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The changing transmission mechanism of US monetary policy

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Abstract We examine the relative importance of the interest rate, exchange rate, and bank-lending channels for the transmission mechanism of monetary policy in the United States over the past fifty years. Our analysis is based on a structural vector autoregressive model that includes bank loans and uses sign restrictions to identify monetary policy shocks. Given these identified policy shocks, we quantify the relative importance of different transmission channels via counterfactual analysis. Our results suggest a nontrivial role for the bank-lending channel at the aggregate level, but its importance has been greatly diminished since the early 1980s. Despite the timing, we find no support for a link between this change in the transmission mechanism and the concurrent reduction in output volatility associated with the Great Moderation. There is, however, some evidence of a link to the reduction in inflation volatility occurring at the same time.

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1 Introduction

Although there is much agreement that monetary policy has a significant influence on the real economy (see, for example, Bernanke and Blinder 1992; Christiano and Eichenbaum 1995; Leeper et al. 1996; Christiano et al. 1999; Kim 1999; Uhlig 2005, and Forni and Gambetti 2010), there is no consensus about the mechanisms through which it does so. Taylor (1995) classified different theories of the transmission mechanism of monetary policy into two broad categories. The financial market price view, also known as the "money" view, which primarily consists of the interest rate and exchange rate channels, stresses the impact of policy on prices and rates of return of financial assets and therefore on the spending decisions by firms and households. Alternatively, the "credit" view emphasizes the balance sheet and bank-lending channels, which are also hypothesized to affect spending behavior. The existence of these credit channels is contingent on assumptions about the size and nature of capital market imperfections.[1] Previous research on the importance of these channels has produced mixed results. For example, Bernanke and Gertler (1995) provide some illustrative evidence of a direct link between the credit channels and monetary policy shocks, while Romer and Romer (1990) and Ramey (1993) find that the credit channels play an insignificant role in transmitting monetary policy shocks.

In this paper, we quantify the relative importance of the different channels associated with the money and credit views of the monetary transmission mechanism. Specifically, for the "money" view, we look at the interest rate and exchange rate channels, while for the "credit" view, we focus on the bank-lending channel. Due to the well-documented decline in macroeconomic volatility in the early 1980s (the so-called Great Moderation, see, for example, Boivin and Giannoni 2006), as well as structural changes in the banking sector because of banking deregulation, and a possible change in monetary policy regime, we believe that there have been large changes in the relative importance of the various transmission channels over time. To test our hypothesis, we identify monetary policy shocks in a structural vector autoregression (SVAR) framework using sign restrictions in both the pre- and post-1984 periods and then employ counterfactual analysis to quantify the relative importance of different transmission channels by considering constrained versions of the SVAR model in which the transmission variable under examination is held constant. Comparisons of the responses of output to monetary policy shocks between the benchmark and the constrained models provide our measure of relative importance of a given channel.

Our results show a dramatic change in the transmission mechanism of monetary policy over the past 50 years. Estimates for the pre-1984 period indicate that the bank-lending channel and the interest rate channel were about equally important for the transmission of monetary policy shocks during that time. However, since the early 1980s, the bank-lending channel appears to have played a much diminished role, while the interest rate channel has exerted a greater influence relative to the bank-lending channel in transmitting monetary shocks. Notably, this result has important

[1] The balance sheet channel operates through the net worth of business firms and arises from the problems of adverse selection and moral hazard (Mishkin 1995). The bank-lending channel emphasizes the role of banks in determining the supply of loans in an environment where information is not symmetric.

implications for the design of nonstandard monetary policy actions during the recent zero-lower-bound period, supporting the Federal Reserve's greater focus on financial prices rather than the quantity of credit.

We believe that our paper is the first in quantifying the relative importance of the monetary transmission channels (instead of simply assessing whether the channel operates or not), as well as highlighting the change in the relative importance of the channels since the Great Moderation began.[2] Our identification strategy using sign restrictions motivated by economic theory helps us avoid circularity between identification and inference and also allows us to consider relatively large VAR systems in order to minimize issues arising from omitted variables. In addition to assessing the changes in monetary transmission channels, we also explore possible connections between these changes and the volatility reduction in output and inflation in the mid-1980s. The observed evolution of the transmission mechanism raises the question of whether the macroeconomic volatility reduction was due to smaller and less frequent shocks in the economy or to changes in the propagation of these shocks. Clearly, changes in the transmission mechanism of monetary policy could play a role in altering the dynamic structure of the economy. We proceed by conducting additional counterfactual experiments in the spirit of Stock and Watson (2002), Ahmed et al. (2004), Boivin and Giannoni (2006), and Kim et al. (2008), among many others. From these experiments, we do not find a strong connection between changes in the monetary transmission mechanism and the observed reduction in volatility of output. However, we do find that these changes could have had some influence on stabilizing inflation.

The rest of the paper is organized as follows: Section 2 reviews the theoretical background for the different views of the monetary transmission mechanism. Section 3 presents details of our approach to identifying monetary policy shocks and the quantification of the relative importance of different channels. Section 4 reports the empirical results. Section 5 examines the relationship between changes in the monetary transmission mechanism and the moderation of macroeconomic volatility since the early 1980s. Section 6 concludes.

2 Theoretical background for the monetary transmission mechanism

In this section, we discuss in greater detail the money and credit views of the monetary transmission mechanism that provide the theoretical background for our empirical analysis. We begin with the money view, focusing on the interest rate and exchange rate channels, and then proceed to the credit view, in particular outlining the bank-lending channel. For more comprehensive discussions of the monetary transmission mechanism, see Mishkin (1995) or, more recently, Boivin et al. (2010).

[2] Most papers that study monetary transmission channels, specifically the bank-lending channel, consider a single sample period (such as Ramey 1993; Bernanke and Gertler 1995; Kashyap and Stein 1995, 2000; Kishan and Opiela 2000; Den Haan et al. 2007, among many others). Bernanke and Gertler (1995) did question the validity of some of the assumptions needed for the operation of the bank-lending channel since the early 1980s, although they did not empirically assess the changes. Dave et al. (2009), the working paper version of Dave et al. (2013), did, as a robustness check, analyze the post-1984 sample period and find that the strength of the bank-lending channel weakens for this period.

2.1 Money view

Taylor's (1995) broad classification of the financial market price view originates from the argument advocated by what is traditionally known in the literature as the "money view." This view emphasizes the role of monetary aggregates and operates via the interest rate channel. The theory underpinning the money view relies on a two-asset model with money and bonds as imperfect substitutes in portfolios. The interest rate adjusts to give equilibrium in the asset market, as widely illustrated in the literature by applying the IS–LM framework (Bernanke and Blinder 1988). Given rational expectations and sticky prices, a contractionary monetary policy shock leads to an increase in long-term real interest rates, which increases the cost of capital, thereby causing a reduction in investment, leading to a contraction in aggregate demand and a decline in output. In addition to affecting businesses' decisions about investment, the interest rate channel is also recognized to affect consumers' decisions about spending on housing and consumer durables.

The exchange rate also potentially affects monetary transmission because of its effect on net exports. With a flexible exchange rate regime, an appreciation of the country's exchange rate will lead to the decline in exports and an increase in imports. A contractionary monetary policy shock raises the domestic real interest rate. Based on the traditional Mundell–Fleming framework, the interest rate effect on the exchange rate is determined by the movement in the flows of capital. Following the assumption of perfect capital mobility, a higher interest rate induces an inflow of capital into the country, leading to an appreciation in the value of the domestic currency relative to the other currency. The higher value of the domestic currency makes domestic goods more expensive than foreign goods. Export volume decreases due to the deterioration in the country's competitiveness in the world market, while imports increase as a result of expenditure switching by residents in favor of foreign goods, thereby causing a fall in net exports. This generates a reduction in aggregate demand and output.

2.2 Credit view

The credit view emphasizes how imperfect information and other "frictions" in the credit market work as an important channel of monetary policy. Bernanke and Gertler (1995) argue that, because of information asymmetry in the credit market and costly enforcement, agency problems arise in the financial market and create an "external finance premium." The external finance premium is defined as the difference in cost between funds raised externally (by issuing equity or debt) and the opportunity cost of funds generated internally (by retaining earnings). They postulate that monetary policy shocks change the external finance premium faced by borrowers. Consequently, this channel magnifies the effect of monetary policy on real spending.

The bank-lending channel is one specific mechanism in the credit view. According to Bernanke and Gertler (1995), the bank-lending channel operates on the premise that bank loans are of special importance, particularly for small firms that rely on bank loans as their main source of financing. The change in monetary policy then affects the external finance premium through shifts in the supply of intermediated credit, particularly the quantity of loans supplied by banking institutions to the credit markets. The critical part of this argument is the presumption that monetary policy significantly affects the supply of bank loans (i.e., the assets side of the banks' balance sheet). The Bernanke and Blinder (1988) model of the bank-lending channel suggests that when monetary policy is tightened, the central bank drains reserve and hence deposit from the banking system.[3] This in turn limits the supply of bank loans by reducing banks' access to loanable funds.[4] This is the key difference in the theoretical foundation between the credit and money views. According to the proponents of the credit view, the use of a two-asset model (i.e., either money or bonds) in the analysis of the money view is too simplistic. Bank loans differ from bonds, and as such are not a perfect substitute of each other. Thus, proponents of the credit view extend the basic IS–LM framework into a three-asset model, namely into money, bonds, and loans. See Bernanke and Blinder (1988) for further discussion of the extended IS–LM model.

3 Methods

Studies of monetary policy transmission must grapple with the identification of monetary policy shocks and their effects. SVAR models are designed to achieve this identification without imposing too much structure on the economy's dynamics and are consistent with reduced-form solutions for a range of theoretical dynamic stochastic general equilibrium models (see, for example, the discussion in Fernández-Villaverde et al. 2007). This section briefly outlines key issues surrounding structural identification that have been the focus of debate in the SVAR literature, and it presents the particular approach used in this paper. We also go over our strategy for measuring the importance of various transmission channels.

3.1 The SVAR model

A typical model in the monetary transmission literature consists of variables that represent (i) immediate target or policy instrument; (ii) intermediate targets, i.e., transmission channels; and (iii) final targets such as output and price. Letting $\boldsymbol{y}_t$ denote an $n \times 1$ vector of such variables observed at time t, an SVAR model has the following specification:

$$\boldsymbol{B}_0 \boldsymbol{y}_t = \boldsymbol{B}_1 \boldsymbol{y}_{t-1} + \cdots + \boldsymbol{B}_p \boldsymbol{y}_{t-p} + \boldsymbol{\varepsilon}_t, \tag{1}$$

[3] Contraction of bank loans reduces spending of firms and households that depend on bank loans. Capital market imperfections imply that some, perhaps most, agents cannot directly issue securities in imperfect capital markets. These agents depend on intermediated credit for external finance. See Fazzari et al. (1988). Also, bank loans are usually a precondition for bond issuance by firms (Gorton 2009), so without a bank loan firms may be shut out of capital markets altogether.

[4] Bernanke and Gertler (1995) discuss the justification for why banks cannot easily replace the lost deposits with other source of funds. In contrast, Kashyap and Stein (1994) show that it is sufficient to argue that banks do not face a perfectly elastic demand for their open-market liabilities and, hence, central bank operations that shrink their core deposit base will force them to rely more on managed liabilities and also increases their cost of funds. The latter will shift the supply of loans inward and in turn will negatively affect bank-dependent borrowers and raise the external finance premium.

where each $\boldsymbol{B}$ is an $n \times n$ matrix of coefficients and $\boldsymbol{\varepsilon}_t$ is a vector of serially uncorrelated shocks with mean zero and variance covariance matrix $\boldsymbol{D}$, a diagonal matrix with positive elements on the diagonal.

The reduced-form solution of the model in Eq. (1) is

$$\boldsymbol{y}_t = \boldsymbol{\Phi}_1 \boldsymbol{y}_{t-1} + \cdots + \boldsymbol{\Phi}_p \boldsymbol{y}_{t-p} + \boldsymbol{e}_t, \tag{2}$$

where $\boldsymbol{\Phi}_i = \boldsymbol{B}_0^{-1} \boldsymbol{B}_i, \; i = 1, \ldots, p$ and $\boldsymbol{e}_t = \boldsymbol{B}_0^{-1} \boldsymbol{\varepsilon}_t$ is a vector of serially uncorrelated forecast errors with variance covariance matrix, $\boldsymbol{\Sigma} = \boldsymbol{B}_0^{-1} \boldsymbol{D} \boldsymbol{B}_0^{-1'}$. Then, a vector moving average (MA) representation in terms of the forecast errors is given by

$$\boldsymbol{y}_t = \boldsymbol{\Psi}(L) \boldsymbol{e}_t, \tag{3}$$

where $\boldsymbol{\Psi}(L) = \boldsymbol{I} + \boldsymbol{\Psi}_1 L + \boldsymbol{\Psi}_2 L^2 + \cdots$, thus $\boldsymbol{\Psi}(L) = (\boldsymbol{I} - \boldsymbol{\Phi}_1 L - \cdots - \boldsymbol{\Phi}_p L^p)^{-1}$. Rewriting the vector MA representation in terms of the structural shocks yields

$$\boldsymbol{y}_t = \boldsymbol{\Psi}(L) \boldsymbol{B}_0^{-1} \boldsymbol{\varepsilon}_t = \boldsymbol{\theta}(L) \boldsymbol{\varepsilon}_t, \tag{4}$$

where $\boldsymbol{\theta}(L) = \boldsymbol{\Psi}(L) \boldsymbol{B}_0^{-1} = \boldsymbol{\Psi}_0 \boldsymbol{B}_0^{-1} + \boldsymbol{\Psi}_1 \boldsymbol{B}_0^{-1} L + \boldsymbol{\Psi}_2 \boldsymbol{B}_0^{-1} L^2 + \cdots$ or $\boldsymbol{\theta}_i = \boldsymbol{\Psi}_i \boldsymbol{B}_0^{-1}$, with $\boldsymbol{\Psi}_0 = \boldsymbol{I}$, capture the impulse responses to structural shocks.

3.2 Identification of monetary policy shocks

Upon estimating a reduced-form model as in Eq. (2), the challenge is to obtain the structural shocks in Eqs. (1) and (4). The approach used to obtain these shocks or, more technically, to derive a particular orthogonal decomposition of the vector $\boldsymbol{e}_t$ is a crucial aspect of SVAR analysis. Following Canova and De Nicoló (2002), Faust (1998), Uhlig (2005), and many others, we make use of sign restrictions to pin down a particular orthogonal decomposition.[5] Specifically, we adhere to the strategy laid out in Fry and Pagan (2011), which is detailed below.

This method first involves extracting orthogonal innovations from the reduced-form model. These innovations have, in principle, no economic interpretation, but they have the property of being contemporaneously and serially uncorrelated. Next, the signs of the theoretical comovements of selected variables in response to an orthogonal innovation based on macroeconomic theory are used to study the information content of the disturbances, which then allows us to assign a structural interpretation to them. We believe there are several advantages to using this method of identification relative to competing ones such as short-run or long-run recursive restrictions. First, this procedure clearly separates the statistical problem of orthogonalizing the covariance matrix of reduced-form forecast errors from issues concerning the identification of structural shocks. Second, unlike many other SVAR approaches, it achieves identification with-

[5] For a critical survey of SVAR analysis based on sign restrictions, see Fry and Pagan (2011).

out having to impose the zero constraints on impact responses.[6] Third, because all of the constraints are explicitly stated in the model, there is no circularity between identification and inference.

From Eq. (3), an orthogonal decomposition of a vector MA representation with contemporaneously uncorrelated shocks featuring unit variance will have the following form:

$$\boldsymbol{y}_t = \boldsymbol{C}(L)\boldsymbol{\eta}_t, \quad \boldsymbol{\eta}_t \sim iid(0, \boldsymbol{I}). \tag{5}$$

Note that $\boldsymbol{C}(L) = \boldsymbol{\Psi}(L)\boldsymbol{T}$, $\boldsymbol{\eta}_t = \boldsymbol{T}^{-1}\boldsymbol{e}_t$ and $\boldsymbol{\Sigma} = \boldsymbol{T}\boldsymbol{T}'$. The impulse response of each variable to any orthogonal shock, α, is therefore given by the coefficients of the vector of lag polynomials $\boldsymbol{C}(L)\alpha$ where $\alpha'\alpha = 1$. It follows that for any orthonormal matrix $\boldsymbol{Q}$ such that $\boldsymbol{Q}\boldsymbol{Q}' = \boldsymbol{I}$, $\boldsymbol{\Sigma} = \boldsymbol{T}\boldsymbol{Q}\boldsymbol{Q}'\boldsymbol{T}' = \boldsymbol{T}^*\boldsymbol{T}^{*\prime}$ is an admissible decomposition of $\boldsymbol{\Sigma}$. This will yield an infinite number of candidates ($\boldsymbol{T}^*$) for the decomposition of $\boldsymbol{\Sigma}$.

There are three challenges to identification here. The first is to figure out how to transform the variance covariance matrix $\boldsymbol{\Sigma}$ into candidates of orthogonal eigenvalue-eigenvector decompositions, $\boldsymbol{T}^*$. Second, because the space for $\boldsymbol{T}^*$ is un-countably large, we need to develop a procedure to search through the space of $\boldsymbol{T}^*$ for particular orthogonal decompositions of $\boldsymbol{\Sigma}$ that satisfies a set of criteria based on economic theory. Third, after collecting a set of candidate decompositions that fit our criteria, we need to define a method to summarize and report the range of information presented by the set of possible decomposition rather than a single unique decomposition.

Following Fry and Pagan (2011), we address the first challenge by making use of the Givens rotation to construct candidate $\boldsymbol{Q}$'s, which can be used to generate candidate $\boldsymbol{T}^*$'s. Suppose we have a four-variable system, then

$$\boldsymbol{Q} = \boldsymbol{Q}_{1,2}(\omega_1) \times \boldsymbol{Q}_{1,3}(\omega_2) \times \boldsymbol{Q}_{1,4}(\omega_3) \times \boldsymbol{Q}_{2,3}(\omega_4) \times \boldsymbol{Q}_{2,4}(\omega_5) \times \boldsymbol{Q}_{3,4}(\omega_6),$$

where each $\boldsymbol{Q}_{\mathrm{m,n}}$ is an identity matrix with the (m, m) element replaced with cosω; (n, n) element replaced with cosω; (m, n) element replaced with—sinω; and (n, m) element replaced with sinω. For example,

$$\boldsymbol{Q}_{2,3}(\omega) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega & 0 \\ 0 & \sin\omega & \cos\omega & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

Each ω_j is a radian measure between 0 and π. The matrix $\boldsymbol{Q}$ as specified above for a four-variable system is a combination of six Givens rotation matrices. In general, for an n-variable system, $\boldsymbol{Q}$ will be constructed using a combination of $n(n-1)/2$ Givens rotation matrices. Note that each $\boldsymbol{Q}$ will be unique depending on the values of ω_j. Therefore, we can generate candidate $\boldsymbol{Q}$ matrices by conducting random draws of ω_j from a uniform distribution over $(0, \pi)$.

To address the second challenge of how to search through the space of $\boldsymbol{T}^*$ for particular decompositions of $\boldsymbol{\Sigma}$, we impose sign restrictions on the short-run comovement of

[6] Faust (1998) provides anecdotal and quantitative examples of the danger in restricting contemporaneous interactions among variables.

variables, following the strategy laid out in Canova and De Nicoló (2002). To elaborate further, economic theory provides important information on the signs of the pair-wise dynamic cross-correlations between certain variables in response to structural shocks, and we make use of that information to help us locate candidate decompositions. Note that the dynamic cross-correlation function of y_{it} and $y_{j,t+r,}$ at $r = 0, 1, 2, \ldots$ can be expressed as:

$$\rho_{ij}(r) \equiv \mathrm{Corr}(y_{it}, y_{j,t+r}) = \frac{E\left[\boldsymbol{C}^i(L)\boldsymbol{\eta}_t \boldsymbol{C}^j(L)\boldsymbol{\eta}_{t+r}\right]}{\sqrt{E\left[\boldsymbol{C}^i(L)\boldsymbol{\eta}_t\right]^2 E\left[\boldsymbol{C}^j(L)\boldsymbol{\eta}_{t+r}\right]^2}}, \tag{6}$$

where $E[.]$ denotes unconditional expectations and C^h indicates the h^{th} row of matrix $\boldsymbol{C}(L)$ in Eq. (5). Hence, the pair-wise dynamic cross-correlation conditional on the particular shock defined by α is

$$\rho_{ij|\alpha}(r) \equiv \mathrm{Corr}(y_{it}, y_{j,t+r}|\alpha) = \frac{(\boldsymbol{C}^i(L)\alpha)(\boldsymbol{C}^j(L+r)\alpha)}{\sqrt{(\boldsymbol{C}^i(L)\alpha)^2(\boldsymbol{C}^j(L+r)\alpha)^2}}. \tag{7}$$

Given any orthogonal candidate, we can check whether the shock α produces a $\rho_{ij|\alpha}$ that correspond to the sign of the cross-correlation between variables i and j as prescribed by economic theory.[7]

An issue that arises in most papers that use sign/shape restrictions for SVAR identification is the lack of uniqueness in the impulse responses. Specifically, the restrictions produce a distribution of impulse responses rather than a single one. So the final challenge is how to summarize and present the range of possible results, with a common strategy being to sort the impulse responses and report the median value. This sorting is typically done forecast period by forecast period and variable by variable. What this means is that there may no longer be a single set of shocks (which is identified by a particular set of ω's that give us a particular $\boldsymbol{Q}$ and hence $\boldsymbol{T}^*$) that generates the recorded median impulse responses.[8]

Even though reporting median responses are common in the literature, we concur with the arguments in Fry and Pagan (2011) against using this approach and adopt their solution to the reporting problem. Their median target (MT) method provides a way to choose a single model with impulse responses that are as close to the median

[7] Canova and De Nicoló (2002) present a model based on an economy with limited participation to derive the signs of cross-correlation functions to use as sign restrictions. For example, a monetary disturbance generates a positive contemporaneous comovement between output and the price level, between the price level and real money balances, and between real money balances and output. A technology disturbance, on the other hand, would generate a negative contemporaneous comovement between output and the price level, and between the price level and real money balances, but a positive contemporaneous movement between real money balances and output. The various sign restrictions are sufficient to distinguish between monetary, fiscal, and technology shocks.

[8] For example, say we have a set of 1000 candidate decompositions. If we construct the median impulse response for output to monetary shock for on impact of the shock and 10 quarters after, the impulse responses for each forecast horizon (there are 1000 for each forecast horizon) are sorted and the median values reported. Hence, there is no guarantee that the median impulse response at one horizon is generated by the same $\boldsymbol{Q}$ as the median impulse response at another horizon.

values as possible. This preserves the idea that the median is a good summary of the central tendency of the impulse responses across models, but avoids the aforementioned problem of mixing up impulse responses produced by different SVAR models. Under the MT approach, the impulse responses for each candidate decomposition d are first standardized by subtracting off their medians and dividing by their standard deviations. Next, the standardized impulses are placed in a vector $\boldsymbol{\phi}^{(d)}$ and we choose the d that minimizes $\text{MT} = \boldsymbol{\phi}^{(d)'} \boldsymbol{\phi}^{(d)}$. This chosen d is then used to produce the full set of impulse responses.

3.3 Examining the importance of a transmission channel

We investigate the relative importance of different channels for monetary policy using counterfactual experiments for the SVAR model. First, an unconstrained SVAR model is estimated and a monetary policy shock is identified as in the preceding section. Then, a benchmark impulse response function for output with respect to a monetary policy shock is calculated and plotted. Next, a channel is shut down by assuming that the related variable is exogenous. Specifically, dynamic response coefficients for the related variable are set to zero in a constrained version of the SVAR model. The resulting constrained impulse response function for output with respect to a monetary policy shock is compared to the benchmark.[9] The difference between the benchmark and constrained impulse response functions provides a measure of the relative importance of the excluded variable in the transmission mechanism. A large change in the path of output implies that the channel that was shut down was an important part of the transmission mechanism. Conversely, the closer the constrained impulse response function is to the benchmark case, the less important the channel. This way of looking at transmission channels is similar to the approach employed in Ramey (1993) investigating the importance of the credit channel. More recently, Peersman (2004) and Barigozzi et al. (2013) have also adopted an analogous approach in a slightly different context of comparing monetary transmission across European countries.[10]

[9] As a caveat, we assume the structural impact matrix remains the same when shutting down a channel. We do so to ensure the interpretation of shocks does not change in a fundamental way when comparing to the benchmark. This is somewhat analogous to Fry and Pagan (2011) arguing that it is important for interpretation to fix the structural impact matrix when considering sign restrictions in order to avoid mixing different structural models. However, it means that we are really only comparing the differences in dynamic responses, not impact responses, when shutting down a channel. We note that this approach is in contrast with some other studies that consider shutting down transmission channels, such as Ludvigson et al. (2002), in which the structural impact matrix is recalculated when treating a given variable as exogenous.

[10] Such reduced-form counterfactual analysis is possibly susceptible to the Lucas Critique in the sense that a change in structural parameters related to policy might change all of the reduced-form VAR parameters. However, we assume that the changes in the reduced-form VAR parameters would be relatively small, an approach implicitly and sometimes explicitly taken in other studies that employ reduced-form counterfactuals. As empirical support for our argument, we note the results in Liu and Morley (2014) that show reduced-form parameters for the "private-sector" equations in a three-variable VAR of the US economy do not appear to change significantly at the same time as parameters for the policy equation. But we acknowledge that a counterfactual based on setting certain SVAR parameters to zero while assuming the remaining parameters are unchanged may not be as relevant or informative about the importance of a given channel as a counterfactual based on a fully specified structural model in which the channel can be shut down by changing deep structural parameters that determine its importance for the macroeconomy.

Let the impulse response functions of output (y_y) with respect to a monetary policy shock (ε^m) for forecast period s be written as follows:

$$\frac{\delta y_{y,t+s}}{\delta \varepsilon_t^m} = \theta_{y,m,s}^j \tag{8}$$

with $j = b$ or c; where b and c denote the benchmark and constrained impulse responses, respectively. We then measure the distance between the benchmark and constrained impulse responses for forecast period s by calculating the difference of the θ's between the constrained and benchmark cases at each horizon:

$$\text{Distance} = \theta_{y,m,s}^b - \theta_{y,m,s}^c. \tag{9}$$

We also consider a standardized distance measure which takes the difference calculated in Eq. (9) above and then dividing it by $\theta_{y,m,\max}^b$, the maximal impact of the monetary shock on output, to give the interpretation of distance as a percentage of the maximal impact of the shock.

$$\text{Standardized Distance} = \frac{\left(\theta_{y,m,s}^b - \theta_{y,m,s}^c\right)}{\theta_{y,m,\max}^b}. \tag{10}$$

4 Results

4.1 Data and SVAR specification

Our SVAR model includes eight quarterly variables: output, the price level, commodity prices, nominal exchange rate, bank loans (proxied by the "mix" variable in Kashyap et al. 1993),[11] real money balances, the risk spread (difference between corporate bond yield and treasury yield), and the federal funds rate. Table 1 presents details on each variable and their sources. All data are converted to natural logs except for our loan measure and interest rate variables. The variables included in the model are fairly typical of SVAR models used to study monetary policy effects, such as those in Christiano et al. (1999), but augmented with additional variables, most notably a bank loan measure.

In order to interpret responses to disturbances as short-term dynamics around a steady state, the SVAR should be stationary, possibly around a deterministic trend. The inability to reject the null hypothesis of a unit root in most of the series raises concerns about asymptotically biased estimates given data in (log) levels.[12] To address this issue, we take first differences of all series found to be nonstationary over the full

[11] Instead of using total bank loans, we opt for the "mix" variable, which is constructed as the ratio of total bank loans to the sum of bank loans and commercial paper issuance. We refer readers to Kashyap et al. (1993) for the full argument as to why the "mix" variable is better than total bank loans in identifying the bank-lending channel.

[12] Many studies in the monetary policy shock literature ignore this issue and proceed to estimate models in levels. See, for example, Bernanke and Blinder (1992), Eichenbaum and Evans (1995), and Leeper et al. (1996).

Table 1 Variable definitions and data sources

Variable	Definition and sources
Output (y)	US real gross domestic product (FRED: GDPC1)
Price level (p)	Personal consumption expenditures, 2005 = 100 (FRED: PCECTPI)
Commodity prices (cp)	Producer price index: all commodities, 1982 = 100, average (FRED: PPIACO)
Nominal exchange rate (e)	Trade weighted US dollar index: major currencies, March 1973 = 100, end of period (FRED: TWEXMMTH)
KSW "Mix" (l)	Total loans/(commercial paper + total loans)
	Total loans = nonfinancial corporate business depository institution loans, n.e.c. + nonfinancial noncorporate business depository institution loans, n.e.c. (flow of funds accounts of the US Board of Governors of the Federal Reserve System)
	Commercial paper = nonfinancial corporate business commercial paper (flow of funds accounts of the US Board of Governors of the Federal Reserve System)
Real money balances (m)	M2 money stock, average (FRED: M2SL) deflated by personal consumption expenditure
Risk spread (rs)	Moody's seasoned baa corporate bond yield—10-year treasury constant maturity rate, end of period (FRED: BAA and GS10)
Fed funds rate (i)	Effective federal funds rate, end of period (FRED: FEDFUNDS)

sample period (1959Q3–2012Q4) except for the interest rate variables.[13] However, impulse responses are cumulated to show the impact of a monetary policy shock on the (log) levels of the variables.

Based on the timing of the Great Moderation documented in many studies (e.g., Kim and Nelson 1999, and McConnell and Perez-Quiros 2000), we split our full sample period into two subsamples of 1959Q3–1984Q1 and 1984Q2–2012Q4.[14] This allows us to easily see whether any apparent changes in the transmission mechanisms of monetary policy over these two subsamples can be linked to the reductions in output and inflation volatility associated with the Great Moderation, which we consider in Sect. 5.

4.2 Estimation

Using the methods outlined in Sect. 3, we estimate the specified eight-variable SVAR model for the two subsamples, both with just one lag based on the BIC lag length selection criterion. The number of candidate decompositions we have chosen to keep is 1000, and the cross-correlation sign restrictions we impose in order to single out

[13] Unit root test results are available upon request. We keep interest rate variables in levels because the evidence for unit roots is borderline, and it is standard to treat them as stationary in the SVAR literature.

[14] We also considered a shortened second subsample (1984Q1–2008Q3) to avoid the recent zero-lower-bound period. The results are qualitatively similar; hence, we only report results for the longer subsample below.

Table 2 Cross-correlation sign restrictions for a monetary policy shock

Comovement between	Cross-correlation sign
Output and price	Positive
Price and real balance	Positive
Real balance and output	Positive
Real balance and fed funds rate	Negative
Fed funds rate and mix	Negative
Fed funds rate and nominal exchange rate	Positive

monetary policy shock are tabulated in Table 2. The restrictions hold for on impact of the shock and four quarters after ($r = 0, 1,\ldots, 4$), which is the minimum necessary to produce impulse responses that are consistent with those generated by typical monetary models.[15] In addition to the restrictions listed in Table 2, we also impose a normalization restriction where we confine the response of the monetary policy variable, the fed funds rate, to stay negative for 4 quarters following a contractionary shock. This way we can ensure the candidate decompositions chosen are all comparable in that the impulse response are all for an expansionary monetary policy shock.

The cross-correlation sign restrictions listed in Table 2 are fairly generic and intuitive. For example, an expansionary monetary policy shock should cause both output and the price level to increase ($\rho_{yp|\varepsilon^m} > 0$); both the price level and real money balances to increase ($\rho_{pm|\varepsilon^m} > 0$); both real money balances and output to increase ($\rho_{my|\varepsilon^m} > 0$); and both the fed funds rate and the nominal exchange rate to decrease ($\rho_{ie|\varepsilon^m} > 0$).[16] Also, real money balances and the fed funds rate should move in opposite directions in response to a monetary policy shock ($\rho_{mi|\varepsilon^m} < 0$). This holds true for the fed funds rate and the "mix" variable as well ($\rho_{il|\varepsilon^m} < 0$).[17] These cross-correlation restrictions should rule out the possibility of mislabeling a real aggregate demand shock such as a fiscal shock (which would have $\rho_{pm|\varepsilon} < 0$ and $\rho_{my|\varepsilon} < 0$), or an aggregate supply shock such as a technology shock (which would have $\rho_{yp|\varepsilon} < 0$ and $\rho_{pm|\varepsilon} < 0$) as a monetary policy shock.

Because there are eight variables in the SVAR model, there will be eight orthogonalized disturbances to investigate for each candidate decomposition. In cases where

[15] Canova and Paustian (2010) believe that being too agnostic in the identification process may have important costs for inference. They advocate imposing enough sign restrictions to make the results of monetary SVAR analysis meaningful since monetary shocks are typically considered a minor source of contemporaneous output growth and inflation fluctuations. Disturbances with small relative variability and with an insufficient number of restrictions may lead to mismeasurement in transmission properties.

[16] The nominal exchange rate here is an index, where an increase in the exchange rate is an appreciation of the US dollar, while a decrease is a depreciation of the US dollar.

[17] There is probably less consensus in the literature regarding this particular cross-correlation sign restriction since earlier studies of the bank-lending channel often have a hard time finding convincing empirical evidence that support the idea that a decline in aggregate bank lending should follow a contractionary monetary policy shock, as predicted by theory (see discussion in Gertler and Gilchrist 1993). However, Dave et al. (2013), using a factor augmented VAR (FAVAR) approach, show that aggregate loans do decrease in response to a contractionary monetary policy shock. Here we take the view that presupposes the existence of the bank-lending channel in aggregate by imposing this particular restriction in our benchmark model. But we have also considered models where we remove this restriction. Even in the absence of the restriction, we still find candidate decompositions that produce very similar results to what we present in this section.

more than one orthogonalized disturbance per decomposition passes through our list of cross-correlation restrictions, we keep the one with the largest impact on output at $r = 0$.

4.3 Impulse response analysis

4.3.1 First subsample: 1959Q3–1984Q1

Figure 1 displays the impulse response functions for the first subsample. The solid lines are the "median" impulse responses of the eight variables to a monetary policy shock generated using the MT approach discussed above. Because all impulse responses are produced using the same candidate decomposition, it facilitates comparisons across variables, forecast horizons, and subsamples. The dashed lines are 68% symmetric bootstrapped bands.[18]

A glance at these impulse response functions confirms that all variables are responding to a monetary policy shock (normalized to be a 100-basis-point shock) according to the predictions obtained from theory. An expansionary shock lowers the fed funds rate, increases real money balances, increases output and the price level, and depreciates the nominal exchange rate. However, Fig. 1 shows that the peak response of output to the expansionary monetary policy shock does not occur until 6 quarters after the initial impact of the shock. The depreciation of the exchange rate also appears to be delayed with the peak effect occurring after about 8 quarters.[19] The "mix" variable increases on impact and for 5 quarters after, before flattening out, indicating an expansion of loans.[20]

4.3.2 Second subsample: 1984Q2–2012Q4

Figure 2 displays the impulse response functions for the second subsample. These responses to a 100-basis-point monetary policy shock paint a similar picture to those in the first subsample, albeit with somewhat wider confidence bands. All of the impulse responses behave as expected: a decrease in the fed funds rate, increase in real money balances, increase in output and the price level, a depreciation of the nominal exchange rate, and an increase in the "mix" variable. For the same decrease in the fed funds rate, the change in real money balances appears to be smaller and output and the price level reactions are milder compared with the first subsample. This difference could

[18] The bootstrapped bands were constructed conditional on the selected candidate decomposition using the MT approach.

[19] This delayed overshooting feature of the nominal exchange rate is not uncommon in the empirical literature. See, for example, Eichenbaum and Evans (1995).

[20] Den Haan et al. (2007) argue that different types of loans in a bank's loan portfolio react differently in response to monetary policy shocks. Real estate and consumer loans are most sensitive, and both decrease in response to a contractionary policy shock, while commercial and industrial loans tend to increase instead. As robustness, we make use of the Call Report data provided by the authors to see whether different types of loans behave differently within our empirical estimation framework. We find qualitatively similar results to our benchmark model regardless of the type of loan considered, and our general conclusion regarding the strength of the bank-lending channel across the subsamples remains consistent.

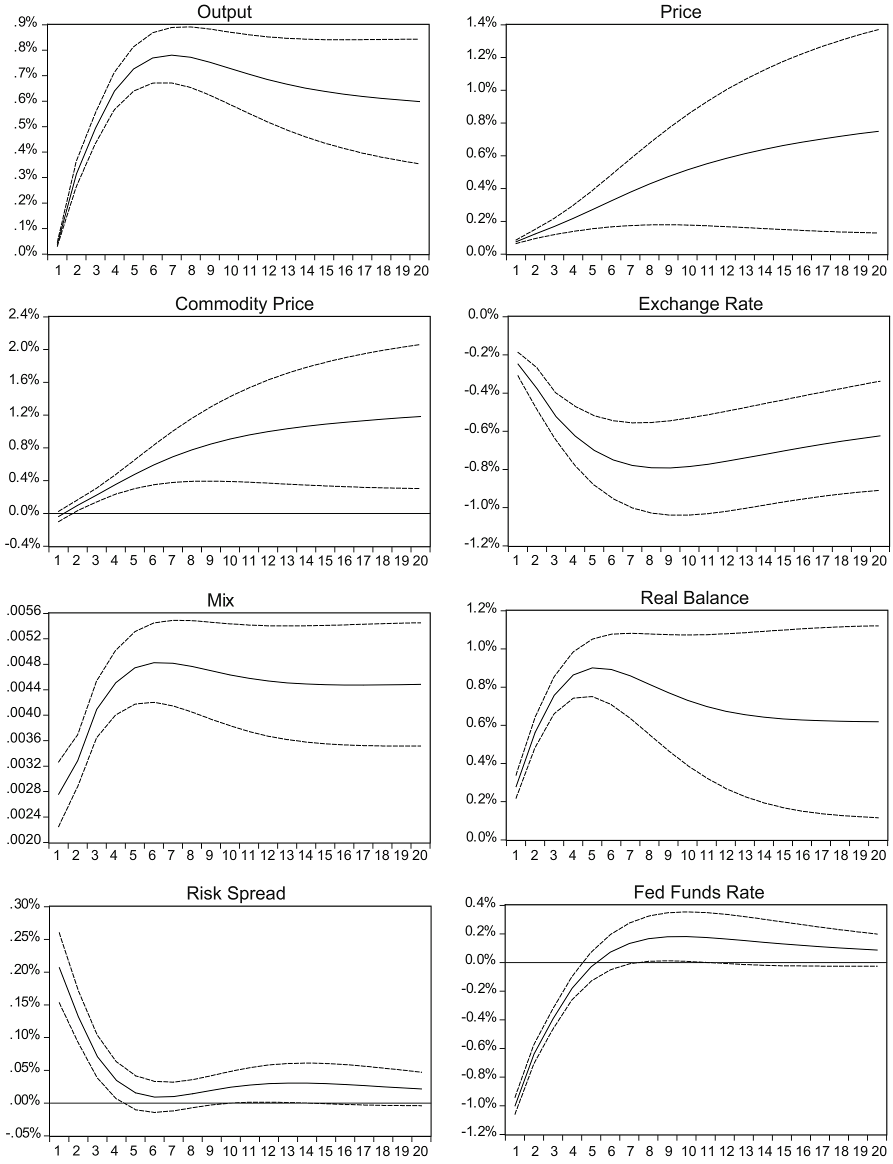

Fig. 1 Impulse responses to a monetary policy shock (1959Q3–1984Q1). *Note* the impulse responses here are normalized such that each is in response to a monetary policy shock that leads to an on impact reduction of 100 basis points in the fed funds rate. The *solid lines* are the "median" responses selected using the MT approach described in Fry and Pagan (2011), and the *dashed lines* are 68% bootstrap bands. The scales on the *vertical* axes are all in percentages except for the "mix" variable, which is a ratio that ranges between 0 and 1. The *horizontal* axes are quarters after the shock

be due to a variety of factors, but changes in the monetary transmission mechanism are certainly a possibility. The results we presented above for the two subsamples are broadly consistent with those reported in Boivin et al. (2010) who use a FAVAR

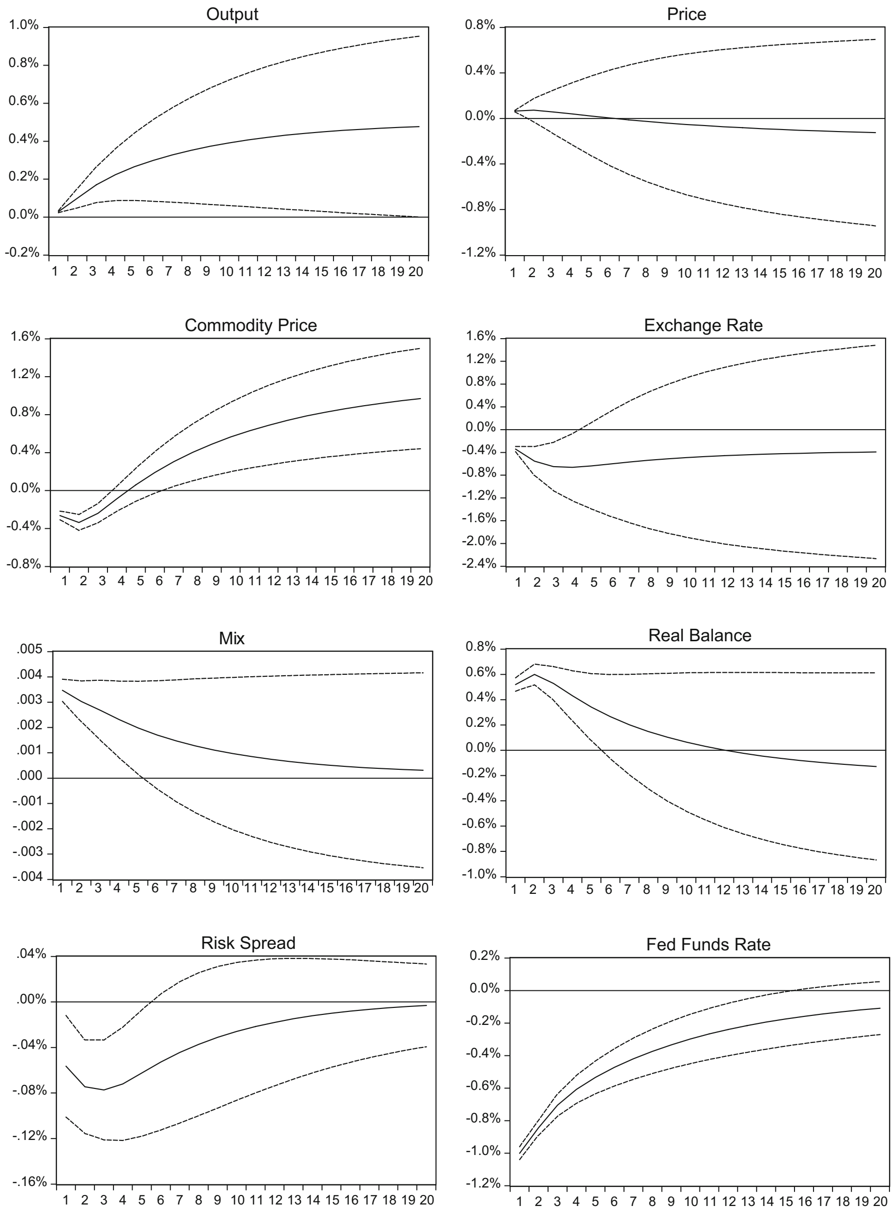

Fig. 2 Impulse responses to a monetary policy shock (1984Q2–2012Q4). *Note* the impulse responses here are normalized such that each is in response to a monetary policy shock that leads to an on impact reduction of 100 basis points in the fed funds rate. The *solid lines* are the "median" responses selected using the MT approach described in Fry and Pagan (2011) and the *dashed lines* are 68% bootstrap bands. The scales on the *vertical* axes are all in percentages except for the "mix" variable, which is a ratio that ranges between 0 and 1. The *horizontal* axes are quarters after the shock

approach in their study with similar sample periods.[21] They also find the effect of monetary policy actions on output, inflation, and risk spreads smaller in the more recent subsample.

4.4 Analysis of transmission channels

4.4.1 First subsample: 1959Q3–1984Q1

Figure 3 displays results related to the importance of the different channels of monetary policy. The lines show the response of output to a 100-basis-point monetary policy shock. The line "Benchmark" is derived from the estimated model. The lines "IR Channel Blocked," "ER Channel Blocked" and "BL Channel Blocked" refer to results from excluding the impact of the interest rate, exchange rate, and bank-lending channels, respectively.

An inspection of the figure shows that, if we block off the interest rate channel, output would have reacted much less strongly to the monetary policy shock, as we would expect if interest rates are indeed an important transmission channel for monetary policy. Similarly, shutting down the bank-lending channel reduces the impact of the monetary policy shock on output. The impact of the interest rate channel and the bank-lending channel appear to be fairly similar for the first subsample. Finally, the result for blocking the exchange rate channel is a bit surprising. The impulse response function goes above the benchmark, suggesting that, in the absence of the exchange rate channel, output would have increased more in response to an expansionary monetary policy shock. This puzzling result could be due to the fact that the USA and many of its trading partners were under the fixed exchange rate arrangement of Bretton Woods for a substantial part of the first subsample.

Next, we compute the difference between the benchmark and constrained impulse response functions (the distance measure) seen in Fig. 3 in order to quantify the importance of the various channels. Due to the long and variable lags of monetary policy transmission, we focus our analysis on assessing the horizons $r = 5$–16 quarters. This also avoids the horizons for which we have imposed sign restrictions. Figure 4 graphically illustrates the distance measure and Fig. 5 reports the standardized distance measure in bar chart format.

The "median" distance measure is reported as the solid line in the panels in Fig. 4. The upper dashed line is the 97.5th percentile and the lower dashed line the 2.5th percentile of the distribution of the distance measure for each quarter computed from the 1000 candidate decompositions. The further the lines deviate away from zero, the more important the particular channel is. Looking at the top and bottom panels of Fig. 4, we can see that both the interest rate and the bank-lending channels matter, and the magnitudes of their importance are quite similar when we focus on the "median" draw. However, the height of the upper dashed line for the benchmark minus bank-lending channel distance measure (bottom panel) indicates that the bank-lending channel could

[21] Boivin et al. (2010) estimate their model over the sample periods of 1962:1–1979:9 and 1984:1–2008:12.

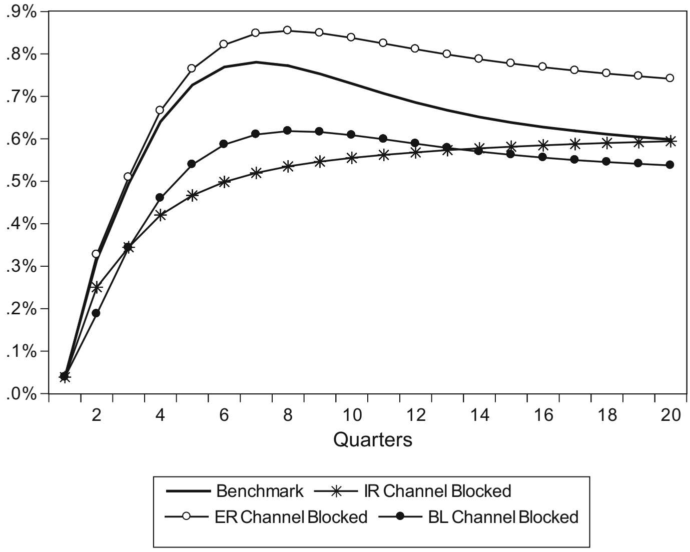

Fig. 3 Impulse response of output to a monetary policy shock with different channels blocked (1959Q3–1984Q1)

have had a very strong effect during this subsample period, more so than the other transmission channels under investigation.

To give the distance measure a more intuitive numerical interpretation, we standardize the median distance measure by the maximal impact of the monetary policy shock on output and present it as a percentage of the maximal impact of the shock in Fig. 5. From the figure, it is evident that the bank-lending channel matters in transmitting monetary policy shocks, and in fact, plays a greater role than the interest rate channel for longer horizons during the first subsample. At the peak it, accounts for about 23% and declines to about 10% by the 16th quarter.

As discussed in Sect. 2, one of the fundamental assumptions for the credit view is that it is difficult for banks to replace the lost deposits following monetary tightening, which in turn shifts the supply of bank loans (Bernanke and Blinder 1988). Together with the assumption that bank loans and bonds are not perfect substitutes, proponents of the credit view have highlighted the importance of the bank-lending channel. Thus, we argue that these assumptions adequately fit in the description of the banking system for the USA in the 1960s and 1970s based on the results of our analysis for this early sample period. Indeed, prior to the 1980s, the imposition of “Regulation Q” by the Federal Reserve on banks placed a ceiling on the interest rates banks could pay depositors. It follows, therefore, that during monetary contraction, when open-market interest rates went above the ceiling, banks had no way of competing for funds and suffered great declines in deposits. Moreover, there were reserve requirements on large CDs, inhibiting further the ability of banks to raise funds. In addition, the markets for bank liabilities were relatively shallow and illiquid during this period (Bernanke and Gertler 1995). Another important aspect of the bank-lending channel is the idea that bank loans play a special role, namely for small firms which rely on bank loans as their

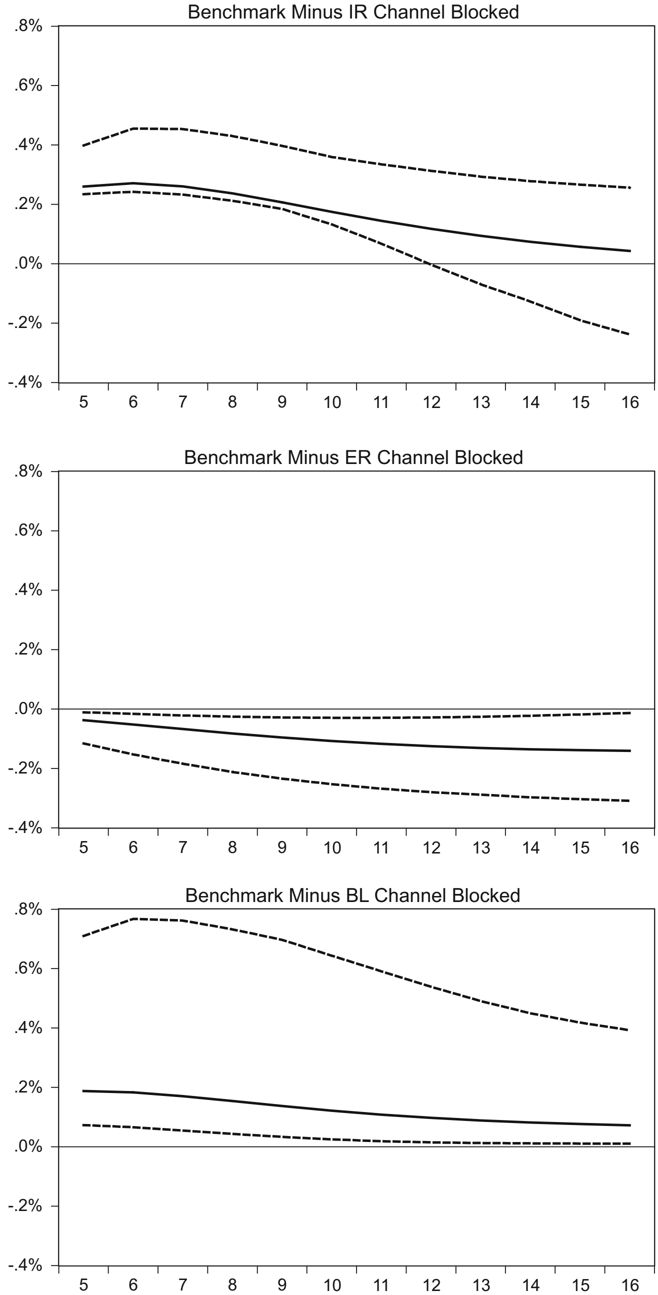

Fig. 4 Distance measure (1959Q3–1984Q1). *Note* distance measures reported here are constructed as difference between the normalized benchmark impulse response and impulse response with respective transmission channel blocked. The *solid line* is distance measure based on the "median" responses selected using the MT approach described in Fry and Pagan (2011). The *upper dashed line* is the 97.5th percentile and the *lower dashed line* the 2.5th percentile of the distribution of the distance measure for each quarter computed from the 1000 candidate decompositions. The *horizontal* axes are quarters after the shock

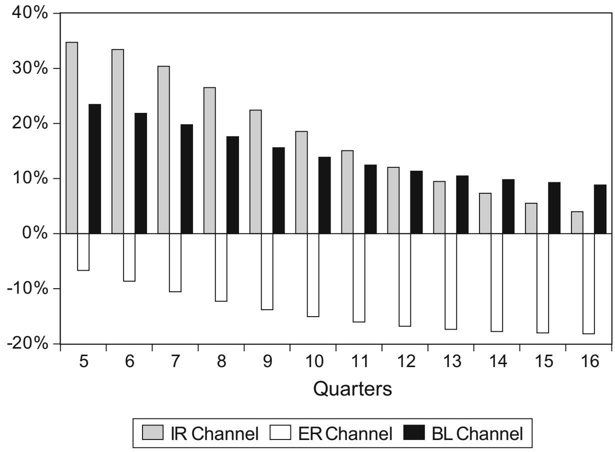

Fig. 5 Standardized distance measure illustrating importance of different monetary transmission channels (1959Q3–1984Q1)

main source of financing. The inability of small firms to raise funds elsewhere without incurring an exceptionally high cost, termed as financial constraints, is part of the reason for the importance of bank-lending channel. Many studies (for example, Fazzari et al. 1988) find evidence that during this period firms were financially constrained. This finding strengthens the role of bank loans in propagating monetary shocks.

Yet, despite the support for the credit view in the first subsample, the money view of monetary transmission is clearly quite relevant. Figure 5 shows that, at the peak, the interest rate channel contributes close to 35% of the maximal impact of monetary policy shock on output. The interest rate channel is thought to influence output through investment or consumption, and these are important and standard features in large scale macroeconometric models used for forecasting and policy analysis in major central banks around the world, such as the Federal Reserve's FRB/US model (Reifschneider et al. 1999) or the European Central Bank's Area-Wide-Model (Fagan et al. 2005). The results here support these features of the large scale macroeconometric models and contrast somewhat with empirical studies based on firm or household data that tease out the importance of the interest rate channel by estimating sensitivity of investment or consumption to changes in interest rates, which often lead to fairly modest results.

4.4.2 Second subsample: 1984Q2–2012Q4

Figure 6 plots the impulse response functions for the benchmark and various constrained cases for the second subsample, and Figs. 7 and 8 plot the corresponding distance and standardized distance measures. The results in this case, particularly for the bank-lending channel, are in stark contrast with those for the first subsample. The interest rate channel is clearly the most important transmission channel of monetary policy since the early 1980s. Figure 6 shows that shutting down this channel would have produced a much smaller increase in output in response to an expansionary monetary policy shock. The standardized distance measure gives us a numerical measure of

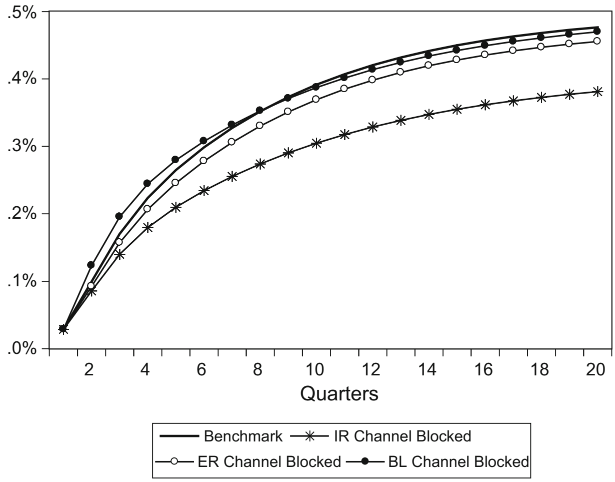

Fig. 6 Impulse response of output to a monetary policy shock with different channels blocked (1984Q2–2012Q4)

the relative importance of the interest rate channel. Figure 8 suggests that the interest rate channel can account for about 21% of the maximal impact of monetary policy shock on output.[22]

Another channel under the money view, the exchange rate channel, operates more as expected in the second subsample. Shutting down the exchange rate channel also dampens the response of output, although not by as much as shutting down the interest rate channel. Figure 8 reports that the exchange rate channel only accounts for at most about 5% of the maximal impact of monetary policy shock on output. This is consistent with research that has shown exchange rate to be somewhat insensitive to interest rate movements in the USA, which is a large but relatively speaking less open economy (Boivin et al. 2010).

The bank-lending channel appears to have weakened dramatically compared to the first subsample, producing an impulse response function that hovers around the benchmark in Fig. 6. The bottom panel in Fig. 7 confirms our observation showing the distance measure essentially equal to zero, and Fig. 8 shows the bank-lending channel explaining almost none of the impact of the monetary policy shock on output. This result, though striking, can be related to major structural changes in the US banking and financial system that occurred around the early 1980s. It is also consistent with the results reported in Perez (1998) and Dave et al. (2013), using aggregate data, and Ashcraft (2006), and Brady (2011), using disaggregated lending data.

In terms of changes in the US banking and financial system, Mishkin (2007) reports that the bank share of total nonfinancial borrowing peaked in the mid 1970s at around 40%, but fell to less than 30% by the mid 1980s and has remained below since then.

[22] Even though there are few studies that have shown an increase in the strength of the interest rate channel for the USA, Angeloni et al. (2003) find that the interest rate channel is important and is the dominant transmission channel of monetary policy in most Euro countries using data from the 1980s to the 1990s.

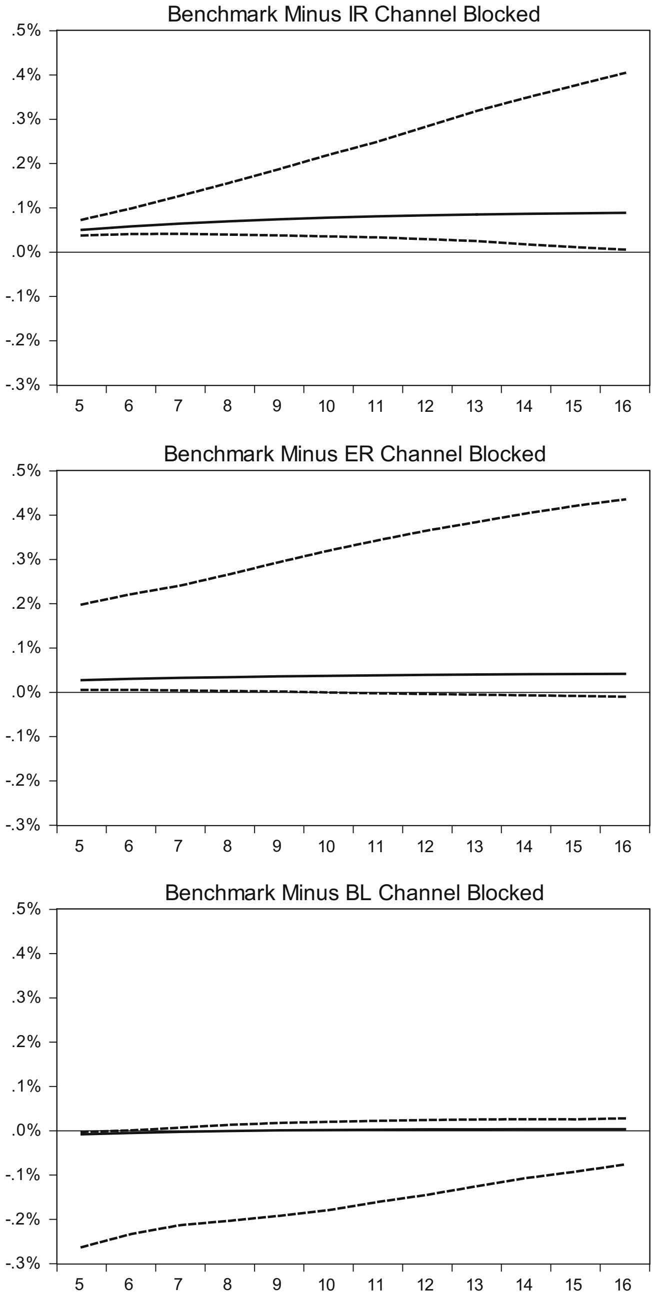

Fig. 7 Distance measure (1984Q2–2012Q4). *Note* Distance measures reported here are constructed as difference between the normalized benchmark impulse response and impulse response with respective transmission channel blocked. The *solid line* is distance measure based on the "median" responses selected using the MT approach described in Fry and Pagan (2011). The *upper dashed line* is the 97.5th percentile, and the *lower dashed line* the 2.5th percentile of the distribution of the distance measure for each quarter computed from the 1000 candidate decompositions. The *horizontal* axes are quarters after the shock

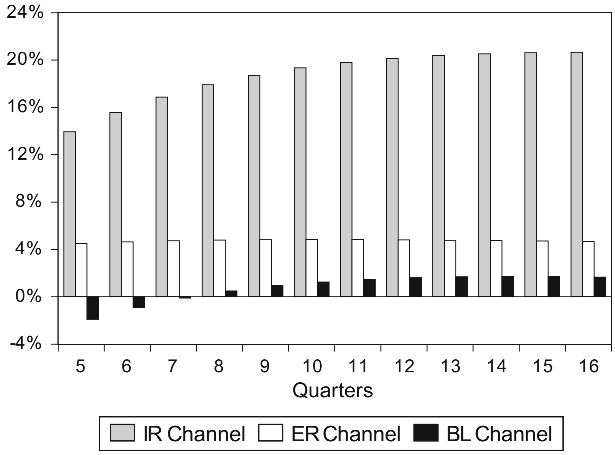

Fig. 8 Importance of different channels (1984Q2–2012Q4)

This decline in traditional bank-lending business is related to developments in capital markets and side effects of banking regulations. For example, the rise of money market mutual funds in the 1970s was the result of the binding interest rate ceilings. This new financial innovation competed with traditional banks for funds, which prompted the banks to push for deregulation in the 1980s. However, even after the phasing out of Regulation Q when banks were no longer constrained by interest rate ceilings, their cost advantages in acquiring funds were greatly diminished. Specifically, advancements in information technology allowed a wider set of institutions and investors to become lenders and borrowers, as seen by the spectacular growth in commercial paper and junk bond markets at the time. All of these developments meant that financial constraints were less severe.[23] In particular, there were new ways for firms and consumers to raise funds and bypass traditional banks, weakening the role of bank lending in propagating monetary policy shocks.[24]

4.5 Comparison across subsamples

Our results can be broadly interpreted as follows. In the first subsample, the bank-lending channel is operational and relatively important. Bank loans appear to be imperfect substitutes for other assets, particularly for financially constrained firms.

[23] Chen (2004) finds that financial constraints among firms have become less severe. Brady (2011) reports the statistical and economic significance of the consumer loan supply effect has weakened over time.

[24] It should be noted that a decline in the bank-lending channel of the monetary transmission mechanism does not necessarily imply a decline in the credit channel of monetary policy transmission. The credit channel includes various other avenues through which monetary policy shocks could influence aggregate output, such as the balance sheet channel or bank capital channel. Indeed, after the Great Recession, there has been a resurgence of interest in the financial accelerator framework of Bernanke et al. (1999). Brady (2011) also finds suggestive evidence of a strengthening of the balance sheet channel. However, our results still make it clear that the bank-lending channel, as the traditional center of the credit view, does not seem to operate as it did prior to the early 1980s.

Table 3 Absolute importance of channels for a 3-year window (standard deviation)

	1st Subsample: 1959Q3–1984Q1	2nd Subsample: 1984Q2–2012Q4
Size of monetary policy shock	0.00306	0.00352
Bank-lending channel	1.39218	0.06884
Interest rate channel	2.38117	1.61756

Absolute importance of channels calculated by dividing the average distance measure for each of the channels over the 5th–16th quarter horizon by the standard deviation of a monetary policy shock in terms of its impact on output reported in the first row of the table

Hence, with an expansionary monetary policy shock, the demand for bank loans increases with the supply. However, the role of the bank-lending channel is much weaker in the second subsample. While the interest rate channel has also weakened somewhat in the second subsample, it has declined by a much smaller proportion. Thus, our study makes a contribution to the debate on the monetary transmission mechanism by providing evidence for the importance of the bank-lending channel, but also showing that its role has diminished within the last few decades.

Recognizing that the above analysis is only in terms of the relative importance of channels, we also measure the absolute importance of each channel for the variation in output across the two subsamples. This analysis provides further support for a weakening role of the bank-lending channel. We calculate the absolute importance of these channels for output by evaluating the average distance measure for each of the channels over the 5–16 quarter horizons (same window used for the distance measure earlier), scaled by the standard deviation of a monetary policy shock in terms of its impact on output. The results are reported in Table 3.

Table 3 presents two important findings analogous to the results reported earlier. First, the bank-lending channel plays an economically significant role in transmitting monetary policy in the first subsample. Second, there is a drastic decline in the absolute role of the bank-lending channel over the four decades, whereas the decline in the absolute role of interest rate channel is much milder.

5 Transmission changes and the great moderation

Apart from illustrating the changing roles of different transmission channels over the past 50 years, the results in the previous section beg the question of whether the changes in the transmission mechanism are related to concurrent changes in output and inflation volatility associated with the Great Moderation.

Studies by Niemira and Klein (1994), Kim and Nelson (1999), and McConnell and Perez-Quiros (2000) have documented a sharp decline, or break, in the volatility of US output growth in the mid-1980s. These papers have motivated a huge literature that characterizes this decline in volatility and investigates the reasons for it, including Stock and Watson (2002), Kim et al. (2004), Ahmed et al. (2004), Boivin and Giannoni (2006), and Kim et al. (2008), among many others. These studies investigate whether the reduction in output growth volatility is associated with a reduction in its conditional variances or changes in its conditional mean. In the context of SVAR models or their reduced-form counterparts, these studies investigate whether the observed reduction in volatility is associated with a change in the magnitude of shocks and forecast errors or a change in the dynamic propagation of shocks. This section presents counterfactual experiments similar to those in the previous literature and motivated by the conjecture that the changes in transmission channels may alter the dynamic propagation of monetary policy shocks and hence lead to the reduction in volatility of output growth and inflation.

5.1 Variance counterfactuals

The basic idea of variance counterfactuals can be illustrated as follows. Recall Eq. (2), which gives us the reduced-form version of the model. This reduced-form equation can be expanded to give us the following:

$$\boldsymbol{y}_t = \boldsymbol{c}^{(i)} + \boldsymbol{\Phi}_1^{(i)}\boldsymbol{y}_{t-1} + \cdots + \boldsymbol{\Phi}_p^{(i)}\boldsymbol{y}_{t-p} + \boldsymbol{e}_t, \quad \mathrm{Var}(\boldsymbol{e}) = \boldsymbol{\Sigma}^{(i)}. \tag{10}$$

The superscript $i = 1, 2$ denotes the subsample under investigation (i.e., 1 indicates before a structural break in model parameters and 2 afterward). Let $\boldsymbol{\Psi}_k^{(i)}$ be the matrix of coefficients of the kth lag in the matrix polynomial $\boldsymbol{\Psi}_k^{(i)} = (\mathbf{I} - \boldsymbol{\Phi}_1^{(i)}L - \cdots - \boldsymbol{\Phi}_p^{(i)}L^p)^{-1}$. With this notation, the variance of the nth series in $\boldsymbol{y}_t$ can be written as:

$$\mathrm{Var}(\boldsymbol{y}_n)^{(i,j)} = \sum_{k=0}^{\infty} \boldsymbol{\Psi}_k^{(i)}\boldsymbol{\Sigma}^{(j)}\boldsymbol{\Psi}_k^{(i)'} = \sigma_n^2 \tag{11}$$

Note here that the superscript $j = 1, 2$ also denotes the subsample. From Eq. (11), we can see that the standard deviation of y_{nt} is a function of $\boldsymbol{\Psi}$ (and hence $\boldsymbol{\Phi}$) and $\boldsymbol{\Sigma}$. So standard deviation of y_{nt} in subsample 1 is $\sigma_n = f(\boldsymbol{\Phi}^{(1)}, \boldsymbol{\Sigma}^{(1)})$and in subsample 2 is $\sigma_n = f(\boldsymbol{\Phi}^{(2)}, \boldsymbol{\Sigma}^{(2)})$. By evaluating the expression in Eq. (11) for different $\boldsymbol{\Phi}$ (propagation) and $\boldsymbol{\Sigma}$ (shocks), we can compute counterfactual variance of y_{nt} that would have been obtained had either $\boldsymbol{\Phi}$ or $\boldsymbol{\Sigma}$ had taken on different values. For instance, $\sigma_n = f(\boldsymbol{\Phi}^{(1)}, \boldsymbol{\Sigma}^{(2)})$ would be the counterfactual standard deviation of y_{nt} had the propagation from the first subsample been associated with the shocks of the second subsample rather than its own shocks. See Kim et al. (2008) for a full discussion of the issues surrounding variance counterfactual experiments.

5.2 Results from variance counterfactuals

We utilize the benchmark models estimated for the two subsamples of 1959Q3–1984Q1 and 1984Q2–2012Q4 from the preceding section to investigate how much of the reduction in output and inflation volatility can be related to changes in the reduced-form VAR coefficients and how much can be related to changes in the covariance matrix for the forecast errors.

Table 4 shows the results of our counterfactual experiments. The first two columns provide the sample standard deviation of the output growth and inflation series calculated from actual data for the two subsample periods. The last two columns give the counterfactual standard deviations. First, consider the results for output growth. The estimated counterfactual standard deviation for the first subsample propagation matched up with second subsample shocks (0.0091) is of a similar magnitude to the actual standard deviation before the mid-1980s (0.0109). By contrast, the counterfactual standard deviation corresponding to a change in shocks but not propagation for the second subsample (0.0098) is of closer magnitude to the actual standard deviation before the mid-1980s (0.0109) rather than after (0.0063). Intuitively, these results suggest that if the shocks of the second subsample had occurred in the 1960s and 1970s, output growth would have been almost as stable as it has been during the Great Moderation. Similarly, had the first subsample shocks occurred in the second subsample, output growth would have been much more volatile in recent years. Hence, we can deduce that the change in the size of the shocks across the two subsamples is the primary driver of the reduction in the observed volatility of output growth.[25] Thus, we are therefore unable to make any connection between the changes in the transmission mechanisms of monetary policy observed in Sect. 4 and the concurrent reduction in US output volatility.

The same experiments for inflation suggest a different conclusion. In this case, the magnitude of the counterfactual standard deviation corresponding to a change in shocks but not propagation is very similar to the actual standard deviation calculated for the first subsample. It follows, therefore, that changes in the propagation mechanism of shocks in the economy in recent years may have made inflation less sensitive to shocks, and this change in propagation mechanism could be due to the changes in transmission mechanism of monetary policy found in Sect. 4. This is in contrast to the results reported in Canova and Gambetti (2009), but is in line with those reported in, for example, Boivin and Giannoni (2006).

However, we must be somewhat cautious in interpreting our results. Boivin et al. (2010) argue that increasing attention should be paid to the changes in the systematic nature of monetary policy and expectations formation. Monetary policy has become substantially more focused on inflation stabilization since the early 1980s. Boivin et al. (2010) postulate that the change in policy preferences has affected the volatility of inflation and the response of output to nonmonetary disturbances. The Federal Reserve's focus on price stability means that they will accommodate increases in output coming from the supply side, but defend against such changes coming from the demand side. This implies that a greater emphasis on inflation stabilization is likely to

[25] There is much debate in the literature regarding the causes of the Great Moderation (shock vs. propagation or good luck vs. good policy), particularly for output growth. Giannone et al. (2008) provide an excellent summary of the debate. Our counterfactual analysis approach using SVAR is similar to that employed by Stock and Watson (2002), and Ahmed et al. (2004), among many others, and we obtain similar results that suggest shocks are the main cause for the reduction in output growth volatility. Using a theoretical approach through the estimation of dynamic stochastic general equilibrium (DSGE) models, many authors (such as Lubik and Schorfheide 2004; Boivin and Giannoni 2006) find more support for the good policy hypothesis. Recently, Benati and Surico (2009) have also suggested that SVAR methods for studying the Great Moderation may lead to misinterpretation of the good policy explanation as being due to good luck.

Table 4 Results from counterfactual variance experiment

	Sample standard deviation		Standard deviation using counterfactual experiments	
	1st Subsample: 1959Q3–1984Q1	2nd Subsample: 1984Q2–2012Q4	1st subsample propagation 2nd Subsample shocks	2nd subsample propagation 1st Subsample shocks
Output growth	0.0109	0.0063	0.0091	0.0098
Inflation	0.0074	0.0038	0.0081	0.0039

lead to greater stability in inflation, but not necessarily in output. The timing of this shift in policy preferences coincides with the various other structural changes occurring in the credit and financial markets detailed earlier. Hence, the results in Table 4 could be driven by a change in the transmission mechanism, a change in policy preferences, or some complex interaction of both.

6 Conclusion

We have analyzed the transmission mechanism of monetary policy in the US economy, with special attention paid to the relative importance of the interest rate and bank-lending channels. Our analysis makes use of short-run sign restrictions to identify structural shocks in an SVAR model. Contrary to most other SVAR approaches, this does not arbitrarily impose restrictions on the contemporaneous impact of the shocks. This approach also avoids recurrent problems of circularity between identification and inference since all of the constraints are explicitly stated in the model. Having identified our monetary policy shocks, we use counterfactual experiments to compare the strength and importance of different transmission channels.

The results point toward a role for both the bank-lending and interest rate channels over the past 50 years in the transmission of monetary policy to the aggregate economy, while the exchange rate channel takes more of a backseat. Our finding also provides further empirical support that the bank-lending channel exists in more than just the small credit-constrained banks since we make use of aggregate lending data in our SVAR analysis. However, the bank-lending channel is more important in the earlier sample period covering 1959Q3–1984Q1, while the interest rate channel plays a significantly greater role in transmitting policy impulses in the later sample period of 1984Q2–2012Q4. This is consistent with the results reported in Dave et al. (2009). Results from analysis of the absolute importance of these channels to the variation in output growth provide further justification for the weakening of the role of the credit channel in the recent years. We note that this weakening is consistent with financial liberalization that occurred over the same time period and has important implications for the design of nonstandard monetary policy during the zero-lower-bound period. Specifically, the results suggest that policies focusing on financial prices should be more effective than those focusing on quantities of credit.

The evidence that the US monetary transmission mechanism has changed over the past 50 years motivates the last part of our study. Again using counterfactual experiments, we look for connections between changes in the transmission mechanism and increased economic stability with the Great Moderation. Perhaps surprisingly, we do not find any link between changes in the nature of the transmission mechanism of monetary policy and the observed reduction in output volatility. However, we find suggestive evidence that a change in monetary transmission reduced the volatility of inflation, although our result is also consistent with the view expressed in Boivin et al. (2010) that changes in monetary policy preferences have led to a stabilization of inflation expectations and hence inflation, but not necessarily a stabilization of output fluctuations.

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