alpha)\lambda$, and the analysis becomes the same as discussed in this section.

policy rate hurts welfare: a higher nominal policy rate increases the opportunity cost of holding liquidity, induces agents to carry less liquidity, and reduces the quantity of goods they can afford. In this economy, however, the Friedman rule—implementing zero nominal policy rate—is suboptimal. The rationale is as follows. When meeting a firm for trade, consumers can meet a firm that financed only by issuing corporate bonds, or a firm that obtained a loan from a bank. Increasing the nominal policy rate has the opposite effects across the two types of meetings. On the one hand, increasing the nominal policy rate makes issuing corporate bonds less expensive and thus helps firms raise more funds and bring a larger amount of intermediate goods. More precisely, a higher nominal policy rate increases the price of corporate bonds by increasing their liquidity premium from (7); the higher price of corporate bonds makes issuing corporate bonds cheaper, allowing firms to raise more funds from (5); and firms can produce more goods by bringing a larger amount of intermediate goods. On the other hand, increasing the nominal policy rate increases the cost of holding money and makes consumers carry less liquidity, which in turn makes firms borrow less from banks due to the lower demand and hurts the latter type of meeting. More precisely, a higher nominal policy rate reduces the real amount of liquidity that consumers carry with themselves from (6); due to the lower demand, firms will borrow less from banks from (3); and a smaller amount of goods are traded.

Now suppose that the nominal policy rate is currently low, so that the borrowing cost in the corporate bond market is high and a relatively small amount of goods are traded in the former type of meeting, while the borrowing cost in the bank loan market is low and already a large amount of goods are traded in the latter type of meeting. In such a case, the welfare loss from an increase in the nominal policy rate in the latter type of meeting is only second order, while the welfare gain in the former type of meeting is first order. More precisely, in $\partial \mathcal{W}/\partial i = (1-\lambda) \cdot \partial(u(q_L) - q_L)/\partial i + \lambda \cdot \partial(u(q_B) - q_B)/\partial i$, the first term represents the welfare loss in the latter type of meeting, and the second term represents the welfare gain in the former type of meeting as $\partial(u(q_L) - q_L)/\partial i < 0$ since $\partial q_L/\partial i < 0$ and $\partial(u(q_B) - q_B)/\partial i > 0$ since

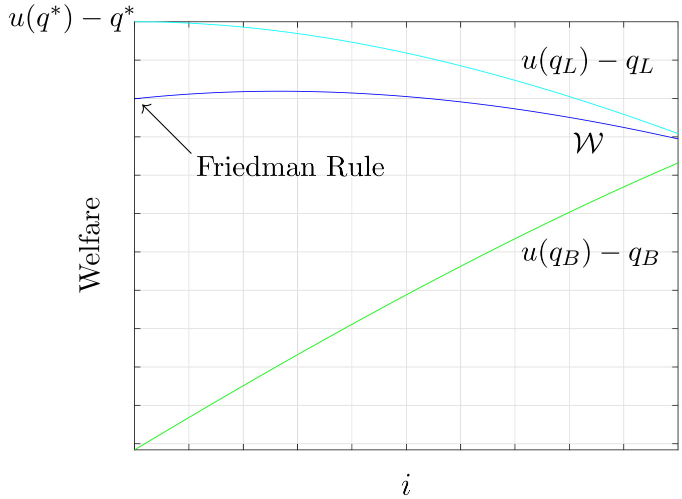

Figure 6: The suboptimality of the Friedman rule

$\partial q_B/\partial i > 0$. At the Friedman rule, however, when $i \to 0$, $\partial(u(q_L) - q_L)/\partial i \to 0$ because $q_L \to q^*$ as $i \to 0$ and $u'(q^*) = 1$. Therefore, when $i \to 0$, $\partial \mathcal{W}/\partial i = \lambda \cdot \partial(u(q_B) - q_B)/\partial i > 0$. That is, at the Friedman rule, increasing the nominal policy rate will be welfare improving. The following proposition summarizes the discussion.

Proposition 3. *A deviation from the Friedman rule is optimal, i.e., the optimal monetary policy requires $i > 0$.*

Figure 6 depicts (11) and shows that the welfare is maximized at a positive nominal policy rate, visualizing the discussion that leads to Proposition 3. The main force that drives this result is the liquidity premium channel of monetary policy transmission. Therefore, the stronger the channel, the higher the optimal policy rate. Figure 7 illustrates this argument. In particular, the optimal nominal policy rate depends on the corporate bond secondary market liquidity, χ, and the corporate finance structure of an economy, λ. The more liquid the corporate bond secondary market (a higher χ), or the more firms financing through issuing corporate bonds (a higher λ), the higher the optimal policy rate.

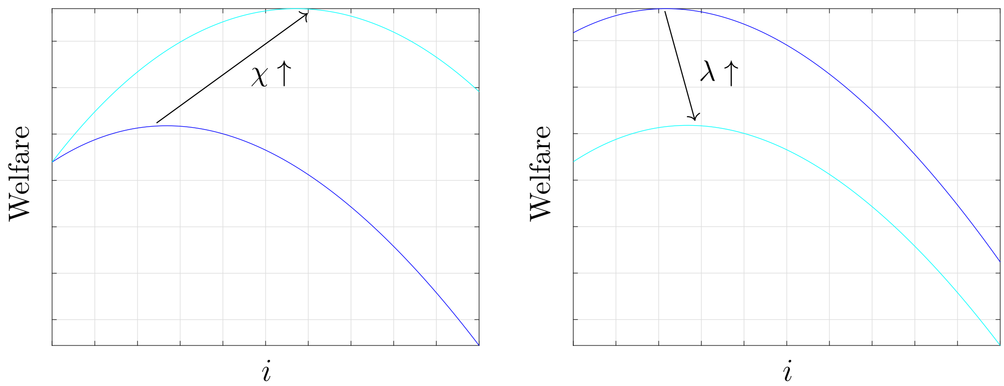

Figure 7: The corporate bond secondary market liquidity and the distribution of firms along their ways of financing matters for the optimal policy rate.

7 Conclusion

Central banks influence firms' investment through controlling the nominal policy rate, which then gets transmitted to the real rates at which firms borrow. I study this transmission mechanism in a general equilibrium macroeconomic model where firms finance by issuing corporate bonds or by obtaining bank loans, and where corporate bonds are not just stores of value but also serve a liquidity role. The model delivers three predictions. First, an increase in the nominal policy rate can lower the borrowing cost in the corporate bond market, while increasing that in the bank loan market. This is in sharp contrast with the common belief that all the rates in the economy move in the same direction in response to changes in monetary policy, and I provide empirical evidence that supports the result. Second, a higher nominal policy rate induces firms to substitute corporate bonds for bank loans, and this result is supported by the existing empirical evidence. Third, the Friedman rule is suboptimal so that keeping the cost of holding liquidity at a positive level is socially optimal. The optimal policy rate is an increasing function of the degree of the corporate bond secondary market liquidity.

Acknowledgements. I am deeply indebted to my advisor Athanasios Geromichalos for his invaluable guidance and support, and Nicolas Caramp, Andrés

Carvajal, and James Cloyne for their continued discussions and suggestions. I am also grateful to Gianluca Benigno, Bulat Gafarov, Òscar Jordà, Ioannis Kospentaris, Ina Simonovska, Anna Sokolova, Alan Taylor, Cathy Zhang, and Shengxing Zhang for helpful comments and suggestions.

References

Adrian, Tobias, Paolo Colla, and Hyun Song Shin. 2013. "Which Financial Frictions? Parsing the Evidence from the Financial Crisis of 2007–09." In *NBER Macroeconomics Annual 2012*, Volume 27, edited by D. Acemoglu, J. Parker, and M. Woodford, 159–214.

Adrian, Tobias, Michael Fleming, Or Shachar, and Erik Vogt. 2016. "Market Liquidity After the Financial Crisis." *Annual Review of Financial Economics* 9: 43–83.

Andolfatto, David, Aleksander Berentsen, and Christopher Waller. 2014. "Optimal Disclosure Policy and Undue Diligence." *Journal of Economic Theory* 149: 128–152.

Bao, Jack, Jun Pan, and Jiang Wang. 2011. "The Illiquidity of Corporate Bonds." *Journal of Finance* 66 (3): 911–946.

Becker, Bo, and Victoria Ivashina. 2014. "Cyclicality of Credit Supply: Firm Level Evidence." *Journal of Monetary Economics* 62: 76–93.

Berentsen, Aleksander, Gabriele Camera, and Christopher Waller. 2007. "Money, Credit and Banking." *Journal of Economic Theory* 135 (1): 171–195.

Berentsen, Aleksander, Samuel Huber, and Alessandro Marchesiani. 2014. "Degreasing the Wheels of Finance." *International Economic Review* 55 (3): 735–763.

Berentsen, Aleksander, Samuel Huber, and Alessandro Marchesiani. 2016. "The Societal Benefits of a Financial Transaction Tax." *European Economic Review* 89: 303–323.

Berentsen, Aleksander, Guillaume Rocheteau, and Shouyong Shi. 2007. "Friedman Meets Hosios: Efficiency in Search Models of Money." *Economic*

Journal 117 (516): 174–195.

Bernanke, Ben S., and Mark Gertler. 1989. "Agency Costs, Net Worth, and Business Fluctuations." *American Economic Review* 79 (1): 14–31.

Bernanke, Ben S., and Mark Gertler. 1995. "Inside the Black Box: The Credit Channel of Monetary Policy Transmission." *Journal of Economic Perspectives* 9 (4): 27–48.

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. 1996. "The Financial Accelerator and the Flight to Quality." *Review of Economics and Statistics* 78 (1): 1–15.

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics*, Volume 1, edited by J. B. Taylor and M. Woodford, 1341–1393.

Bessembinder, Hendrik, and William Maxwell. 2008. "Markets: Transparency and the Corporate Bond Market." *Journal of Economic Perspectives* 22 (2): 217–234.

Bessembinder, Hendrik, William Maxwell, and Kumar Venkataramanc. 2006. "Market Transparency, Liquidity Externalities, And Institutional Trading Costs in Corporate Bonds." *Journal of Financial Economics* 82 (2): 251–288.

Biais, Bruno, and Richard Green. 2019. "The Microstructure of the Bond Market in the 20th Century." *Review of Economic Dynamics* 33: 250–271.

Cloyne, James, Clodomiro Ferreira, Maren Froemel, and Paolo Surico. 2019. "Monetary Policy, Corporate Finance and Investment." Working Paper.

Denis, Davis J., and Vassil T. Mihov. 2003. "The Choice between Bank Debt, Non-Bank Private Debt and Public Debt: Evidence from New Corporate Borrowings." *Journal of Financial Economics* 70 (1): 3–28.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl. 2018. "A Model of Monetary Policy and Risk Premia." *Journal of Finance* 73 (1): 317–373.

Edwards, Amy K., Lawrence E. Harris, and Michael S. Piwowar. 2007. "Corporate Bond Market Transaction Costs and Transparency." *Journal of Finance* 62 (3): 1421–1451.

FINRA (Financial Industry Regulatory Authority). 2005. "TRACE Fact Book – 2005."

Geromichalos, Athanasios, and Lucas Herrenbrueck. 2016. "Monetary Policy, Asset Prices, and Liquidity in Over-the-Counter Markets." *Journal of Money, Credit and Banking* 48 (1): 35–79.

Geromichalos, Athanasios, and Lucas Herrenbrueck. 2022. "The Liquidity-Augmented Model of Macroeconomic Aggregates." *Review of Economic Dynamics* 45: 134–167.

Geromichalos, Athanasios, Lucas Herrenbrueck, and Sukjoon Lee. 2018. "Asset Safety versus Asset Liquidity." Forthcoming at *Journal of Political Economy.*

Geromichalos, Athanasios, Lucas Herrenbrueck, and Sukjoon Lee. 2022. "The Strategic Determination of the Supply of Liquid Assets." Forthcoming at *Review of Economic Dynamics.*

Geromichalos, Athanasios, Lucas Herrenbrueck, and Kevin Salyer. 2016. "A Search-Theoretic Model of the Term Premium." *Theoretical Economics* 11 (3): 897–935.

Geromichalos, Athanasios, and Kuk Mo Jung, 2019. "Monetary Policy and Efficiency in Over-the-Counter Financial Trade." *Canadian Journal of Economics* 52 (4): 1699–1754.

Geromichalos, Athanasios, Juan Manuel Licari, and José Suárez-Lledó. 2007. "Monetary Policy and Asset Prices." *Review of Economic Dynamics* 10 (4): 761–779.

Gertler, Mark, and Simon Gilchrist. 1994. "Monetary Policy, Business Cycles, and the Behavior of Small Manufacturing Firms." *Quarterly Journal of Economics* 109 (2): 309–340.

Gertler, Mark, and Peter Karadi. 2015. "Monetary Policy Surprises, Credit Costs, and Economic Activity." *American Economic Journal: Macroeconomics* 7 (1): 44–76.

Gilchrist, Simon, and Egon Zakrajšek. 2012. "Credit Spreads and Business Cycle Fluctuations." *American Economic Review* 102 (4): 1692–1720.

Goldstein, Michael A., Edith S. Hotchkiss, and Erik R. Sirri. 2006. "Transparency and Liquidity: A Controlled Experiment on Corporate Bonds." *Review of Financial Studies* 20 (2): 235–273.

Grosse-Rueschkamp, Benjamin, Sascha Steffen, and Daniel Streitz. 2019. "A Capital Structure Channel of Monetary Policy." *Journal of Financial Economics* 133(2): 357–378.

He, Zhiguo, and Konstantin Milbradt. 2014. "Endogenous Liquidity and Defaultable Bonds." *Econometrica* 82 (4): 1443–1508.

Herrenbrueck, Lucas. 2019a. "Frictional Asset Markets and the Liquidity Channel of Monetary Policy." *Journal of Economic Theory* 181: 82–120.

Herrenbrueck, Lucas. 2019b. "Interest Rates, Moneyness, and the Fisher Equation." Working Paper.

Herrenbrueck, Lucas, and Athanasios Geromichalos. 2017. "A Tractable Model of Indirect Asset Liquidity." *Journal of Economic Theory* 168: 252–260.

Holm-Hadulla, Fédéric, and Claire Thürwächter. 2021. "Heterogeneity in Corporate Debt Structures and the Transmission of Monetary Policy." *European Economic Review* 136 (103743): 1–22.

Hu, Tai-Wei, and Guillaume Rocheteau. 2015. "Monetary Policy and Asset Prices: A Mechanism Design Approach." *Journal of Money, Credit and Banking* 47 (2): 39–76.

Jarociński, Marek, and Peter Karadi. 2020. "Deconstructing Monetary Policy Surprises–The Role of Information Shocks." *American Economic Journal: Macroeconomics* 12 (2): 1–43.

Jeenas, Priit. 2019. "Firm Balance Sheet Liquidity, Monetary Policy Shocks, and Investment Dynamics." Working Paper.

Jones, Charles I. 2017. *Macroeconomics.* 4th edition. W. W. Norton.

Jordà, Òscar. 2005. "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review* 95 (1): 161–182.

Jordà, Òscar, Moritz Schularick, and Alan M. Taylor. 2020. "The Effects of Quasi-Random Monetary Experiments." *Journal of Monetary Economics* 112: 22–40.

Kalai, Ehud. 1977. "Proportional Solutions to Bargaining Situations: Interpersonal Utility Comparisons." *Econometrica* 45 (7): 1623–1630.

Kashyap, Anil K., Owen A. Lamont, and Jeremy C. Stein. 1994. "Credit Conditions and the Cyclical Behavior of Inventories." *Quarterly Journal of Economics* 109 (3): 565–592.

Kiyotaki, Nobuhiro and John Moore. 1997. "Credit Cycles." *Journal of Political Economy* 105 (2): 211–248.

Kiyotaki, Nobuhiro and Randall Wright. 1993. "A Search-Theoretic Approach to Monetary Economics." *American Economic Review* 83 (1): 63–77.

Lagos, Ricardo. 2011. "Asset Prices, Liquidity, and Monetary Policy in an Exchange Economy." *Journal of Money, Credit and Banking* 43 (7): 521–552.

Lagos, Ricardo, Guillaume Rocheteau, and Randall Wright. 2017. "Liquidity: A New Monetarist Perspective." *Journal of Economic Literature* 55 (2): 371–440.

Lagos, Ricardo, and Randall Wright. 2005. "A Unified Framework for Monetary Theory and Policy Analysis." *Journal of Political Economy* 113 (3): 463–484.

Lagos, Ricardo, and Shengxing Zhang. 2020. "Turnover Liquidity and the Transmission of Monetary Policy." *American Economic Review* 110 (6): 1635–1672.

Madison, Florian. 2019. "Frictional Asset Reallocation under Adverse Selection." *Journal of Economic Dynamics and Control* 100: 115–130.

Mattesini, Fabrizio, and Ed Nosal. 2016. "Liquidity and Asset Prices in a Monetary Model with OTC Asset Markets." *Journal of Economic Theory* 164: 187–217.

McCracken, Michael W., and Serena Ng. 2016. "FRED-MD: A Monthly Database for Macroeconomic Research." *Journal of Business and Economic Statistics* 34 (4): 574–589.

Mertens, Karel, and Morten O. Ravn. 2013. "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States." *American Economic Review* 103 (4): 1212–1247.

Molico, Miguel. 2006. "The Distribution of Money and Prices in Search Equilibrium." *International Economic Review*: 47 (3): 701–722.

Nagel, Stefan. 2016. "The Liquidity Premium of Near-Money Assets." *Quarterly Journal of Economics* 131 (4): 1927–1971.

Nosal, Ed, and Guillaume Rocheteau. 2013. "Pairwise Trade, Asset Prices and Monetary Policy." *Journal of Economic Dynamics and Control* 37 (1): 1–17.

Nosal, Ed, and Guillaume Rocheteau. 2017. *Money, Payments, and Liquidity.* 2nd edition. MIT Press.

Oliner, Stephen D., and Glenn D. Rudebusch. 1992. "Sources of the Financing Hierarchy for Business Investment." *Review of Economics and Statistics* 74 (4): 643–654.

Ottonello, Pablo, and Thomas Winberry. 2020. "Financial Heterogeneity and the Investment Channel of Monetary Policy." *Econometrica* 88 (6): 2473–2502.

Rocheteau, Guillaume, Pierre-Olivier Weill, and Russell Wong. 2019. "An Heterogeneous-Agent New-Monetarist Model with an Application to Unemployment." *Journal of Monetary Economics.*

Rocheteau, Guillaume, and Randall Wright. 2005. "Money in Search Equilibrium, in Competitive Equilibrium, and in Competitive Search Equilibrium." *Econometrica* 73 (1): 175–202.

Rocheteau, Guillaume, Randall Wright, and Cathy Zhang. 2018. "Corporate Finance and Monetary Policy." *American Economic Review* 108 (4–5): 1147–1186.

Schwert, Michael. 2018. "Bank Capital and Lending Relationships." *Journal of Finance* 73 (2): 787–830.

Stock, James H. 2008. "Lecture 7 - Recent Developments in Structural VAR Modeling." Presented at the National Bureau of Economic Research Summer Institute Minicourse: What's New in Econometrics: Time Series.

Stock, James H., and Mark W. Watson. 2018. "Identification and Estimation of Dynamic Causal Effects in Macroeconomics Using External Instruments." *Economic Journal* 128 (610): 917–948.

Stock, James H., Jonathan H. Wright, and Motohiro Yogo. 2002. "A Survey of Weak Instruments and Weak Identification in Generalized Method of

Moments." *Journal of Business and Economic Statistics* 20 (4): 518–529.

Swanson, Eric T., and John C. Williams. 2014. "Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates." *American Economic Review* 104 (10): 3154–3185.

Online Appendices for "Liquidity Premium, Credit Costs, and Optimal Monetary Policy"

Sukjoon Lee, August 2022

A Theory Appendix

A.1 Details of the Model in Section 3

A.1.1 Value Functions

Consumers. First consider a consumer in the second subperiod who carries to the CM financial wealth w, denominated in numeraire, and chooses a portfolio of real balances and corporate bonds to bring to the DM in the next period. The value function of the consumer is

$$W^C(w) = \max_{c,\,\hat{m}\geq 0,\,\hat{a}\geq 0} c + \beta V^C(\hat{m}, \hat{a}) \quad \text{s.t.} \quad c + (1+\pi)\hat{m} + \psi\hat{a} = w + T,$$

where V^C is the value function of the consumer in the DM in the first subperiod, c is consumption (or production if $c < 0$) of the general good, $\hat{m}$ is real balances (units of money in terms of numeraire), $\hat{a}$ is the amount of corporate bonds purchased, ψ is the price of corporate bonds, and T is the monetary lump-sum transfer in terms of numeraire (or taxes if $T < 0$). Since the rate of return on money is $1/(1+\pi)$, a consumer accumulates $(1+\pi)\hat{m}$ of real balances this period to hold $\hat{m}$ at the start of the next period. Eliminating c using the constraint, the value function reduces to

$$W^C(w) = w + T + \max_{\hat{m}\geq 0,\,\hat{a}\geq 0} \big\{ -(1+\pi)\hat{m} - \psi\hat{a} + \beta V^C(\hat{m}, \hat{a}) \big\}, \tag{A.1}$$

which shows that W^C is linear in w and that the optimal portfolio choice of $(\hat{m}, \hat{a})$ is independent of w.

In the following first subperiod, in the DM the consumer randomly matches with a firm and trades the special good. The consumer bargains with the firm over how many DM goods to purchase from the firm, q, and how much financial wealth to transfer to the firm in return for the DM goods, p. With probability $1-\lambda$, the consumer will match with a firm that finances through borrowing from a bank, and the terms of trade with such a firm are denoted by (q_L, p_L). With probability λ, the consumer will match with a firm that finances through issuing corporate bonds, and the terms of trade with such a firm are denoted by (q_B, p_B). When purchasing q amount of the DM goods, the consumer derives $u(q)$ of utility from consuming them. After paying p amount of financial wealth to a firm in exchange for the DM goods purchased, the consumer brings $\hat{m}+\hat{a}-p$ amount of leftover financial wealth to the CM. The value function of a consumer who brings $\hat{m}$ amount of real balances and $\hat{a}$ amount of corporate bonds to the DM is

$$V^C(\hat{m},\hat{a}) = (1-\lambda)[u(q_L)+W^C(\hat{m}+\hat{a}-p_L)] + \lambda[u(q_B)+W^C(\hat{m}+\hat{a}-p_B)],$$

which, using the linearity of W^C, reduces to

$$V^C(\hat{m},\hat{a}) = (1-\lambda)[u(q_L)-p_L] + \lambda[u(q_B)-p_B] + W^C(\hat{m}+\hat{a}). \tag{A.2}$$

Suppliers. Next consider the value function of an intermediate good supplier in the second subperiod:

$$W^S = \max_{c,\,k\geq 0} c + \beta W^S \quad \text{s.t.} \quad c+k = p_k k,$$

where k is the amount of the intermediate goods produced and p_k is their price. In the competitive market for intermediate goods, suppliers choose the amount of intermediate goods to produce, k, at a linear cost taking its price, p_k, as given. A supplier finds k that maximizes $-k+p_k k$. If the intermediate goods market is active, $p_k = 1$. Suppliers do not trade in the DM and do not carry any money or corporate bond because there is the cost of holding money and corporate bonds will be priced at the liquidity premium.

Banks. In the OTC market for loans, a bank provides a loan to a firm. The terms of a loan contract, denoted by (k_ℓ, r_ℓ), are determined through bargaining between a firm and a bank: a firm borrows k_ℓ amount of numeraire from a bank and pays back $(1+r_\ell)k$ amount of numeraire to the bank in the next period's CM. The value function of a bank in the CM with financial wealth w, denominated in numeraire, and a loan contract (k_ℓ, r_ℓ) is

$$W^B(w) = \max_c c + \beta W^B((1+r_\ell)k_\ell) \quad \text{s.t.} \quad c + k_\ell = w.$$

The constraint can be written as $k_\ell = w - c$, and this represents the balance sheet of the bank: the amount of a loan provided to a firm, k_ℓ, should be covered by the financial wealth of the bank, $w - c$, which can be thought of as bank capital. Eliminating c using the constraint, the value function reduces to

$$W^B(w) = w - k_\ell + \beta W^B((1+r_\ell)k_\ell).$$

Firms. Now consider a firm in the second subperiod that is just born and finances through borrowing from a bank under the terms of a loan contract (k_ℓ, r_ℓ). With k_ℓ amount of numeraire borrowed from a bank, the firm proceeds to the intermediate goods market and purchases k_ℓ amount of intermediate goods from suppliers at price $p_k = 1$. In the following first subperiod, in the DM the firm matches with a consumer and trades the special good, and the terms of trade are denoted by (q_L, p_L). After trading in the DM, the firm brings $k_\ell - q_L$ of leftover intermediate goods and p_L of financial wealth to the CM and pays back $(1+r_\ell)k_\ell$ amount of numeraire to the bank. The DM value function in the first subperiod of a firm with a loan contract (k_ℓ, r_ℓ) is

$$V^F(k_\ell, (1+r_\ell)k_\ell) = W^F(k_\ell - q_L, p_L, (1+r_\ell)k_\ell), \tag{A.3}$$

W^F is the value function of the firm in the CM in the second subperiod after trading in the DM, and it is given by

$$W^F(k_\ell - q_L, p_L, (1+r_\ell)k_\ell) = \max_c c \quad \text{s.t.} \quad c = k_\ell - q_L + p_L - (1+r_\ell)k_\ell,$$

which simply reduces to

$$W^F(k_\ell - q_L, p_L, (1+r_\ell)k_\ell) = k_\ell - q_L + p_L - (1+r_\ell)k_\ell. \tag{A.4}$$

A firm that finances through issuing corporate bonds decides how many units of corporate bonds to issue, $\hat{A}$, taking their price ψ in the CM as given. With $\psi\hat{A}$ amount of numeraire acquired by issuing corporate bonds, the firm proceeds to the intermediate goods market and purchases $\psi\hat{A}$ amount of intermediate goods from suppliers at price $p_k = 1$. In the following first subperiod, in the DM the firm matches with a consumer and trades the special good, and the terms of trade are denoted by (q_B, p_B). After trading in the DM, the firm brings $\psi\hat{A}/ - q_B$ of leftover intermediate goods and p_B of financial wealth to the CM and pays $\hat{A}$ units of numeraire to the consumers who hold the corporate bonds. The DM value function in the first subperiod of a firm that issued $\hat{A}$ units of corporate bonds in the CM in the previous second subperiod at price ψ is

$$V^F(\psi\hat{A}, \hat{A}) = W^F(\psi\hat{A} - q_B, p_B, \hat{A}). \tag{A.5}$$

W^F is the value function of the firm in the CM in the second subperiod after trading in the DM, and it is given by

$$W^F(\psi\hat{A} - q_B, p_B, \hat{A}) = \max_c c \quad \text{s.t.} \quad c = \psi\hat{A} - q_B + p_B - \hat{A},$$

which simply reduces to

$$W^F(\psi\hat{A} - q_B, p_B, \hat{A}) = \psi\hat{A} - q_B + p_B - \hat{A}. \tag{A.6}$$

Using the linearity of W^F, a newborn firm in the second subperiod decides the amount of corporate bonds to issue by solving

$$\max_{\hat{A}\geq 0} \beta V^F(\psi\hat{A}, \hat{A}) = \max_{\hat{A}\geq 0} \beta\big\{(p_B - q_B) - (1-\psi)\hat{A}\big\}.$$

A.1.2 Terms of Trade

Consider a meeting in the DM between a consumer who carries m amount of real balances and a amount of corporate bonds and a firm that brings k amount of intermediate goods. The two parties bargain over the quantity of the DM goods to trade, q, and the amount of financial wealth for the consumer to transfer to the firm, p. Corporate bonds are partially liquid, and only a fraction χ can be used as a medium of exchange. Hence, the maximum amount of financial wealth that the consumer can use towards trade is $m + \chi a$. The firm can produce the DM goods with linear technology up to k units. Trade is therefore subject to both the consumer's liquidity constraint, $p \leq m + \chi a$, and the firm's capacity constraint, $q \leq k$.

The total surplus generated within a meeting is split according to Kalai's proportional bargaining solution, and the consumer's bargaining power is θ. The consumer's continuation value with trade is $u(q) + W^C(m + a - p)$, and the consumer's continuation value without trade is $W^C(m + a)$. Thus the consumer's surplus is $u(q) + W^C(m + a - p) - W^C(m + a)$, which, using the linearity of W^C, reduces to $u(q) - p$. The firm's continuation value with trade is $W^F(k - q, p, \cdot\,)$, where the last argument is the liabilities that the firm needs to pay back in the CM in the subsequent second subperiod to either consumers (who hold the corporate bonds if the firm financed through issuing corporate bonds) or a bank (according to a loan contract if the firm financed through borrowing from a bank). The firm brings $k - q$ amount of leftover intermediate goods after producing q amount of the DM goods with linear technology and p amount of financial wealth that it received from the consumer as a payment. The firm's continuation value without trade is $W^F(k, 0, \cdot\,)$. Thus the firm's surplus is $W^F(k - q, p, \cdot\,) - W^F(k, 0, \cdot\,)$, which, using the linearity of W^F, reduces to $p - q$. The total surplus is the sum of the consumer's surplus and the firm's surplus and equals $u(q) - q$.

The bargaining problem is

$$\max_{p,q} u(q) - p \quad \text{s.t.} \quad u(q) - p = \frac{\theta}{1-\theta}(p - q), \;\; p \leq m + \chi a, \;\; q \leq k,$$

and its solution is given by

$$p = v(q) \equiv (1-\theta)u(q) + \theta q, \quad v'(q) > 0, \tag{A.7}$$

$$q = \min\{v^{-1}(m + \chi a), k\}. \tag{A.8}$$

The consumer must transfer $p = v(q)$ amount of financial wealth to the firm to get q amount of the DM goods, and a larger amount of financial wealth needs to be transferred to purchase a larger amount of the DM goods. As a result of bargaining, the consumer takes θ share of the total surplus, and the firm takes $1-\theta$ share. The first best solution to the bargaining problem that maximizes the total surplus is denoted by (p^*, q^*), where $p^* = v(q^*)$ and q^* satisfies $u'(q^*) = 1$. With $m + \chi a$ amount of financial wealth that can be used towards trade, the consumer can purchase up to $v^{-1}(m + \chi a)$ amount of the DM goods. With k amount of intermediate goods in hand, the firm can produce up to k amount of the DM goods. In equilibrium, $m + \chi a \leq v(q^*)$ and $k \leq q^*$ hold: the consumer will not want to bring more financial wealth than she needs to buy q^* amount of the DM goods, and the firm will not want to bring more intermediate goods than it needs to produce q^* amount of the DM goods. Observing that the total surplus $u(q) - q$ increases in q until $q = q^*$, the shorter side between the consumer's liquidity position and the firm's production capacity determines the bargaining solution. Thus, q is given by the minimum between $v^{-1}(m + \chi a)$ and k.

A.1.3 Loan Contract

Consider a meeting in the OTC market for loans between a bank with w amount of bank capital that can be lent as a loan and a firm that finances through borrowing from a bank. The two parties bargain over the amount of numeraire that the bank lends to the firm, k_ℓ, and the amount of numeraire that the firm needs to repay to the bank in the next period's CM, $(1 + r_\ell)k_\ell$, where r_ℓ is the real lending rate.

The terms of a loan contract are determined through Kalai's proportional bargaining between the firm and the bank, and the bank's bargaining power is η.

The firm's continuation value with a loan contract (k_ℓ, r_ℓ) is $\beta V^F(k_\ell, (1+r_\ell)k_\ell)$, and the firm's continuation value without a loan contract is $\beta V^F(0,0)$. Thus the firm's surplus is $\beta[V^F(k_\ell, (1+r_\ell)k_\ell) - V^F(0,0)]$, which, using (A.3) and the linearity of W^F, reduces to $\beta[p_L - q_L - r_\ell k_\ell]$. Using (A.7) and (A.8), it further reduces to $\beta[(1-\theta)(u(q_L)-q_L) - r_\ell k_\ell]$, where $q_L = \min\{v^{-1}(\tilde{m}+\chi\tilde{a}), k_\ell\}$ when the firm believes that a typical consumer will carry $\tilde{m}$ amount of real balances and $\tilde{a}$ amount of corporate bonds to the DM. Since the firm will not want to borrow more than it needs to produce the amount of the DM goods that a consumer can afford, $v^{-1}(\tilde{m}+\chi\tilde{a})$, it simply reduces to $q_L = k_\ell$. The bank's continuation value with a loan contract (k_ℓ, r_ℓ) is $\beta W^B(w - k_\ell + (1+r_\ell)k_\ell)$, and the bank's continuation value without a loan contract is $\beta W^B(w)$.[19] Thus the bank's surplus is $\beta[w - k_\ell + W^B((1+r_\ell)k_\ell) - W^B(w)]$, which, using the linearity of W^B, reduces to $\beta r_\ell k_\ell$. The total surplus is the sum of the firm's surplus and the bank's surplus and equals $\beta(1-\theta)(u(q_L)-q_L)$.

The bargaining problem is

$$\max_{k_\ell \le v^{-1}(\tilde{m}+\chi\tilde{a}),\, r_\ell} r_\ell k_\ell \quad \text{s.t.} \quad r_\ell k_\ell = \frac{\eta}{1-\eta}[(1-\theta)(u(k_\ell)-k_\ell) - r_\ell k_\ell],$$

and its solution is given by

$$k_\ell = v^{-1}(\tilde{m}+\chi\tilde{a}), \tag{A.9}$$

$$r_\ell = \frac{\eta(1-\theta)(u(k_\ell)-k_\ell)}{k_\ell}, \quad \frac{dr_\ell}{dk_\ell} < 0, \tag{A.10}$$

The solution is such that k_ℓ maximizes the total surplus, $(1-\theta)(u(k_\ell)-k_\ell)$, subject to $k_\ell \le v^{-1}(\tilde{m}+\chi\tilde{a})$. Since $u(k_\ell) - k_\ell$ increases in k_ℓ until $k_\ell = q^*$, $k_\ell = \min\{v^{-1}(\tilde{m}+\chi\tilde{a}), q^*\}$. Observing that $v^{-1}(\tilde{m}+\chi\tilde{a}) \le q^*$ in equilibrium since a consumer will not want to bring more financial wealth than she needs to

[19] It is assumed that a bank can use its bank capital (which is in numeraire) that was not lent in the following way. Assume that a bank lent only $k_\ell < w$ amount of numeraire to a firm and is left with $w - k_\ell$ amount of numeraire in hand. It then goes to the intermediate goods market, exchanges the leftover nuemraire with intermediate goods, and, in the next period's CM, produces the general good using the intermediate goods at unit cost. Banks are assumed to have access to this technology. But this technology is not used on the equilibrium path, and it is just for simplifying the exposition and immaterial to any of the results.

buy q^* amount of the DM goods, the solution is given by $k_\ell = v^{-1}(\tilde{m} + \chi\tilde{a})$. As a result of bargaining, the bank takes η share of the total surplus, and the firm takes $1-\eta$ share. The more a firm borrows, the lower the real interest rate, as it depends positively on the marginal benefit of the loan, which decreases in the size of the loan.

A.1.4 Equilibrium

First start with the optimal behavior of a firm that finances through issuing corporate bonds. From (A.6), at a given price ψ, the firm chooses the amount of corporate bonds to issue, A, that maximizes $(p_B - q_B) - (1-\psi)A$, which, using (A.7) and (A.8), reduces to $(1-\theta)(u(q_B) - q_B) - (1-\psi)A$, where $q_B = \min\{v^{-1}(\tilde{m} + \chi\tilde{a}), \psi A\}$ when believing that a consumer will carry $\tilde{m}$ amount of real balances and $\tilde{a}$ amount of corporate bonds to the DM. An equilibrium exists when $\psi < 1$, that is, when borrowing through the corporate bond market is costly. Since the firm will not want to bring more intermediate goods to the DM than it needs to produce the amount of the DM goods that a consumer can afford, $v^{-1}(\tilde{m} + \chi\tilde{a})$, the maximization problem becomes

$$\max_{0 \le A \le v^{-1}(\tilde{m}+\chi\tilde{a})/\psi} \Big\{(1-\theta)(u(\psi A) - \psi A) - (1-\psi)A\Big\}.$$

The solution describes the optimal corporate bond issuance decision of the firm, or the supply of corporate bonds, which is given by

$$A = \min\big\{v^{-1}(\tilde{m} + \chi\tilde{a})/\psi, \bar{A}\big\},$$

where $\bar{A}$ solves

$$\frac{1}{\psi} - 1 = (1-\theta)(u'(\psi\bar{A}) - 1). \tag{A.11}$$

The amount of funds raised, and the amount of intermediate goods that the firm can acquire, through issuing corporate bonds, when $\bar{A} \leq v^{-1}(\tilde{m}+\chi\tilde{a})/\psi$, is

$$\psi\bar{A} = (u')^{-1}\left(\frac{1/\psi - 1}{1-\theta} + 1\right), \tag{A.12}$$

which is an increasing function of ψ, the price of corporate bonds. The higher price makes financing through issuing corporate bonds less expensive and thus allows firms to acquire more intermediate goods.

Now consider the optimal behavior of a consumer. From (A.1), the consumer chooses the amount of real balances, m, and the amount of corporate bonds, a, that maximize $-(1+\pi)m - \psi a + \beta V^C(m,a)$, which, using (A.2) and the linearity of W^C, becomes

$$\max_{m\geq 0, a\geq 0}\Big\{-(1+\pi)m - \psi a + \beta m + \beta a + \beta(1-\lambda)[u(q_L) - p_L] + \beta\lambda[u(q_B) - p_B]\Big\}.$$

Here I restrict attention to the case where the price of corporate bonds, ψ, is not so high that firms will not be able to bring enough amount of intermediate goods to the DM to meet the consumers' demand.[20] In this case, $q_B = \psi\bar{A} < v^{-1}(m+\chi a)$, and $q_L = v^{-1}(m+\chi a)$ given (A.9), and the maximization problem becomes

$$\max_{m\geq 0,\, a\geq 0}\Big\{-(1+\pi)m - \psi a + \beta m + \beta a + \beta(1-\lambda)\big[u(v^{-1}(m+\chi a)) - v(v^{-1}(m+\chi a))\big]\Big\}.$$

The optimal behavior of the consumer is given by

$$1+\pi = \beta\left\{1 + (1-\lambda)\left(\frac{u'(v^{-1}(m+\chi a))}{v'(v^{-1}(m+\chi a))} - 1\right)\right\},$$
$$\psi = \beta\left\{1 + (1-\lambda)\chi\left(\frac{u'(v^{-1}(m+\chi a))}{v'(v^{-1}(m+\chi a))} - 1\right)\right\},$$

where the first is the consumer's money demand and the second is the consumer's

[20] This essentially means that i is not too high (Assumption 1). Online Appendix A.3 provides the characterization of the equilibrium outside this parameter space.

bond demand. These expressions simplify to

$$i = (1-\lambda)L(m+\chi a), \tag{A.13}$$

$$\psi = \beta(1+\chi i). \tag{A.14}$$

where $i \equiv (1+\pi)/\beta - 1$ and $L(\cdot) \equiv u'(v^{-1}(\cdot))/v'(v^{-1}(\cdot)) - 1$ with $L'(\cdot) < 0$.

The following assumption ensures that the price of corporate bonds is not too high so that financing through corporate bonds is expensive and that firms financing through corporate bonds are not able to fully satisfy the consumer's demand in the DM.

Assumption 1. $i < \bar{\imath} \equiv \dfrac{(1-\lambda)(1-\beta)\theta}{1-\theta+(1-\lambda)\beta\theta\chi}$.

Notice that this assumption implies that $i < (1-\beta)/(\beta\chi)$ so that $\psi < 1$ and thus also guarantees a well-defined bond supply function.

The equilibrium is defined as below.

Definition 1. *A steady state equilibrium of the economy corresponds to a constant sequence $(q_L, q_B, m, a, A, \psi, k_\ell, r_\ell)$, where q_L is the DM goods traded between a consumer and a firm that finances through borrowing from a bank, q_B is the DM goods traded between a consumer and a firm that finances through issuing corporate bonds, m is the consumer's real balance holdings, a is the consumer's corporate bond holdings, A is the supply of corporate bonds issued by firms, ψ is the price of corporate bonds, k_ℓ is the size of a loan that a bank lends to a firm, and r_ℓ is the real lending rate of loans. Under Assumption 1, (q_L, q_B) satisfy*

$$q_L = v^{-1}\left(L^{-1}\left(\frac{i}{1-\lambda}\right)\right), \tag{A.15}$$

$$q_B = (u')^{-1}\left(\frac{1-\beta(1+\chi i)}{\beta(1+\chi i)(1-\theta)} + 1\right), \tag{A.16}$$

(m, a, A, ψ) satisfy

$$\psi = \beta(1+\chi i), \tag{A.17}$$

$$A = q_B/\psi, \tag{A.18}$$

$$a = \lambda A, \tag{A.19}$$

$$m = v(q_L) - \chi a, \tag{A.20}$$

and (k_ℓ, r_ℓ) *satisfy*

$$k_\ell = q_L = v^{-1}(m + \chi a), \tag{A.21}$$

$$r_\ell = \frac{\eta(1-\theta)(u(k_\ell) - k_\ell)}{k_\ell}, \tag{A.22}$$

where

$$v(\cdot) = (1-\theta)u(\cdot) + \theta\,\cdot\,, \quad v'(\cdot) > 0, \tag{A.23}$$

$$L(\cdot) = u'(v^{-1}(\cdot))/v'(v^{-1}(\cdot)) - 1, \quad L'(\cdot) < 0. \tag{A.24}$$

A.2 Details of the Model in Section 5

A.2.1 Value Functions

The value function of suppliers remain the same as in Online Appendix A.1. A bank in the second subperiod randomly matches with one of the two types of firms: one that has access to the corporate bond market and the other that does not. Denote the terms of a loan contract between a bank and a firm that cannot issue corporate bonds by (k^L, r_ℓ^L) and those between a bank and a firm that can issue corporate bonds by (k_ℓ^B, r_ℓ^B). The value function of a bank that matched with a firm is

$$W^B(w) = \max_c\, c + \beta W^B((1 + r_\ell^j)k_\ell^j) \quad \text{s.t.} \quad c + k_\ell^j = w, \quad j = L, B.$$

The value function of a firm that does not have access to the corporate bond market and thus has to borrow only from a bank remains the same as (A.3) and (A.4), but now the terms of a loan contract are denoted by (k^L, r_ℓ^L). The value function of a firm that has access to the corporate bond market but could not borrow from a bank is the same as (A.5) and (A.6).

Now consider a firm that has access to the corporate bond market and also was able to find a bank that is willing to provide a loan. The terms of a loan contract for this type of firms are denoted by (k^B, r_ℓ^B). The DM value function in the first subperiod of a firm that issued $\hat{A}$ amount of corporate bonds at price ψ and that obtained k_ℓ^B amount of a loan from a bank at a real lending rate r_ℓ^B in the previous second subperiod is

$$V^F(\psi\hat{A} + k_\ell^B, \hat{A} + (1 + r_\ell^B)k_\ell^B) = W^F(\psi\hat{A} + k_\ell^B - q, p, \hat{A} + (1 + r_\ell^B)k_\ell^B), \tag{A.25}$$

where (p, q) are the terms of DM trade. The CM value function of the firm in the second subperiod after trading in the DM is

$$\begin{aligned} W^F(\psi\hat{A} + k_\ell^B - q, p, \hat{A} + (1 + r_\ell^B)k_\ell^B) &= \max_c \; c \\ \text{s.t.} \quad c = \psi\hat{A} + k_\ell^B - q + p - \hat{A} &- (1 + r_\ell^B)k_\ell^B, \end{aligned}$$

which simply reduces to

$$W^F(\psi\hat{A} + k_\ell^B - q, p, \hat{A} + (1 + r_\ell^B)k_\ell^B) = \psi\hat{A} + k_\ell^B - q + p - \hat{A} - (1 + r_\ell^B)k_\ell^B.$$

Using the linearity of W^F, a newborn firm in the second subperiod with a loan contract (k^B, r_ℓ^B) decides the amount of corporate bonds to issue by solving

$$\max_{\hat{A} \geq 0} \beta V^F(\psi\hat{A} + k_\ell^B, \hat{A} + (1 + r_\ell^B)k_\ell^B) = \max_{\hat{A} \geq 0} \beta\{(p - q) - (1 - \psi)\hat{A} - r_\ell^B k_\ell^B\}. \tag{A.26}$$

A consumer in the DM randomly matches with one of the three types of firms: a firm that does not have access to the corporate bond market but was able to borrow from a bank with probability $\alpha(1 - \lambda)/(\alpha + (1 - \alpha)\lambda)$, a firm that has access to the corporate bond market and also was able to borrow from a bank with probability $\alpha\lambda/(\alpha + (1 - \alpha)\lambda)$, and a firm that has access to the corporate bond market but was not able to borrow from a bank with probability $(1 - \alpha)\lambda/(\alpha + (1 - \alpha)\lambda)$. Thus, the value function of a consumer who brings $\hat{m}$ amount of real balances and $\hat{a}$ amount of corporate bonds to the DM is

$$V^C(\hat{m}, \hat{a}) = W^C(\hat{m} + \hat{a})$$
$$+ \frac{\alpha(1-\lambda)}{\alpha + (1-\alpha)\lambda} [u(q_L) - p_L] + \frac{\alpha\lambda}{\alpha + (1-\alpha)\lambda} [u(q) - p] + \frac{(1-\alpha)\lambda}{\alpha + (1-\alpha)\lambda} [u(q_B) - p_B] .$$

The CM value function of a consumer remains the same as (A.1).

A.2.2 Loan Contract

Now there are two types of meetings in the OTC market for loans: one between a bank and a firm with no access to the corporate bond market, and the other between a bank and a firm with access to the corporate bond market and thus has issued corporate bonds before entering the OTC market for loans. The bargaining problem in the former meeting is the same as in Online Appendix A.1, and the solution is given by (A.9) and (A.10).

In the latter meeting, a bank and a firm bargain over the terms of a loan contract, (k^B, r_ℓ^B). Consider a meeting between a bank and a firm that has already raised ψA amount of funds by issuing A amount of corporate bonds at price ψ. I restrict attention as in Online Appendix A.1.4 under Assumption 1 to the case where the price of corporate bonds is not too high so that financing through corporate bonds is expensive and that firms cannot fully satisfy the consumer's demand in the DM only through corporate bond issuance. The firm's continuation value with a loan contract (k_ℓ^B, r_ℓ^B) is $\beta V^F(\psi A + k_\ell^B, A + (1+r_\ell^B)k_\ell^B)$, and the firm's continuation value without a loan contract is $\beta V^F(\psi A, A)$. Thus the firm's surplus is $\beta[V^F(\psi A + k_\ell^B, A + (1+r_\ell^B)k_\ell^B) - V^F(\psi A, A)]$. Given that the firm will not raise funds more than what it needs to satisfy the consumer's demand, using (A.7), (A.8), and (A.25), this reduces to $\beta[(1-\theta)(u(\psi A + k_\ell^B) - (\psi A + k_\ell^B)) - (1-\psi)A - r_\ell^B k_\ell^B] - \beta[(1-\theta)(u(\psi A) - \psi A) - (1-\psi)A]$. The bargaining problem is subject to $k_\ell^B \leq v^{-1}(\tilde{m} + \chi\tilde{a}) - \psi A$: the firm would like to use the loan to meet the consumer's demand that it could not satisfy with corporate bond issuance. The bank's surplus is $\beta r_\ell^B k_\ell^B$ as before. The bargaining problem is

$$\max_{k_\ell^B \le v^{-1}(\tilde{m}+\chi\tilde{a})-\psi A,\, r_\ell^B} r_\ell^B k_\ell^B$$
$$\text{s.t.} \quad r_\ell^B k_\ell^B = \frac{\eta}{1-\eta}[(1-\theta)(u(\psi A + k_\ell^B) - u(\psi A) - k_\ell^B) - r_\ell^B k_\ell^B],$$

and its solution is given by

$$k_\ell^B = v^{-1}(\tilde{m} + \chi\tilde{a}) - \psi A, \tag{A.27}$$
$$r_\ell^B = \eta(1-\theta)\left[\frac{u(\psi A + k_\ell^B) - u(\psi A)}{k_\ell^B} - 1\right]. \tag{A.28}$$

The solution is such that k_ℓ^B maximizes the total surplus, $(1-\theta)(u(\psi A + k_\ell^B) - u(\psi A) - k_\ell^B)$, subject to $k^B \le v^{-1}(\tilde{m} + \chi\tilde{a}) - \psi A$, and, as a result of bargaining, the bank takes η share of the total surplus, and the firm takes $1-\eta$ share.

A.2.3 Bond Supply

From (A.7), (A.8), (A.26), (A.27), and (A.28), at a given price ψ, the firm chooses the amount of corporate bonds to issue, A, to maximize

$$\max_A \, (1-\theta)[u(v^{-1}(m+\chi a)) - v^{-1}(m+\chi a)] - (1-\psi)A - r_\ell^B k_\ell^B, \tag{A.29}$$

which is equivalent to maximizing

$$\max_A \, \eta(1-\theta)[u(\psi A) - \psi A] - (1-\psi)A. \tag{A.30}$$

The optimal bond issuance decision of the firm, or the bond supply, A, solves

$$\frac{1}{\psi} - 1 = \eta(1-\theta)(u'(\psi A) - 1),$$

and the amount of funds that firms will raise by issuing corporate bonds, ψA, is

$$\psi A = (u')^{-1}\left(\frac{1/\psi - 1}{\eta(1-\theta)} + 1\right). \tag{A.31}$$

A.3 The Full Characterization of the Equilibrium of the Model in Section 3

This section characterizes the equilibrium of the model in Section 3 beyond the parameter space in Assumption 1. First start with the optimal behavior of a firm that finances through issuing corporate bonds. From (A.6), at a given price ψ, the firm chooses the amount of corporate bonds to issue, $A \geq 0$, that maximizes $(p_B - q_B) - (1-\psi)A$, which, using (A.7) and (A.8), reduces to $(1-\theta)(u(q_B) - q_B) - (1-\psi)A$, where $q_B = \min\{v^{-1}(\tilde{m} + \chi\tilde{a}), \psi A\}$ when believing that a consumer will carry $\tilde{m}$ amount of real balances and $\tilde{a}$ amount of corporate bonds to the DM. An equilibrium exists when $\psi < 1$, that is, when borrowing through the corporate bond market is costly. Assumption 2, given below, guarantees that this is the case. Since the firm will not want to bring more intermediate goods to the DM than it needs to produce the amount of the DM goods that a consumer can afford, $v^{-1}(\tilde{m} + \chi\tilde{a})$, the maximization problem becomes

$$\max_{0 \leq A \leq v^{-1}(\tilde{m}+\chi\tilde{a})/\psi} \Big\{(1-\theta)(u(\psi A) - \psi A) - (1-\psi)A\Big\}.$$

The solution describes the optimal corporate bond issuance decision of the firm, or the supply of corporate bonds, which is given by

$$A = \min\big\{v^{-1}(\tilde{m} + \chi\tilde{a})/\psi, \bar{A}\big\}, \tag{A.32}$$

where $\bar{A}$ solves

$$\frac{1}{\psi} - 1 = (1-\theta)(u'(\psi\bar{A}) - 1).$$

Now consider the optimal behavior of a consumer. From (A.1), the consumer chooses the amount of real balances, m, and the amount of corporate bonds, a, that maximize $-(1+\pi)m - \psi a + \beta V^C(m, a)$, which, using (A.2) and the linearity of W^C, becomes

$$\max_{m \geq 0,\, a \geq 0} \Big\{ -(1+\pi)m - \psi a + \beta m + \beta a + \beta(1-\lambda)[u(q_L) - p_L] + \beta\lambda[u(q_B) - p_B] \Big\}.$$

When believing that a firm with access to the corporate bond market will issue $\tilde{A}$ amount of corporate bonds and bring $\psi\tilde{A}$ amount of intermediate goods to the DM and that a firm that borrows from a bank will bring $\tilde{k}_\ell$ amount of intermediate goods to the DM, $q_L = \min\{v^{-1}(m + \chi a), \tilde{k}_\ell\}$ and $q_B = \min\{v^{-1}(m + \chi a), \psi\tilde{A}\}$. Depending on the relative size of $\tilde{k}_\ell$, $\psi\tilde{A}$, and $v^{-1}(m + \chi a)$, the maximization problem is:

For $m + \chi a \leq \min\{v(\tilde{k}_\ell), v(\psi\tilde{A})\}$,

$$\max_{m \geq 0,\, a \geq 0} \Big\{ -(1+\pi)m - \psi a + \beta m + \beta a + \beta\big[u(v^{-1}(m + \chi a)) - v(v^{-1}(m + \chi a))\big] \Big\}, \tag{A.33}$$

for $\min\{v(\tilde{k}_\ell), v(\psi\tilde{A})\} < m + \chi a \leq \max\{v(\tilde{k}_\ell), v(\psi\tilde{A})\}$, if $\psi\tilde{A} < \tilde{k}_\ell$,

$$\max_{m \geq 0,\, a \geq 0} \Big\{ -(1+\pi)m - \psi a + \beta m + \beta a + \beta(1-\lambda)\big[u(v^{-1}(m + \chi a)) - v(v^{-1}(m + \chi a))\big] \Big\}, \tag{A.34}$$

for $\min\{v(\tilde{k}_\ell), v(\psi\tilde{A})\} < m + \chi a \leq \max\{v(\tilde{k}_\ell), v(\psi\tilde{A})\}$, if $\tilde{k}_\ell < \psi\tilde{A}$,

$$\max_{m \geq 0,\, a \geq 0} \Big\{ -(1+\pi)m - \psi a + \beta m + \beta a + \beta\lambda\big[u(v^{-1}(m + \chi a)) - v(v^{-1}(m + \chi a))\big] \Big\}, \tag{A.35}$$

and for $\max\{v(\tilde{k}_\ell), v(\psi\tilde{A})\} < m + \chi a$,

$$\max_{m \geq 0,\, a \geq 0} \Big\{ -(1+\pi)m - \psi a + \beta m + \beta a \Big\}. \tag{A.36}$$

I consider an equilibrium where the expectations are rational. (A.35) is not a relevant case with $\psi\tilde{A} < \tilde{k}_\ell$ from (A.9) and (A.32), and (A.36) does not have a solution. The solution describes the optimal portfolio choice of real balances and corporate bonds of the consumer, or the demand for real balances and corporate bonds. The solution to (A.34) satisfies

$$m + \chi a = \max\{v(\psi \tilde{A}), \bar{m} + \chi \bar{a}\},$$

where $\bar{m} + \chi \bar{a}$ solves

$$1 + \pi = \beta \left\{1 + (1 - \lambda)\left(\frac{u'(v^{-1}(\bar{m} + \chi \bar{a}))}{v'(v^{-1}(\bar{m} + \chi \bar{a}))} - 1\right)\right\},$$

which simplify to

$$i = (1 - \lambda)L(\bar{m} + \chi \bar{a}), \tag{A.37}$$

where $i \equiv (1 + \pi)/\beta - 1$ and $L(\cdot) \equiv u'(v^{-1}(\cdot))/v'(v^{-1}(\cdot)) - 1$ with $L'(\cdot) < 0$. The solution to (A.33) satisfies

$$m + \chi a = \min\{v(\psi \tilde{A}), \bar{\bar{m}} + \chi \bar{\bar{a}}\},$$

where $\bar{\bar{m}} + \chi \bar{\bar{a}}$ solves

$$1 + \pi = \beta \left\{1 + \left(\frac{u'(v^{-1}(\bar{\bar{m}} + \chi \bar{\bar{a}}))}{v'(v^{-1}(\bar{\bar{m}} + \chi \bar{\bar{a}}))} - 1\right)\right\},$$

which simplify to

$$i = L(\bar{\bar{m}} + \chi \bar{\bar{a}}). \tag{A.38}$$

For both cases, the price of corporate bonds is given by

$$\psi = \beta(1 + \chi i).$$

Note that $\bar{m} + \chi \bar{a}$ is the amount of liquidity that consumers would decide to bring to the DM when their liquidity position will be the shorter side of the bargaining constraints only if they trade with a firm that borrows from a bank, and that $\bar{\bar{m}} + \chi \bar{\bar{a}}$ is the amount of liquidity that consumers would decide to bring to the DM when their liquidity position will always be the shorter side of the bargaining constraints whether a firm they meet finances through borrowing from a bank or issuing corporate bonds. By comparing (A.37) and (A.38), we see that $\bar{m} + \chi\bar{a} < \bar{\bar{m}} + \chi\bar{\bar{a}}$.

There are three cases depending on the relative size of $v(\psi\bar{A})$, $\bar{m} + \chi\bar{a}$, and $\bar{\bar{m}} + \chi\bar{\bar{a}}$ given i. Define $\bar{\imath}$ and $\bar{\bar{\imath}}$ as follows:

$$
\begin{aligned}
\bar{\imath} &\equiv \frac{(1-\lambda)(1-\beta)\theta}{1-\theta+(1-\lambda)\beta\theta\chi}, \\
\bar{\bar{\imath}} &\equiv \frac{(1-\beta)\theta}{1-\theta+\beta\theta\chi}.
\end{aligned}
$$

The first case is when $i \leq \bar{\imath}$ and $v(\psi\bar{A}) \leq \bar{m} + \chi\bar{a} < \bar{\bar{m}} + \chi\bar{\bar{a}}$. This is when the price of corporate bonds is not high enough for firms to raise enough funds to fully satisfy the consumer's demand, $\bar{m} + \chi\bar{a}$. Hence, the firms that are borrowing from a bank and thus can satisfy the consumer's demand are at the margin of the consumer's decision on how much liquidity to bring to the DM. The second case is when $\bar{\imath} < i \leq \bar{\bar{\imath}}$ and $\bar{m}+\chi\bar{a} < v(\psi\bar{A}) \leq \bar{\bar{m}}+\chi\bar{\bar{a}}$. This is when the price of corporate bonds is high enough for firms to raise enough funds to satisfy $\bar{m} + \chi\bar{a}$, but not enough to satisfy $\bar{\bar{m}} + \chi\bar{\bar{a}}$. When this is the case, a consumer will bring liquidity that is just enough to purchase $\psi\bar{A}$ amount of the DM goods, and the consumer will be on the shorter side of the bargaining whether she meets a firm borrowing from a bank and a firm issuing corporate bonds. The third case is when $\bar{\bar{\imath}} < i$ and $\bar{m} + \chi\bar{a} < \bar{\bar{m}} + \chi\bar{\bar{a}} \leq v(\psi\bar{A})$. This is when the price of corporate bonds is high enough to satisfy $\bar{\bar{m}} + \chi\bar{\bar{a}}$. In this case, a consumer will decide how much liquidity to bring to the DM considering both the firms that are borrowing from a bank and the firms that are issuing corporate bonds at the same margin. The firms with access to the corporate bond market will issue corporate bonds just enough to satisfy $\bar{\bar{m}} + \chi\bar{\bar{a}}$.[21]

The following assumption ensures $\psi < 1$ so that borrowing through the corporate bond market is costly and that the bond supply function is

[21] For each given i, there are more equilibria other than those described above. The most trivial one is when no one brings anything, thinking that everyone else will bring nothing. Although this belief can be consistent in equilibrium, however, such an equilibrium is not Pareto efficient. Here I consider only the Pareto efficient equilibrium for each i.

well-defined.

Assumption 2. $i < \dfrac{1-\beta}{\beta\chi}$.

The equilibrium is defined as below.

Definition 2. *A steady state equilibrium of the economy corresponds to a constant sequence* $(q_L, q_B, m, a, A, \psi, k_\ell, r_\ell)$*, where* q_L *is the DM goods traded between a consumer and a firm that finances through borrowing from a bank,* q_B *is the DM goods traded between a consumer and a firm that finances through issuing corporate bonds,* m *is the consumer's real balance holdings,* a *is the consumer's corporate bond holdings,* A *is the supply of corporate bonds issued by firms,* ψ *is the price of corporate bonds,* k_ℓ *is the size of a loan that a bank lends to a firm, and* r_ℓ *is the real lending rate of loans. Under Assumption 2,* (q_L, q_B) *satisfy:*

For $i \leq \bar{\iota}$*,*

$$q_L = v^{-1}\left(L^{-1}\left(\frac{i}{1-\lambda}\right)\right), \tag{A.39}$$

$$q_B = (u')^{-1}\left(\frac{1-\beta(1+\chi i)}{\beta(1+\chi i)(1-\theta)} + 1\right), \tag{A.40}$$

for $\bar{\iota} < i \leq \bar{\bar{\iota}}$*,*

$$q_L = q_B = (u')^{-1}\left(\frac{1-\beta(1+\chi i)}{\beta(1+\chi i)(1-\theta)} + 1\right), \tag{A.41}$$

and for $\bar{\bar{\iota}} < i$*,*

$$q_L = q_B = v^{-1}(L^{-1}(i)). \tag{A.42}$$

(m, a, A, ψ) *satisfy*

$$\psi = \beta(1+\chi i),$$
$$A = q_B/\psi,$$

$$a = \lambda A,$$
$$m = v(q_L) - \chi a,$$

and (k, r_ℓ) *satisfy*

$$k = q_L = v^{-1}(m + \chi a),$$
$$r_\ell = \frac{\eta(1-\theta)(u(k) - k)}{k},$$

where

$$v(\cdot) = (1-\theta)u(\cdot) + \theta\,\cdot\,, \quad v'(\cdot) > 0,$$
$$L(\cdot) = u'(v^{-1}(\cdot))/v'(v^{-1}(\cdot)) - 1, \quad L'(\cdot) < 0.$$

A.3.1 Optimal Monetary Policy

Among $i \leq \bar{\imath}$, the welfare-maximizing nominal policy rate depends on the relative size of $(1-\lambda) \cdot \partial(u(q_L) - q_L)/\partial i < 0$ and $\lambda \cdot \partial(u(q_B) - q_B)/\partial i > 0$. When neither λ nor χ is large, the latter force is not so large that the welfare-maximizing policy rate satisfying $\partial \mathcal{W}/\partial i = 0$ exists in the interior. When either λ or χ is large, the latter force becomes so large that the welfare-maximizing policy rate exists on the right boundary at $i = \bar{\imath}$. In addition, note that when $\bar{\imath} < i \leq \bar{\bar{\imath}}$, $\partial \mathcal{W}/\partial i > 0$ as can be seen from (A.41), that when $\bar{\bar{\imath}} \leq i$, $\partial \mathcal{W}/\partial i < 0$ as can be seen from (A.42), and therefore that among $i > \bar{\imath}$, $i = \bar{\bar{\imath}}$ maximizes the welfare. These together imply that when neither λ nor χ is large, there will be a welfare-maximizing policy rate that is less than $\bar{\imath}$, and that when either λ or χ is large, the welfare-maximizing policy rate will be $\bar{\bar{\imath}}$. Figures A.1 and A.2 illustrate these observations. Figures A.3 (for small λ and small χ), A.4 (for large λ and small χ) and A.5 (for small λ and large χ) show the effect of the nominal policy rate on the aggregate variables: the welfare, the amount of external financing through bonds and loans, the bond premium, the real lending rate, and the average output. In all figures, there are two kinks, and the first and the second correspond to $i = \bar{\imath}$ and $i = \bar{\bar{\imath}}$, respectively. Exceptions are the figures for the amount of external financing through issuing corporate bonds that display only one kink, which corresponds to $i = \bar{\bar{\imath}}$ as can be seen from (A.40), (A.41), and (A.42). In all figures, we can see that the Friedman rule, $i \to 0$, is not optimal. Also, notice that the relationship between the welfare and the average output is non-monotone, due to the heterogeneity in the effect of the nominal policy rate across the firms using different financing sources. Figure A.6 illustrates this point.

B Appendix for Empirical Analysis

B.1 Data

For the macro time-series data, I use data from the Federal Reserve Economic Data (FRED). The 1-year and 2-year policy rates are the 1-Year and 2-year Treasury Constant Maturity Rates (FRED series `GS1` and `GS2`). Industrial production is Industrial Production Index (FRED series `INDPRO`). Consumer Price Index is Consumer Price Index for All Urban Consumers (FRED series `CPIAUCSL`). The nominal bank loan rate is Bank Prime Loan Rate (FRED series `mprime`). The expected inflation rate is the 5-Year Forward Inflation Expectation Rate (FRED series `T5YIFRM`). The excess bond premium is constructed by Gilchrist and Zakrajšek (2012) and updated by Favara, Gilchrist, Lewis, and Zakrajšek at https://www.federalreserve.gov/econresdata/notes/feds-notes/2016/files/ebp_csv.csv. The bid-ask spreads and the trading volume of corporate bonds are calculated from the Transaction Reporting and Compliance Engine (TRACE). Monetary policy shocks are the high-frequency identified surprises from Federal Funds futures around the Federal Open Market Committee policy announcements constructed by Gertler and Karadi (2015), and the series is updated until 2016:12 by Jarociński and Karadi (2020).

B.2 Sensitivity Analysis

B.2.1 Corporate Bond Premium and Monetary Policy Shocks

In this section, I check the robustness of the results in Section 4.2.

Factor-augmented LP-IV. If there are any other variables that are correlated with the shocks, including those variables could increase the precision of the estimation. Following the suggestion by Stock and Watson (2018), I add to the LP-IV specification lags of the principal components, computed from the FRED-MD database by McCracken and Ng (2016). The results are shown in Figure B.1. The results with the additional controls are consistent with (and stronger than) the results from the basic specification.

Test for a structural break. To formally test the structural break induced by the introduction of the TRACE, I interact all the regressors in LP-IV and factor-augmented LP-IV with the post-TRACE year dummy. Figure B.2 shows the base and the post-TRACE responses of the excess bond premium to a one-percent increase in the nominal policy rate estimated using LP-IV, and Figure B.3 estimates the responses using factor-augmented LP-IV. The results show that an increase in the nominal policy rate has a statistically significant negative impact during the post-TRACE period in medium and long horizons. The null hypothesis of no structural break is rejected for all horizons with p-value 0 for both LP-IV and factor-augmented LP-IV.

Zero lower bound. One concern is that the sample period, in particular the post-TRACE period, includes the Great Recession, during which the short-term interest rate reached the zero lower bound. However, such a concern is not so worrisome given that the 1-year Treasury rate (the policy rate in the basic specifications) remained positive during the whole sample period. Swanson and Williams (2014) provide evidence that the 1-year Treasury rate was indeed not constrained by the zero lower bound. The authors show that the 2-year rate was even less constrained, and I further address the concern regarding the zero lower bound by showing that the results are robust to using the 2-year Treasury rate, instead of the 1-year rate. The results are shown in Figure B.4, B.5 and B.6 using LP-IV, factor-augmented LP-IV, and SVAR-IV, respectively. All results are consistent with those using the 1-year rate.

Estimates during the shorter period around the introduction of the TRACE. Another concern over the fact that the post-TRACE period includes the Great Recession is that it might have been a very different period in terms of the effectiveness of monetary policy, compared to the pre-TRACE period. Swanson and Williams (2014) make the case that this is not really a concern, providing evidence that monetary policy was as effective as usual during the crisis period. I further address the concern by focusing on a shorter window around the introduction of the TRACE, excluding the crisis period. Specifically, I consider 1997:11–2003:2 for the pre-TRACE period and 2003:3–2008:6 for the post-

TRACE period. The results using LP-IV are shown in Figure B.7, and those using SVAR-IV are shown in Figures B.8. All results remain consistent: all figures show the contrasting responses of the excess bond premium across the pre- and the post-TRACE periods.

Alternative breakpoints. The results are robust also to using alternative breakpoints, such as 2002:7 (when the TRACE was first executed), 2003:4 (when it was applied to additional 120 selected BBB-rated bonds), 2005:2 (when the it was applied to all but newly issued or lightly traded bonds), or 2006:1 (when the it was applied to all publicly issued bonds).

B.2.2 Liquidity Premium and Monetary Policy Shocks

In this section, I check the robustness of the results in Section 4.3. First, I augment the LP-IV specification with the macro factors from the FRED-MD database by McCracken and Ng (2016), and the results, shown in Figure B.9, are overall consistent: while the response of the trading volume is less clear, the response of the bid-ask spreads is consistent with (and stronger than) the results from the basic specification. To address the concern regarding the zero lower bound during the Great Recession, I redo the exercise with the 2-year Treasury rate instead of the 1-year rate (the results are shown in Figures B.10 and B.11) and using alternative breakpoints (see Online Appendix B.2.1), and all results remain consistent.

B.2.3 Bank Loan Rates and Monetary Policy Shocks

In this section, I check the robustness of the results in Section 4.4. First, I augment the LP-IV specification with the macro factors from the FRED-MD database by McCracken and Ng (2016), and the results, shown in Figure B.12, are consistent with those from the basic specification. To address the concern regarding the zero lower bound during the Great Recession, I redo the exercise with the 2-year Treasury rate instead of the 1-year rate (the results are shown in Figure B.13) and using alternative breakpoints (see Online Appendix B.2.1), and all results remain consistent.

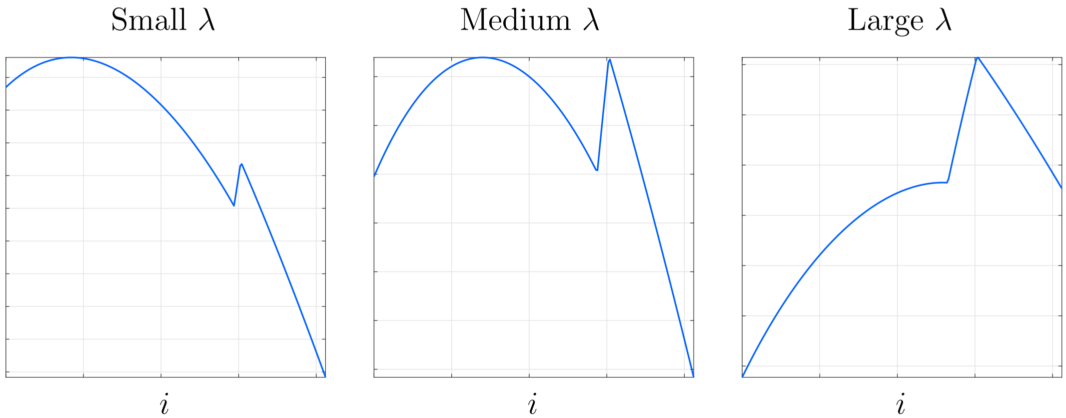

Figure A.1: The effect of monetary policy on the welfare of the economy for different values of λ. Parameter values: Log utility; $\beta = 0.97$; $\lambda = 0.1$ (left), 0.165 (middle), 0.35 (right); $\chi = 0.15$; $\eta = 0.8$; $\theta = 0.95$.

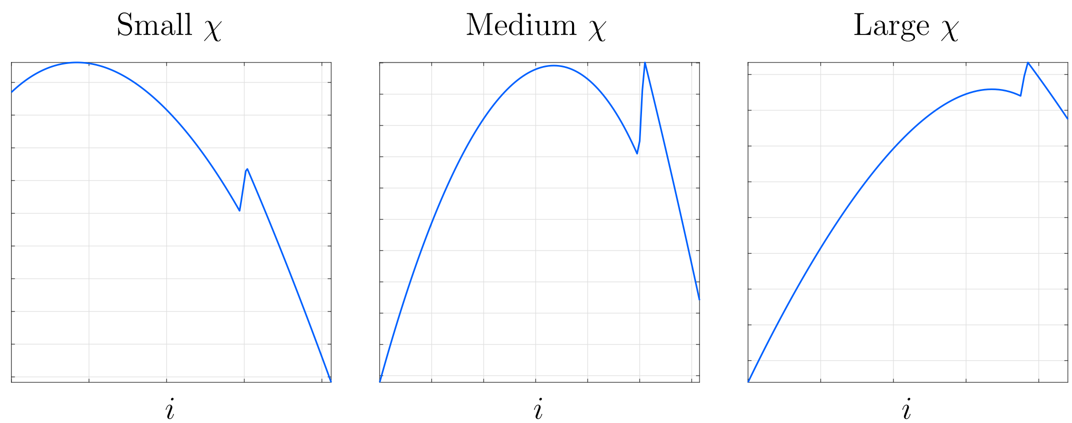

Figure A.2: The effect of monetary policy on the welfare of the economy for different values of χ. Parameter values: Log utility; $\beta = 0.97$; $\lambda = 0.1$; $\chi = 0.15$ (left), 0.25 (middle), 0.35 (right); $\eta = 0.8$; $\theta = 0.95$.

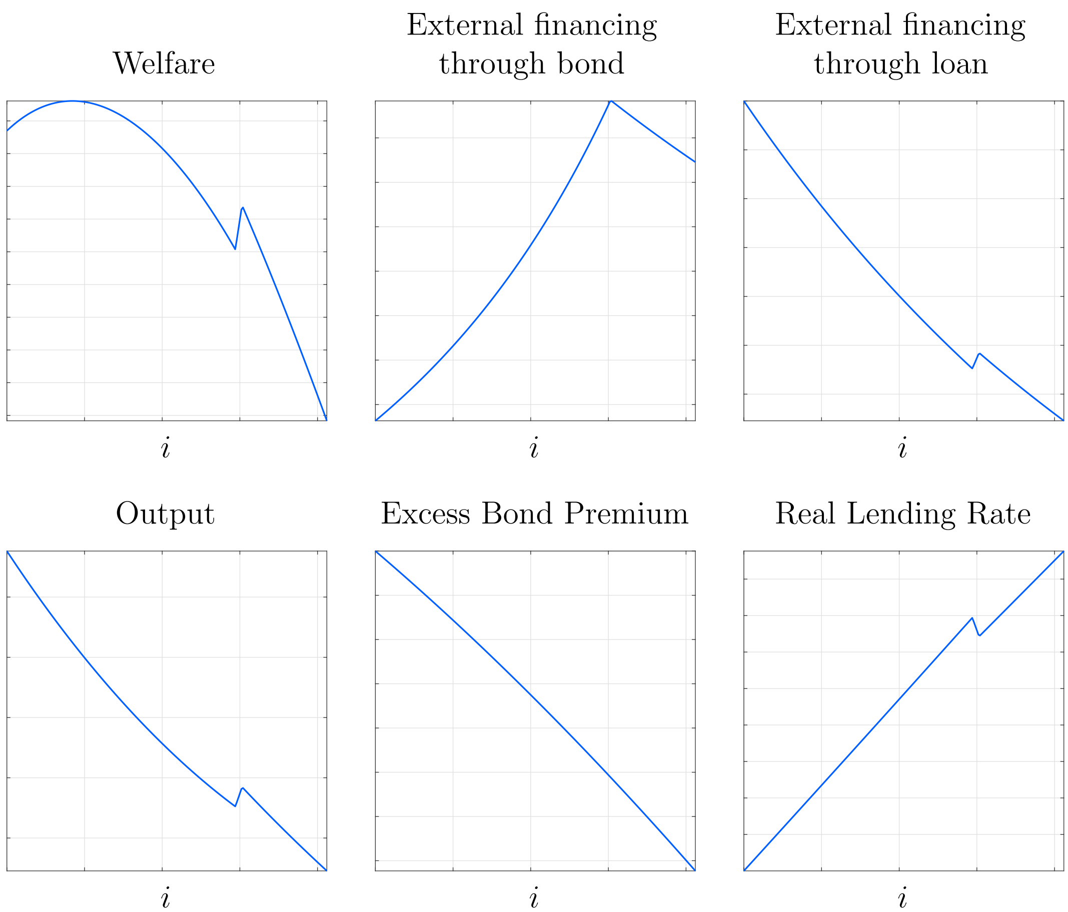

Figure A.3: The effect of monetary policy, when the fraction of the firms with access to the corporate bond market is small (small λ) and the corporate bond secondary market is not so liquid (small χ). Parameter values: Log utility; $\beta = 0.97$; $\lambda = 0.1$; $\chi = 0.15$; $\eta = 0.8$; $\theta = 0.95$.

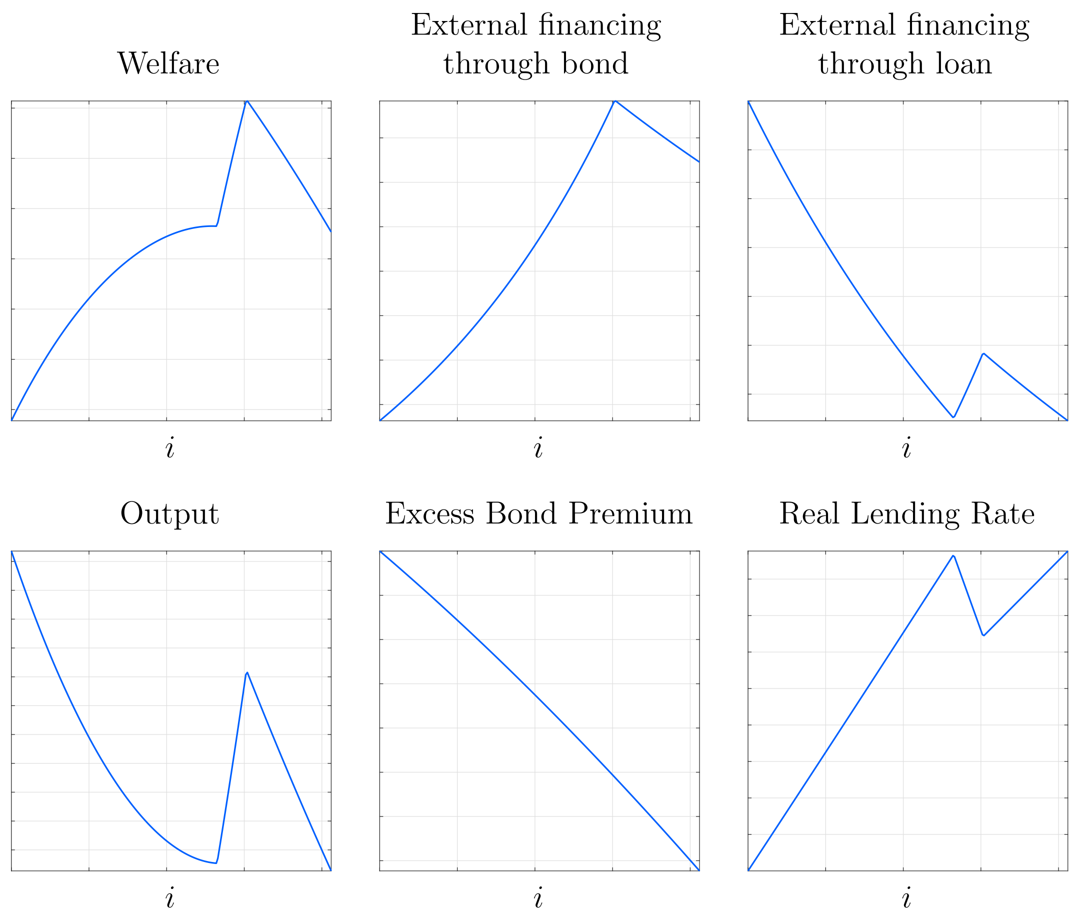

Figure A.4: The effect of monetary policy, when the fraction of the firms with access to the corporate bond market is large (large λ) and the corporate bond secondary market is not so liquid (small χ). Parameter values: Log utility; $\beta = 0.97$; $\lambda = 0.35$; $\chi = 0.15$; $\eta = 0.8$; $\theta = 0.95$.

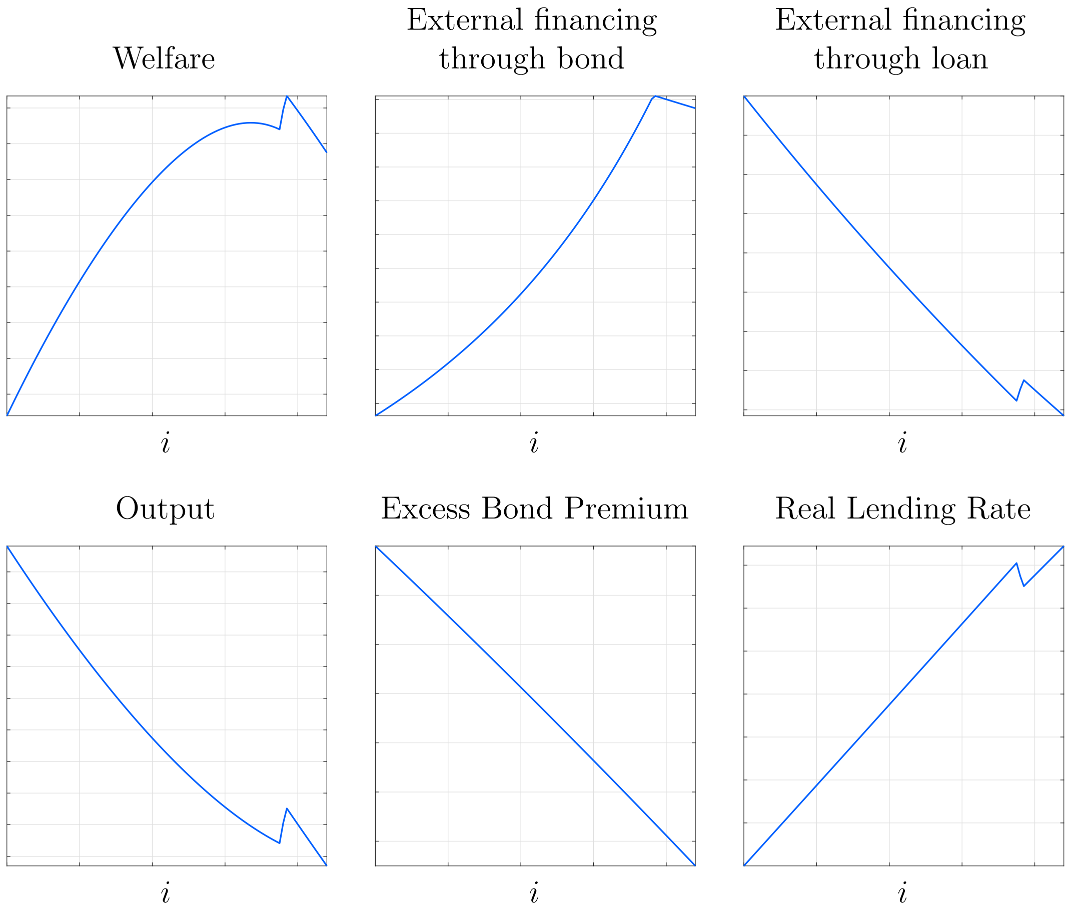

Figure A.5: The effect of monetary policy, when the fraction of the firms with access to the corporate bond market is small (small λ) and the corporate bond secondary market is highly liquid (large χ). Parameter values: Log utility; $\beta = 0.97$; $\lambda = 0.1$; $\chi = 0.35$; $\eta = 0.8$; $\theta = 0.95$.

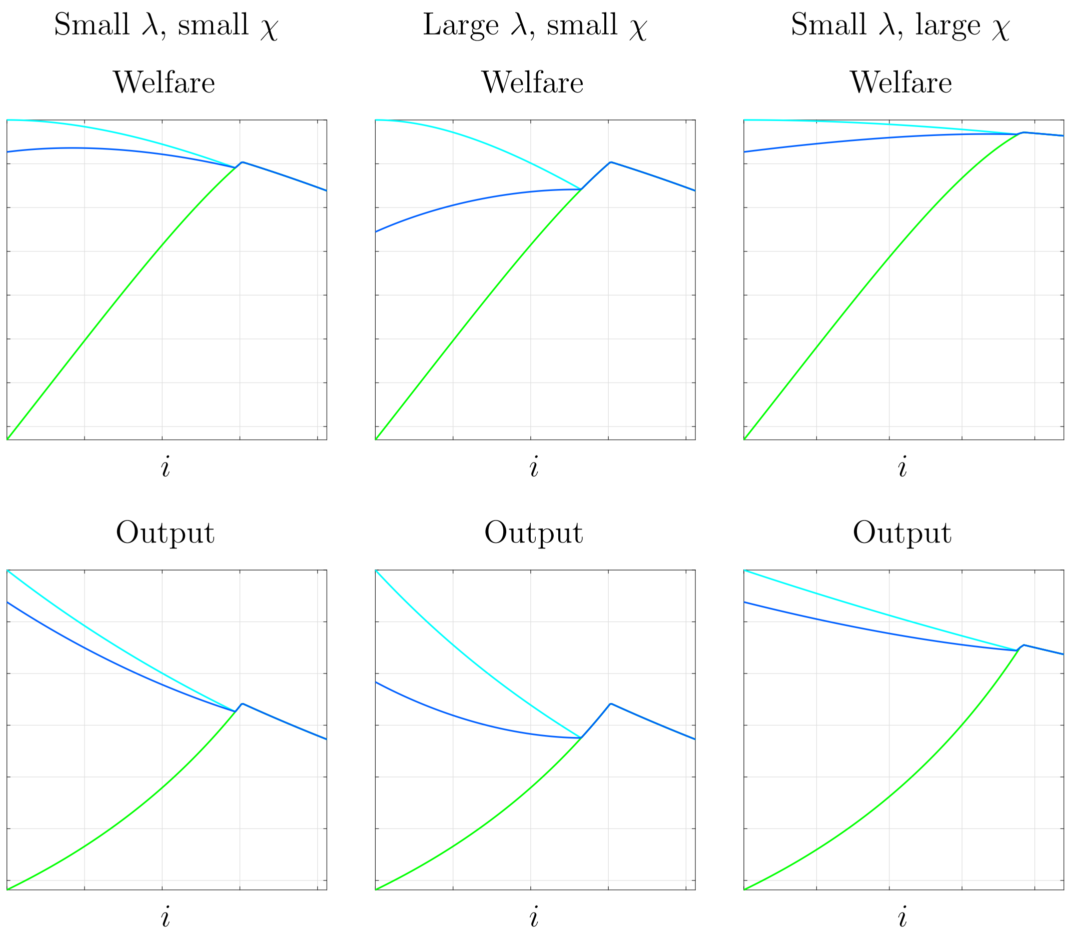

Figure A.6: The effect of monetary policy on the welfare and the output of the economy for small λ (the fraction of the firms with access to the corporate bond market) and small χ (the liquidity of the corporate bond secondary market) (left), large λ and small χ (middle), and small λ and large χ (right). For each figure for the welfare, the top line (in bright blue) plots $u(q_L) - q_L$, the bottom line (in bright green) plots $u(q_B) - q_B$, and the middle line (in blue) plots $(1-\lambda)[u(q_L) - q_L] + \lambda[u(q_B) - q_B]$. For each figure for the output, the top line (in bright blue) plots q_L, the bottom line (in bright green) plots q_B, and the middle line (in blue) plots $(1-\lambda)q_L + \lambda q_B$. For the parameter values used, refer to the notes in Figure A.3 for small λ and small χ, Figure A.4 for large λ and small χ, and Figure A.5 for small λ and large χ.

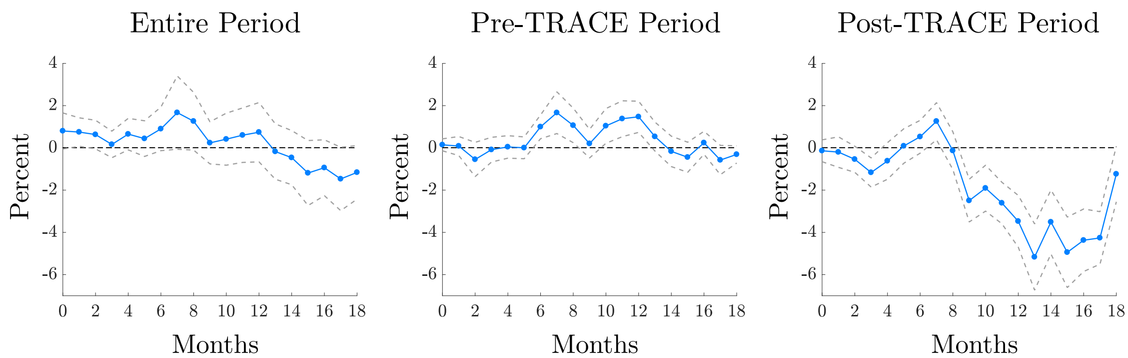

Figure B.1: The response of the excess bond premium to a one-percent increase in the nominal policy rate for different sample periods, estimated using Factor-Augmented LP-IV with unit effect normalization. Sample period: 1990:2–2016:12; pre-TRACE period: 1990:2–2003:2; post-TRACE period: 2003:3–2016:12. The 12-month lags of the four main variables and the FRED-MD factors and the 4-month lags of the instrument are included. The standard errors are calculated using the Newey-West heteroskedastic and autocorrelation consistent standard errors. The dashed lines are the 95% confidence interval. For the entire period, the first-stage F-statistic is 19.1, and the heteroscedasticity-robust first-stage F-statistic is 22.3. For the pre-TRACE period, the first-stage F-statistic is 6, and the heteroscedasticity-robust first-stage F-statistic is 21.4. For the post-TRACE period, the first-stage F-statistic is 10.7, and the heteroscedasticity-robust first-stage F-statistic is 20.4.

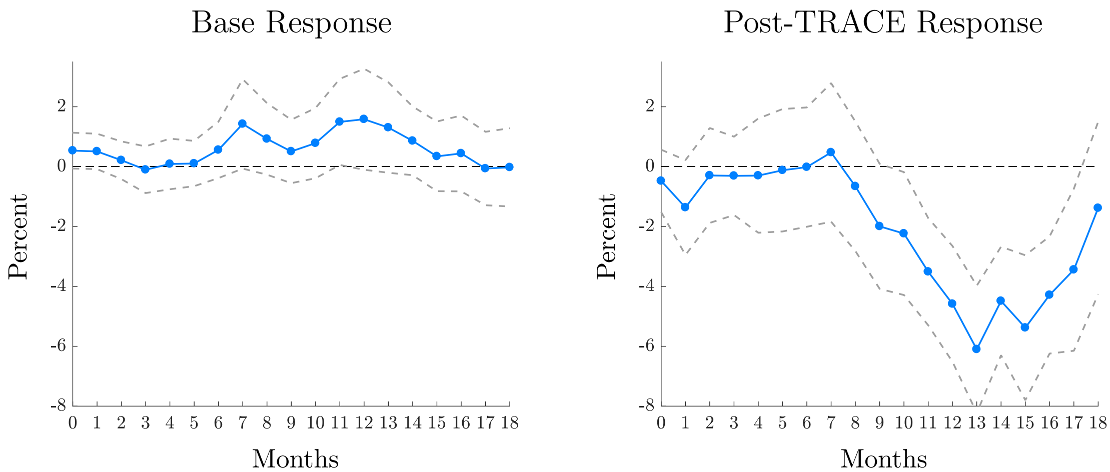

Figure B.2: The base and post-TRACE responses of the excess bond premium to a one-percent increase in the nominal policy rate, estimated using LP-IV with unit effect normalization. Sample period: 1990:2–2016:12; post-TRACE period: 2003:3–2016:12. The 12-month lags of the four main variables and the 4-month lags of the instrument are included. Standard errors are calculated using the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap. The dashed lines are the 95% confidence interval. The first-stage F-statistic is 15, and the heteroscedasticity-robust first-stage F-statistic is 10.7.

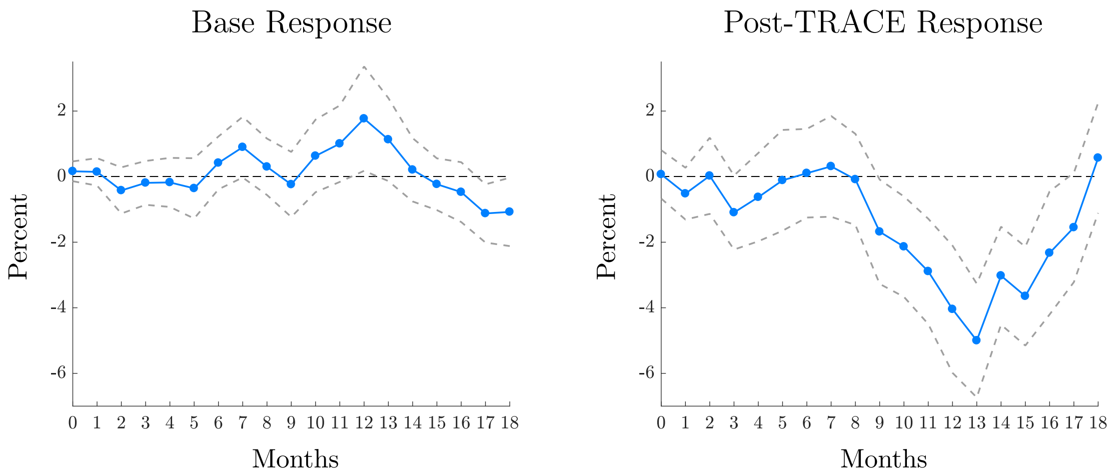

Figure B.3: The base and post-TRACE responses of the excess bond premium to a one-percent increase in the nominal policy rate, estimated using Factor-Augmented LP-IV with unit effect normalization. Sample period: 1990:2–2016:12; post-TRACE period: 2003:3–2016:12. The 12-month lags of the four main variables and the FRED-MD factors and the 4-month lags of the instrument are included. The standard errors are calculated using the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap. The dashed lines are the 95% confidence interval. The first-stage F-statistic is 13.7, and the heteroscedasticity-robust first-stage F-statistic is 18.6.

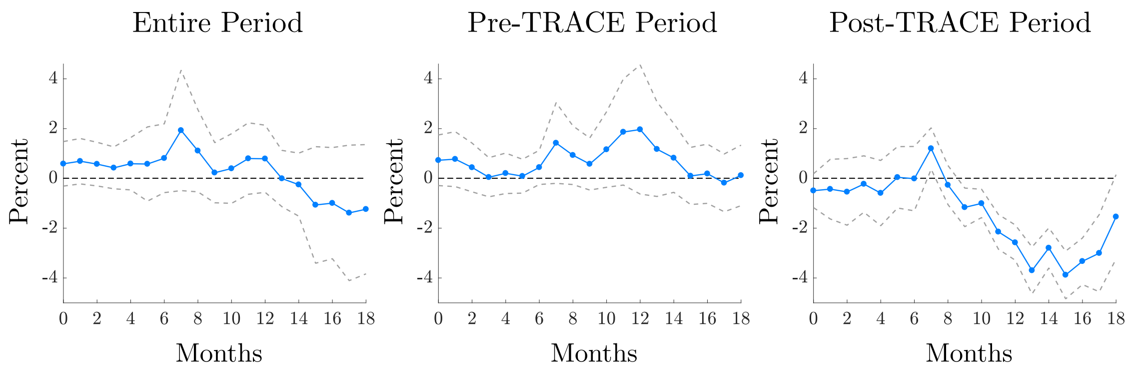

Figure B.4: The response of the excess bond premium to a one-percent increase in the nominal policy rate for different sample periods, estimated using LP-IV with unit effect normalization. Sample period: 1990:2–2016:12; pre-TRACE period: 1990:2–2003:2; post-TRACE period: 2003:3–2016:12. The 12-month lags of the four main variables (2-year Treasury constant maturity rate, industrial production, inflation rate, and the excess bond premium) and the 4-month lags of the instrument are included. The standard errors are calculated using the Newey-West heteroskedastic and autocorrelation consistent standard errors. The dashed lines are the 95% confidence interval. The first-stage F-statistic and the heteroscedasticity-robust first-stage F-statistic are 14.2 and 8.3 for the entire period, 7.7 and 9 for the pre-TRACE period, and 10.6 and 12.7 for the post-TRACE period.

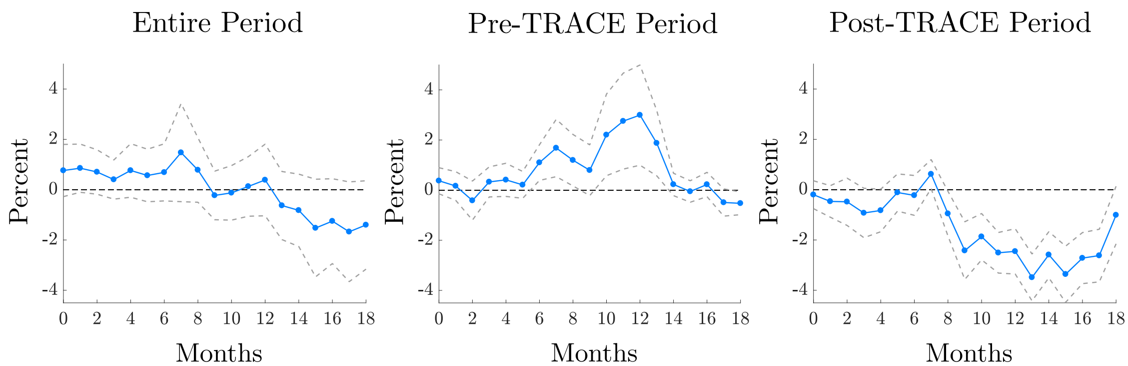

Figure B.5: The response of the excess bond premium to a one-percent increase in the nominal policy rate for different sample periods, estimated using Factor-Augmented LP-IV with unit effect normalization. Sample period: 1990:2–2016:12; pre-TRACE period: 1990:2–2003:2; post-TRACE period: 2003:3–2016:12. The 12-month lags of the four main variables (2-year Treasury constant maturity rate, industrial production, inflation rate, and the excess bond premium) and the FRED-MD factors and the 4-month lags of the instrument are included. The standard errors are calculated using the Newey-West heteroskedastic and autocorrelation consistent standard errors. The dashed lines are the 95% confidence interval. The first-stage F-statistic and the heteroscedasticity-robust first-stage F-statistic are 12.5 and 13 for the entire period, 3.2 and 11 for the pre-TRACE period, and 12.2 and 23 for the post-TRACE period.

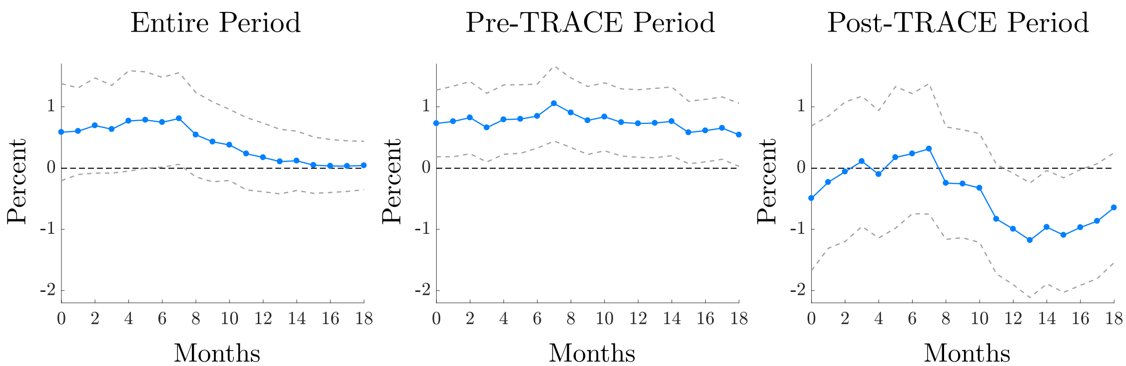

Figure B.6: The response of the excess bond premium to a one-percent increase in the nominal policy rate for different sample periods, estimated using SVAR-IV with unit effect normalization. Sample period: 1990:2–2016:12; pre-TRACE period: 1990:2–2003:2; post-TRACE period: 2003:3–2016:12. The 12-month lags of the four main variables (2-year Treasury constant maturity rate, industrial production, inflation rate, and the excess bond premium) and the 4-month lags of the instrument are included. The standard errors are calculated using the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap. The dashed lines are the 95% confidence interval. The first-stage F-statistic and the heteroscedasticity-robust first-stage F-statistic are 14.2 and 8.3 for the entire period, 7.7 and 9 for the pre-TRACE period, and 10.6 and 12.7 for the post-TRACE period.

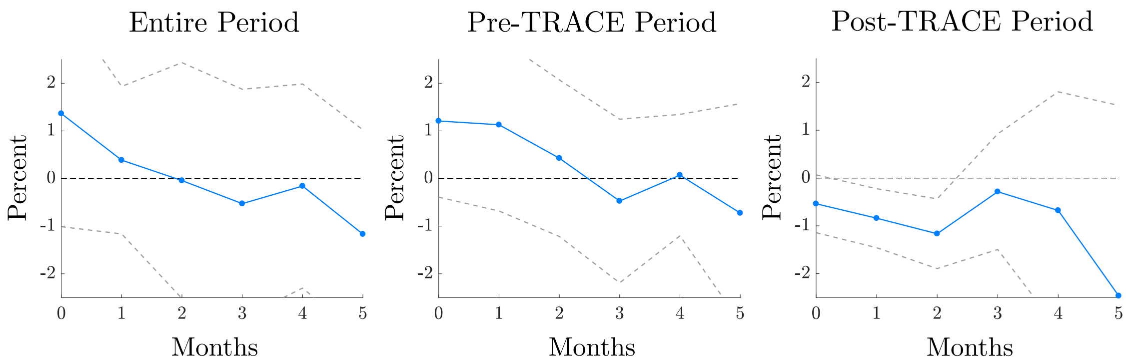

Figure B.7: The response of the excess bond premium to a one-percent increase in the nominal policy rate for different sample periods, estimated using LP-IV with unit effect normalization, during the short period around the introduction of the TRACE. Sample period: 1997:11–2008:6; pre-TRACE period: 1997:11–2003:2; post-TRACE period: 2003:3–2008:6. The 4-month lags of the four main variables and the 2-month lags of the instrument are included. The standard errors are calculated using the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap. The dashed lines are the 95% confidence interval. The first-stage F-statistic and the heteroscedasticity-robust first-stage F-statistic are 2.5 and 1.7 for the entire period, 2.9 and 2.7 for the pre-TRACE period, and 4.2 and 5.6 for the post-TRACE period.

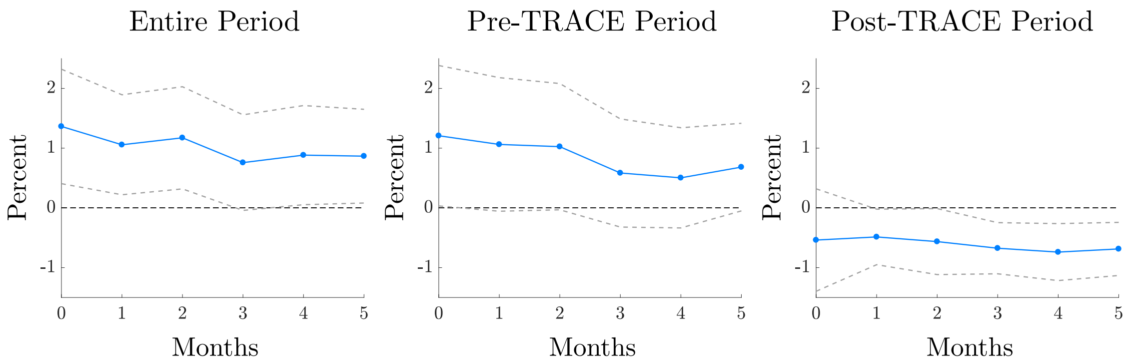

Figure B.8: The response of the excess bond premium to a one-percent increase in the nominal policy rate for different sample periods, estimated using SVAR-IV with unit effect normalization, during the short period around the introduction of the TRACE. Sample period: 1997:11–2008:6; pre-TRACE period: 1997:11–2003:2; post-TRACE period: 2003:3–2008:6. The 4-month lags of the four main variables and the 2-month lags of the instrument are included. The standard errors are calculated using the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap. The dashed lines are the 95% confidence interval. The first-stage F-statistic and the heteroscedasticity-robust first-stage F-statistic are 2.5 and 1.7 for the entire period, 2.9 and 2.7 for the pre-TRACE period, and 4.2 and 5.6 for the post-TRACE period.

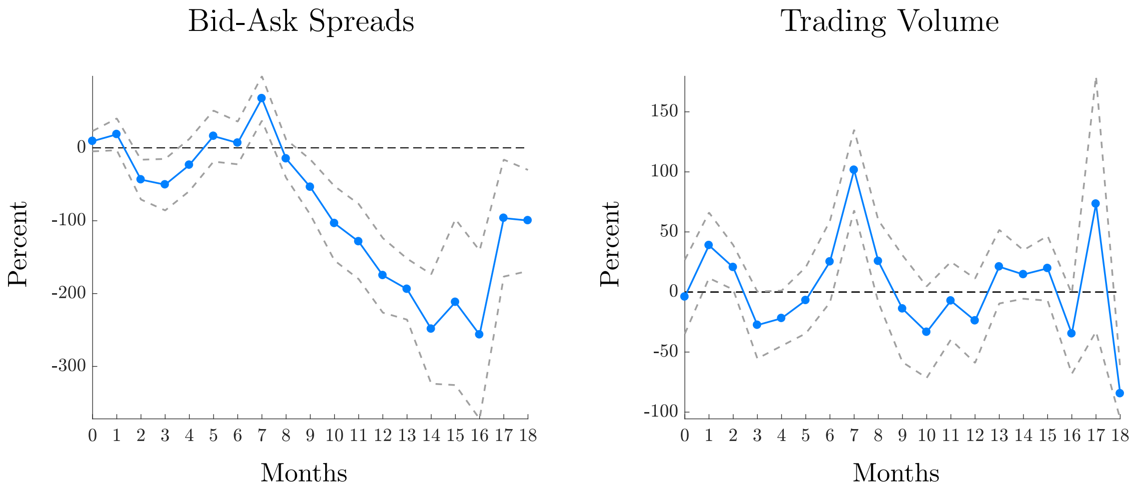

Figure B.9: The response of the bid-ask spreads and the trading volume of corporate bonds to a one-percent increase in the nominal policy rate during the post-TRACE period, estimated using Factor-Augmented LP-IV with unit effect normalization. Sample period: 2003:3–2016:12. The 12-month lags of the six main variables and the FRED-MD factors and the 4-month lags of the instrument are included. The standard errors are calculated using the Newey-West heteroskedastic and autocorrelation consistent standard errors. The dashed lines are the 95% confidence interval. For the bid-ask spreads, the first-stage F-statistic is 5.6, and the heteroscedasticity-robust first-stage F-statistic is 25.9. For the trading volume, the first-stage F-statistic is 5.5, and the heteroscedasticity-robust first-stage F-statistic is 27.5.

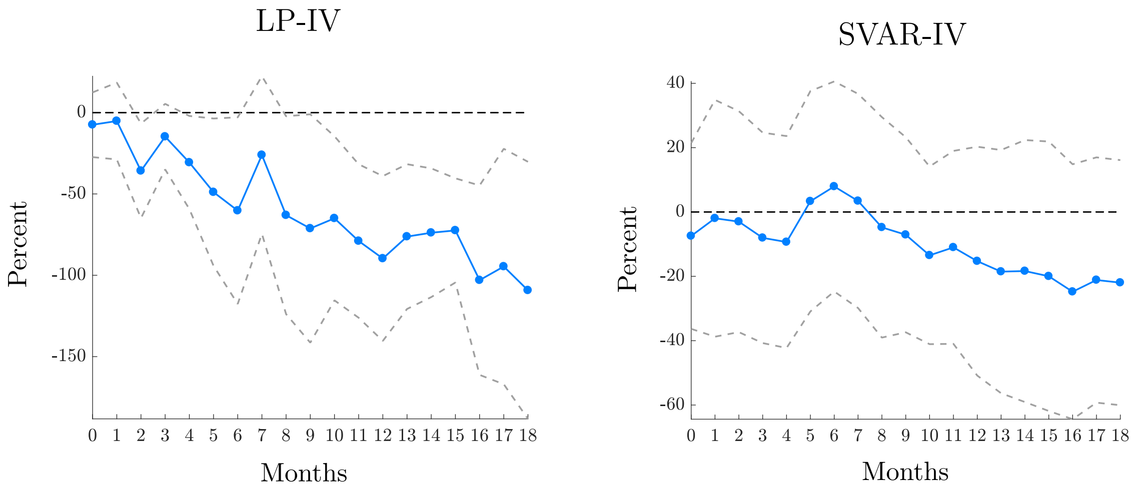

Figure B.10: The response of the bid-ask spreads of corporate bonds to a one-percent increase in the nominal policy rate during the post-TRACE period, estimated using LP-IV (left) and SVAR-IV (right) with unit effect normalization. Sample period: 2003:3–2016:12. The 12-month lags of the six main variables (2-year Treasury constant maturity rate, industrial production, inflation rate, the excess bond premium, the bid-ask spreads, and inflation expectation) and the 4-month lags of the instrument are included. The standard errors are calculated using the Newey-West heteroskedastic and autocorrelation consistent standard errors for LP-IV and the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap for SVAR-IV. The dashed lines are the 95% confidence interval. The first-stage F-statistic is 9, and the heteroscedasticity-robust first-stage F-statistic is 15.6.

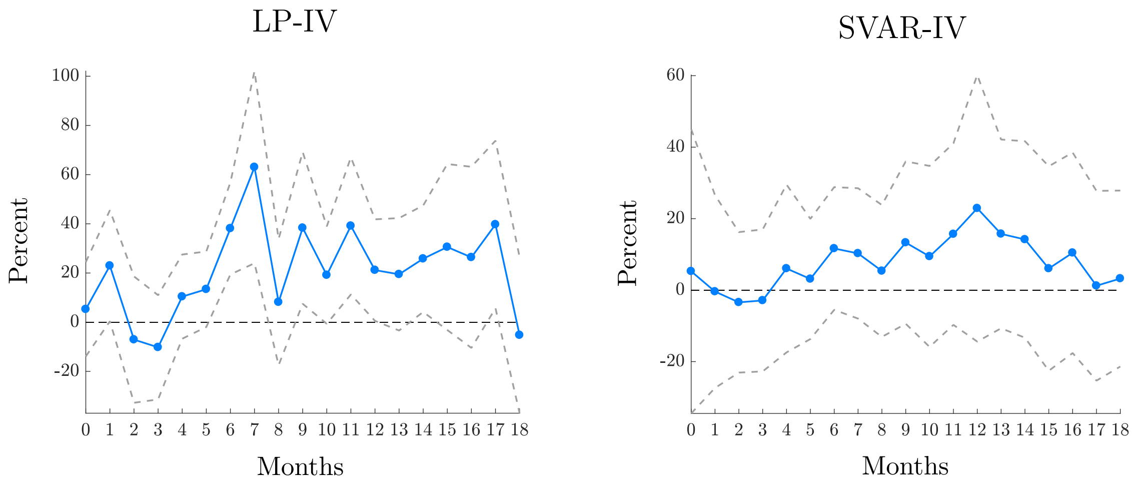

Figure B.11: The response of the trading volume of corporate bonds to a one-percent increase in the nominal policy rate during the post-TRACE period, estimated using LP-IV (left) and SVAR-IV (right) with unit effect normalization. Sample period: 2003:3–2016:12. The 12-month lags of the six main variables (2-year Treasury constant maturity rate, industrial production, inflation rate, the excess bond premium, the trading volume, and inflation expectation) and the 4-month lags of the instrument are included. The standard errors are calculated using the Newey-West heteroskedastic and autocorrelation consistent standard errors for LP-IV and the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap for SVAR-IV. The dashed lines are the 95% confidence interval. The first-stage F-statistic is 11.5, and the heteroscedasticity-robust first-stage F-statistic is 21.

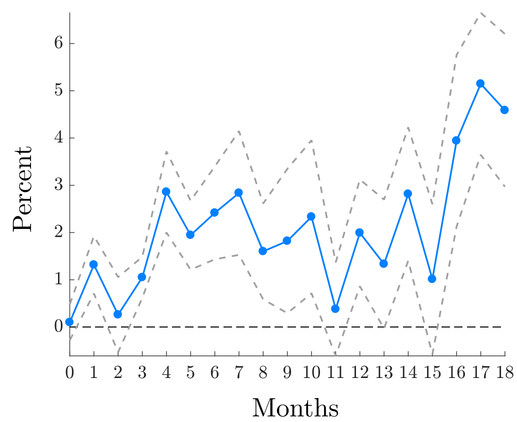

Figure B.12: The response of the real loan rate to a one-percent increase in the nominal policy rate during the post-TRACE period, estimated using Factor-Augmented LP-IV with unit effect normalization. Sample period: 2003:3–2016:12. The 12-month lags of the five main variables and the FRED-MD factors and the 4-month lags of the instrument are included. The standard errors are calculated using the Newey-West heteroskedastic and autocorrelation consistent standard errors. The dashed lines are the 95% confidence interval. The first-stage F-statistic is 6, and the heteroscedasticity-robust first-stage F-statistic is 14.5.

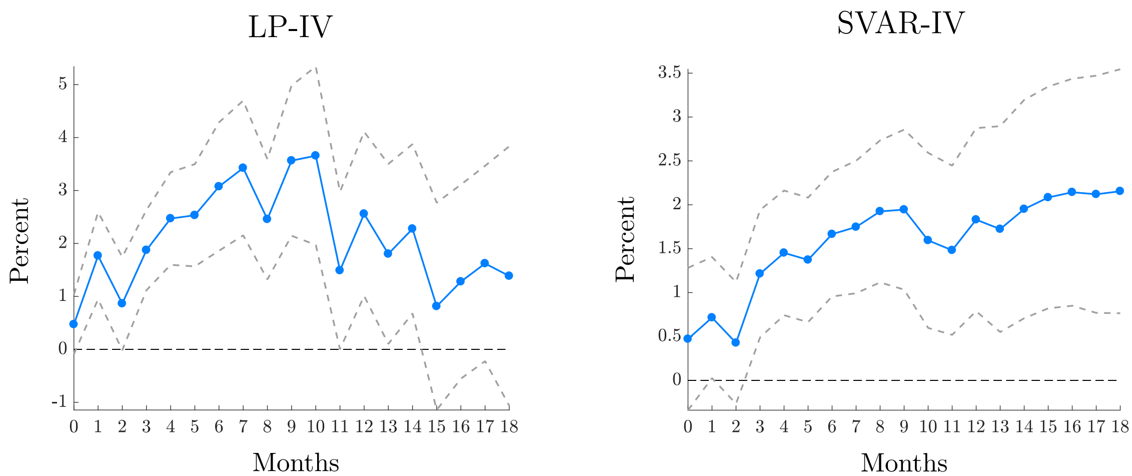

Figure B.13: The response of the real loan rate to a one-percent increase in the nominal policy rate during the post-TRACE period, estimated using LP-IV (left) and SVAR-IV (right) with unit effect normalization. Sample period: 2003:3–2016:12. The 12-month lags of the five main variables (2-year Treasury constant maturity rate, industrial production, inflation rate, the excess bond premium, and the real loan rate) and the 4-month lags of the instrument are included. The standard errors are calculated using the Newey-West heteroskedastic and autocorrelation consistent standard errors for LP-IV and the sample variances computed from 1,000 draws from a parametric Gaussian bootstrap for SVAR-IV. The dashed lines are the 95% confidence interval. The first-stage F-statistic is 8.6, and the heteroscedasticity-robust first-stage F-statistic is 11.7.