BANK OF GREECE
EUROSYSTEM

Working Paper

The credit channel of monetary transmission in the US: Is it a bank lending channel, a balance sheet channel, or both, or neither?

Sophocles N. Brissimis
Michalis-Panayiotis Papafilis

300

JULY 2022

BANK OF GREECE
Economic Analysis and Research Department – Special Studies Division
21, E. Venizelos Avenue
GR-102 50 Athens
Tel: +30210-320 3610
Fax: +30210-320 2432

www.bankofgreece.gr

Published by the Bank of Greece, Athens, Greece

ISSN: 2654-1912 (online)
DOI: https://doi.org/10.52903/wp2022300

THE CREDIT CHANNEL OF MONETARY TRANSMISSION IN THE US: IS IT A BANK LENDING CHANNEL, A BALANCE SHEET CHANNEL, OR BOTH, OR NEITHER?

Sophocles N. Brissimis
University of Piraeus and Bank of Greece

Michalis-Panayiotis Papafilis
University of Piraeus

Abstract

We develop a theoretical framework that extends the Bernanke and Blinder (1988) model to incorporate imperfect substitution between internal and external finance of firms in order to study the operation of both the bank lending and the balance sheet channels of monetary transmission in the US. Our model is used to quantify the financial accelerator effects due to the operation of these channels. Empirically, we employ multivariate cointegration techniques to identify the equilibrium relationships included in our model, and we provide evidence that only the balance sheet channel is operational for the period before and after the global financial crisis.

Keywords: Monetary transmission mechanism; bank lending channel; balance sheet channel; financial structure; multivariate cointegration

JEL-classifications: C32, C52, E44, E51, E52

Acknowledgements: We are grateful to Nikos Magginas, Thomas Vlassopoulos, Gikas Hardouvelis and Alexandros Bechlioulis for helpful and constructive comments.

Correspondence:
Sophocles N. Brissimis
University of Piraeus and Bank of Greece
Email:sbrisimis@yahoo.gr

1. Introduction

In the traditional "money" view of monetary transmission, exemplified by the simple IS-LM model, monetary policy operates through the liabilities side of bank balance sheets. Through the reserves market or through the supply and demand for money more broadly, monetary transmission through the primary mechanism, which is the interest rate channel, focuses on influencing the real rate of interest and the user cost of capital and, subsequently, firm investment and consumption of durables (Kuttner and Mosser, 2002). The standard interest rate channel, however, fell short of explaining the apparent strength of monetary policy effects on the economy. Thus research moved toward the "credit" view of monetary transmission that builds on the assumption of incomplete markets characterized by imperfect information.

There are two independent channels of monetary transmission that arise as a result of information problems in credit markets (Mishkin, 1995): the bank lending channel and the balance sheet channel, both of which are conduits of the credit channel for monetary transmission. In the case of the bank lending channel, monetary policy is assumed to influence the supply side of the loan market and, given the imperfect substitutability between loans and bonds caused by imperfect information problems, it produces an enhanced effect on aggregate demand and output in the economy. On the other hand, in the case of the balance sheet channel, monetary policy influences the demand side of the loan market by influencing net worth of borrowers that in turn influences demand for loans, given the imperfect substitutability between loans (external finance) and retained earnings (internal finance). Again, through the balance channel, the initial effects of monetary policy on aggregate economic activity are reinforced – under the so-called financial accelerator mechanism (see e.g., Bernanke and Gertler, 1995; Bernanke et al., 1996, 1999; Gertler and Kiyotaki, 2010).

Empirical work to examine the strength of the bank lending and the balance sheet channels looks at various aspects of the workings of these channels; a review of this work is given in Section 2. The findings of this literature confirm that the lending channel is unlikely to be operative in the US, although this channel may still be important for economies that remain relatively more bank-dependent (Bernanke, 2007). In contrast, there is widespread belief that

the balance sheet channel is operative. Nevertheless, our review of Section 2 shows that empirical work on this channel is rather limited in scope, is not generally based on a structural equations model but uses proxies for balance sheet strength in the context of single equation models, and does not attempt any comparison between the two channels. This is not surprising: Bernanke and Gertler (1995) point out to the difficulty in identifying the independent effects by noting that "it is extremely difficult to carry out an empirical test that would conclusively separate the bank lending channel from the balance sheet channel. For this reason, we are more confident in the existence of a credit channel in general than we are in our ability to distinguish sharply between the two mechanisms of the credit channel" (Bernanke and Gertler, 1995, p.42).

In our study we aim to capture both loan demand and supply effects so as to address the identification issue and to examine the operation of the two channels simultaneously. Bernanke and Blinder (1988) provide the necessary theoretical background for our methodological approach – they examine only the operation of the bank lending channel. Here we develop a theoretical framework that is based on the Bernanke and Blinder model, extended to incorporate imperfect substitution between internal and external finance of firms, and thus allowing us to assess both the bank lending and balance sheet channels. Imperfect substitution implies that firms are facing a cost differential when raising finance from different sources and thus make their financial decisions on the basis of their relative financial structure.

The paper seeks to give an answer to a number of interesting questions. What are the conditions for the non-operation of the bank lending and/or the balance sheet channel? Are the basic transmission channels of monetary policy – bank lending, balance sheet and interest rate channels – operational before and after the financial crisis of 2007-2008 in the US? How can we assess the possible magnifying effects of the components of the credit channel after a monetary shift? The findings of this study indeed help us to attain an appreciation of how the operation of the transmission channels that we analyze has affected the potency of monetary policy.

The operation of the bank lending and balance sheet channels in the US is investigated empirically by applying the Johansen multivariate analysis to the model we develop theoretically. In particular, we identify the relationships included in this model as equilibrium

relationships (cointegrating vectors) from a vector error correction (VEC) model by using the methodology developed by Pesaran and Shin (2002) and test appropriate restrictions on estimated cointegrating vectors that pertain to the existence of the bank lending and balance sheet channels. Our analysis shows that if we identify three cointegrating vectors, the bank lending and balance sheet channels will be operative (in addition to the interest rate channel). If two cointegrating vectors are found, this signifies the operation of the balance sheet channel only. Finally, if we find only one cointegration relationship, then none of the two sub-channels of the credit channel is in operation.

Based on our empirical analysis, a structural breakpoint is detected in the fourth quarter of 2008 that coincides with the spread of the US financial crisis around the world. The results of the Johansen test reveal that only two cointegrating vectors are identified in both sub-periods. Thus, it appears that only the interest rate and the balance sheet channels are operational in the whole sample period in the US. There is no evidence for the operation of the bank lending channel in both sub-periods, as we accept the hypothesis that there is perfect asset substitutability for borrowers and banks. This could be justified because of the stronger relationships between banking institutions and financial markets in the last decades, which involved firm funding through alternative financial instruments and reduced credit supply effects after a monetary policy shift. Also, the significant support to the banking system through equity injections, debt guarantees and new loans by the US government at the end of 2008, contributed to limiting the adverse effects of monetary shocks during the crisis period.

Our paper contributes to the existing literature on both components of the credit channel for monetary transmission in a number of respects. First, it sets up a theoretical model extending the Bernanke and Blinder (1988) model to incorporate imperfect substitution between firms' internal and external finance. This permits us to test under what conditions the bank lending and the balance sheet channel operate in monetary transmission. The methodology we follow is to specify a vector error correction model, derive the cointegrating relationships according to this model, and test a number of restrictions that are necessary for the existence of perfect/imperfect asset substitutability. Second, in the context of our model, we derive analytically the amplifying effect of monetary policy shifts through the operation of

the bank lending and the balance sheet channels. The effect of monetary policy on total output is greater when the three transmission channels are in operation simultaneously, relative to the case where the interest rate and the balance sheet channel or only the interest rate channel are operational. Third, the study allows us to examine empirically if the structural changes observed in the financial markets over the last thirty years, the financial deregulation in the banking system and the unconventional monetary policy measures that were applied during the recent global financial crisis have limited the operation of the two components of the credit channel.

The rest of this paper is organized as follows. Section 2 provides a detailed overview of the operation of the bank lending and the balance sheet channels and reviews the existing relevant literature. Section 3 develops the theoretical model which is used to examine the operation of the above two transmission channels and their amplifying effect on monetary policy. Section 4 reformulates the theoretical model in a suitable form for empirical testing, displays the empirical approach, describes the data and presents the empirical results. Section 5 summarizes the main findings and offers concluding remarks.

2. The literature on the credit channel

The interest rate channel is the basic channel for the transmission of monetary policy. Monetary policy actions that cause changes in short-term interest rates imply a variation in the cost of capital (or user cost of capital), which in turn leads to changes in firms' investment and in consumers' durable expenditure and finally on aggregate output. However, monetary policy actions may also affect the cost of capital through the operation of the credit channel (Bernanke and Gertler, 1995). The credit channel operates complementary to the interest rate channel and its operation contributes to the amplification of monetary policy effects. Indeed, the basic idea of the operation of the credit channel is that information asymmetries between borrowers and lenders in the economy, which arise because of the presence of financial frictions, enhance the impact of shifts in monetary policy on interest rates.

The credit channel consists of two independent channels, the bank lending channel and the balance sheet channel[1]. The bank lending channel emphasizes changes in the supply of loans after a change in monetary policy. On the other hand, the balance sheet channel underlines the consequences of monetary policy changes for borrowers' balance sheets. A prerequisite for the bank lending channel is the imperfect substitution between loans and bonds for borrowers and/or banks, while for the balance sheet channel the imperfect substitution between internal and external financing for borrowers, due to the existence of incomplete financial markets.

2.1 Overview of the bank lending channel

Monetary policy can have significant effects on the real economy that are being transmitted not only via the interest rate channel but also via the operation of the bank lending channel. In fact, it has been suggested (Bernanke and Blinder, 1988) that the effect of monetary policy on aggregate demand through interest rates can be enhanced by conditions of asymmetric information in financial markets and the existence of imperfect substitutability between loans and bonds as a means of borrowing for firms and also in bank portfolios. Bernanke and Blinder (1988) develop a short-run equilibrium model which is practically the only structural model available and the benchmark model as regards the assessment of the bank lending channel. Their model departs from the IS-LM framework by taking into account the loan market. A key result of this model is that the existence of imperfect substitutability between bank loans and bonds provides another transmission channel of monetary policy, the operation of which enhances the monetary policy effect on the economy. Thus a contractionary monetary policy reduces bank deposits, which in turn implies a reduction in aggregate loan supply. Given the imperfect substitutability between bank loans and bonds for borrowers and/or banks, the operation of the bank lending channel strengthens the interest rate induced effect of monetary policy on the real economy. The bank lending channel does not operate when both loan demand and loan supply are perfectly elastic with respect to the loan rate and output demand is not

[1] The bank lending channel is also called narrow credit channel (e.g., Kashyap et al., 1993)) and the balance sheet channel is labeled as broad credit channel (e.g., Gertler and Gilchrist, 1993). A variant of the balance sheet channel is the cash flow channel operating through the effect of monetary policy on cash flow and firms' balance sheet (see Boivin et al., 2010).

responsive to changes in the loan rate. Both conditions imply that Modigliani and Miller's "financial irrelevance" applies to borrowers.

To test for the existence of a bank lending channel, Bernanke and Blinder (1992) apply VAR analysis to US data to examine impulse responses of bank loans, deposits, securities and unemployment following a contractionary monetary policy. Their empirical analysis shows that bank loans decline over a relatively long period of time in response to monetary policy tightening. However, the decline could reflect a reduction in loans demanded as the economy slows down following the tighter monetary policy, rather than the contraction of loans supplied by banks, since loans responded with the same lag as unemployment to the policy shock.

It is important to determine the different effects that movements in loan demand and loan supply exert on the quantity of bank loans and on aggregate demand. There are different methodological approaches to solve the identification problem. Brissimis and Magginas (2005) directly assess the Bernanke and Blinder model. The authors use time series data and multivariate cointegration techniques in order to identify the equilibrium relationships included in the Bernanke-Blinder model and test appropriate restrictions that pertain to the existence of perfect asset substitutability. They observe that, as the modern financial system tends, more and more, to a market-based structure, the role of the bank lending channel, regarding the transmission of monetary policy, is weakened. Their empirical results show that the bank lending channel is inoperative in the US during the 80s and the 90s.

Furthermore, Brissimis and Delis (2009) use panel data to overcome the identification problem and adopt the assumption of a competitive market for loans and that individual banks can be considered as price takers for a given time period. This approach allows the direct estimation of the loan supply function. The operation of the bank lending channel is strongly rejected for the US and the period 1996 to 2003.

The bulk of empirical studies on the bank lending channel used panel data to solve the identification problem of the lending channel, i.e. distinguishing between shifts in loan demand and shifts in loan supply. These studies tested for loan supply shifts through estimation of reduced form equations that examine the relationship between bank lending, a monetary policy variable and bank characteristics. Their strategy relies on the hypothesis that bank

characteristics influence only loan supply movements, while loan demand is independent of these characteristics. Thus, when heterogeneity in bank characteristics is present, loan supply shifts can be traced.

Using bank balance sheet data, Kashyap and Stein (2000) propose size and liquidity to be the relevant bank-specific characteristics for the above identification strategy. They demonstrate that US smaller-sized banks and those that hold less liquid assets are forced to restrict lending during periods of monetary tightening, since raising external finance becomes more difficult. Nevertheless, they conclude that the operation of the bank lending channel concerns that part of the banking system that is responsible only for a small share of total bank lending in the US. Campello (2002) shows that small-sized banks can respond to a change in monetary policy, without reducing their debt, as long as they are part of a large banking network that can provide them with additional funding through internal capital markets. Kishan and Opiela (2000) find that banks with higher capitalization, and therefore less leverage, respond more effectively in safeguarding their ability to supply loans in case monetary policy makes financing harder. Ashcraft (2006) shows that the existence of internal capital markets in bank-holding companies limits the negative effects of a reduction in the available bank credit caused by a monetary contraction. This in turn limits the operation of the bank lending channel. Cetorelli and Goldberg (2012) report that banks running global operations are insulated from changes in monetary policy, while banks without global operations are more affected by monetary policy than previously found. Finally, Brissimis et al. (2014) find that bank market power is the main bank characteristic reducing the potency of the bank lending channel, compared with other bank characteristics, although their empirical results suggest that the potency of the lending channel has increased since 2007.

Indeed, with the 2007-2009 financial crisis and the launching of Quantitative Easing (QE), the role of the supply of credit and thus of the bank lending channel might have been expected to become more important.

Several studies present evidence, sometimes indirect, for a lending channel during the recent financial crisis. Campello et al. (2010) derive a survey-based measure of financial constraint during the global financial crisis of 2008 and find that the inability of many firms to

borrow externally caused them to rein in many of their investment projects. Carvalho et al. (2015) study the transmission of bank distress to non-financial firms in a large number of countries during the 2007-2009 financial crisis and find that bank distress is associated with investment cuts to borrower firms with the strongest lending relationships with banks. Chodorow-Reich (2014) investigates the effects of bank lending frictions on employment outcomes in a large sample of non-financial firms during the 2008-2009 crisis. Using the dispersion in lender health as an index of the availability of credit to borrowers, he reports that firms that had pre-crisis relationships with less healthy lenders paid a higher interest rate if they borrowed during the crisis, and reduced employment by more compared to the pre-crisis borrowers from healthier lenders. The empirical analysis shows that lender health had a significant effect on employment of small and medium firms, but no effect on the largest firms. Edgerton (2012) finds that lenders' distress during the financial crisis of 2008 affected significantly firm-level investment outcomes after the crisis, accounting for about one-third of the total decline in financing in the sample of small businesses that he used. Ivashina and Scharfstein (2010) show that stresses on bank liquidity in 2008 led them to cut lending, and this reduction was greater for banks that were more vulnerable to credit-line drawdowns after the failure of Lehman Brothers and smaller for banks that had better access to deposit financing.

However, evidence from other research casts doubt on the importance of the bank lending channel in the crisis period. Kahle and Stulz (2013) question the significance of the causal link between corporate credit supply and capital expenditures since, inter alia, bank dependent firms hoarded cash during the crisis compared with unlevered firms, and also the average cumulative decrease in net equity issuance from the start of the crisis through to the first quarter of 2009 was more than twice the average decrease in net debt issuance. Campello et al. (2011) using a large dataset show that credit lines eased the impact on corporate spending during the 2008-2011 financial crisis; they find that credit lines were associated with greater spending when companies were not constrained in their operation by a lack of internal finance. Also, De Fiore and Uhlig (2015) present a DSGE model in which firms optimally choose among alternative instruments of external finance. In this way, they explain the observed shift from bank finance to bond finance during the financial crisis of 2008-2009 when the cost of market debt rose above the cost of bank loans.

The Great Recession of 2007-2009 has led the Fed to conduct unconventional monetary policy aiming to reduce long-term yields given the zero lower bound on short-term rates, boost lending, and stimulate economic activity. The most prominent tool used in this respect was the purchase of financial assets, such as Treasury securities or mortgage-backed securities (MBS), known as quantitative easing. The recent literature on the impact of quantitative easing is sparse. Some academics or policy makers think that QE helped the post-crisis recovery, which would have been slower without it. Others think that QE might have been by and large ineffective.

Chakraborty et al. (2019) using micro-level data examine the effects through the bank lending channel of the three rounds of QE (QE1, QE2, QE3) and of the Maturity Extension Program (MEP), consisting of purchases by the Fed made in response to maturing securities so that the size of its balance sheet would be maintained. The authors find that banks which benefited from MBS purchases (in the context of QE1 and QE3) increased mortgage lending but at the expense of commercial and industrial lending, which was reduced for firms that borrowed from those banks, and the consequence of which was a decrease in investment. The effect of purchases of Treasury securities (in the period through QE2 and the MEP) is found to be insignificant in most cases. Other recent studies reach similar conclusions, complementing the above findings. Thus, Rodnyansky and Darmouni (2017) report a strong impact on lending by the third round of quantitative easing (QE3), and a significant impact by QE1, though smaller than that of QE3; QE2 had no significant impact, consistent with the relatively small holdings of Treasuries by banks. Di Maggio et al. (2016) examining the effect of unconventional monetary policy on mortgage lending, find that financial institutions originated more mortgages of the type that were eligible for purchase by the Fed, which led to additional mortgage refinancing and consumption. There is also evidence (Foley-Fisher et al., 2016) that some firms, because of their capital structure, may have obtained advantageous financing due to QE.

2.2 Overview of the balance sheet channel

Information asymmetries between borrowers and lenders are also underlying the imperfect substitution between internal and external finance of firms, which is an additional source of

increased impact of monetary policy on the economy through the operation of the balance sheet channel. Because of the existence of these asymmetries, it may be difficult for firms to gain access to external sources of finance. In order to overcome financial constraints, firms are obliged to rely on their own funds to self-finance investment. In this case, firms' investment decisions will be determined not only by the net present value of investment projects but also by the level of their available internal funds (balance sheet conditions**).**

The higher these asymmetries are, the lower the substitution between internal and external funds becomes and the larger the wedge between the cost of these two financing options. In turn, the larger this wedge is, the higher are the financial constraints that firms will have to face in realizing their investment plans. The wedge between the cost of capital raised from external sources, i.e. equity, bond or debt markets, and the cost of capital raised internally by retaining earnings, also known as the external finance premium (Bernanke and Gertler (1995)), is of critical importance for the operation of the balance sheet channel.

In this respect, after a monetary policy shock, firms with lower internal funds (net worth) face higher credit constraints and larger financing costs, and are obliged to reduce more their investment projects over the business cycle, implying overall additional negative effects on aggregate economic activity. This amplification is referred to as the financial accelerator[2] (Bernanke et al. (1996)).

Two main assumptions provide the basis for the financial accelerator (Bernanke et al. (1996)). First, the cost of internal finance is lower than the cost of external finance, and second, there is a negative relationship between the firm's net worth and the external finance premium, due to the existence of capital market imperfections. Because there is a cost for lenders to overcome these imperfections, this cost will be passed on to borrowers. For this reason it is assumed that the cost of external finance is always greater than the cost of internal finance. The

[2] The terms balance sheet channel and financial accelerator describe identical mechanisms when a monetary shock occurs; both mechanisms contribute to the enhancement and propagation of this shock, through the borrowers' balance sheet conditions. The first term was introduced by Bernanke and Gertler (1995) and the second by Bernanke et al. (1996). Note that the starting point for the financial accelerator effect could also be a technology shock, a productivity shock, a banking crisis shock, a shock in the labor market, or a government shock, among others.

higher the dependence on external financing is, the stronger the effects from the operation of the balance sheet channel are. A reduction in capital market imperfections decreases the wedge between the cost of internal and external funds, as the information asymmetries between borrowers and lenders become less severe.[3]

The imperfect substitution between the borrower's internal and external funds is the main impulse and the sine qua non for the operation of the balance sheet channel. This channel, which operates complementary to the interest rate channel, plays a distinct and crucial role in the implementation of monetary policy. The operation of the balance sheet channel can be illustrated as follows. An increase in the short-term interest rate, after a contractionary monetary policy, implies not only a decrease in the demand for capital, but also a decrease in equity prices and net worth. Furthermore, borrowers' asset prices decline and this causes a reduction in the value of collateral that they can use in order to increase their financing.

As a result, loan supply declines due to the amplification of adverse selection and moral hazard problems, and consequently investment and aggregate demand also decrease (Mishkin (1995)).[4] Under these circumstances, borrowers lack adequate capital and the required collateral that they could use in order to increase their external financing. Thus, they will have to pay a higher external financing cost to lenders so as to raise the external funds that are necessary for the implementation of their investment projects in the event their internal funds are insufficient. This rise in the external finance premium is caused by the asymmetric information that increases the risk which creditors undertake. Thus, a negative relation between borrowers' balance sheets and the external finance premium, which influences investment spending, is observed.

[3] Many researchers, among them, Bernanke and Gertler (1989), Gertler (1992), Greenwald and Stiglitz (1993), Kiyotaki and Moore (1997), Schiantarelli (1996), Almeida and Campello (2007), Agca and Mozumdar (2008) and Guariglia (2008), have examined the effects of these imperfections – through changes in the external finance premium – on business investment policy.

[4] The consequences on aggregate economic activity will be more serious after a tightening of monetary policy for borrowers whose investment depends, to a great extent, on bank credit. According to Bernanke (1993), this may restrict their access to bank loans or raise the cost of bank credit, which in turn will reduce their investment expenditure to a greater extent.

However, there is a problem of definition concerning the external finance premium, which has not been highlighted in the literature thus far. In particular, most studies consider the above premium as the difference between the cost of external finance and the opportunity cost[5] of internal finance, which is not the same as the cost of internal finance. To address this issue, in this paper the return on retained earnings to firm owners is used in order to specify the cost of internal finance. In this respect, Brissimis and Papafilis (2021) have shown that the basic assumption that the cost of external finance is always greater than the cost of internal finance is not valid. Thus, the term "cost differential" rather than "external finance premium" describes better the relation between external and internal finance.

As regards the empirical investigation of the balance sheet channel, Bernanke et al. (1996) point out the difficulties of incorporating a financial accelerator mechanism in a fully articulated model of the business cycle, as certain factors would complicate the calculation of the equilibrium in such a model. This prevented researchers from developing theoretical frameworks that are both tractable and able to fit well the data. However, a number of studies have developed DSGE models that feature a financial accelerator, although in a relatively stylized way.

Most work in this field of research aims to capture and describe the financial accelerator mechanism on the basis of the external finance premium. Bernanke and Gertler (1989) were the first to develop a neoclassical model of the business cycle in order to capture the financial accelerator effect. In their model, the external finance premium creates a link between borrowers' balance sheet conditions (net worth) and real variables (investment, output). An exogenous productivity shock weakens borrowers' balance sheets and amplifies the need for external financing due to the reduction of internal cash flows. This in turn increases the external finance premium and reduces more the level of investment demand. The initial shock is strengthened because lower investment contributes to lower cash flows and lower economic growth in the following periods. Bernanke and Gertler (1989) also provide evidence that the financial accelerator effect is stronger for borrowers with lower net worth (cash flows).

[5] See, e.g., Bernanke and Gertler (1995); Serven and Solimano (1992); Bernanke et al. (1999); Gertler and Kiyotaki (2010).

Bernanke et al. (1999), in a more structural approach, develop a dynamic general equilibrium model of a closed economy with non-flexible prices, in order to capture the financial accelerator effect. Their model allows the specification of the interaction between the financial conditions of a firm and its investment behavior after a shock, by including the external finance premium. Procyclical variations in the firm's net worth will cause countercyclical changes in the external finance premium over the business cycle. The authors show empirically that those entrepreneurs with a higher level of financial constraints (i.e. a higher external finance premium) present higher investment sensitivity after a monetary policy shock, while the magnitude, persistence and diffusion of this shock to the real economy will be greater.

There are alternative approaches that are not based on the external finance premium to describe the financial accelerator mechanism. Greenwald and Stiglitz (1993) develop a general equilibrium macroeconomic model and show that the financial accelerator effect arises due to the existence of information asymmetries in equity and in the behavior of the firm's management, which is risk averse because of personal interests. Moreover, Kiyotaki and Moore (1997) build a general equilibrium model in which changes in net worth are caused not only by changes in borrowers' cash flow, but also by changes in asset prices.

As noted by Bernanke et al. (1996), an indication of the operation of the financial accelerator is a greater reduction of available credit for those borrowers who face higher agency costs, when a monetary policy shock occurs – firms with lower net worth bear a higher cost of external financing relative to those firms whose access to credit markets continues in a steady way. Therefore, the former are obliged to reduce their investment spending earlier and more sharply when there is an economic recession, as they experience reduced access to credit from lenders who exhibit a "flight to quality". This in turn amplifies the consequences of a monetary shock. However, Bernanke et al. (1996) claim that by using aggregate data, it is not possible to specify the timing relationships between aggregate output and aggregate credit, and distinguish the financial accelerator theory from alternative approaches.

Empirical studies exploring disaggregated data have been more successful in assessing the operation of the balance sheet channel. There are several econometric approaches that have

been applied in this respect. They all test the importance of the borrowers' financial constraints for investment in the model derived under conditions of perfect capital markets (Schiantarelli, 1996); they encompass the neoclassical model, the accelerator model, the Tobin's Q model and the Euler equation model. In these models, different variables are added in the investment equation as proxies for firms' internal funds (cash flow, coverage ratio, net worth, stock of liquid assets or total debt as a fraction of total assets) and their significance is tested for borrowers' investment.

In the neoclassical model (Fazzari et al., 1988) the optimal level of investment is specified as a function of the user cost of capital, output and cash flow. Also, the accelerator model (Abel and Blanchard, 1988) links the demand for capital goods to the level or change in a firm's output or sales, and proxies for internal finance. A weakness of the model is that it does not take into consideration any price variable in the empirical specification.

Two alternative models, based on the assumption that the real user cost of capital does not change, are Tobin's Q and the Euler equation. The Tobin's Q model (Tobin, 1969), frequently encountered in the empirical literature, does not include the user cost of capital but the value of the firm's assets.[6] It also uses a number of different variables (e.g. cash flow and liquid assets), which capture the firm's potential to expand investment based on its own funds, in order to estimate the effects of financial constraints (Fazzari et al. (1988); Devereux and Schiantarelli (1990); Gertler and Hubbard (1988), among others). If these variables are found to have significant effects on investment, this will provide evidence for the operation of the balance sheet channel.

The standard Euler equation model (Gilchrist (1990); Hubbard and Kashyap (1992); Whited (1992); Hubbard et al. (1995), among others.) is preferred to the Tobin's Q model when there is no information about firms in the stock markets or there is insufficient data to construct the Q variable. The Euler equation is derived from the firm's value maximization problem. As in the Q model, a variable is included as a proxy for borrower's financial conditions.

[6] This variable is defined as the ratio of the firm's total value to the replacement cost of its total capital stock (average Tobin's Q).

Undoubtedly, the financial variable most used in investment equations to test the importance of the borrowers' financial constraints has been cash flow, which measures the capacity of firms to finance investment with their own funds. Many studies using panel data document a strong association between firm cash flow and investment. The basic hypothesis about the sensitivity of investment to cash flow is that this sensitivity is higher for those firms that are subject to credit constraints. The research strategy followed has been to estimate investment equations for different groups of firms sorted according to a priori criteria, notably size, which seek to identify financially constrained firms. The seminal work in this very large literature is Fazzari et al. (1988). Although financial imperfections play an important role in the link between cash flow and investment, other factors, such as the correlation of the cash flow with future profitability, could lead to such linkages. Studies using various techniques to control for such factors confirmed the relevance of imperfections (Claessens and Kose, 2017). Firms with relevant asymmetric information problems will face high external financing costs or constraints on the amount of credit obtained.

The balance sheets of firms deteriorated during the Great Recession, although not as severely as those of households. Cross-sectional studies show that firms with initially weaker balance sheets (in terms of higher leverage, lower internal cash or less collateral), or smaller or younger firms, have been more sensitive to deteriorating financial conditions. Giroux and Mueller (2017) find that during the Great Recession high-leveraged firms reduced employment significantly more than other firms did in response to a decline in household demand. They conclude that firms' balance sheets were an important part of the link between final demand and employment. Similarly, Duchin et al. (2010) find that corporate investment declined significantly after the start of the crisis, the decline being greater for firms that had low cash reserves or high net short-term debt, were financially constrained or operated in industries dependent on external finance. Finally, Gilchrist et al. (2017) analyze inflation dynamics during the financial crisis with a novel approach. They note that in the nadir of the crisis, in the presence of financial frictions, firms with weak balance sheets and limited internal liquidity found it necessary to raise their prices to preserve internal liquidity and avoid costly external finance in response to adverse demand and financial shocks. By contrast, their liquidity unconstrained counterparts lowered prices in the same period. Such pricing behavior led to a

further deterioration in the liquidity position of financially constrained firms which amplified the large contraction of aggregate output due to the crisis but dampened the downward pressure on prices that accompanied the severe economic slowdown.

The literature on the balance sheet transmission channel is even thinner for the period of unconventional monetary policies due to the lack of supporting empirical evidence. Gurkaynak et al. (2021) using firm-level data (S&P firms) in a sample spanning the period from 2004 to 2018, examine the cash-flow effect of monetary policy, which propagates through changes in balance sheets and ultimately influences investment behavior, and provide strong evidence for investment sensitivity to cash flow. Also, they provide evidence that the cash-flow sensitivity of investment was not different at the zero lower bound (ZLB) period of interest rates implying that the ZLB did not disrupt the cash-flow channel of monetary policy. A further test of the cash-flow channel involved examining the behavior of net worth which is a key variable for all financial accelerator mechanisms where having less cash in a firm leads to persistently lower net worth. Again, their empirical results validate the cash-flow channel, showing that its working was not altered by the ZLB. Finally, Gurkaynak et al. (2021) use a measure of financial constraint applicable to listed US firms to test whether financial frictions drive the real effects of monetary policy and report that financial constraints indeed matter and that more constrained firms show large sensitivity to cash flows triggered by monetary policy shocks.

3. The theoretical framework

3.1 The model

In this section we develop the theoretical framework that is based on the Bernanke and Blinder (1988) model, extended to incorporate imperfect substitution between internal and external finance of firms, and thus allowing to put to a structural test both the bank lending and balance sheet channels of monetary policy transmission.

Two essential features of the proposed framework are distinguished. Firstly, because of the existence inter alia of informational asymmetries, different types of finance for firms are imperfect substitutes. The bank lending channel assumes imperfect substitution between loans

and bonds, both of which are types of external finance. The balance sheet channel, on the other hand, assumes imperfect substitution between internal and external finance. With a changing financial structure, firms face a cost differential when raising finance from different sources. Secondly, the cost of capital influencing investment decisions is a weighted average of the cost of individual types of finance and this in turn implies interdependence between changes in financial structure and investment demand (and thus output demand).[7]

Our model is assumed to be linear for analytical convenience and contains the basic components of the financial structure by specifying demand equations for these components. It also contains a supply of loans equation, which, together with the relevant equilibrium condition, integrates the loan market in the model. Loans are a component of firms' external finance. The model specification is completed by a conventional LM curve (demand for deposits equation) and an IS curve (output demand equation) that coincides with the traditional IS curve when there is perfect substitutability between all types of finance as suggested by the irrelevance proposition of Modigliani and Miller (1958). The market for bonds is not considered, as in Bernanke and Blinder (1988), by appealing to Walras's law. Also, as in the above study, we assume that the expected inflation rate is constant, so we suppress it because a Keynesian type model takes both the price level and inflation as given. Finally, we assume for simplicity that there are no reserve requirements, an assumption that is not crucial for developing our tests.[8]

Table 3.1 and Figure 3.1 below presenting the structure of total liabilities in the firms' balance sheets and the cost of the main components, help us in making a number of simplifying assumptions that allow us to obtain analytical results: (i) The "other liabilities" item of external finance (see Table 3.1), including inter alia trade accounts and all other liabilities, both current (e.g. excise and sales taxes) and non-current (e.g. deferred income taxes), are not considered in

[7] We note that the stylized model proposed by Bernanke and Blinder (1988) for analyzing the bank lending channel explicitly incorporates this interdependence. The model was estimated as a structural system for six major economies by Brissimis and Magginas (2005).

[8] The results in our model do not depend on the use of reserve requirements as an instrument of monetary control; monetary policy could have tightened through an open market operation reducing the reserve base, with increased leverage in the presence of a bank lending channel and a balance sheet channel.

the present study; these represent about one third of total liabilities and are not likely to be influenced by (real) rates of return. (ii) Equity finance is also not considered, as firms tend to maintain an inflexible level of dividends per share, an empirical regularity already pointed out in the seminal work by Lintner (1956), which still has continuing validity.

Table 3.1: Sources of finance (end-year figures, percent of total)

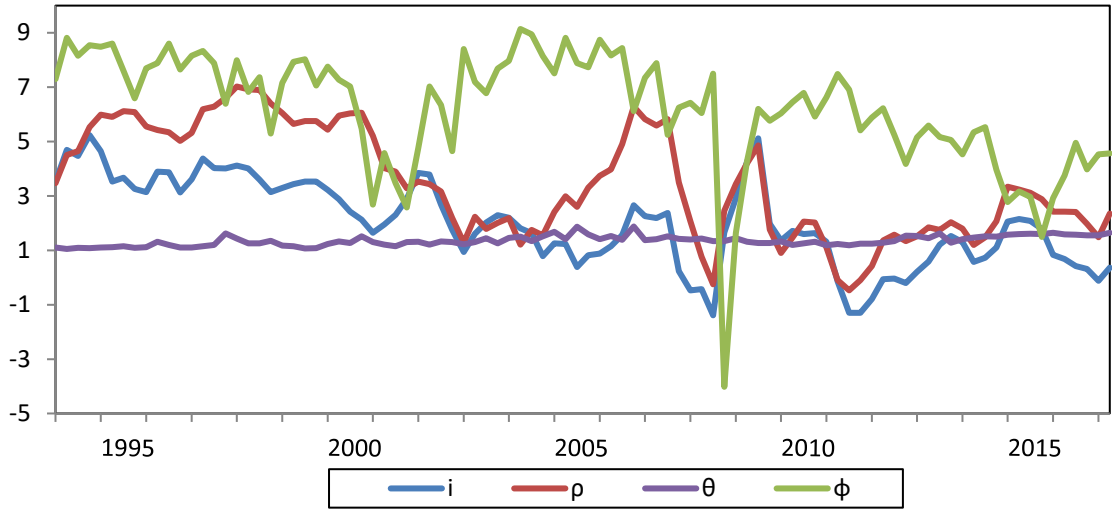
Type of finance	1994	1995	2000	2005	2010	2015	2017[a]
Internal finance							
Retained Earnings (R)	22.1	22.7	23.3	24.8	28.3	29.6	28.0
External finance							
Loans (L)	9.3	9.5	9.8	6.6	6.3	6.7	6.8
Bonds (B)	16.4	16.0	15.0	14.1	17.0	21.1	21.7
Equity (E)	13.9	13.9	15.5	17.5	16.0	10.5	11.9
Other Liabilities (O)	38.3	37.9	36.3	37.0	32.5	32.1	31.5
Total (bn USD)	4036	4381	6058	7744	10068	13128	14199

Notes: R: retained earnings (stock); L: bank loans; B: bonds; E: stockholders' equity; O:other liabilities.

[a] The figures refer to 2017:Q2.

Source: QFR database and authors' calculations.

Figure 3.1: Real cost of corporate finance (in percent)



Notes: i: bond rate (10-year Government Benchmark bond yield); ρ: bank lending rate (bank prime loan rate); φ: cost of retained earnings; θ: cost of equity.

* The cost of equity (θ) is defined as the ratio of total dividends to total capitalization.

Source: FRED and QFR databases and authors' calculations.

Figure 3.1, presenting the real cost of the various forms of corporate finance, shows that the cost of equity has historically, at least in our sample, been "sticky", in contrast to the cost of other types of finance, which fluctuated considerably.

We define the cost of retained earnings by noting that this cost is really the return on retained earnings (whether we choose to call it a "cost" or a "return" is a matter of perspective). The return on retained earnings in a given period can be seen to have two components: (a) the flow of retained earnings (ΔRE) in the period, where RE is the stock of retained earnings, and (b) the depreciation flow, i.e. the amount of earnings required to finance capital consumption of

the period (DEP).[9,10] The sum of these components as a percentage of retained earnings gives the (real) cost of retained earnings for the firm (see Brissimis and Papafilis, 2021). Given the cost of retained earnings φ, firms make their financial decisions on the basis of their relative capital structure.

The loan market in the model is specified as follows:

$$L^d = a_0 + a_1 y - a_2(\rho - i) - a_3(\rho - \varphi) \qquad a_1, a_2, a_3 > 0 \qquad (3.1)$$

$$L^s = b_0 + b_1 D + b_2(\rho - i) \qquad b_1, b_2 > 0 \qquad (3.2)$$

$$L^d = L^s = L \qquad (3.3)$$

where L, y and D are real loans, output and deposits, (ρ-i) is the spread between the bank lending rate (ρ) and the bond rate (i), (ρ-φ) is the spread between the bank lending rate (ρ) and the rate of return on retained earnings (φ), while superscripts d and s refer to loan demand and loan supply, respectively.[11] Loan demand is negatively related to both interest rate spreads and positively to the output variable. The latter is the scale variable in Eq. (3.1), while the deposit variable has the same role in Eq. (3.2). Variations in the interest rate spread (ρ-i) and deposits affect loan supply positively. The inclusion of the spreads in Eqs. (3.1) and (3.2) is based on the premise that borrowers' financing decisions and bank portfolio decisions are characterized by rate of return homogeneity. In this case, an equal increase in the financing costs for all forms of borrowing will not affect the structure of firms' liabilities, while banks' loan supply policy depends on the relative return on loans. Moreover, the inclusion of the interest rate spread in both equations implies that loans and bonds are imperfect substitutes in bank portfolios or as sources of external finance for borrowers. Eq. (3.3) is the equilibrium condition for the loan market.

[9] We use an operational definition for the cost of internal finance that distinguishes it from the opportunity cost of internal finance, which is a fundamental part of the external finance premium employed extensively in the literature, but also from the cost of equity capital, given that equity capital constitutes an external source of corporate finance.

[10] These earnings are already deducted from accounting measures of net earnings and therefore need to be added back to the flow of retained earnings as they represent the minimum return the firm, as a going concern, has to deliver in order to maintain its physical capital stock in operation.

[11] Rates of return are real rates.

The demand for retained earnings equation is specified as:[12]

$$R = c_0 + c_1 y - c_2(\rho - i) + c_3(\rho - \varphi) \qquad c_1, c_2, c_3 > 0 \qquad (3.4)$$

where R is the stock of retained earnings. It incorporates the notion that retained earnings are characterized by imperfect substitutability with the two types of external finance considered here.

The money market can be expressed as follows:

$$D = d_0 + d_1 y - d_2 i \qquad d_1, d_2 > 0 \qquad (3.5)$$

where D is demand for deposits, which is related positively to income and negatively to the bond rate.[13]

Assuming that output is demand determined, the output market is specified by the following equation:[14]

$$y = e_0 - e_1 i - e_2(\rho - i) + e_3(\rho - \varphi) \qquad e_1, e_2, e_3 > 0 \qquad (3.6)$$

Aggregate demand is related negatively to the bond rate and the spread between the loan and bond rates, and positively to the spread between the loan rate and the rate of return on retained earnings. Eq. (3.6) is a modified IS curve when there is imperfect substitution between loans, bonds and retained earnings for borrowers.

Two conditions must be met for a bank lending channel to exist. First, borrowers are not able to fully insulate their real spending from a decline in the availability of bank loans, i.e. loans are imperfect substitutes for other sources of external finance. Second, there are no perfect substitutes for loans in bank portfolios. Respectively, a necessary condition for the operation of the balance sheet channel is the existence of imperfect substitution between borrowers' internal and external finance.

---

[12] Eq. (3.4) arises from the following reformulation of the initial specification: $R = m_0 + m_1 y + m_2(\rho - \varphi) + m_3(i - \varphi) = m_0 + m_1 y + (m_2 + m_3)(\rho - \varphi) - m_3(\rho - i)$.

[13] We assume that total wealth is constant while the rate of return on deposits is exogenously fixed and normalized to zero.

[14] Eq. (3.6) is the result of the following reformulation: $y = w_0 - w_1 i - w_2 \rho - w_3 \varphi = w_0 - (w_1 + w_2 + w_3)i - (w_2 + w_3)(\rho - i) + w_3(\rho - \varphi)$.

Imperfect substitution implies that the derivatives of loan demand and loan supply with respect to the spreads (coefficients a_2, a_3 and b_2) and the corresponding derivatives of the demand for retained earnings (coefficients c_2 and c_3) are finite, and moreover that output demand responds to the spreads (e_2, $e_3 > 0$), as well as to the interest rate. When, on the other hand, loan supply is perfectly elastic with respect to the spread (ρ-i) (i.e. $b_2 \to \infty$) and hence ρ-i=0 (i.e. $a_2=c_2=e_2=0$), loans and bonds will be perfect substitutes for either borrowers or banks. In this case, the bank lending channel does not operate, the loan supply function, due to the existence of perfect substitution, cannot be defined separately for banking institutions, and the (ρ-i) spread is zero and therefore is not a determining factor in the demand equations for loans, retained earnings and output.

Also, when the demand for retained earnings is perfectly elastic with respect to the spread (ρ-φ) (i.e. $c_3 \to \infty$) and hence ρ-φ=0 (i.e. $a_3=e_3=0$), retained earnings will be perfect substitutes for both loans and bonds for borrowers. In this case, the balance sheet channel does not operate.

When the values of the critical parameters of the system of structural equations (i.e. a_2, a_3, b_2, c_2, c_3, e_2, e_3) are not subject to the restrictions specified above, this implies that there is imperfect substitutability between bonds and loans and also between internal and external sources of finance, and the bank lending and balance sheet channels are both operational.

The system of Eqs. (3.1) to (3.6) can be reduced to a set of three equations that can be used as a basis for assessing the potency of both the bank lending and balance sheet channels. The first of these equations represents an inverted loan supply function, the second is an inverted demand function for retained earnings and the last combines the demand function for loans, deposits and output.

Bank loans are an important source of funding for firms. Monetary policy variations could have significant effects on financing decisions of firms and investment through changes in loan supply, especially for borrowers with significant dependence on bank loans. Thus, identification of the loan supply function would enable an assessment of the importance of the lending channel. We express Eq. (3.2) in an equivalent way, as an inverted loan supply function:

$$\rho - i = -b_0/b_2 - (b_1/b_2)D + (1/b_2)\mathrm{L} \qquad (3.7)$$

Based on Eq. (3.7), we are able to directly identify the structural parameters of the loan supply function by testing the restriction that $b_2 \to \infty$. If $b_2 \to \infty$, loan supply would be perfectly elastic with respect to the interest rate spread. In this case, as already noted, the loan supply function is not defined, the two rates on loans and bonds are equal, $\rho = i$, and the bank lending channel will be non-operational.

Eq. (3.4) can be solved for $(\rho-\varphi)$ as a function of y, R and $(\rho-i)$:

$$\rho - \varphi = -c_0/c_3 - (c_1/c_3)y + (1/c_3)R + (c_2/c_3)(\rho - i) \qquad (3.8)$$

Under conditions of perfect substitutability between the two sources of external finance, i.e. loans and bonds, the bank lending channel does not operate and the spread $(\rho-i)$ drops from the equation (i.e. $c_2=0$). Perfect substitutability, on the other hand, between loans and retained earnings (i.e. $c_3 \to \infty$) implies that the spread $(\rho-\varphi)$ is zero and this time the balance sheet channel does not operate.

Finally, we solve Eq. (3.1) for the spread $(\rho-\varphi)$:

$$\rho - \varphi = a_0/a_3 + (a_1/a_3)y - (1/a_3)L - (a_2/a_3)(\rho - i) \qquad (3.9)$$

and Eq. (3.5) for the bond rate:

$$i = d_0/d_2 \; + (d_1/d_2)\; y - (1/d_2)D \qquad (3.10)$$

Substitution of Eqs. (3.9) and (3.10) into Eq. (3.6) yields the following equation:

$$y = [(e_0 - e_1\, d_0/d_2 + e_3 a_0/a_3) + (e_1/d_2)D - (e_3/a_3)L$$
$$-(e_2 + e_3 a_2/a_3)(\rho - i)]/(1 + e_1 d_1/d_2 - e_3 a_1/a_3) \qquad (3.11)$$

According to this specification, when there is perfect substitutability between internal and external finance for borrowers (i.e. $a_3 \to \infty$, $e_3=0$) the loan variable drops from Eq. (3.11) and the balance sheet channel will not work, while when loans and bonds are perfect substitutes for borrowers (i.e. $a_2=0$, $e_2=0$), the spread $(\rho-i)$ drops from the equation and the irrelevance of the bank lending channel is established.

Through the system of the three Eqs. (3.7), (3.8) and (3.11), our aim is to examine the operation of the bank lending and balance sheet channels following a monetary policy shock.

To recapitulate, Eq. (3.7) captures the structural parameters of the loan supply function under conditions of equilibrium in the loan market, Eq. (3.8) captures the parameters of the demand function for retained earnings, and the last quasi-reduced form Eq. (3.11) describes the combined demand side of the loan, deposit and output markets.

3.2 The amplifying effect of monetary policy

Both the bank lending and the balance sheet monetary transmission channels have been shown to amplify monetary policy shocks to the economy. The bank lending channel, whose existence is based on credit market imperfections caused inter alia by asymmetric information, makes monetary policy more expansionary than in the IS-LM model (Bernanke and Blinder, 1988). In the context of the Bernanke-Blinder model, the loan market plays a central role in amplifying monetary impulses, which can influence aggregate demand, not only through interest rates as in the traditional interest rate channel, but also through their impact on the supply of bank loans, assuming that these loans are imperfect substitutes with debt securities (bonds) for borrowers and banks. Thus, when monetary policy is tightened, the bank loan supply schedule shifts up and to the left, which complements the interest-rate induced effect on aggregate demand.

Whilst the bank lending channel analyzes the impact of monetary policy shocks on the supply of loans by depository institutions, the balance sheet channel focuses on the potential impact of shocks on firms' balance sheets and their ability to borrow. Thus, a monetary shock that causes a rise in interest rates worsens borrowers' financial conditions and increases the wedge between the cost of external and internal finance, which reduces firms' loan demand. This mechanism (balance sheet channel) reinforces the initial effects on aggregate economic activity.

Although the bank lending and the balance sheet channels are theoretically different, they both incorporate a key fundamental, the financial accelerator. The financial accelerator hypothesis states that information costs that arise from imperfect/asymmetric information between borrowers and lenders alter the costs of firms' financing that have significant consequences on output, amplifying the effect of monetary policy. Below, we show this by using the model consisting of Eqs. (3.7), (3.8) and (3.11). An important result is that the

amplification is much stronger if both channels are in operation compared to the case where only one plays a role in monetary transmission.

In particular, in cases where the bank lending and the balance sheet channels are operational, the above system of equations may be written in matrix notation as follows: AX=BZ, where:

$$A = \begin{pmatrix} 1 & 0 & 0 \\ -c_2/c_3 & 1 & c_1/c_3 \\ e_2 + e_3 a_2/a_3 & 0 & 1 + e_1 d_1/d_2 - e_3 a_1/a_3 \end{pmatrix}$$

$$B = \begin{pmatrix} -b_0/b_2 & 1/b_2 & 0 & -b_1/b_2 \\ -c_0/c_3 & 0 & 1/c_3 & 0 \\ e_0 - e_1\, d_0/d_2 + e_3 a_0/a_3 & -e_3/a_3 & 0 & e_1/d_2 \end{pmatrix}$$

$$X = \begin{pmatrix} \rho - i \\ \rho - \varphi \\ Y \end{pmatrix} \qquad Z = \begin{pmatrix} Con \\ L \\ R \\ D \end{pmatrix}$$

In this case the effect of monetary policy on output is given by the derivative (dY/dD), which is the element in the third row and fourth column of the matrix $A^{-1}B$. This effect is shown in Table 3.2, line 1.

If only the balance sheet channel is operational, the A and B matrices become:

$$A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & c_1/c_3 \\ 0 & 0 & 1 + e_1 d_1/d_2 - e_3 a_1/a_3 \end{pmatrix}$$

$$B = \begin{pmatrix} 0 & 0 & 0 & 0 \\ -c_0/c_3 & 0 & 1/c_3 & 0 \\ e_0 - e_1\, d_0/d_2 + e_3 a_0/a_3 & -e_3/a_3 & 0 & e_1/d_2 \end{pmatrix}$$

and the effect of monetary policy on output, shown in Table 3.2, line 2, is now smaller since the amplification mechanism is constrained from the non-operation of the bank lending channel.

Finally, if neither the balance sheet channel nor the bank lending channel is operational, the A and B matrices become:

$$A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 + e_1 d_1/d_2 \end{pmatrix} \qquad B = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ e_0 - e_1\, d_0/d_2 & 0 & 0 & e_1/d_2 \end{pmatrix}$$

and the effect of monetary policy on output is limited further, as shown in Table 3.2, line 3, and this indicates that we have no amplification effects at all when there no component of the credit channel at work.

Table 3.2: The amplifying effect of monetary policy through the operation of monetary transmission channels

Channels in operation	Effect of expansionary monetary policy on output (dY/dD)
Interest rate, bank lending and balance sheet channels	$A1 = \frac{e_1 + (e_2 + e_3 a_2/a_3) d_2 (b_1/b_2)}{d_2 + e_1 d_1 - (e_3 a_1 d_2)/a_3}$
Interest rate and balance sheet channels	$A2 = \frac{e_1}{d_2 + e_1 d_1 - (e_3 a_1 d_2)/a_3} < A1$
Interest rate channel	$A3 = \frac{e_1}{d_2 + e_1 d_1} < A2$

Source: Authors' calculations

4. Empirical evidence

Based on the theoretical structural relationships developed in Section 3 (Eqs. (3.1) to (3.6)), we investigate empirically the operation of the bank lending and balance sheet channels in the US by using the Johansen multivariate cointegration analysis. We identify the relationships included in our model as equilibrium relationships (cointegrating vectors) from a VEC model and test appropriate restrictions on estimated cointegrating vectors that pertain to the existence of the bank lending and balance sheet channels.

The three-equation system derived above (Eqs. (3.7), (3.8) and (3.11)) and used for assessing theoretically the magnifying effect of monetary policy on real economic activity when one or two monetary transmission channels are in operation, is not suitable for empirically testing the existence of the two components of the credit channel, since it is not exactly identified. It is therefore necessary to reformulate it, in order to achieve exact identification of the equilibrium parameters, in conformity with Pesaran and Shin's (2002) theory of identification of an equilibrium structure in a VEC model. Thus, based on the system of structural equations (Eqs.(3.1) to (3.6)), we specify a re-parameterization of equilibrium relationships that is amenable to estimation.

More specifically, we substitute Eqs. (3.1) and (3.2) in Eq. (3.3) and solve for the spread (ρ-i), as follows:

$$\rho - i = f_0 + f_1 y - f_2(\rho - \varphi) - f_3 D \qquad f_1, f_2, f_3 > 0 \qquad (4.1)$$

where $f_0 = (a_0 - b_0)/(a_2 + b_2)$, $f_1 = a_1/(a_2 + b_2)$, $f_2 = a_3/(a_2 + b_2)$,

$f_3 = b_1/(a_2 + b_2)$,

Solving Eq. (3.4) for the spread (ρ-φ), we obtain:

$$\rho - \varphi = g_0 - g_1\, y + g_2 R + g_3(\rho - i) \qquad g_1, g_2, g_3 > 0 \qquad (4.2)$$

where $g_0 = -c_0/c_3$, $g_1 = c_1/c_3$, $g_2 = 1/c_3$, $g_3 = c_2/c_3$

Finally, substitution of Eq. (3.10) into Eq. (3.6) yields:

$$y = h_0 + h_1 D - h_2(\rho - i) + h_3(\rho - \varphi) \qquad h_1, h_2, h_3 > 0 \qquad (4.3)$$

where $h_0 = (e_0 - e_1\, d_0/d_2)/(1 + e_1 d_1/d_2)$

$h_1 = (e_1/d_2)/(1 + e_1 d_1/d_2)$

$h_2 = (e_2)/(1 + e_1 d_1/d_2)$

$h_3 = (e_3)/(1 + e_1 d_1/d_2)$

Therefore, the equilibrium relationships on which we focus are Eqs. (4.1), (4.2) and (4.3). If we identify empirically the existence of these three equations, this implies the operation of the bank lending and balance sheet channels in addition to the interest rate channel. If there are

no information asymmetries in the loan and bond markets, the identification of a distinct loan demand function is not possible because loans and bonds are perfect substitutes for borrowers and ρ=i. Similarly, loans and bonds are perfect substitutes in bank portfolios. Under these conditions, only two equilibrium relationships can be identified, i.e. Eqs. (4.2) and (4.3):

$$\rho - \varphi = g_0{}' - g_1{}' y + g_2{}' R \qquad g_1{}', g_2{}' > 0 \qquad (4.4)$$

$$y = h_0' + h_1' D + h_2{}'(\rho - \varphi) \qquad h_1{}', h_2{}' > 0 \qquad (4.5)$$

In this case, of the two components of the credit channel, only the balance sheet channel is operating.[15] If, in addition, there are no information asymmetries in the firms' access to internal and external finance, loans and retained earnings are perfect substitutes and ρ=φ. As a result, there is a further reduction of the two-equation system to one equation, which is:

$$y = h_0{}'' + h_1'' D \qquad h_1{}'' > 0 \qquad (4.6)$$

As mentioned in Section 3, perfect substitutability between loans and bonds for banks and borrowers implies that the bank lending channel is not operational. In addition, perfect substitutability between internal and external finance for borrowers renders the balance sheet channel non-operational. As already indicated, the existence of informational asymmetries is a necessary condition for the operation of both channels. Otherwise, when the channels are not active, the identification of distinct loan demand and supply functions is not possible, while output demand and the demand for retained earnings are not responsive to changes in the spreads.

Thus, in what follows, we will seek to disentangle shifts in loan supply from shifts in loan demand and identify shifts in the demand for retained earnings in an attempt to quantify empirically the two components of the credit channel. However, internal and external sources of finance have experienced profound changes in the last decades, especially after the financial crisis of 2008, which may have caused significant changes in the transmission of monetary policy. Accordingly, we will examine how these changes have manifested themselves as

[15] If, however, loans and retained earnings are perfect substitutes (i.e. ρ=φ), the two equilibrium relationships would be: $\rho - i = f_0{}' + f_1{}' y - f_2{}' D$ and $y = h_0{}' + h_1{}' D - h_2{}'(\rho - i)$ and the bank lending channel, rather than the balance sheet channel, would be operating. This hypothesis is examined and rejected below by testing the appropriate over-identifying restrictions.

changes in the underlying equilibrium relationships (Eqs. (4.2), (4.3) and (4.4)), which can take the form of changes in the number of these relationships and/or in the parameters of the cointegrating vectors.

In order to specify the existence of cointegrating relationships among the variables, we estimate an unrestricted vector autoregressive (VAR) model over the entire sample period and over two subperiods (see below), which are determined according to the recursive and breakpoint stability tests. The general reduced form of a VAR (k,p) model with k variables and p lags is:

$$y_t = \delta + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + B x_t + e_t$$

where $y_t = [y_{1t}, \dots, y_{kt}]'$ is a k×1 vector of k endogenous non-stationary variables, $x_t = [x_{1t}, \dots, x_{dt}]'$ is a d×1 vector of exogenous and/or deterministic variables, $A_1,\dots A_p$ are kxk matrices of the coefficients of endogenous variables for i = 1,2,...,p, p is the order of the VAR model, B is a k×(d+1) matrix of the coefficients of exogenous variables, e_t is a white noise k×1 vector of error terms and δ is a k×1 vector of intercepts.

The VAR model can be re-parameterized as a VEC model (Hendry, 1995). A VEC model is given by the following form:

$$\Delta y_t = \delta + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + B x_t + e_t$$

where $\Pi = \sum_{j=1}^{p} A_j - I_k$, Π is a (k×k) matrix of equilibrium parameters, $\Gamma_i = -\sum_{j=i+1}^{p} A_j$, Γ_i is the matrix of short-run adjustment parameters, p is the order of the VEC model and Δ is the first-difference operator. Based on the test statistics of Johansen and Juselius (1990) and Johansen (1995), the rank r of the matrix Π determines the appropriate model specification. If r<k, i.e. Π has reduced rank, and the variables are I(1), there must be r cointegrating relationships among them that are stationary. In this case, the matrix Π can be factorized as a product of two matrices α and β, such that Π=αβ′, where α is the matrix of loading factors which capture the speed of adjustment toward equilibrium and β is the matrix of r cointegrating vectors. By using the Johansen cointegration technique, the orthogonalization of β implies a unique estimation of α and β, which satisfies the equation Π=αβ′.

The above identification method sets a number of specific restrictions. Pesaran and Shin (2002) criticize this approach claiming that there is no economic theoretical background for its support. For reasons of mathematical convenience it is not possible to test restrictions predicted by economic theory or other relevant a priori information. Therefore, in order to be able to derive conclusions according to economic theory, it is necessary to impose and examine a number of appropriate restrictions concerning the parameters of the β matrix. The imposition of r^2 restrictions is a necessary and sufficient condition for the exact identification of the cointegrating vectors (r restrictions in each of the r cointegrating vectors), in agreement with specific theoretical economic assumptions**.** By imposing linear over-identifying restrictions on the elements of matrix β, according to the cointegration approach developed by Pesaran and Shin (2002), we are in a position to test the validity of a series of economically meaningful hypotheses, based on the theoretical restrictions developed in Section 3. In this way, we will be able to examine the existence of the bank lending and the balance sheet channels.

We investigate the operation of the bank lending and balance sheet channels in the US over the period from 1994:Q1 to 2017:Q2, by using aggregate data. In the empirical analysis, we use quarterly observations. Bank loans (L), deposits (D) and retained earnings (stock) (R) are end-of-quarter variables, deflated by the consumer price index. These variables and real GDP are expressed in logarithms and are seasonally adjusted.

As for the interest rate/rate of return variables, these are real variables. The real loan rate (ρ) and real bond rate (i) are calculated by subtracting the annual inflation rate from their nominal values, and are expressed as quarterly averages. The inflation rate is computed in terms of the consumer price index as the year-on-year percentage change. The rate of return on retained earnings (φ) is calculated as the ratio of the flow of retained earnings and depreciation to the stock of retained earnings, where for this calculation primary data are used. The main sources of the data are the Federal Reserve Economic Data (FRED) and Quarterly Financial

Report (QFR)[16,17] databases. In the appendix, we cite the definitions and sources of all variables.

To start with, we estimate an unrestricted VAR model for the full sample period. The specification of the lag length is based on the Schwarz Information Criterion (SIC). We also perform the standard diagnostic tests for heteroskedasticity, normality and autocorrelation.

As a preliminary step for the VAR analysis, we test the time series for stationarity applying the Phillips-Perron (PP), and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) standard unit root tests over the entire sample period.[18] We also examine the stationarity properties of the series applying a modified augmented Dickey-Fuller unit root test, which allows the identification of a breakpoint in the series endogenously from the data.[19] We test the null hypothesis that the series has a unit root with a possible intercept break, versus the alternative that the series is stationary with a breakpoint.

The lag structure in the above tests is specified based on the Schwarz criterion. We consider that a time series has a unit root when at least two of the above three tests show the existence of a unit root at a 5% significance level. We find that all variables have a unit root. In this case, we calculate first-differences in order to achieve stationarity and repeat the unit

[16] The QFR database includes quarterly data for all sizes of Manufacturing, Mining, Wholesale, Trade and selected Service Industries. One of the advantages of the QFR data is that they include firms that are publicly traded and firms that are not, while they are available at a quarterly frequency (Oliner and Rudebusch, 1996). Thus, the database captures the behavior of small and large firms (Gertler and Gilchrist, 1994; Bernanke et al., 1996) and permits quantitative assessment of the aggregate implications of credit constraints. Moreover, aggregate time series are available also in disaggregated form, according to firm size class and industry class.

[17] The sectoral classification for QFR data was changed in 2000:Q4. Up to 2000:Q3 the Standard Industrial Classification (SIC) classification was used, while from 2000:Q4 onwards, the North American Industry Classification System (NAICS) classification is followed. As a result of this change, some sectors have been reclassified. In addition, the total across all sectors has been affected as some sectors covered under the previous classification are no longer covered and vice-versa. To deal with the resulting break in the series, these have been spliced, using the relationship of the series for the period for which reporting under both classification schemes is available (2000:Q4-2001:Q2).

[18] In testing for stationarity, the KPSS test is more reliable for small samples. The null hypothesis of the KPSS test is that the series is stationary, in contrast to the PP unit root test where the null hypothesis is that the series has a unit root.

[19] Perron (1989) has shown that this approach is more robust, in case where the variables are trend stationary, while standard unit root test results are biased toward the non-rejection of the null hypothesis when there is a structural break in the mean of a stationary time series.

root tests. The first differences are stationary. We conclude that our variables are integrated of order one, i.e. I(1).

We then proceed to examine for cointegration, based on the Johansen maximum eigenvalue test (1995),[20,21] in order to estimate the number of cointegrating relationships among the non-stationary time series in our sample. We find evidence for two cointegrating relationships among the variables.

Before proceeding to estimation, we need to test for temporal instability which, if existent, may bias seriously our estimates. The recent financial crisis could be a case in point. Thus, we run a series of stability tests to identify potential structural breakpoints. In particular, plots of the restricted cointegrating relationships after imposing just-identifying restrictions (Figure 4.1) and the one-step forecast (probability) and recursive residuals stability tests for the system as a whole (Figure 4.2) indicate abnormal variations in 2008:Q4. This could be a sign of a possible break. This instability is also verified by the Bai-Perron breakpoint test, which determines the structural breakpoints endogenously from the data.[22] The results show that there was a structural change after the financial crisis of 2008, which represents a shift in the underlying financial structure. Thus, we set the breakpoint in 2008:Q4[23] and split our sample,

[20] More specifically, we specify the number of cointegrating relationships according to the maximum eigenvalue test results, at the 5% significance level. The maximum eigenvalue test is λ_{max}= -T ln (1-$\hat{\lambda}_{r+1}$), r=0,1, ..., k-1. The H_o hypothesis is $r \leq r_0$ for r_0=0,1,...,k-1, where k is the number of variables. The H_1 hypothesis assumes that there are r_0+1 cointegrating vectors. We include a constant (intercept) in each cointegrating equation, which reflects in a more plausible way the generating mechanism of the data.

[21] Lütkepohl et al. (2001), based on Monte Carlo simulations, compare the maximum eigenvalue and the trace tests for the specification of the cointegrating rank of a VAR process. They provide evidence that the trace test has superior power performance relative to the maximum eigenvalue test in some situations. However, they show that the trace test tends to have more distorted size in small samples in comparison with its competitor. Juselius (2006) also argues that size and power distortions could arise with the application of the trace test when the sample is small. Since in our case the sample is relatively small, we prefer the maximum eigenvalue test for the determination of the cointegrating rank.

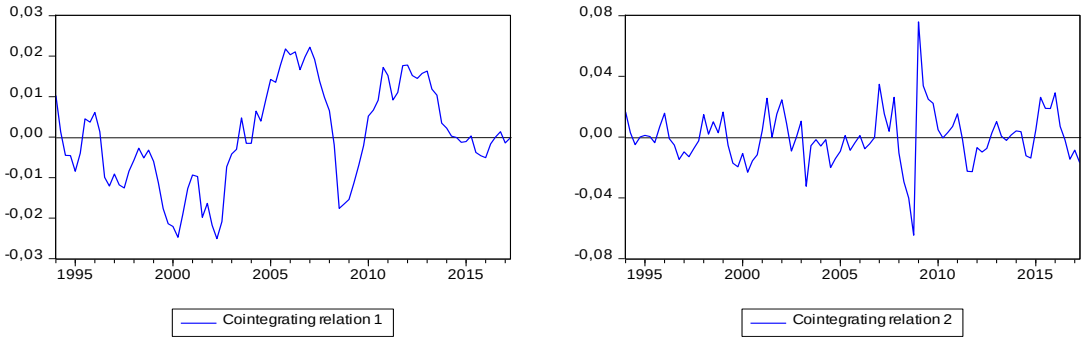
[22] The Bai-Perron test allows the error distribution to vary across breaks.

[23] Our findings are also robust when we test for the potential breakpoint based on the Chow test.

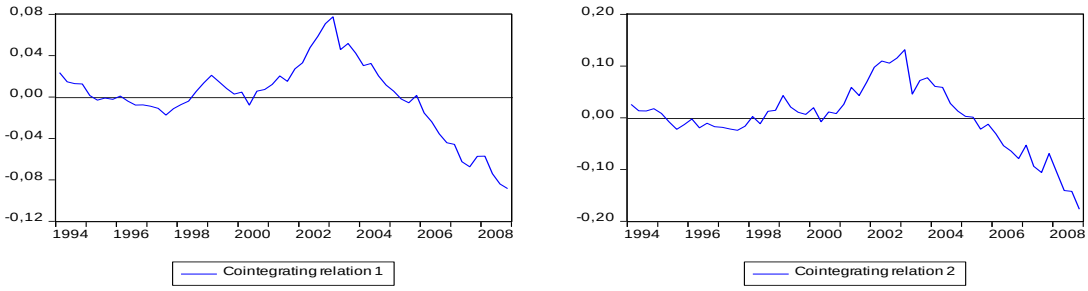
in order to ensure parameter constancy. A dummy variable is also included in the VEC model in the first subperiod, in order to capture the effects of abnormal variations in 2002:Q3.[24,25]

Figure 4.1: Plots of the restricted cointegrating vectors

A. 1994:Q1 - 2017:Q2



B. 1994:Q1 - 2008:Q4



C. 2009:Q1 - 2017:Q2

[24] We examine the residuals of the initial VEC model, and if we find outliers greater than 3 standard deviations, we include a series of point dummy variables – as exogenous variables – to capture specific abnormal events during the period under study. Our results are robust to a range of threshold values between 2.5 and 3.5 standard deviations.

[25] We do not split the sample in 2002:Q3 because there is no structural change with permanent effects, while the size of the sample is not sufficient to obtain reliable results. This breakpoint possibly captures the US stock market downturn in September 2002.

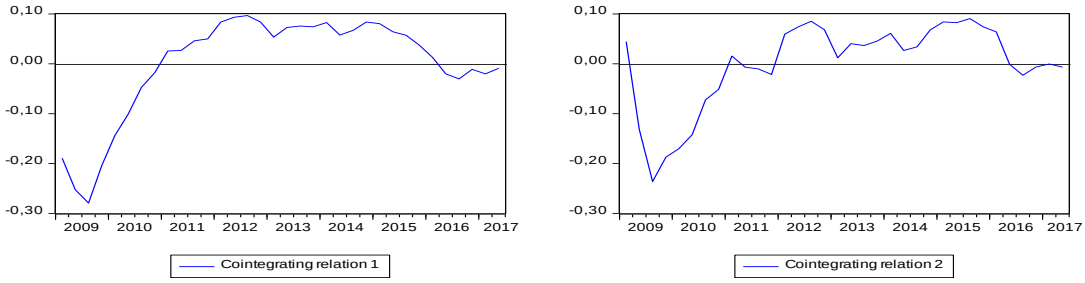
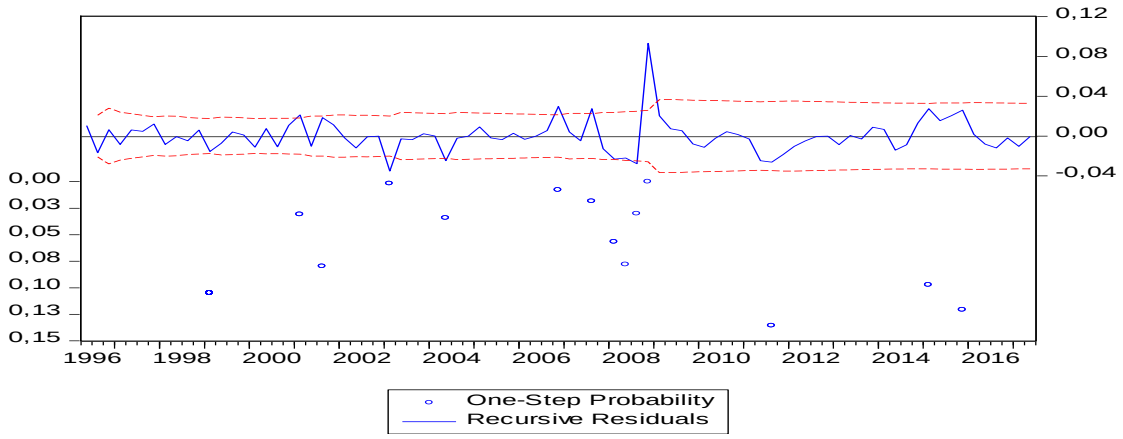
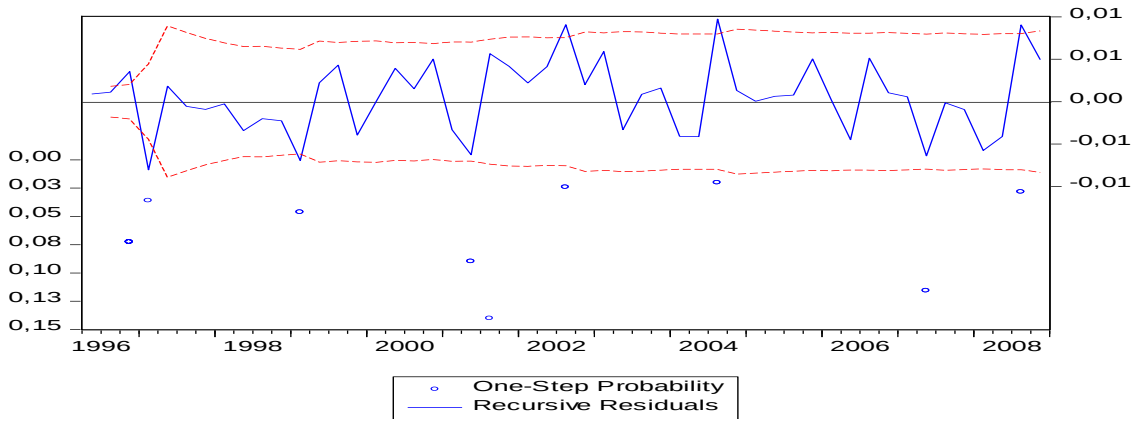


Figure 4.2: One-step probability and recursive residuals stability tests

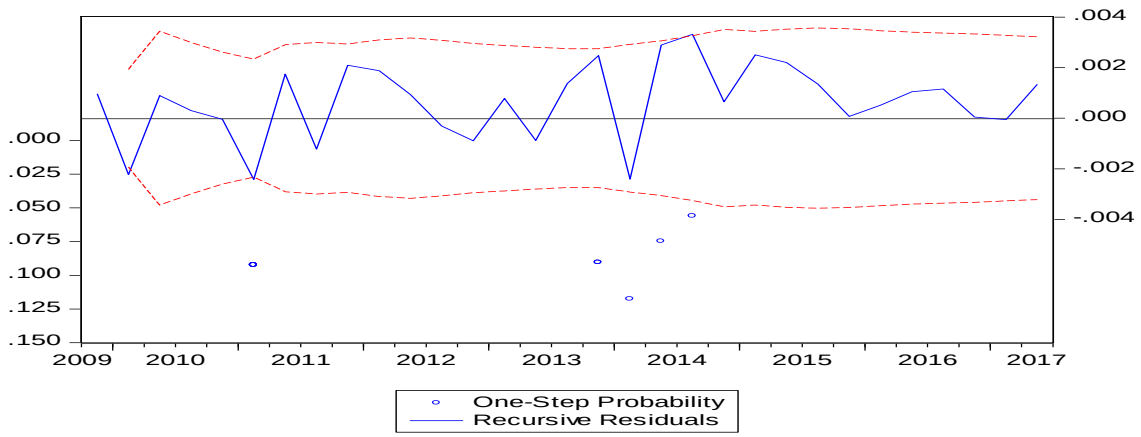
A. 1994:Q1 - 2017:Q2



B. 1994:Q1-2008:Q4



C. 2009:Q1 - 2017:Q2



Once we have split our sample into the two subperiods, we estimate VAR models for these subperiods in order to specify the optimal lag length. The optimal length, specified according to the Schwarz criterion, is equal to 2 and 1, for the first and second subperiod, respectively. Diagnostic test results provide evidence that there is no autocorrelation, the residuals are multivariate normal, while there is no heteroskedasticity.

Once again, we run the aforementioned unit root tests but this time in each subperiod. All the variables are also found to be I(1). Stability test results, for each subperiod verify that the cointegrating parameters are relatively constant. We perform the Johansen cointegration test on the subsamples. We assume unrestricted intercepts and no trends in the cointegration test and the VAR model. Johansen's maximum eigenvalue test results are presented in Table 4.1, for both subperiods. The cointegration results provide evidence for the existence of only two cointegrating vectors in both subperiods. In this case, we have to examine that only one of the sub-channels of the credit channel is operational in these subperiods, and works additionally to the traditional interest rate channel.

For this purpose, we need to impose a number of over-identifying restrictions in the cointegrating relationships in order to test the operation of the monetary channels in both subperiods, under conditions of imperfect substitutability between alternative sources of external financing, or between sources of internal and external financing. The restrictions which are imposed to identify the appropriate cointegrating vectors rely on the economic assumptions defined above, in accordance with our theoretical setup. We start by testing the operation of the balance sheet channel. By using the likelihood ratio test of Johansen and

Juselius (1994), we test the over-identifying restrictions that lead to the system of equations (4.4) and (4.5) against the exactly-identifying restrictions that underlie the system of equations (4.2) and (4.3).[26]

[26] The standard likelihood ratio test of the over-identifying restrictions follows asymptotically a $x^2(k-r)$ distribution, where k is the number of restrictions and r is the number of cointegrating relationships.

Table 4.1: Cointegration analysis

Panel A: Johansen cointegration test				
Period	1994:Q1 – 2008:Q4		2009:Q1 – 2017:Q2	
Number of cointegrating vectors[a]	2		2	
Maximum eigenvalue test	27.584 (0.0538)		24.831 (0.1082)	
Panel B: Coefficients on cointegrating vector variables[b]				
Period	1994:Q1 – 2008:Q4		2009:Q1 – 2017:Q2	
Variables	Vector1	Vector2	Vector1	Vector2
ρ-i	0.000	0.000	0.000	0.000
ρ-φ	1.000	-1.478 (0.225) [-6.558]	1.000	0.326 (0.013) [25.051]
Y	1.697 (0.258) [6.568]	1.000	1.061 (0.169) [6.256]	1.000
R	-1.224 (0.174) [-7.035]	0.000	-0.742 (0.047) [-15.481]	0.000
L	0.000	0.000	0.000	0.000
D	0.000	-0.792 (0.053) [-14.714]	0.000	-0.481 (0.016) [-29.913]
LR test[c,d]	$x^2(4)=10.002$ (0.040)		$x^2(4)=4.231$ (0.375)	

Note: [a] Numbers in parenthesis are the Mackinnon-Haug-Michelis (1999) probability values to accept the null hypothesis at the 5% significance level.

[b] Numbers in parentheses are asymptotic standard errors, while numbers in brackets are the t-statistics.

[c] Numbers in parentheses are probabilities to accept the over-identifying restrictions.

[d] *,** and *** denote rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table 4.1 reports the maximum likelihood estimates of the over-identified model in both subperiods. The likelihood ratio test is equal to 10.002 (p-value=0.040) and 4.231 (p-value=0.375) in the first and second subperiod, respectively. Based on these test results, we cannot reject the zero restriction on the coefficient of the (ρ-i) spread variable in both subperiods. This implies the existence of perfect asset substitutability for borrowers and banks, and as a result the non-operation of the bank lending channel. Moreover, all the coefficients of the estimated cointegrating vectors are significant and correctly signed in both subperiods. The only exception is the sign of the coefficient of the spread variable (ρ-φ) in the second subperiod. This divergence is possibly attributed to the restricted sample size.[27]

5. Conclusions

In this paper we developed a small-scale structural model based on the Bernanke and Blinder (1988) model to study the operation of both components of the credit channel of monetary transmission, i.e. the bank lending and the balance sheet channel. The Bernanke and Blinder model was extended to incorporate imperfect substitution between internal and external finance of firms so that the new model incorporated the most important elements of a changing financial structure. The latter implies that firms are facing a cost differential when raising internal or external finance, and also that the changes in financial structure themselves are interdependent with investment demand (and thus output demand); these two features are shared by our model. The reason why both the bank lending channel and the balance sheet channel jointly received little attention in the literature may simply be the lack of an available model that concisely captures the essence of both transmission mechanisms.

Our model contains the basic components of the financial structure by specifying demand equations for these components. It also contains a supply of loans equation which, together with the relevant equilibrium condition, integrates the loan market in the model. The model

[27] To verify the validity of the above results, we also test for the possible operation of the bank lending channel instead of the balance sheet channel, by imposing the appropriate over-identifying restriction (ρ-φ=0) in the system of Eqs. (4.1) and (4.3). The likelihood ratio test results show that we cannot accept the null hypothesis (p-value=0) in both subperiods, which implies that there is imperfect substitution between loans and retained earnings (i.e. ρ≠φ). Thus, we proceed by considering that only the balance sheet channel is operational, since in the first place we have identified the existence of two cointegrating vectors.

specification is completed by a conventional LM curve and an IS curve. Before going ahead to estimation, we used the model to quantify the financial accelerator effects due to the operation of the two sub-channels of the credit channel. An important result of our analysis is that the amplification consequences of monetary policy are much stronger if both the bank lending channel and the balance sheet channel are in operation compared to the case where only one plays a role in monetary transmission.

Next, our model was brought to a form suitable for empirical testing by reformulating it so that the identification of a loan supply function and a loan demand function would be possible. Our framework provided us with a number of testable restrictions related to the degree of asset substitution and thus to the effectiveness of the two components of the credit channel. These restrictions were tested in the context of a VEC model that was applied to US aggregate data and was used to identify the equilibrium relationships included in our model, i.e. the cointegrating relationships. We found evidence of two cointegrating relationships among the variables. The restrictions which were then imposed on these relationships were necessary in accordance with our theoretical setup in order to test for the operation of both channels of monetary transmission. It should be reiterated at this point that, according to Pesaran and Shin's (2001) theory, identification of the equilibrium structure and thus testing of restrictions on this structure can be achieved without imposing restrictions on the model's dynamic structure.

Before proceeding to estimation and testing for restrictions in the equilibrium relationships, we needed to test for temporal instability, which, if present, might bias our estimates and test results. The recent financial crisis was a case in point. For this purpose, we ran a series of stability tests indicating a possible break after the financial crisis of 2008. Thus we set the breakpoint in 2008:Q4 and split our sample, in order to ensure parameter constancy. Stability test results for each sub-period verified that the cointegrating parameters were relatively constant. Having determined that the number of cointegrating relationships in each sub-period is two, we went on to examine that only one of the sub-channels of the credit channel is operational in these sub-periods in addition to the traditional interest rate channel. Testing the appropriate overidentifying restrictions in these cointegrating relationships, we arrived at

the conclusion that of the two sub-channels only the balance sheet channel is at work, while the operation of the bank lending channel could not be documented.

The fact that the bank lending channel may not be significant for monetary transmission does not detract from the importance of informational asymmetries which affect the operation of the balance sheet channel. Our results have shed new light on this issue, and at the same time direct our attention to the need for expanding the framework of analysis to include other frictions, such as frictions in goods markets and portfolio choices, investment frictions or habits in consumption, which, if relevant, may produce important changes in the responses of key macroeconomic variables to monetary policy shocks, compared to those reported in other studies that are based on a frictionless model.

References

Abel, A. B., Blanchard, O. J., 1988. Investment and sales: Some empirical evidence. In: Barnett, W. A., Berndt, E. R., White, H. (Eds.), Dynamic Econometric Modeling: Proceedings of the Third Symposium in Economic Theory and Econometrics. Cambridge University Press, Cambridge, pp. 269-296.

Agca, S., Mozumdar, A., 2008. The impact of capital market imperfections on investment-cash flow sensitivity. Journal of Banking and Finance 32, 207-216.

Almeida, H., Campello, M., 2007. Financial constraints, asset tangibility, and corporate investment. Review of Financial Studies 20, 1429-1460.

Ashcraft, A., B., 2006. New evidence on the lending channel. Journal of Money, Credit, and Banking 38, 751-775.

Bai, J., Perron, P., 1998. Estimating and testing linear models with multiple structural changes. Econometrica 66, 47-78.

Bai, J., Perron, P., 2003a. Computation and analysis of multiple structural change models. Journal of Applied Econometrics 18, 1-22.

Bai, J., Perron, P., 2003b. Critical values for multiple structural change tests. Econometrics Journal 6, 72-78.

Bernanke, B.S., 1993. Credit in the macroeconomy. Federal Reserve Bank of New York Quarterly Review. 50-70 (Spring).

Bernanke, B.S., 2007. The financial accelerator and the credit channel. Speech 296, Board of Governors of the Federal Reserve System.

Bernanke, B.S., Blinder, A. S., 1988. Credit, money and aggregate demand. American Economic Review Papers and Proceedings 78, 435-439.

Bernanke, B. S., Blinder, A. S., 1992. The federal funds rate and the channels of monetary transmission. American Economic Review 82, 901-921.

Bernanke, B., Gertler, M., 1989. Agency costs, net worth, and business fluctuations. American Economic Review 79, 14-31.

Bernanke, B.S., Gertler, M., 1995. Inside the black box: The credit channel of monetary policy transmission. Journal of Economic Perspectives 9, 27-48.

Bernanke, B., Gertler, M., Gilchrist, S., 1996. The financial accelerator and the flight to quality. Review of Economics and Statistics 78, 1-15.

Bernanke, B. S., Gertler, M., Gilchrist, S., 1999. The financial accelerator in a quantitative business cycle framework. In: Taylor, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics, Volume 1, Part C. Elsevier, New York, pp. 1341-1393.

Boivin, J., Kiley, M. T., Mishkin, F. S., 2010. How has the monetary transmission mechanism evolved over time? In: Friedman, B. M., Hahn, F. H. (Eds.), Handbook of Monetary Economics, Chapter 8. Elsevier, New York, pp. 369-422.

Brissimis, S. N., Delis, M., D., 2009. Identification of a loan supply function: A cross-country test for the existence of a bank lending channel. Journal of International Financial Markets, Institutions and Money 19, 321-335.

Brissimis, S. N., Delis, M. D., Iosifidi, M., 2014. Bank market power and monetary policy transmission. International Journal of Central Banking 10, 173-214.

Brissimis, S. N., Magginas, N. S., 2005. Changes in financial structure and asset price substitutability: A test of the bank lending channel. Economic Modelling 22, 879-904.

Brissimis, S. N., Papafilis, M.-P., 2021. Reflections on the external finance premium, the measurement of the cost of internal finance and the equilibrium real interest rate. Working Paper.

Campello, M., 2002. Internal capital markets in financial conglomerates: Evidence from small bank responses to monetary policy. Journal of Finance 57, 2773-2805.

Campello, M., Giambona, E., Graham, J.R., Harvey, C., 2011. Liquidity management and corporate investment during a financial crisis. Review of Financial Studies 24, 1944-1979.

Campello, M., Graham, J.R., Harvey, C., 2010. The real effects of financial constraints: Evidence from a financial crisis. Journal of Financial Economics 97, 470-487.

Carvalho, D., Ferreira, M.A., Matos, P., 2015. Lending relationships and the effect of bank distress: Evidence from the 2007-2009 financial crisis. Journal of Financial and Quantitative Analysis 50, 1165-1197.

Cetorelli, N., Goldberg, L. S., 2012. Banking globalization and monetary transmission. Journal of Finance 67, 1811-1843.

Chakraborty, I., Goldstein, I., MacKinlay, A., 2020. Monetary stimulus and bank lending. Journal of Financial Economics 136, 189-218.

Chodorow-Reich, G., 2014. The employment effects of credit market disruptions: Firm-level evidence from the 2008-09 financial crisis. Quarterly Journal of Economics 129, 1-59.

Claessens, S., Kose, M. Y., 2017. Macroeconomic implications of financial imperfections: A survey. BIS Working Paper No. 677.

De Fiore, F., Uhlig, H., 2015. Corporate debt structure and the financial crisis. Journal of Money, Credit and Banking 47, 1571-1598.

Devereux, M., Schiantarelli, P., 1990. Investment, financial factors and cash flow: Evidence from U.K. panel data. In: Hubbard, R.G. (Ed.), Asymmetric Information, Corporate Finance, and Investment. University of Chicago Press, Chicago, 279-306.

Di Maggio, M., Kermani, A., Palmer, C., 2017. The effects of quantitative easing on bank lending behavior. Review of Financial Studies 30, 3858-3887.

Duchin, R., Ozbas, O., Sensoy, B. A., 2010. Costly external finance, corporate investment, and the subprime mortgage credit crisis. Journal of Financial Economics 97, 415-435.

Edgerton, J., 2012. Credit supply and business investment during the Great Recession: Evidence from public records of equipment financing. Working Paper.

Fazzari, S. M., Hubbard, R. G., Petersen, B. C., 1988. Financing constraints and corporate investment. Brookings Papers on Economic Activity 19, 141-206 (Spring).

Foley-Fischer, N., Ramcharan, R., Yu, E., 2016. The impact of unconventional monetary policy on firm financing constraints: Evidence from the maturity extension program. Journal of Financial Economics 122, 409-429.

Gertler, M., 1992. Financial capacity and output fluctuations in an economy with multiperiod financial relationships. Review of Economic Studies 59, 455-472.

Gertler, M., Gilchrist, S., 1993. The role of credit market imperfections in the monetary transmission mechanism: Arguments and evidence. Scandinavian Journal of Economics 95, 43-64.

Gertler, M., Gilchrist, S., 1994. Monetary policy, business cycles, and the behavior of small manufacturing firms. Quarterly Journal of Economics 109, 309-340.

Gertler, M., Hubbard, R. G., 1988. Financial factors in business fluctuations. Proceedings-Economic Policy Symposium-Jackson Hole, Federal Reserve Bank of Kansas City, pp. 33-78.

Gertler, M., Kiyotaki, N., 2010. Financial intermediation and credit policy in business cycle analysis. In: Friedman, B.M., Woodford, M. (Eds.), Handbook of Monetary Economics, Volume 3. Elsevier, New York, pp. 547-599.

Gilchrist, S., 1990. An empirical analysis of corporate investment and financing hierarchies using firm level panel data. Unpublished, Board of Governors of the Federal Reserve System.

Gilchrist, S., Schoenle, R., Sim, J., Zakrajsek, E., 2017. Inflation dynamics during the financial crisis. American Economic Review 107, 785-823.

Giroux, X., Mueller, H. M., 2017. Firm leverage, consumer demand and employment losses during the Great Recession. Quarterly Journal of Economics 132, 271-316.

Greenwald, B. C., Stiglitz, J. E., 1993. Financial market imperfections and business cycles. Quarterly Journal of Economics 108, 77-114.

Guariglia, A., 2008. Internal financial constraints, external financial constraints, and investment choice: Evidence from a panel of UK firms. Journal of Banking and Finance 32, 1795-1809.

Gurkaynak, R. S., Karasoy-Can, H. G., Lee S. S., 2021. Stock market's assessment of monetary policy transmission: The cash flow effect. Working Paper.

Hendry, D.F., 1995. Dynamic Econometrics. Oxford University Press, Oxford.

Hubbard, R. G., Kashyap, A. K., 1992. Internal net worth and the investment process: An application to U.S. agriculture. Journal of Political Economy 100, 506-534.

Hubbard, R. G., Kashyap, A. K., Whited, T. M., 1995. Internal finance and firm investment. Journal of Money, Credit, and Banking 27, 683-701.

Ivashina, V., Scharfstein, D., 2010. Bank lending during the financial crisis of 2008. Journal of Financial Economics 97, 319-338.

Johansen, S., 1995. Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford University Press, Oxford.

Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration – with applications to the demand for money. Oxford Bulletin of Economics and Statistics 52, 169-210.

Johansen, S., Juselius, K., 1994. Identification of the long-run and the short-run structure: An application to the IS-LM model. Journal of Econometrics 63, 7-36.

Kahle, K. M., Stulz, R. M., 2013. Access to capital, investment, and the financial crisis. Journal of Financial Economics 110, 286-299.

Kashyap, A. K., Stein, J. C., 2000. What do a million observations on banks say about the transmission of monetary policy? American Economic Review 90, 407-428.

Kashyap, A. K., Stein, J. C., Wilcox, D. W., 1993. Monetary policy and credit conditions: Evidence from the composition of external finance. American Economic Review 83, 78-98.

Kishan, R. P., Opiela, T. P., 2000. Bank size, bank capital, and the bank lending channel. Journal of Money, Credit, and Banking 32, 121-141.

Kiyotaki, N., Moore, J., 1997. Credit cycles. Quarterly Journal of Economics 108, 77-114.

Kuttner, K. N., Mosser, P. C., 2002. The monetary transmission mechanism: Some answers and further questions. Federal Reserve Bank of New York Economic Policy Review, 15-26 (May).

Lintner, J., 1956. Distribution of incomes of corporations among dividends, retained earnings and taxes. American Economic Review Papers and Proceedings 46, 97-113.

Lutkepohl, H., Saikkonen, P., Trenkler, C., 2001. Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process. Econometrics Journal 4, 287-310.

Mishkin, F. S., 1995. Symposium on the monetary transmission mechanism. Journal of Economic Perspectives 9, 3-10 (Fall).

Modigliani, F., Miller, M. H., 1958. The cost of capital, corporation finance and the theory of investment. American Economic Review 48, 261-297.

Oliner, S.D., Rudebusch, F.D., 1996. Monetary policy and credit conditions: Evidence from the composition of external finance: Comment. American Economic Review 86, 300-309.

Perron, P., 1989. The great crash, the oil-price shock, and the unit root hypothesis. Econometrica 57, 1361-1401.

Pesaran, M. H., Shin, Y., 2002. Long-run structural modelling. Econometric Reviews 21, 49-87.

Rodnyansky, A., Darmouni, O. M., 2017. The effects of quantitative easing on bank lending behavior. Review of Financial Studies 30, 3858-3887.

Schiantarelli, F., 1996. Financial constraints and investment: Methodological issues and international evidence. Oxford Review of Economic Policy 12, 70-89.

Serven, L., Solimano, A., 1992. Private investment and macroeconomic adjustment: A survey. World Bank Research Observer 7, 95-114.

Whited, T. M., 1992. Debt, liquidity constraints, and corporate investment: Evidence from panel data. Journal of Finance 47, 1425-1460.

Appendix: Data definitions and sources

The dataset begins in 1994:Q_1 and ends in 2017:Q2. Sources of the data are the Federal Reserve Economic Data (FRED) and Quarterly Financial Report (QFR) databases published by the Federal Reserve Bank of St. Louis and the U.S. Census Bureau, respectively. The definition of the data and the corresponding sources are as follows:

- Loans: Commercial and industrial loans, all commercial banks - (FRED)
- Deposits: Deposits, all commercial banks - (FRED)
- GDP: Real gross domestic product, billions of chained 2009 dollars, annual rate - (FRED)
- Retained earnings (stock): Retained earnings of manufacturing, mining and trade corporations - (QFR)
- Retained earnings (flow): Retained earnings of manufacturing, mining and trade corporations - (QFR)
- Depreciation (flow): Depreciation of manufacturing, mining and trade corporations - (QFR)
- Lending rate: Bank prime loan rate - (FRED)
- Bond rate: 10-year government benchmark bond yield - (FRED)
- CPI: Consumer price index, Total all items for the United States, index 2010=1 - (FRED)

BANK OF GREECE WORKING PAPERS

285. Avramidis, P., I. Asimakopoulos, D. Malliaropulos, "Bank consolidation, firm-bank relationship and firms' strategic default decision: evidence from the tourism industry during the Greek economic crisis", January 2021.

286. Papageorgiou, D. and S. Tsiaras, "The Greek Great Depression from a neoclassical perspective", February 2021.

287. Lazaris, P., A. Petropoulos, V. Siakoulis, E. Stavroulakis and N. Vlachogiannakis, "Interest Rate Pass Through in the Deposit and Loan Products Provided by Greek Banks", February 2021.

288. Kollintzas, T., D. Papageorgiou and V. Vassilatos, "Implications of Market and Political Power Interactions for Growth and the Business Cycle I: Private Sector Equilibrium", March 2021.

289. Lolos, S., P. Palaios and E. Papapetrou, "The Greek Tourism-Led Growth Revisited: Insights and Prospects", June 2021.

290. Kakridis, A., "Nobody's Child: The Bank of Greece in the Interwar Years", July 2021.

291. Hondroyiannis, G. and D. Papaoikonomou, "The Effect of Eurosystem Asset Purchase Programmes on Euro Area Sovereign Bond Yields During The Covid-19 Pandemic, July 2021.

292. Bragoudakis, Z. and D. Panas, "Investigating Government Spending Multiplier for the US Economy: Empirical Evidence Using a Triple Lasso Approach", October 2021.

293. Sideris, D. and G. Pavlou, "Disaggregate Income and Wealth Effects on Private Consumption in Greece", November 2021

294. Tsionas G. M., "Novel Techniques for Bayesian Inference in Univariate and Multivariate Stochastic Volatility Models", February 2022.

295. Consolo, A and F. Petroulakis "Did Covid-19 Induce a Reallocation Wave?, March 2022.

296. Filis, G., S. Degiannakis and Z. Bragoudakis, "Forecasting Macroeconomic Indicators for Eurozone and Greece: How Useful are the Oil Price Assumptions?", April 2022.

297. Milionis E. A., G. N. Galanopoulos, P. Hatzopoulos and A. Sagianou, "Forecasting Actuarial Time Series: A Practical Study of the Effect of Statistical Pre-Adjustments", May 2022.

298. Konstantinou Th. Panagiotis, A. Partheniou and A. Tagkalakis, "A Functional Classification Analysis of Government Spending Multipliers", June 2022.

299. Brissimis, N.S., and E.A. Georgiou, "The Effects of Federal Reserve's Quantitative Easing and Balance Sheet Normalization Policies on Long-Term Interest Rates", June 2022.