BALÁZS VONNÁK

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Estimating the Effect of Monetary Policy with Dissenting Votes as Instrument *

(A monetáris politika hatásának becslése az ellenszavazatok mint instrumentális változó segítségével)

Written by Balázs Vonnák

Budapest, August 2021

Published by the Magyar Nemzeti Bank

Publisher in charge: Eszter Hergár

Szabadság tér 9., H-1054 Budapest

www.mnb.hu

ISSN 1585-5600 (online)

*I am indebted to Róbert Lieli for his valuable feedback on my research. I am also greatful to Sergey Lychagin, Zoltán Reppa, Giovanni Ricco and the participants of the discussion of the paper at the MNB and at the CEU for their useful comments.

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Abstract

In this paper a new instrument for monetary policy shocks is presented. Exogenous variation of the policy rate may come from frictions of collective decision-making. Dissenting votes indicate how far the final decision of the decision making body is from the mean of the members' individually preferred interest rates and thus correlate with the policy shocks caused by the decision-making frictions. Measures of dissent are used as external instrument in a structural VAR. Results for the U.S. show significant effect of the Fed's interest rate policy on real variables with the expected sign. On the other hand, the estimated effect on nominal variables is reminiscent of the price puzzle. Usual remedies, such as inclusion of commodity prices, inflation expectations or starting the sample in the middle of the eighties do not change the qualitative results casting doubt on the usual interpretation that the price puzzle is a statistical artifact.

JEL: C32, C36, E52.

Keywords: monetary policy, structural vector autoregression, instrumental variable, price puzzle.

Összefoglaló

Tanulmányomban egy új változót mutatok be a monetáris politika sokkjainak instrumentálására. A testületi döntéshozatal során olyan kompromisszumos döntésre törekednek a jegybankok, amely az irányadó kamatban exogén változásokat eredményezhet. A közös döntéstől eltérő szavazatok jelzik, hogy ezek a kompromisszumok milyen irányban térítették el a kamatdöntést az egyénileg preferált kamatszintek átlagához képest, így korrelálnak a döntéshozatali mechanizmusból következő sokkokkal. Egy, az ellenszavazatokból képzett változót használok külső instrumentumként strukturális VAR keretben. Az amerikai adatokra ily módon elvégzett becslés azt mutatja, hogy a Fed kamatlépéseinek szignifikáns hatása van a reálgazdasági változókra, mégpedig az előzetes várakozásoknak megfelelő előjellel. A nominális változók ezzel szemben az elmélet alapján várttal ellentétes irányba reagálnak, vagyis például egy kamatemelés hatására emelkednek. Ez az irodalomban ismert úgynevezett "price puzzle" jelenség nem tűnik el akkor sem, amikor kontrollálok a nyersanyagárakra, inflációs várakozásokra vagy a becslési mintát a nyolcvanas évek közepétől indítom.

1 Introduction

There is a large body of empirical literature on the effect of monetary policy. Most of the studies use identified or structural VAR to estimate this effect. The main challenge is to circumvent the endogeneity problem, namely that the economy and the monetary policy may react to the same shock rendering causal interpretation of impulse responses impossible. The most common approach is to take the linear combination of the VAR residuals that meets some predefined identifying restrictions, and to call this time series exogenous policy shocks, that is the source of the exogenous changes in the policy variable.

Recently, Stock and Watson (2012) proposed using external instruments for identifying exogenous shocks. External here means that the exogenous variation of the policy variable does not come from the VAR residuals, but from an additional variable not included in the VAR. Mertens and O. Ravn (2013) used external instrument in a SVAR to estimate the effect of tax changes. Gertler and Karádi (2015) estimated the effect of monetary policy using the surprise content of the interest rate decisions as external instrument.

In this paper I use voting records of the Fed for constructing an instrument for the policy rate. There are two features of central banks' decision making process that may generate exogenous variation in monetary policy. The first is rounding: the policy rates are in most cases multiples of one quarter of a percentage point. The second feature is the consensus-seeking principle, that is the interest rate supported by as many members as possible is chosen as the decision of the committee. Riboni and Ruge-Murcia (2014) call the these features ”size friction” and ”decision-making friction”, respectively. In another study (Riboni and Ruge-Murcia, 2010) they consider different voting protocols and find that the consensus model fits major central banks' interest rate decisions best. Due to the above-mentioned frictions, the decision outcome may differ from its expected value, and part of this difference can be regarded as an exogenous policy shock.

A simple example could be the case when roughly half of the decision making body finds current level of interest rate appropriate, and the other half would like to cut it by 25 basis points. If individual members' preferences are more or less (but not perfectly) known by the public, the expected value of the decision will be a 12.5 basis point cut. The final decision may depend on one or two votes in an almost random way. Either holding the policy rate or cutting by 25 basis points would hit the market as a surprise (either 12.5 or -12.5 basis points) and can be considered as exogenous variation in the sense that it is not correlated with economic variables that influence both the policy rate and the future path of the economy.

Dissenting votes indicate the direction of the surprise. If the final decision is a cut, but dissenting members would have held the interest rate, the policy shock is an easing shock. In the opposite case when the decision making body does not change the policy rate but several members would have done it, the outcome is a tighter than expected monetary policy.

In line with the tendency to make monetary policy more transparent, many central banks publish voting records of committee members. I use the history of FOMC members' dissent record collected by Thornton and Wheelock (2014). I create an index of dissent from this dataset to approximate the sign and size of the monetary policy shock for each rate setting decision. Then I estimate a VAR from data on the main U.S. macroeconomic variables and instrument the policy rate residual of the VAR by the index.

Within the same proxy-SVAR framework, Gertler and Karádi (2015) build on the surprise movements in Fed funds futures around the announcements of FOMC decisions. As emphasised in Jarociński and Karádi (2020), this instrument contains not only policy shocks, but information shocks, too. The latter comes from the Fed's assessment of the state of the economy which may differ from market participants' view. If the central bank has more precise information on trends in the economy, the surprises in the interest rates may be dominated by that knowledge, which is correlated with state of the economy. Consequently, the estimated effects are biased. Jarociński and Karádi (2020) disentangle information shocks from monetary shocks by imposing additional identifying assumptions, and show that the effect of monetary policy estimated by them is different from what Gertler and Karádi (2015) found.

The same problem is less likely to arise with the dissent instrument proposed in this paper. Although the distribution of votes indicate where the interest rate would be in the absence of decision-making frictions, and this depends on the central bank's assessment of the state of the economy, both the actual and the ”frictionless” rate reflect the same assessment, and thus their difference is not much related to the possible information asymmetry between the central bank and the public. The proposed measure of dissent is a proxy for that difference, therefore, when using as external instrument in a SVAR, no additional identifying restrictions are necessary to eliminate the information shocks.

I find that monetary policy shocks have significant effect on real variables with the expected sign, especially in the long run. An unexpected tightening lowers GDP, industrial production and employment. On the other hand, the response of nominal variables are insignificant, and their sign contradicts to the conventional views of the transmission of monetary policy and is reminiscent of the ”price puzzle” phenomenon.

These qualitative results remain robust when I change the variables in the VAR, the frequency of the time series and the sample. The conventional explanation of the price puzzle (Sims, 1992) is based on the argument that central banks look at expected future inflation when setting interest rates and use information not included in the econometrician’s data. Castelnuovo and Surico (2010) argues that the omission of forward-looking variables generates price puzzle especially when the monetary policy does not respond strongly enough to inflation, just as in the pre-Volcker era. With the dissent-based identification, however, changing the sample period or including variables such as inflation expectations and commodity prices does not alter the big picture. Therefore, as long as the dissent index is a valid instrument, the price puzzle seems to be a feature rather than an artifact.

The paper is structured as follows. First, I present simulations with a stylized model of collective decision making and demonstrate that dissents can be a valid instrument for identifying exogenous variation in the policy variable. Then I introduce an index of dissents created from FOMC members voting record. In Section 4 the methodology of the estimation is described. In Section 5 the proxy-SVAR results are discussed. Section 6 concludes.

2 Simulation with a stylized model of collective decision making with dissent

Making group decision is a more complex procedure than individual decision-making if there are diverse views on the optimal outcome. Monetary policy committees typically make strong effort to reconcile views of its members in order to arrive at a decision that has strong enough support to convince the public that the policy change will be persistent. The consequence of this effort is that the final outcome will almost never coincide with any member's most preferred policy.

Riboni and Ruge-Murcia (2014) call the desire to reconcile different views on the optimal interest rate ”decision-making friction”. One tool to decrease diversity among members is to restrict the available options, which typically means considering only interest rate changes that are multiple of 25 basis points. Riboni and Ruge-Murcia (2014) call this ”size-friction”.

Gerlach-Kristen (2004) finds that dissenting votes can help predict future interest rate decisions of the Bank of England. Riboni and Ruge-Murcia (2014) demonstrates that this result is due to the two aforementioned frictions. In an earlier paper (Riboni and Ruge-Murcia, 2014) they show that major central banks make interest rate decisions in a way that is observationally equivalently to the consensus-seeking model, which implies these frictions.

In the following I will demonstrate how information on dissenting votes may help solve the endogeneity problem. First, I highlight the main intuition with the help of some very simple examples. Then I present simulations with a stylized model of collective decision-making characterised by frictions to show that the measure of dissent can be a valid instrument.

2.1 THE MAIN INTUITION

First consider a simple example, in which the decision making body consists of a single member. Of course, in this case there is no friction due to consensus-seeking, but it can shed light on how the ”optimal” decision is distorted by the size-friction, that is by restricting the set of options to some discrete values.

Let us assume that the decision maker can choose only 0 or 1. Also assume that the optimal value of the policy instrument is a random number j drawn from the $U(0,1)$ uniform distribution. As she cannot choose numbers between 0 and 1, the policy maker rounds the optimal value to the nearest integer J. Clearly, the expected value of J is 0.5, and thus the surprise component of the decision is $J - 0.5$, which is positively and strongly correlated with the distortion, that is with $J - j$, because they always have the same sign.

Now let us add another ”friction” to the decision making procedure, and consider the case when the decision making body consists of three members. Each member's preferred value is drawn from the same $U(0,1)$ distribution, independently from each other. Then they all choose either 0 or 1 depending on which one is closer to the individually preferred policy. The final decision is 0 when at least two members chose it, and 1 otherwise. Due to symmetry, the expected value of the decision-making body's choice is 0.5 again. Thus, the surprise is -0.5 with probability 0.5, and 0.5 with the same probability.

With more than one member dissent can occur. In this example there are dissenting votes if two members vote for 0 and one for 1, or two votes for 1 and one for 0. One measure of dissent can be the number of dissenting votes for lower value minus the number of dissenting votes for higher value divided by the number of total votes. In our case this measure can take the values of $-1/3, 0$ or $1/3$.

Since our measure of dissent is either zero (unanimous voting) or has the same sign as the surprise component of the decision, there is positive comovement between the two. It is very straightforward to derive that the standard deviation of the dissent variable and the surprise is $1/(2\sqrt{3})$ and $1/2$, respectively, their covariance is $1/8$, and thus their correlation is $\sqrt{3}/2 = 0.866$.

These very simple examples showed the main intuition behind looking at dissenting votes as a potential proxy for shocks generated by the decision-making frictions. In real life monetary policy decisions are related to the underlying economic developments that can influence disagreement in a systematic way. If this is the case, a measure of dissenting votes may not be valid instrument and cause bias in estimation.

To see how the state of the economy may interfere with collective monetary policy decision-making, let us suppose that individual preferences regarding the policy instrument are formed by not only pure random shocks but they are state-dependent, too. Let the individually preferred policies be

$$j_i = x + w_i$$

where x is either 0.25 or 0.75 ("low" or "high" states) with 0.5-0.5 probabilities, and the idiosyncratic policy shock w_i is drawn from the uniform distribution $U(-0.5, 0.5)$ for each member independently. Otherwise the model is the same as previously. Consequently, in the low state the distribution of the individually preferred value of the policy variable is $U(-0.25, 0.75)$, while it is $U(0.25, 1.25)$ in the high state. The possible policy outcomes are still 0 or 1, but their conditional probabilities are different, as Table 1 shows. Note that the expected value of the decision is 5/32 in the low state and 27/32 in the high state.

Table 1
Possible outcomes, the corresponding surprises and conditional probabilities in the two states.

$x = 0.25$				$x = 0.75$			
outcome	dissent	surprise	cond. prob.	outcome	dissent	surprise	cond. prob.
0	0	-10/64	27/64	0	0	-54/64	1/64
0	1/3	-10/64	27/64	0	1/3	-54/64	9/64
1	-1/3	54/64	9/64	1	-1/3	10/64	27/64
1	0	54/64	1/64	1	0	10/64	27/64

In the low state, the probability that the dissenting vote is higher than the common decision (second row of Table 1) is higher (27/64) than the opposite case (9/64), in which the dissenting member votes for a lower rate (third row of Table 1). In the high state the opposite is true. This implies correlation between the direction of dissent and the economic shock. Indeed, it can be shown that the correlation between the measure of dissent (defined as previously) and the state of the economy is now 0.375. Nevertheless, the dissent still exhibits stronger comovement with the shocks not related to the underlying economic developments. Assuming that the expectations are formed conditionally on the state of the economy, the correlation between the surprise caused by the decision and the measure of dissent is 0.678.

Although the information content of the vote distribution may be partly driven by the underlying economic shocks, this is not necessarily true always. To see this, consider a modification of the previous example. The only change is that the state variable x can now take the values of 0.5 and 1.5 with the same probabilities. It implies that the distribution of the member specific preferences is $U(0, 1)$ in the low state and $U(1, 2)$ in the high state. The possible outcomes are 0 or 1 in the low state and 1 or 2 in the high state with each conditional probability being 0.5.

Note, that in this case the conditional distribution of the dissent measure is completely the same in the two states (and the same as in the second example), therefore, there is no comovement between the state and our measure of dissent at all, while the correlation between the latter and the surprise is 0.866, again. The explanation of this is that now the effect of the economy on the decision is large enough compared to the distance between the available options.

Based on these simple examples we can conclude that the distribution of dissenting votes is generally correlated with the difference between the expectations and the final outcome. Whether it is correlated with potential confounders depends on the relative size of the shocks and the distance between the potential outcomes of the decision. To give an impression about these dependencies, a simulation with a more detailed model is shown in the next subsection.

2.2 THE MODEL

In this model[1] the state of the economy is captured by an autoregressive process, and the policy makers vote according to a time-varying rule which is heterogeneous across them. Since we are only interested in whether a proper measure of dissent can be a proxy of exogenous shocks to the policy, there is no feedback from the policy variable to the economy.

The state variable x_t follows an AR(1) process with mean 0:

$$x_t = \rho_x x_{t-1} + u_t^x$$

The decision making body consists of n members. They make decision on the policy variable j in each period. Member i's preferred level of the policy variable is described by the policy rule:

$$j_{it} = \phi_{it} x_t + v_t + w_{it}$$

where w_{it} is a white noise idiosyncratic shock to member i's ($i = 1, \dots, n$) decision at period t, v_t is a white noise common policy shock. Idiosyncratic shocks capture unpredictable deviation by a member from her policy rule that are unrelated to others' decision. Common shocks can occur, for example, because the committee's decision is based partly on the staff's economic analysis, and thus any mistake made by the staff can result in unexpected synchronized deviations from the individual policy rules.

The time-varying member-specific reaction coefficient ϕ_{it} is another AR(1) process with mean 1:

$$\phi_{it} = 1 + \rho_\phi(\phi_{i,t-1} - 1) + u_{ti}^\phi.$$

The innovations ($u_t^x, u_{ti}^\phi, v_t, w_{it}$) are white noise processes uncorrelated with each other.

The collective decision is based on individually preferred outcomes according to the following rule: first, each member rounds her preferred level of the policy variable to the nearest integer (J_{it}). Second, the integer number J_t receiving the most votes is chosen as the body's decision. If the mode is not unique, one of the most popular outcomes is picked randomly with equal probabilities for each.[2]

Clearly, the difference between the final decision and the mean of individual preferences comes from two sources: rounding and the collective decision rule, namely that the mode, not the mean of the individual votes is the collective choice. Each of these effects can be considered random as long as the variance of x_t and/or of the policy shocks is large enough to generate many potential decision outcomes.

To evaluate the validity of a potential instrument, we need a definition of the policy shock, which is not straightforward. Generally, the deviation of the policy variable from the policy rule is meant by it. In our model the systematic behaviour of the decision making body cannot be easily captured by a single feedback rule.

Another approach identifies policy shocks with the difference between the actual decision and the decision expected by economic agents. The two approaches are identical if the public is aware of both the common policy rule and the state of the economy, and forms expectations rationally.

Throughout the paper I define the policy shock as the difference between the body's final decision and its expected value,

$$u_t^j = J_t - E(J_t), \tag{1}$$

[1] The model shares many features with those presented in Riboni and Ruge-Murcia (2014) and Gerlach-Kristen (2008), but there are also important differences due to the different purpose.

[2] In real life the last round of the procedure is more complex, since the final outcome typically has to enjoy the support of the (qualified) majority of the members. If the mode has no majority, further rounds of voting take place until a (qualified) majority is formed. In the simulation we consider a simpler decision rule by taking the mode as the final decision. However, the same intuition behind the proposed instrumental variable remains valid even if a majority rule is applied, as in Riboni and Ruge-Murcia (2014).

where E denotes the model consistent expectation with the information set including the state of the economy (x_t) and the policy rule of each member (the ϕ_{it}s), but not the common and the individual policy shocks.

Let us denote the mean of the expected values of the individually preferred policy by $\tilde{E}(J_t)$, that is

$$\tilde{E}(J_t) = \frac{1}{n}\sum_{i=1}^{n} E(j_{it}) = x_t \frac{1}{n}\sum_{i=1}^{n} \phi_{it}.$$

The policy shock then can be decomposed into five terms as follows:

$$u_t^j = J_t - \tilde{E}(J_t) - \left(\tilde{E}(J_t) - E(J_t)\right) = J_t - \frac{1}{n}\sum_{i=1}^{n} \phi_{it} x_t - \left(\tilde{E}(J_t) - E(J_t)\right) = J_t - \frac{1}{n}\sum_{i=1}^{n} (j_{it} - v_t - w_{it}) - \left(\tilde{E}(J_t) - E(J_t)\right) =$$

$$= J_t - \frac{1}{n}\sum_{i=1}^{n} j_{it} + \frac{1}{n}\sum_{i=1}^{n} w_{it} + v_t - \left(\tilde{E}(J_t) - E(J_t)\right) = \left[J_t - \frac{1}{n}\sum_{i=1}^{n} J_{it}\right] + \frac{1}{n}\sum_{i=1}^{n} (J_{it} - j_{it}) + \frac{1}{n}\sum_{i=1}^{n} w_{it} + v_t - \left(\tilde{E}(J_t) - E(J_t)\right)$$

Each component has an intuitive interpretation: the first one is the distortion caused by the aggregation rule (picking the mode instead of mean), the second is the distortion caused by rounding, the third is the average of the idiosyncratic shocks, the fourth is the common decision shock. The last term is the difference between the model consistent expected value and the mean of the individual expected values, which is, according to the simulation results, small in magnitude[3]. Consequently, the final outcome differs from the expectations not only because of the unexpected decision shocks, but also due to the nature of the decision making mechanism, namely, rounding and selecting the mode.

It should be noted that this is not an orthogonal decomposition. While the third and fourth terms are orthogonal to each other by construction, the same is not necessarily true for the first two and for their relationships with the decision shocks.

The first term, the deviation of the collective decision from the mean of the individual votes can be observed as long as the individual votes are disclosed. My proposed proxy for the monetary policy shock is thus the average magnitude of dissents made public by several central banks. To be a valid instrument, it should be correlated with the policy outcome (J_t), but uncorrelated with other shocks in the economy, which is u_t^x in our model. The first condition is likely to be met as long as the other four terms do not completely offset its correlation with the policy shock. The second condition can be met if there is enough variation in the shocks (at least in their effect on the policy variable) compared to the distance between possible outcomes, which is typically 25 basis point in the case of central banks' policy rate.

In the empirical application to be presented later, I use the record of dissenting votes of the Fed collected by Daniel L. Thornton and David C. Wheelock, in which only the direction of the dissent, not the exact value of the alternative votes is indicated. Thus, following Riboni and Ruge-Murcia (2014), I consider the net balance of dissenting votes created as the proportion of votes for weaker action minus the proportion of votes for stronger action, or equivalently

$$d_t = \frac{1}{n}\sum_{i=1}^{n} \mathbb{I}(J_{it} < J_t) - \frac{1}{n}\sum_{i=1}^{n} \mathbb{I}(J_{it} > J_t), \qquad (2)$$

where $\mathbb{I}$ is the indicator function taking value of one when the expression in parenthesis is true, and zero otherwise. Because of the signs in the definition, this proxy is expected to be correlated positively with the policy shock.

It should be stressed that this measure of dissent captures the effect of decision-making frictions on the collective decision rather than the degree of disagreement among members. To see the difference, note that, for example, in a 9-member committee the proxy is zero when there is no dissent, similarly to the case when two members voted for higher and two members for lower interest rate. Thus, it is not directly related to the uncertainty, which influences the second moment of the voting distribution mainly, only indirectly.

[3] To highlight the difference between the two "expected values", consider a simple example with a three-member decision making body. Each member votes for 0 with 1/3, and for 1 with 2/3 probability. Clearly, the mean of the individual expected values is 2/3. The model consistent expected value which takes the decision making mechanism into account is $3 * (2/3)^2 * (1/3) + (2/3)^3 = 20/27$, which is slightly more than 2/3.

2.3 SIMULATION RESULTS

Since the relevance and the validity of the proposed instrument cannot be derived analytically, not even with this simple model, numerical simulations are needed to see the statistical properties of voting balance and how it is related to the underlying shocks.

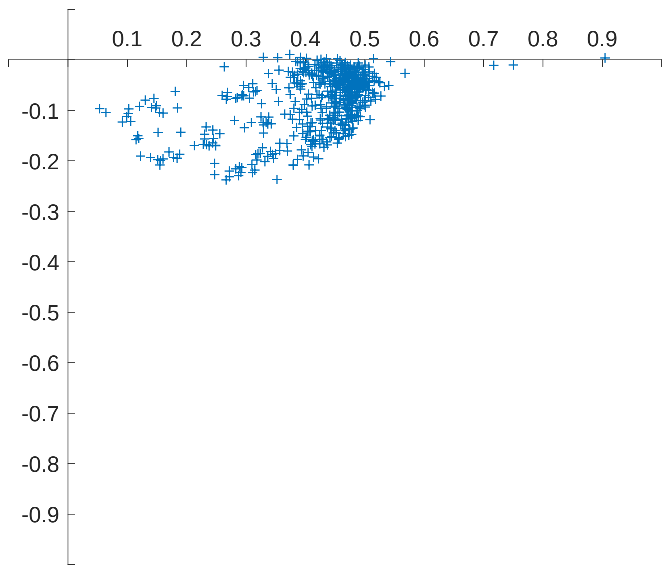
During the simulations I kept the autoregressive parameters fixed: $\rho_x = \rho_\phi = 0.9$, that is the shocks hitting the economy and the policy preferences have fairly persistent effect. As for the other parameters, I experimented with numerous combinations. The standard deviation of v_t, w_{it}, x_t and ϕ_{it} changed independently from 0.05 to 0.25 with 0.05 steps. This means 625 combinations of the four parameters. The decision making body consisted of 7 members ($n = 7$). For each parameter combination I made simulation for 10,000 periods.

To calculate the model consistent expectations some approximation was needed, because the shocks are unbounded and, consequently, the number of possible individual outcomes is infinite even after rounding. As a first step, I simulated the individual votes for a given parameter combination for each period, and assumed that the public knows the distribution of votes from this simulation and considers only potential decision outcomes between the first percentile minus one and the 99th percentile plus one. The true probabilities of the outcomes outside this range were added to those of the two extreme outcomes. Since these probabilities are very small, this kind of truncation of the true distribution results only in negligible distortion when calculating the model consistent expected value.

The policy shock u_t^j is then calculated as the difference between the collective decision and this expectation. It should be noted that this model consistent shock is not equal to the one defined for illustration purpose in (1), but according to the simulation results, they are very close to each other.

The validity of the instrument requires zero correlation with u_t^x and non-zero correlation with J_t. Figure 1 shows the joint empirical distribution of these correlation coefficients.

Figure 1
Simulated correlations of the dissent proxy with the policy variable (horizontal axis) and the economic shocks (vertical axis).



With most parameter combinations the dissent index variable defined in (2) proved to be valid with the exception of very few cases when the correlation with the economic shocks was significantly nonzero (negative). It should be noted here that increasing further (above 0.25) the standard deviation of the policy shocks, the preference shocks and the economic shocks would result in even more valid instrument.[4] In the very few cases when either the correlation with policy shocks was low or the correlation with economic shocks was far from zero, the variance of the shocks in the model were rather low. It is thus worth further investigation, in what parameter regions will our proposed instrument be invalid.

One benchmark for choosing the empirically relevant parameter combinations is the variability of the dissent index. The standard deviation of the monthly instrumental variable used in the empirical application was 0.087, and that of the quarterly one was 0.155. Thus, I consider simulation parameters producing similar statistics, that is standard deviation of the proxy variable between 0.08 and 0.16.

Within the empirically relevant parameter region defined above, the correlation between the proxy and the policy outcome is still high. The mean is 0.46 and 90 percent of the distribution is above 0.27. The correlations with the economic shocks are close to zero but with a fat tale in the negative territory. The mean of the distribution is -0.083, the 10th and 90th percentiles are -0.174 and -0.016, respectively. Thus, even if in most cases the instrumental variable can be considered as valid, there is a non-negligible part of the empirically relevant parameter region in which the instrument co-moves with the economic shocks.

Figure 2
Histograms of simulated correlations with the policy variable (left panel) and the economic shocks (right panel) when the standard deviation of the dissent proxy is in the empirically relevant region.

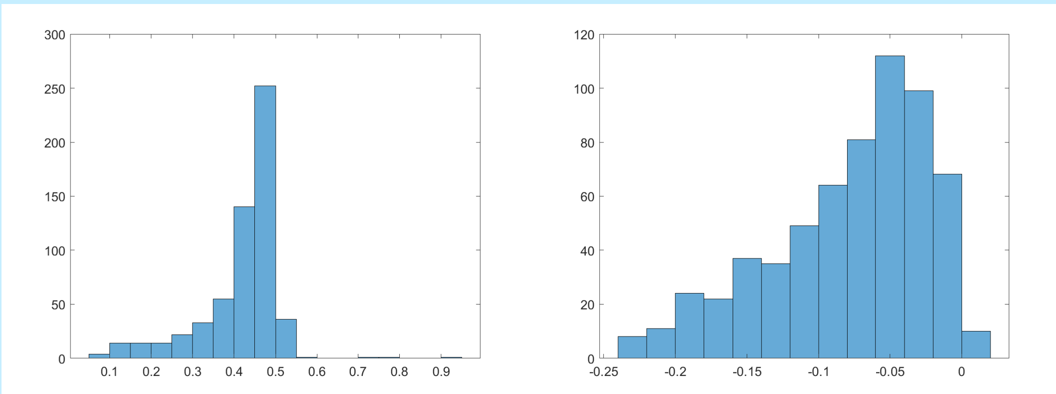


Table 2 summarizes the main statistics of the two parts of the empirically relevant parameter region, where in the second part the correlation between the dissent index and the economic shock is less than -0.1, containing 36 percent of all empirically relevant parameter combinations. Since the mean of the reaction coefficients (ϕ) is one, and both the individual and the common policy shocks enter the reaction function directly, the standard deviation of the economic shocks and the two types of policy shocks can be compared directly in terms of their contribution to the variance of the policy variable.

Table 2
Means of standard deviations and correlations with the proxy variable.

	standard deviation of				correlation of d_t with		
	x_t	v_t	w_{it}	ϕ_{it}	J_t	u_t^j	u_t^x
valid	0.1622	0.186	0.116	0.15	0.442	0.484	-0.045
invalid	0.155	0.095	0.19	0.155	0.357	0.429	-0.153

Note: x_t: state of the economy, v_t: common decision shocks, w_{it}: individual decision shocks, ϕ_{it}: individual reaction function coefficients, J_t: policy variable, u_t^j: total policy shocks, u_t^x: economic shocks. 'Valid' denotes the parameter region in which the correlation between the instrument and the state of the economy is less than 0.1 in absolute terms. Other parameter combinations are labelled as 'invalid'.

The main difference between the two parameter regions is that in the first one, when the instrument is valid as defined above, the variance of the common decision shocks is significantly larger than that of the individual decision shocks. When the correlation between the instrument and the economic shocks is less than -0.1, this relation turns to the opposite as the standard

[4] For the same reason as explained in the previous footnote.

deviation of the individual shocks becomes twice as large as that of the common ones. Nevertheless, the instrument seems to be relevant in each case, as the average correlation with the policy variable is above 0.35.

Unfortunately, in real life we cannot directly observe the relative variances of all shocks incorporated in this simple model. Thus, we cannot *a priori* decide whether the proposed variable will be a valid instrument in empirical applications. All what we can conclude from this simulation exercise is that it will less likely be valid when the common decision shocks are significantly smaller than the individual ones. The main intuition behind this result is that disagreement can generally be driven by the state of the economy, but with large enough common decision shocks it becomes unpredictable in which direction the final decision will be diverted from the optimal policy by the decision-making frictions.

3 The instrumental variable

To approximate the distance between the collective outcome and the mean of individually preferred outcomes, I use the record of dissents on FOMC monetary policy votes, which is an extended version of the database constructed by Daniel L. Thornton and David C. Wheelock and used in their study, Thornton and Wheelock (2014). This database contains the voting records with dissents for all FOMC meetings since 1936.

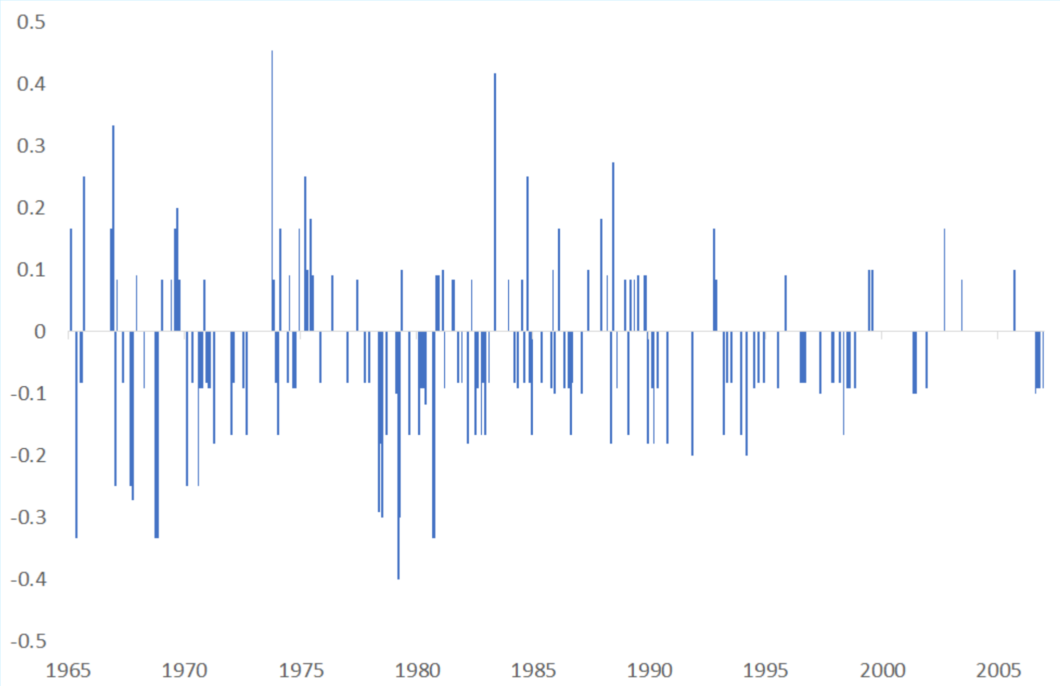
The information from this database I use is the number of members with dissenting votes for tighter and easier policy actions. For the period when the FOMC targeted the federal funds rate, the exact distance between the common decision and the average of individual targets would be a good proxy for the exogenous policy shock described above. In the absence of numerical record of each member's preferred interest rate, I use the net balance of tighter and easier preferences, normalized by the total number of voters. That is, my instrumental variable is

$$d_t = -\frac{n_t^+ - n_t^-}{N_t}, \tag{3}$$

where n_t^+ and n_t^- is the number of votes for tighter and easier policy action, N_t is the number of total votes. The minus sign serves only normalization purposes, because in this way we can expect the the instrument to have positive correlation with the policy shock caused by the collective decision making mechanism. Dividing by the number of votes is motivated by the time-varying size of the decision making body. Apart from the minus sign at the beginning, this index is exactly the same as the first one Riboni and Ruge-Murcia (2014) use for forecasting future interest rate decisions.

For the months without FOMC meeting, the value of this variable is set to zero. When working with quarterly data, I aggregated the dissents by taking the sum of monthly data in each quarter. The monthly evolution of the instrumental variable is presented in Figure 3.

Figure 3
Net balance of dissenting votes as a ratio of total votes.



I also consider alternative proxies based on the assumption that the policy shocks can be larger when the Fed's interest rate target is changing, or when the previous decision caused a big surprise. During prolonged periods of predictably unchanged interest rate, the information content of dissenting votes can be smaller, since the alternative interest rate target they suggest has smaller probability as an outcome. Conversely, when the Fed surprises the market with an interest rate change, the length of the cycle and the level of the fed funds rate in the medium term is more uncertain, thus the surprise content of the next decisions can be larger. Accordingly, the distribution of votes can convey more information about what other outcomes might have been plausible.

According to the argument above, I define alternative instruments, too. To overweight dissents during times of rapidly changing interest rates, I multiply d_t by the absolute change of the effective fed funds rate in the previous period or by the absolute value of the lagged residual of the VAR's interest rate equation. As it turns out, the alternative variables are significantly better instruments than the basic one introduced in (3).

4 Methodology

The proxy-SVAR estimation relies on the assumption that the instrumental variable is correlated with the policy shock, but not with the other structural shocks. With a well specified VAR model, the contemporaneous impact of the policy shock on the VAR's endogenous variables can be consistently estimated by regressing the VAR's non-policy residuals on the policy residuals with the proxy variable as an instrument.

Let x denote one non-policy variable, Y the vector of all endogenous variables. The equation of the VAR corresponding to x can be written as (ignoring exogenous observables and the intercept, and assuming only one lag)

$$x_t = a^x Y_{t-1} + \varepsilon_t^x,$$

where a^x is the corresponding row of the coefficient matrix and ε_t^x is the residual term.

Similarly, the equation of the policy variable i is

$$i_t = a^i Y_{t-1} + \varepsilon_t^i.$$

The residuals are linear combinations of the unobservable structural shocks, with one of them being the policy shock denoted by e_t^p. Particularly, let

$$\varepsilon_t^x = s_{np}^x e_t^{np} + s_p^x e_t^p$$

and

$$\varepsilon_t^i = s_{np}^i e_t^{np} + s_p^i e_t^p,$$

where e_t^{np} is the vector of non-policy shocks, s_{np}^x and s_{np}^i are the corresponding weight vectors (the impact responses), s_p^x and s_p^i are the contemporaneous effects of the policy shock on x and i, respectively.

If d_t is correlated with e_t^p but not with the other structural shocks, then regressing ε_t^x on ε_t^i with the proxy variable d_t as instrument, the regression coefficient will asymptotically be equal to s_p^x / s_p^i. To calculate the contemporaneous effect on each variable, one has to use the fact that $E(SS') = \Sigma$ where S is the matrix of contemporaneous effect of all structural shocks on all endogenous variables and Σ is the variance-covariance matrix of reduced form residuals. For further details see footnote 4 in Gertler and Karádi (2015).

Because some of my instrumental variables are only weakly correlated with the residuals of the interest rate equation, for inference I use the approach of Montiel Olea et al (2020), which is robust to instrument weakness.

5 Results

My benchmark VAR is estimated from monthly observations of fed funds rate (as the policy variable), employment, PCE deflator, commodity price index, non-borrowed reserves and M2 money aggregate, just as in Jordà (2005)[5]. The fed funds rate is monthly average. The instrument is the interaction of the dissent index and the absolute value of the previous period's rate change, measured by the first difference of the fed funds rate variable. As mentioned earlier, the interaction of the pure dissent index with some measure of previous period's interest rate surprise results in stronger correlation with the contemporaneous interest rate.

The sample starts in January 1985 and ends in December 2006. All variables, except from the fed funds rate, are log-differenced. The charts, however, present the impulse responses in level. The lag length is 6.

The choice of this particular specification, sample and instrument was motivated by the relatively low autocorrelation in the residuals according to the LM-test, significant cross-variable effects according to the Wald-test, and high F-statistics in the first stage regression. The latter was 7.64, which is still lower than the rule-of-thumb threshold of 10 recommended in Stock et al (2002). This is why the weak-instrument robust inference of Montiel Olea et al (2020) was employed. It should be noted, however, that conventional inference with the plug-in estimator and δ-method confidence sets would lead to the same qualitative conclusions.

Figure 4 presents the impulse responses to a 25 basis point rate hike shock. The higher interest rate prevails for a relatively long, more than one year period. Employment decreases, as expected, and reaches its trough four years after the shock. A bit surprisingly, employment does not seem to recover: even 8 years after the shock it is still half percent lower than initially, and this difference is statistically significant even at 5 percent.

The behavior of the PCE deflator is different from what standard theories of monetary transmission mechanism predict, as prices rise gradually, despite the subdued activity of the real economy. Nevertheless, the positive effect is not significant statistically at the conventional levels. The same is true for commodity prices, but with an immediate jump. Non-borrowed reserves drop immediately, M2 rises temporarily, with both responses being statistically insignificant.

In the appendix results from alternative VARs are shown. The specification choices were motivated by low residual autocorrelation, joint significance of the VAR coefficients corresponding to variables other than own lags, and the F-test of instrument strength, just as in the benchmark case. In each case the VAR consisted of one real variable (employment, industrial production or GDP), one measure of overall price level (PCE deflator or CPI), and some other controls (inflation expectations[6], commodity price index, M2, non-borrowed reserves, total reserved, and Dow Jones Industrial Average index).

The findings from benchmark estimation are quite robust to changing the specification, including the variables in the VAR, lag length, sample period, data frequency and instrument. The variable capturing the real activity drops gradually, but persistently and quite significantly. The overall price level increases, but this increase is insignificant in most cases.

This pattern is different from conventional view of the monetary transmission mechanism, which predicts falling prices and output (and employment) after a contractionary shock. It is rather reminiscent of the price puzzle, found in many empirical studies investigating the effect of monetary policy [7]

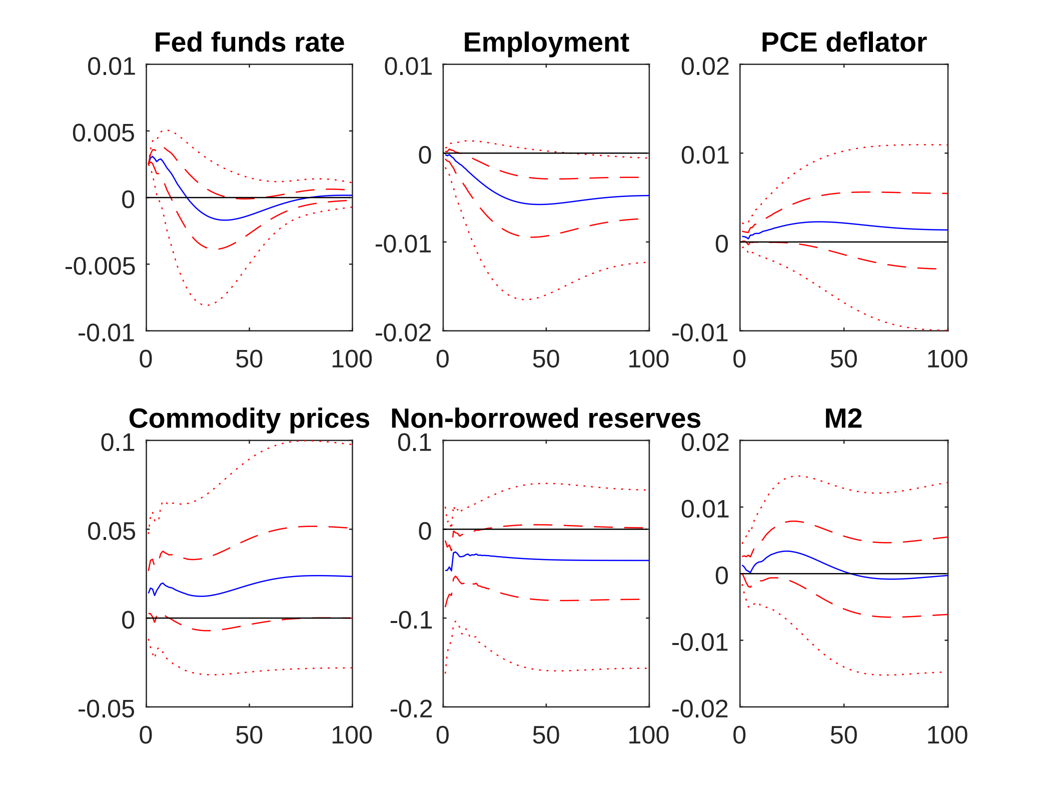
There are several explanations for the price puzzle. One branch of the arguments attributes it to identification failure. Sims (1992) argues that the Fed uses more information than a typical VAR contains. He demonstrates that the inclusion of commodity

[5] The sources of the data can be found in the appendix.

[6] I used the logarithm of the ratio of the mean level forecast for 5 and 4 quarters ahead from the Survey of Professional Forecasters

[7] For a detailed literature survey see Rusnak et al (2013).

Figure 4
Effect of an unexpected 25 basis point interest rate hike.



Note: Estimation from monthly data between January 1985 and December 2006. Point estimates as well as 68 percent and 95 percent confidence intervals are calculated with the code used in Montiel Olea et al (2020).

prices mitigates the puzzle, because it conveys extra information about future inflation. Castelnuovo and Surico (2010) goes further in this direction and show that the omission of inflation expectation is a problem only in the pre-Volcker period, that is when the estimation sample ends before 1979. Their explanation is that prior to Volcker's chairmanship, the Fed's reaction to the inflation was weak, generating sunspot shocks to inflation expectations. Without controlling for them, monetary policy shock estimates may be distorted. They also show that widely used identification schemes do not produce significant price puzzle for the post-Volcker period.

Another branch of the literature argues that increasing prices after a monetary contraction are not statistical artifact, but rather the genuine response of the economy. The explanation of Barth and Ramey (2002) is based on the cost channel. When interest rates are higher, financing working capital becomes more expensive, thus a monetary contraction causes a negative supply side shock with falling output and increasing prices. They emphasise, however, that this channel influences the total effect of monetary policy only in the short run.

An entirely different explanation of the price puzzle is offered by the neo-Fisherian theory (Uribe, 2018). It is based on the Fisher-equation which establishes a positive relationship between inflation and interest rate. Because monetary policy cannot influence the real interest rate in the long run, if the nominal interest rate is changed permanently, it is the inflation rate that has to adjust in the same direction in the long run. This effect exists even in New-Keynesian models (Garín et al, 2018).

Finally, the Fiscal Theory of Price Level also predicts rising prices after a monetary tightening in the case of active fiscal policy rule (Sims, 2011). The main intuition is that after an interest rate hike, the present value of future budget surpluses, which determines the real value of government bonds, decreases, and the equilibrium on the bond market restores through increasing consumer prices.

The results presented in this paper can be considered as another evidence for increasing prices after a monetary contraction as long as the identifying restriction, namely, that the distribution of dissenting votes are uncorrelated with economic shocks is reasonable. An important feature of my results is that the price puzzle is present even if inflation expectations or commodity prices are included, and also for the post-Volcker period, as results from the alternative specifications show.

Uribe (2018) estimates the effect of short run and long run changes in the interest rate separately. He finds that while a temporary rate hike decreases both output and inflation (just as in the conventional view on the monetary transmission mechanism), permanent rate hikes increase both inflation and output, consistently with the neo-Fisherian effect.

My results can be reconciled with Uribe's (2018) result. Since I do not distinguish between permanent and transition interest rate shocks, the monetary shocks identified in this paper are presumably a mixture of them. This is supported by the fact that the fed funds rate's reaction to the initial monetary shock is more persistent than in Uribe (2018) after a temporary shock. If temporary shocks are frequent enough, linear combination of output and price level responses of Uribe's (2018) empirical model can easily produce falling output and rising prices after a "mixed" monetary shock, just as the results presented here.

6 Conclusion

In this paper I presented a novel way to identify the effect of monetary policy on the economy. I used record of dissenting votes on the FOMC rate setting meetings as an instrument. Due to rounding and majority voting the final outcome is likely to differ from the expected outcome. I used a stylized model to demonstrate that this difference is generally unrelated to the underlying economic shocks.

With this instrumental variable, I estimated several proxy-SVARs for the U.S. A very robust finding from the most relevant specifications is that monetary tightening depress the real economy permanently. Another important finding is that consumer prices increase after the monetary contraction, although the impulse responses are less significant than those of the real variables.

The results presented in this paper can be considered as another evidence for price increase after a monetary contraction, a phenomenon known as price puzzle in the literature. Although there are some arguments that the puzzle is a statistical artifact due to identification failure, my approach avoids these traps to some extent. A possible theoretical explanation for the puzzle found in this paper is that unexpected interest rate changes are sometimes permanent ones, that have the opposite effect on inflation, in line with the neo-Fisherian theory.

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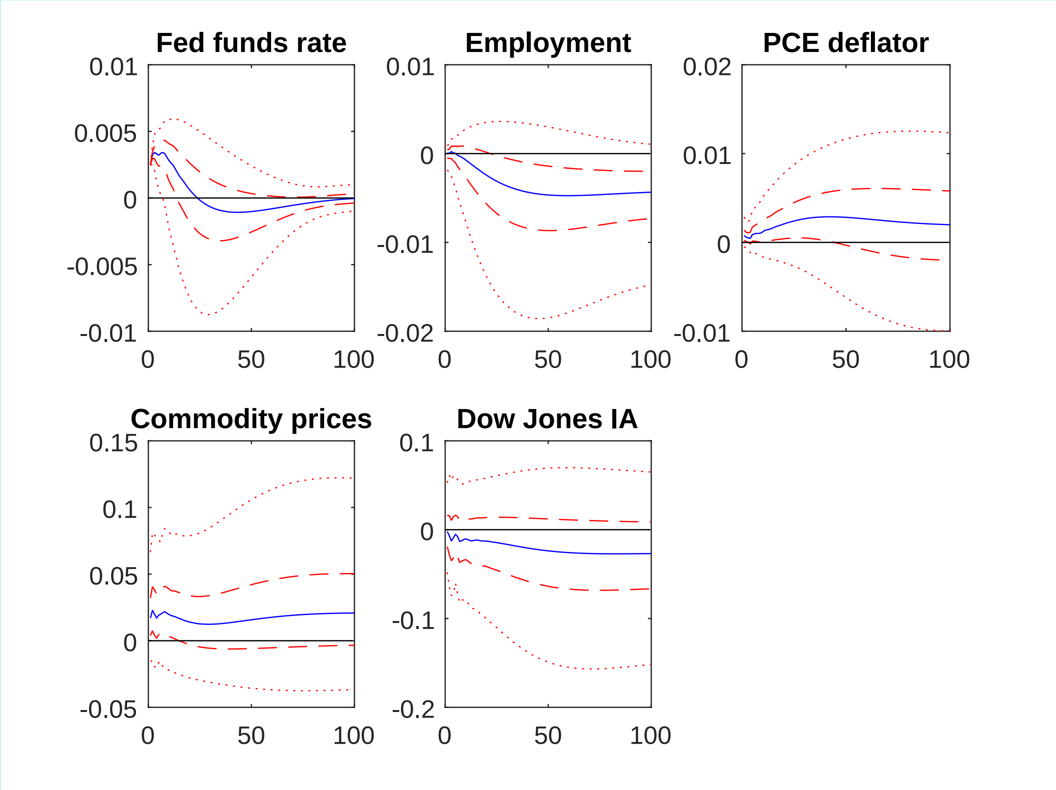
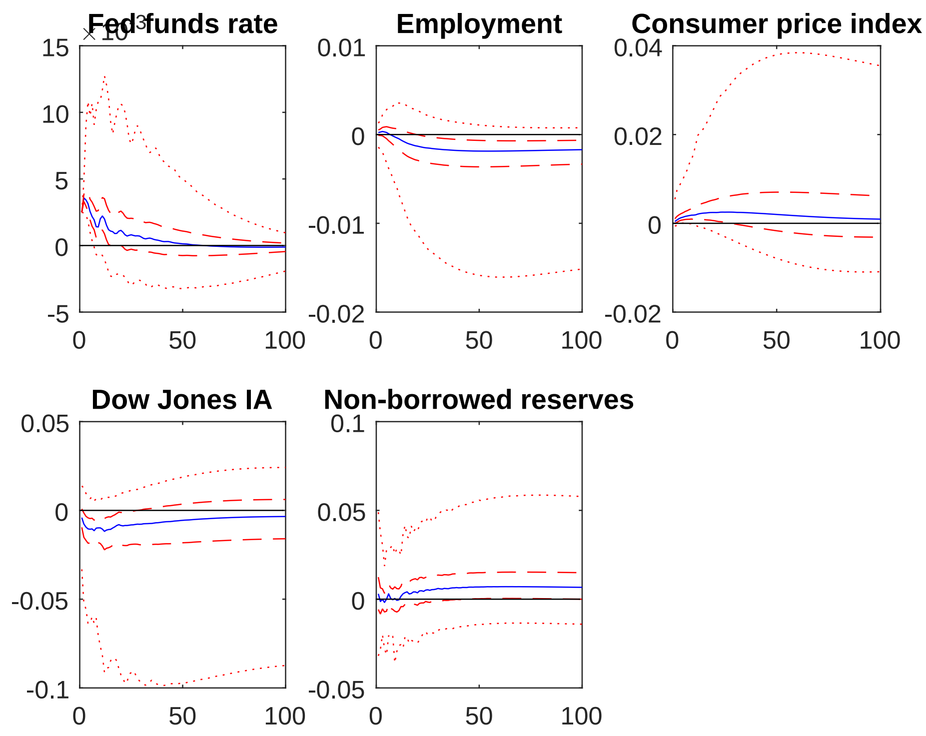
Appendix A Results from alternative VAR specifications

Figure 5
Effect of an unexpected 25 basis point interest rate hike.



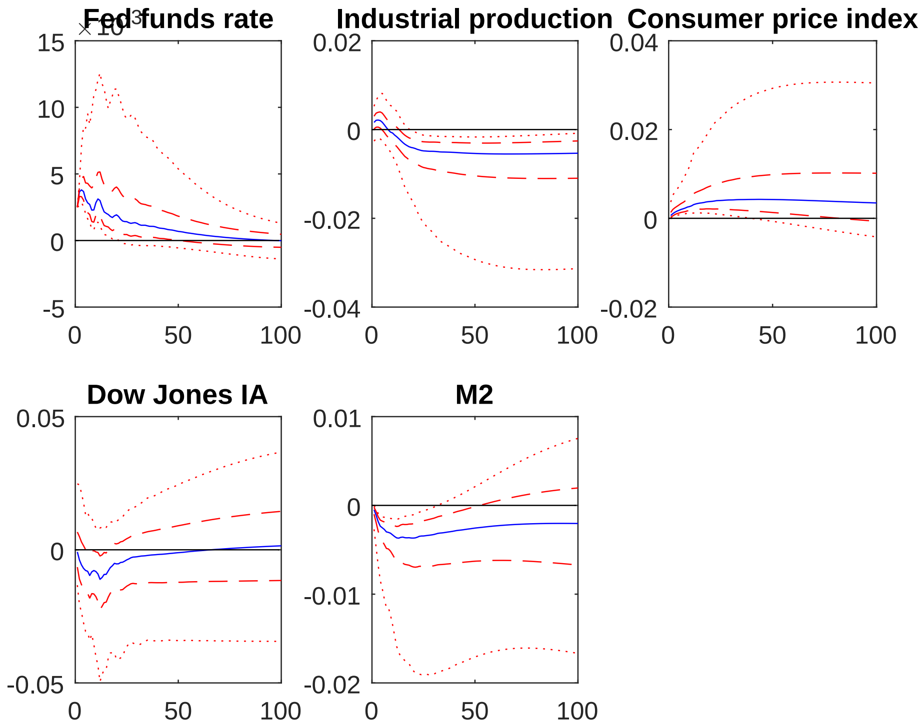
Note: Estimation from monthly data between January 1985 and December 2006. VAR includes 6 lags. The instrument is the product of the dissent index and the fed funds rate's change in the previous month. The first stage F-statistics is 7.27. Point estimates as well as 68 percent and 95 percent confidence intervals are calculated with the code used in Montiel Olea et al. (2020).

Figure 6
Effect of an unexpected 25 basis point interest rate hike.



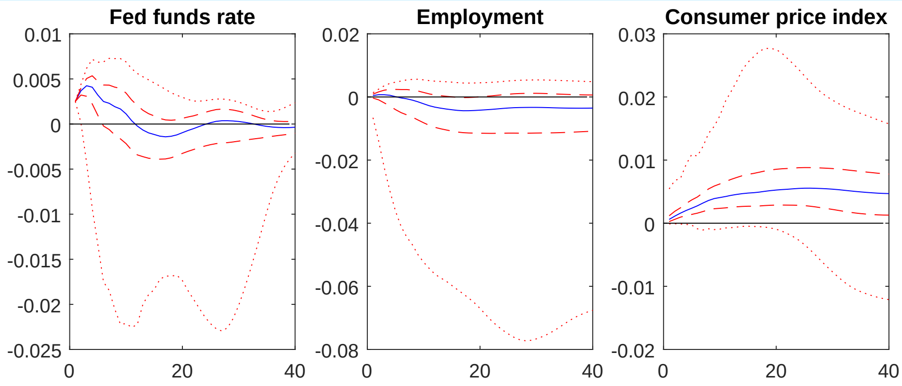
Note: Estimation from monthly data between January 1971 and December 2006. VAR includes 12 lags. The instrument is the product of the dissent index and the lagged estimated residual in the interest rate equation of the VAR. The first stage F-statistics is 8.5. Point estimates as well as 68 percent and 95 percent confidence intervals are calculated with the code used in Montiel Olea et al. (2020).

Figure 7
Effect of an unexpected 25 basis point interest rate hike.



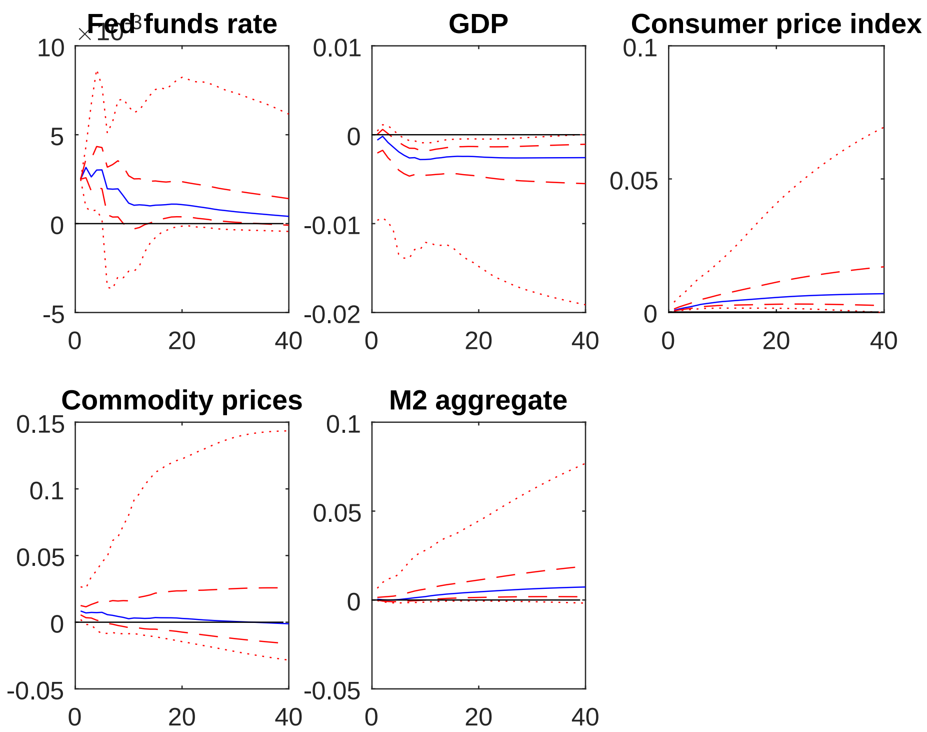
Note: Estimation from monthly data between January 1968 and December 2006. VAR includes 12 lags. The instrument is the product of the dissent index and the lagged estimated residual in the interest rate equation of the VAR. The first stage F-statistics is 9.53. Point estimates as well as 68 percent and 90 percent confidence intervals are calculated with the code used in Montiel Olea et al. (2020). (95 percent confidence intervals are unbounded in this case)

Figure 8
Effect of an unexpected 25 basis point interest rate hike.



Note: Estimation from quarterly data between 1985Q1 and 2006Q4. VAR includes 8 lags. The instrument is the product of the dissent index and the lagged estimated residual in the interest rate equation of the VAR. The first stage F-statistics is 6.73. Point estimates as well as 68 percent and 95 percent confidence intervals are calculated with the code used in Montiel Olea et al. (2020).

Figure 9
Effect of an unexpected 25 basis point interest rate hike.



Note: Estimation from quarterly data between 1985Q1 and 2006Q4. VAR includes 5 lags. The instrument is the product of the dissent index and the fed funds rate's change in the previous quarter. The first stage F-statistics is 7.31. Point estimates as well as 68 percent and 90 percent confidence intervals are calculated with the code used in Montiel Olea et al. (2020). (95 percent confidence intervals are unbounded in this case)

Figure 10
Effect of an unexpected 25 basis point interest rate hike.

Note: Estimation from quarterly data between 1985Q1 and 2006Q4. VAR includes 6 lags. The instrument is the product of the dissent index and the lagged estimated residual in the interest rate equation of the VAR. The first stage F-statistics is 7.79. Point estimates as well as 68 percent and 95 percent confidence intervals are calculated with the code used in Montiel Olea et al. (2020).

Appendix B Data sources

Fed funds rate: 'Effective Federal Funds Rate, Percent, Monthly, Not Seasonally Adjusted' from the FRED database. The quarterly series is the quarterly average of the monthly series.

Employment: 'All Employees: Total Nonfarm Payrolls, Thousands of Persons, Monthly, Seasonally Adjusted' from the FRED database. The quarterly series in level is the quarterly average of the logarithm of the monthly series.

PCE deflator: 'Private Consumption Expenditure Deflator: All Items Non-Food Non-Energy for the United States (DISCONTINUED), Index 2010=1, Monthly, Seasonally Adjusted' from the FRED database.

Non-borrowed reserves: 'Non-Borrowed Reserves of Depository Institutions Plus Term Auction Credit (DISCONTINUED), Billions of Dollars, Monthly, Seasonally Adjusted' from the FRED database.

M2: 'M2 Money Stock, Billions of Dollars, Monthly, Seasonally Adjusted' from the FRED database. The quarterly series in level is the quarterly average of the logarithm of the monthly series.

Industrial production: 'Industrial Production Index, Index 2012=100, Monthly, Seasonally Adjusted' from the FRED database.

Consumer price index: 'Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, Index 1982-1984=100, Monthly, Seasonally Adjusted' and 'Consumer Price Index: Total All Items for the United States, Index 2010=100, Quarterly, Seasonally Adjusted' from the FRED database.

GDP: 'Real Gross Domestic Product, Billions of Chained 2012 Dollars, Quarterly, Seasonally Adjusted Annual Rate' from the FRED database.

Commodity prices: 'CRB Commodity Price Index' from the dataset of Coibion (2012). The quarterly series in level is the quarterly average of the logarithm of the monthly series.

Dow Jones IA: 'Dow Jones Industrial Average, monthly, end of period close value' from S&P Dow Jones Indices LLC, a division of S&P Global.

Inflation expectations: Logarithm of the ratio of the mean level forecast for 5 and 4 quarters ahead from the Survey of Professional Forecasters.

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