The origins of monetary policy disagreement: the role of supply and demand shocks

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May 13, 2019

Abstract

We investigate how dissent in the FOMC is affected by structural macroeconomic shocks obtained using a medium-scale DSGE model. We find that dissent is less (more) frequent when "demand" ("supply") shocks are the predominant source of inflation fluctuations. In addition, demand shocks are found to lower private sector forecasting uncertainty about the path of interest rates, while supply shocks have the opposite effect. Since "supply" shocks impose a trade-off between inflation and output stabilization while "demand" shocks do not, our findings are consistent with heterogeneous preferences over the dual mandate among FOMC members as a driver of policy disagreement.

JEL Classification: E52, E58, D78.

Keywords: FOMC; Committees; Monetary policy; DSGE models.

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1 Introduction

Central bank decision making by a committee of experts is an increasingly ubiquitous feature of monetary policy design (Reis, 2013). This institutional feature is seen as beneficial for aggregating the private assessments of economic conditions (Gerlach-Kristen, 2006) and providing a diversity of views about the best course of action (Hansen et al., 2014). However, precious little is known about the macroeconomic factors that cause disagreement among committee members. In particular, although central bank communication is couched in terms of structural models of the economy, no study has been previously done examining how central bank committee deliberations are affected by structural macroeconomic shocks.

In this paper, we investigate how macroeconomic shocks affect the frequency of dissent votes in the Federal Open Market Committee (FOMC or Committee), which sets the US monetary policy. We obtain structural shocks from the estimation of the medium-scale dynamic stochastic general equilibrium (DSGE) model by Smets and Wouters (2007), which has been shown to perform well in forecasting relative to standard time-series models. We then classify the shocks as either supply shocks, demand shocks or monetary shocks, based on their implications for the behavior of inflation, output and interest rates. We show that FOMC dissent increases when inflation variability is substantially affected by supply shocks. In contrast we observe that FOMC dissent is less frequent when inflation movements are determined by demand and monetary shocks. These effects are precisely estimated and robust across various specifications, using several different measures of dissent, and both in the aggregate time-series and using panel data on individual members voting records.[1]

We interpret this finding using a simple structural model of committee deliberation and dissent, related to the framework in Riboni and Ruge-Murcia (2014) that introduces heterogeneity in the preferences of the committee members. Through the lenses of New Keynesian theory, the distinct feature of supply shocks is that they imply a trade-off between inflation and output stabilization. Thus, the finding that supply shocks lead to higher

[1] In proposing to interpret the actions and judgements of economic practitioners based on structural shocks obtained from a DSGE model, our paper relates to work by Monti (2010), who shows how it is possible to interpret the forecasts of professional forecasters using such shocks.

disagreement at FOMC meetings is consistent with the view that Committee members have heterogeneous preferences over these two objectives. Instead, demand and monetary shocks move inflation and output in the same direction. Thus, if the Committee members have heterogeneous preferences over the dual mandate, demand shocks should be associated with less disagreement among Committee members whereas supply shocks should lead to increased disagreement.

In the baseline empirical specification, we obtain the historical shock decompositions across the supply and demand shocks using a medium-scale DSGE model. Consistent with our posited hypothesis, our main empirical finding is that inflation volatility attributed to supply shocks raises dissent, but volatility attributed to demand shocks lowers dissent. The same empirical result is obtained if external measures of the structural shocks, combined with a structural vector autoregressive (VAR) model, are used to produce the historical shock decomposition of inflation, in lieu of the medium-scale DSGE model. We also show that supply shocks increase dispersion in the expectations of private sector agents concerning the path of interest rates, while demand and monetary shocks lower its dispersion. This indicates that uncertainty regarding the relative preferences of Committee members over inflation and output affects the ability of economic agents to predict the actions of monetary policy makers. At the same time, this offers an interpretation for the finding by Belden (1989) that periods of greater uncertainty about the impact of policy actions are associated with heightened dissent.

The current paper offers a new perspective on the nexus between macroeconomic conditions and monetary policy deliberations by committees. Prior to this work little was known about how macroeconomic conditions affect monetary policy deliberations. Recently, Thornton and Wheelock (2014) found no evidence of a systematic association between FOMC dissent and either inflation or unemployment. Our findings suggest that the apparent absence of any robust macroeconomic predictors of Committee disagreement has to do with the use of observable macroeconomic variables such as unemployment and inflation, instead of the underlying latent shocks responsible for the macroeconomic volatility.

The relative importance of heterogeneity in preferences versus information in shaping committee deliberations is another important question related to this paper. Riboni and Ruge-Murcia (2008) found evidence of heterogeneity in the weights attached to output and inflation stabilization among members of the Bank of England (BoE) whereas, using a different methodology, Besley et al. (2008) found members' preferences to be fairly homogeneous. Thus the findings in Riboni and Ruge-Murcia (2008) and Besley et al. (2008) are somewhat inconclusive. We argue that beyond simple policy rules, it matters which macroeconomic shocks are responsible for the fluctuations in the policy-makers' target variables, as not all shocks imply a trade-off between inflation and output stabilization. Our findings are consistent with heterogeneity in preferences as the underlying cause of disagreement in committees, conditional on supply shocks that impose trade-offs between conflicting policy objectives.

We estimate an empirical model for the frequency of dissent instead of estimating individual interest rate rules. This difference in methodology is important because the estimation of heterogeneous interest rate rules may be subject to large biases, since the estimation of heterogeneous dynamic panel data models is notoriously difficult (Pesaran and Smith, 1995). Our test of preferences heterogeneity as a determinant of monetary policy disagreement does not hinge on testing for heterogeneous coefficients in simple reaction functions. Instead, our test relies on the insight that only supply shocks impose a trade-off between conflicting policy objectives (a point also made by Riboni and Ruge-Murcia, 2008, but which they do not explore empirically). As we focus on the incidence of dissent, we avoid problems to do with the estimation of heterogeneous panel data models.

Although previous literature showed difficulty in accounting for macroeconomic factors able to predict FOMC dissent, individual characteristics have been found helpful in predicting votes of dissent. Recently, Malmendier et al. (2017) found that personal experiences of inflation can affect voting behavior of FOMC members. Belden (1989) and Thornton and Wheelock (2014) find that most dissent votes for easier are cast by governors and most dissent for tighter are by bank presidents. The findings of Havrilesky and Gildea (1991) and Eichler and Lähner (2014) indicate that this can be explained by differences in career background between governors and presidents. However, Tootell (1991) tests and rejects the hypothesis that significant differences exist in the voting behavior of bank presidents and governors.

Finally, we also contribute to the literature looking at the interplay between deliberation by monetary policy committees and the macroeconomy. In an influential paper, Romer and Romer (2008) find support for the hypothesis that differences between the FOMC and Federal Reserve staff forecasts help predict monetary shocks. Gorodnichenko and Weber (2016), find that following monetary policy surprises, narrowly identified around FOMC announcements, the conditional volatility of stock market returns rises more for firms with stickier prices than for firms with more flexible prices. Madeira and Madeira (2019), find robust empirical evidence of positive stock market returns around FOMC meetings when votes are unanimous, but negative returns when dissent occurs. Our results indicate that this could be because financial markets learn information from FOMC votes on the sources of shocks affecting the economy and the ability of monetary policy to adequately counteract such shocks.

The remainder of the paper is organized as follows. Section 2, describes the institutional features of the FOMC and summarizes the main aspects of the FOMC voting records. Section 3, proposes a simple structural model to interpret dissent in committee meetings within the context of a DSGE model. Section 4, presents our main empirical results about the determinants of dissent, and Section 5 considers additional empirical experiments. Finally, Section 6 summarizes our conclusions.

2 Voting in the FOMC

The Federal Open Market Committee (FOMC) oversees US monetary policy and open market operations (purchases and sales of US Treasury securities) of the Federal Reserve System (Fed). The FOMC is composed of twelve members: seven members of the Federal Reserve Board of Governors (who are nominated by the President), the New York Federal Reserve bank president and four of the remaining eleven Federal Reserve bank presidents (who serve one year terms on a rotating basis).

Currently, the Committee specifies policy in terms of a target level for the federal funds rate (the weighted average of interbank overnight loans). The FOMC meeting minutes identify all member votes, including those, if any, who dissented. The first vote of dissent in FOMC meetings after World War II occurred in 1957.[2] We therefore follow Thornton and Wheelock (2014) and focus our analysis on FOMC votes from the beginning of 1957 until the end of the first quarter of 2018 (so as to include the last meeting of Yellen as Chair).

The FOMC currently holds eight regularly scheduled meetings per year, and it may also hold unscheduled meetings as necessary to review economic and financial developments. Table 1 reports the frequency of votes of dissent for each Chair tenure, in terms of the average fraction of votes for dissent (DIS_t) in each quarter. The dissent votes are then split in three categories following the classification made by Thornton and Wheelock (2014) according to the reasons used as justification in official FOMC records: "tighter" (DT_t), "easier" (DE_t) and "other" (DO_t). "Tighter" refers to FOMC members that would have favored decreased money supply growth (and/or higher interest rates) relative to the policy adopted by the majority. Tighter policy is aimed at curbing inflation and spending in the economy. "Easier" refers to dissent votes in favor of a boost to the money supply (and/or lower interest rates) than the FOMC majority as a means to stimulate economic activity further.[3] "Other", means that the motive for dissent is not found in the minutes, or that the cause of dissent was not disagreement from the current policy stance but due to the language in the FOMC directive or possible future policy actions.

Table 1 also reports, for each Chair tenure, the percentage of quarters in which dissent occurs, across dissent category: overall dissent ($DIS_t > 0$); dissent for tighter ($DT_t > 0$); dissent for easier ($DE_t > 0$); dissent with other motives ($DO_t > 0$). The Table reveals that dissent votes are a small fraction of the total votes in FOMC meetings. With the exception of

[2]Thornton and Wheelock (2014) argue that the lack of dissent in preceding years reflected the organization of the Committee at the time (there were only 4 scheduled meetings per year and at "that time directives issued by the full Committee were vaguely worded statements that members may have found little to disagree with"). This changed in 1956 when the Committee started meeting more frequently and with all members voting on the operating directive to the manager of the Open Market Account.

[3]The financial press often refers to FOMC members that favor tighter policy as "hawks" and those that favor easier policy as "doves" (see Sablik, 2014).

the short term of Miller, dissent represents 10% or less of the votes during any Chair's term.[4] Nonetheless, dissent is quite frequently observed over time and all Chairs have observed dissent occurring in over 50% of quarters. Miller and Volcker were the Chairs with the highest observed dissent behavior. In fact, Miller and Volcker observed the highest rate of dissent for both tighter and easier policies, which is interesting since the FOMC obviously could not change its decisions in favor of two opposite directions. Greenspan was the Chair with lowest observed dissent behavior. Close to half of quarters had dissent votes for tighter policy and about one third for easier. Dissent votes for other were few (less than 1% of all votes), but have increased consistently with the Greenspan, Bernanke and Yellen Chair terms. Dissent with a bias in favor of easier monetary policies was rare (present in 25% of the quarters or fewer) in the Greenspan, Bernanke and Yellen terms, but quite common with other Chairs.

One may question if all dissents come from a single member who opposes the Chair in order to defend a different policy agenda. But to the contrary, Table 2 shows that all Chairs had to face dissent from several different FOMC members. While most votes cast are in favor of the policy proposed by the Chair (dissent represents only 6.4% of votes in our sample period, see Table 1), most FOMC members have dissented at some point (81 of a total of 147 FOMC members in our sample period have done so). Thus, dissent is not a minor aspect that can be explained away by the behavior of a few odd members acting as outliers within the Committee. Also, there are no members who dissent in all meetings. Between 1957 and 2018, only four members had a dissent rate equal to 50% or above.

Table 3 shows the distribution of the probability of dissent of each FOMC member over each Chair's term, conditioning on members who dissented at least once. Overall, the median dissenter is someone who disagrees from the Chair in fewer than 10% of the meetings. The strongest dissenting members (that is, those in the percentile 75 of highest dissent rate) had an overall dissent rate below 20%, which is far below someone who disagrees all the

[4]Because there is typically more than one meeting per quarter, ocasionally there are cases in which the first meeting had a different Chair from subsequent meetings in the same quarter. We matched such observations as belonging to the Chair in the first meeting. For example, there were two meetings in the first quarter of 2018. The first meeting was the last meeting with Yellen as Chair. The second meeting was the first meeting with Powell as Chair. We labeled the 2018:1 observation as corresponding to Yellen.

time. For example, during the Volcker and Miller terms the strongest dissenters (those in the percentile 75) had dissent rates of 17.6%. Therefore, although Volcker and Miller faced respectively dissent in 84% and 100% of quarters (Table 1) it is not true that there were particular members who always or almost always opposed them.

3 Making sense of FOMC dissents

In this Section we establish possible structural predictors of FOMC dissent through the lenses of a dynamic stochastic general equilibrium (DSGE) model. We first present a simple framework of monetary policy committee deliberation within the three equation New Keynesian (NK) model. Next, we set the scene for the empirical work in Section 4, by illustrating how structural shocks affect committee disagreement with a calibrated example.

3.1 Committee deliberations in the three equations NK model

This Section presents a simple model of monetary policy deliberation by committee, to identify the determinants of dissent. The economy is described by the canonical three equation NK model as laid out in, for example, Clarida et al. (1999) and Sbordone et al. (2010), as follows

$$y_t = y_{t-1} - (r_t - E_t \pi_{t+1}) - u_t^d, \tag{1}$$

$$\pi_t = \beta E_t \pi_{t+1} + \gamma y_t + u_t^s, \tag{2}$$

$$r_t = \rho r_{t-1} + (1-\rho)\Big[r^\star + r_\pi(\pi_t - \pi^\star) + r_y y_t\Big], \tag{3}$$

with y_t the output gap, r_t the nominal interest rate and π_t the inflation rate. The long-run targets for the nominal interest rate and inflation rate are $r^\star$ and $\pi^\star$. Equation (1) is the traditional IS condition and equation (2) is the Phillips curve. The exogenous disturbances u_t^d and u_t^s are "demand" and "supply" shocks respectively. Equation (3) determines the interest rate preferred by the majority of committee members including the Chair and is, therefore, the chosen interest rate at date t (under simple majority).

However, underpinning the choice of interest rate in (3), is a voting process by a monetary policy committee. We assume the committee adopts an agenda-setting protocol: proposals are passed by simple majority rule; the Chair sets the agenda, which allows him/her to make a policy proposal at every meeting; this proposal is either approved or voted down; if the proposal is voted down, the adopted interest rate is the previous period interest rate r_{t-1}. Since the Chair holds the agenda setting power and is also the median voter, this model collapses to the dictator model, with the Chair able to choose his/her favorite interest rate. This corresponds to what Riboni and Ruge-Murcia (2010) call the frictionless model, in which a committee is observationally equivalent to having the Chair as the single policymaker and, thus, the policy function is indistinguishable from a standard Taylor rule, which has been shown to describe well monetary policy in the US (Taylor, 1993).[5]

Even if we consider the frictionless case, modeling the committee deliberation and voting protocol explicitly allows us to understand dissent. Specifically, we assume as in Riboni and Ruge-Murcia (2014) that at the end of the voting game each member of the monetary policy committee has the opportunity to express dissent. The committee is comprised of N members labeled $i = 1, \ldots, N$. As in Besley et al. (2008) and Riboni and Ruge-Murcia (2014) each member's preferences for the value of the interest rate, $r_{i,t}$, is adequately represented by a simple rule, as follows

$$r_{i,t} = \rho r_{t-1} + (1-\rho)\Big[r^\star + r_{i,\pi}(\pi_t - \pi^\star) + r_{i,y} y_t\Big], \tag{4}$$

with $r_{i,\pi} \geq 0$ and $r_{i,y} \geq 0$ the individual specific weights on the inflation and output stabilization objectives.[6] Members' preferences are symmetric around their bliss point $r_{i,t}$,

[5] Assuming a frictionless model is, of course, a simplification. In fact, Riboni and Ruge-Murcia (2010) estimate different models of monetary policy committee deliberation, and find that the data favors the consensus formation model, in which no committee member controls the agenda and where a super majority is required to adopt a new policy. On the other hand, Riboni (2010) offers a rationale for delegating monetary policy to a committee dominated by a strong Chair, who controls the agenda but is constrained to put her policy to a vote. The committee may offer the Chair a commitment device to implement otherwise time-inconsistent policies (see Coroneo et al., 2018, for a recent empirical test of the time-consistent model of optimal monetary policy in the US economy).

[6] Fendel and Rülke (2012) provide direct empirical evidence, based on individual forecasts of FOMC members, that a Taylor-type rule often similar to that describing the aggregate FOMC behavior also fits

and dissent by committee member i occurs if and only if

$$|r_{i,t} - r_t| \geq \alpha, \tag{5}$$

with $\alpha > 0$ a constant parameter capturing the norms and institutional culture of the committee, which determine how valuable consensus is to the committee's deliberations (as in Riboni and Ruge-Murcia, 2014).

3.2 Calibrated example

In this Section we illustrate why separating between the contribution of supply shocks (which move inflation and output in opposite directions) and demand shocks (which move inflation and output in the same direction) to inflation volatility may help predict dissent.[7]

This is done by considering a calibrated example of the three equation NK model described by equations (1), (2) and (3). We set $r^\star = \pi^\star = 0$. Following Sbordone et al. (2010), we set $\beta = 0.99$ and $\gamma = 0.1$. For the monetary policy rule of the Chair we set $\rho = 0.75$, $r_\pi = 1.5$ and $r_y = 0.5$ which are standard values (i.e., they correspond to the prior mean values in Smets and Wouters, 2007). We assume that the demand (u_t^d) and supply (u_t^s) shocks obey an autoregressive process:

$$u_t^d = \rho_d u_{t-1}^d + \varepsilon_t^d, \tag{6}$$

$$u_t^s = \rho_s u_{t-1}^s + \varepsilon_t^s, \tag{7}$$

with $\rho_d = \rho_s = 0.9$. The example is based on the assumption that there are two minority groups, labeled "hawks" and "doves". These two groups represent two extreme types (in the

Committee members individual behavior. It is worth pointing out that (4) does not predict permanent disagreement between FOMC members, since the steady state nominal interest rate, $r^\star$, is the same for all members. This is consistent with the evidence documented in the previous Section, that no FOMC member has always voted dissent.

[7] Similar definitions of "demand" and "supply" shocks have a long established tradition in the econometric analysis of macroeconomic models and are often used, for example, in structural analysis with vector autoregressions (VAR) models identified with sign restrictions (see, for example, Peersman, 2005; Fry and Pagan, 2011; Canova and Paustian, 2011).

sense that they are not the median voter).[8] The interest rates favored by hawk and dove members, in turn $r_{h,t}$ and $r_{d,t}$, are given by

$$r_{h,t} = \rho r_{t-1} + (1-\rho)\Big[r^\star + r_{h,\pi}\left(\pi_t - \pi^\star\right) + r_{h,y} y_t\Big], \tag{8}$$

$$r_{d,t} = \rho r_{t-1} + (1-\rho)\Big[r^\star + r_{d,\pi}\left(\pi_t - \pi^\star\right) + r_{d,y} y_t\Big]. \tag{9}$$

The hawk/dove committee members differ from the Chair in terms of only the weights attached to inflation ($r_{h,\pi} > r_\pi > r_{d,\pi}$) and output ($r_{h,y} \leq r_y \leq r_{d,y}$). In the baseline case we have that committee members with hawk views adopt an interest rate rule with a higher weight on inflation and a lower weight on output ($r_{h,\pi} = 2$ and $r_{h,y} = 0.25$) whereas members with dove views adopt an interest rate rule with a lower weight on inflation and a higher weight on output ($r_{d,\pi} = 1$ and $r_{d,y} = 0.75$). The model is symmetric in the sense that $|r_t - r_{h,t}| = |r_t - r_{d,t}|$, implying that hawks and doves dissent together. Empirically, we see circumstances where dissent for both tighter and easier coexist but, of course, this needs not be the case.

As implied by condition (5), the relevant variable behind dissent in our framework is the absolute value of the difference between the interest rate favored by the Chair and the interest rate favored by hawk and dove members of the committee, $|r_{h,t} - r_t|$ and $|r_{d,t} - r_t|$. In particular, combining equations (4) and (5) we obtain that dissent by committee member $i = 1, \ldots, N$, occurs if and only if

$$\Delta_{i,t} \equiv \left|\frac{r_{i,t} - r_t}{1-\rho}\right| = \Big|\left(r_{i,\pi} - r_\pi\right)\left(\pi_t - \pi^\star\right) + \left(r_{i,y} - r_y\right) y_t\Big| \geq \left(\frac{\alpha}{1-\rho}\right). \tag{10}$$

[8]Reviewing statements from several FOMC members, Sablik (2014) argues that members labeled as doves are concerned with inflation and that members labeled as hawks also attach weight to employment. Thus, it is wrong to think of hawks as always favoring higher interest rates and doves lower rates. Instead, Sablik (2014) argues that the differences between members are with respect to the weights of monetary policy responses to inflation and economic activity, consistent with our formulation. Similarly, using narrative records in the US press Bordo and Istrefi (2018) argue that within an FOMC, for the same objective and same economic conditions, some members are perceived to be on the hawkish side and some on the dovish side.

Using in (10) the baseline case values for hawk members we obtain:

$$\Delta_{h,t} = \left| \left(r_{h,\pi} - r_{\pi}\right)\left(\pi_t - \pi^{\star}\right) + \left(r_{h,y} - r_y\right) y_t \right| = \left| 0.5\left(\pi_t - \pi^{\star}\right) - 0.25 y_t \right|,$$

which is equal to the same measure for doves ($\Delta_{d,t}$). Thus, $\Delta_{h,t}$ is a measure of "Policy Disagreement", since higher realizations of this variable imply that dissent by hawks (and doves) is more likely. We consider also an alternative case ($\Delta_{h,t} = |(r_{h,\pi} - r_{\pi})\,\pi_t|$) in which hawks/doves differ from the Chair with respect to the weight attached to inflation ($r_{h,\pi} = 2$ and $r_{d,\pi} = 1$, as in the baseline case) but not with respect to the output gap ($r_{h,y} = r_{d,y} = r_y = 0.5$). We consider this alternative specification because it allows us to illustrate that disagreement ia affected differently for supply and demand shocks only if committee members have heterogeneous preferences over both inflation and output stabilization.

We consider shocks which are equivalent in the sense that they both cause inflation to move 1% away from target. In Figure 1 we present the impulse response functions (IRFs) to demand and supply shocks for our calibrated model. The first panel has the IRFs for inflation and the second panel the IRFs for the output gap. The third and fourth panels have the responses to each shock of $\Delta_{h,t}$ (and, equivalently, $\Delta_{d,t}$) for, respectively, the baseline case (with disagreement over both targets) and the alternative case (only inflation).

The IRFs in the top panels illustrate the main difference between supply and demand shocks in the three equation NK model: the supply shock moves inflation and the output gap in opposite directions, while the demand shock moves the two variables in the same direction. Thus, supply shocks yield a trade-off between inflation and output stabilization. The left bottom panel shows that supply shocks generate substantial policy disagreement ($\Delta_{h,t}$) in the baseline case whereas demand shocks do not. The right bottom panel shows little difference between supply and demand shocks with respect to policy disagreement. Comparing the two bottom panels, we can observe that policy disagreement generated by supply shocks is higher (and more persistent) in the baseline case than in the alternative case. On the other hand, policy disagreement generated by demand shocks is lower in the baseline case than in the alternative case.

These results show that with heterogeneous preferences over the dual mandate among FOMC members we should observe more dissent with supply shocks than with demand shocks. In the next Section we investigate this hypothesis empirically, using demand and supply shocks obtained from an estimated medium-scale DSGE model.

4 Structural shocks as predictors of FOMC dissent

In this Section we carry out a formal empirical investigation of the hypothesis that the structural shocks identified using the medium-scale DSGE model are predictors of FOMC dissent. This is done using both time-series data on FOMC aggregate voting records and panel longitudinal data on each individual member's voting records.

4.1 Predictors of dissent based on a medium-scale DSGE model

The first step in our analysis is to obtain structural macroeconomic shocks (which we posit are important drivers of FOMC dissent) using the medium-scale DSGE model developed by Smets and Wouters (2007). A model which has become the workhorse framework to study the business cycle, used in many central banks for policy analysis, forecasting and communication (Debortoli et al., 2018). The model features a variety of frictions including sticky prices and wages, habit formation in consumption and investment adjustments costs. The model's exogenous disturbances include the following seven shocks: productivity, price markup, wage markup, exogenous spending, monetary policy, risk premium and investment.[9]

We estimate the model with the same Bayesian techniques as Smets and Wouters (2007).[10] For the estimation, we use the same seven US quarterly time series used by Smets and Wouters (2007): the log difference of the GDP deflator, real GDP, real consumption, real

[9] Estimating the Smets and Wouters (2007) model for the US economy, Debortoli et al. (2018) find substantial welfare improvements associated with assigning the central bank with a dual mandate over inflation and output stabilization. This indicates a meaningful trade-off between the two policy objectives is faced by policy-makers. The drivers of this trade-off in the estimated model by Debortoli et al. (2018) are the price and wage-markup shocks, which are shocks that we classify as supply shocks.

[10] See An and Schorfheide (2007) and Madeira (2013) for two useful reviews of the Bayesian approach.

investment and real wage, the log of hours worked, and the federal funds rate. Our estimation only differs from Smets and Wouters (2007) in the choice of data range. Smets and Wouters (2007) estimated their model for the period 1966:1 – 2004:4. We estimate our model for the period 1950:1 – 2018:1. We extend the sample period start and end dates so that we can obtain a reliable historical shock decomposition from 1957:1 until 2018:1.

The estimated mean IRFs for deviations of output, inflation and the interest rate from the steady state of each shock are shown in Figure 2. The seven structural shocks are classified as either, "supply", "demand" or "monetary" shocks, based on the shock's contemporaneous impact on output, inflation and the interest rate. The shocks classified as supply are the wage markup, price markup and productivity shocks. The shocks classified as demand are the exogenous spending, risk premium and investment shocks, and there is a single monetary policy shock, which corresponds to the shock to the interest rate policy rule.

We consider supply shocks to be those that cause inflation and output to move in opposite directions, while demand shocks are those which cause inflation and output to move in the same direction. While the monetary shock is (using our classification) also a demand shock we treat it separately for two reasons. First, monetary shocks are the result of decisions by the FOMC and, therefore, may play a different role in determining FOMC dissent than the other demand shocks. Second, while the other demand shocks cause the interest rate to move in the same direction as inflation and output, monetary policy shocks cause the interest rate to move in the opposite direction of inflation and output.[11]

In our empirical analysis on the determinants of FOMC dissent we propose as our main set of dissent predictors, the absolute value of the contribution of each shock category to inflation: $|\pi_t^{\text{sup}}|$, $\left|\pi_t^{\text{dem}}\right|$, and $|\pi_t^{\text{mon}}|$. We focus on inflation because the Federal Reserve's long run goals consist of targeting inflation and "concerns about prospective inflation were often given as a reason for members' dissents" (see Thornton and Wheelock, 2014), and to avoid collinearity from also including the historical shock decomposition for the output gap. We are interested in inflation variability, and thus the realized absolute value of inflation should be

[11]For this reason Keating (2013) also considers monetary policy shocks apart from other demand shocks.

interpreted as a measure of inflation volatility. The absolute value is preferred to the squared realization of inflation because it is more robust to the presence of measurement error, jumps and outliers.

The historical shock decomposition for inflation is shown in Figure 3. We find supply shocks to be important in the mid 1970s to early 1980s, and again in the late 1990s. Demand shocks are an important source of inflation volatility in the late 1950s, in the 1980s and from the mid 1990s onwards. Monetary shocks are important in the late 1970s and early 1980s and again in the early 2000s and around 2010.

The time series of $|\pi_t^{\text{sup}}|$, $\left|\pi_t^{\text{dem}}\right|$, and $|\pi_t^{\text{mon}}|$, for the sample 1957:1 – 2018:1, are shown in Figure 4, together with the fraction of votes for dissent (reported in all panels). The fourth panel aggregates the demand and monetary shocks, $\left|\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\right|$. In support of the arguments presented earlier, we observe that when the contributions of either the demand or monetary shocks to movements in inflation are high there are fewer dissenting votes in the FOMC deliberations (period prior to the mid 1970s and from the mid 1990s to the start of the Great Recession at the end of 2007). Instead, when the contribution of the supply shocks is high, the frequency of dissent increases (as in the period from the mid 1970s to early 1980s).

4.2 Time-series regressions

We now test formally the hypothesis that supply shocks lead to increased dissent whereas demand and monetary shocks lower dissent. In this Section we present results using time-series data. The baseline regression specification we propose for our test is as follows

$$V_t = \theta_0 + \theta_1 \pi_t + \theta_2 u_t + \theta_3 |\pi_t^{\text{sup}}| + \theta_4 \left|\pi_t^{\text{dem}}\right| + \theta_5 |\pi_t^{\text{mon}}| + F_t + T_t + \varepsilon_t, \tag{11}$$

with V_t being a measure of dissent. We consider several different measures of dissent. Specifically, DIS_t which is the fraction of votes for dissent at quarter t, $DIS_t > 0$ which is a dummy variable for whether there was dissent at quarter t, $DT_t > 0$ which is a dummy variable for whether there was dissent for tighter at quarter t, and finally $DE_t > 0$ which is a dummy variable for whether there was dissent for easier at quarter t.

The model main specification includes includes year fixed effects (T_t) to control for lower frequency shocks and because Committee members change at the beginning of every calendar year (due to rotation between Federal Reserve bank presidents). We also include Chair fixed effects (F_t) to control for differences in the Chair's ability to generate consensus in meetings (for evidence, see Belden, 1989, and Blinder, 2007).[12]

The "fundamental" predictors of dissent we propose are the variability of inflation attributed to the supply, demand and monetary shocks ($|\pi_t^{\text{sup}}|$, $\left|\pi_t^{\text{dem}}\right|$ and $|\pi_t^{\text{mon}}|$), and in addition we control for the level of inflation (π_t) and the unemployment rate (u_t), as there may be a relationship between the volatility of inflation and unemployment and its levels (Ball et al., 1990). We opted to use unemployment instead of the output gap to facilitate comparison with previous empirical papers on FOMC dissent, such as Thornton and Wheelock (2014) and Havrilesky and Gildea (1991).[13]

We estimate (11) using ordinary least squares (OLS) from 1957:1 to 2018:1, and we report robust standard errors. The first set of results are shown in Table 4, where the dependent variable is DIS_t. In column (a) we estimate a specification of (11) that includes only the constant, π_t, u_t and Fed Chair fixed effects (F_t). The specification in column (b) is the same as that in (a) but we have also added year (T_t) fixed effects. The specification in column (c) is the same as that in (a) but we now include the absolute value of the contribution of supply, demand and monetary shocks to inflation (respectively, $|\pi_t^{\text{sup}}|$, $\left|\pi_t^{\text{dem}}\right|$ and $|\pi_t^{\text{mon}}|$). The specification in column (d) is the same as that in (c) but we have also added year (T_t) fixed effects. Finally, specification (e) is the same as (d) but considers demand and monetary

[12]Our findings about structural shocks as predictors of dissent apply at quarterly frequency. At lower frequencies, clearly there is clustering over time in the frequency of dissent (see Figure 4). Thus inclusion of year fixed effects captures both the medium frequency clustering (periodicity of one year or more) and lower frequency movements in dissent frequency. However, the findings about the predictors of dissent are obtained also when the time effects are omitted (column c. in Table 4). The inclusion of Chair fixed effects captures low frequency changes in the intensity of dissent that may be related to changes in meeting protocols under each Chair. For example, Table 2 shows that the frequency of meetings has changed over time.

[13]Ball et al. (2013) show the Okun's nexus between the output gap and unemployment is stable over time.

shocks jointly (that is, we impose the restriction that $\theta_4 = \theta_5$), since these two set of shocks have similar implications for the conditional responses of output and inflation (as shown in Figure 2).

In all five specifications, the level of inflation is found not to affect dissent. The coefficient on unemployment is positive and statistically significant at the 10% level, if year fixed effects are not included. Thus, when the economy is weak the FOMC's ability to form consensus is lower. The effect of business cycle conditions is absorbed by the inclusion of the year fixed effects (T_t) and thus unemployment is no longer relevant in column (b). The finding that the statistical significance of unemployment is not robust is consistent with the results of Thornton and Wheelock (2014) who showed that after excluding outliers unemployment is not correlated with FOMC dissent. The inclusion of the year fixed effects is found to substantially increases the regression's R^2, confirming the importance of clustering and lower frequency changes in FOMC voting.

The structural shocks are found to be important in predicting dissent in the FOMC. In particular, in all specifications the frequency of dissent is increased when the contribution of supply shocks to inflation volatility ($|\pi_t^{\text{sup}}|$) is high. This effect is precisely estimated, both in the model that omits year fixed effects, in column (c), and in the model including year fixed effects, in columns (d) and (e).

On the other hand, the variables $\left|\pi_t^{\text{dem}}\right|$ and $|\pi_t^{\text{mon}}|$, measuring the contribution of demand and monetary shocks to inflation volatility, are found to lower the frequency of dissent. Without year fixed effects, see column (c), the coefficient on $\left|\pi_t^{\text{dem}}\right|$ is not statistically significant whereas the coefficient on $|\pi_t^{\text{mon}}|$ is statistically significant at the 5% level. With year fixed effects, see column (d), the effect of $\left|\pi_t^{\text{dem}}\right|$ is large and highly statistically significant, however $|\pi_t^{\text{mon}}|$ is not statistically significant.

As in column (b), the inclusion of the year fixed effects significantly improves the fit to the data. Therefore, we maintain year fixed effects throughout the remainder of this Section. In column (e), the monetary and demand shocks are aggregated together as a non-supply shock, $\left|\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\right|$. Joining the two shocks is justified because a monetary shock is also a “demand” shock, since conditional on such shocks inflation and output move in the same direction. This alternative specification fits the data better, as it yields a higher R^2 with fewer explanatory variables. Supply shocks are still found to raise dissent, and non-supply shocks lead to lower dissent. Both predictors are statistically significant at the 1% level.

Previous studies find a change in the character of FOMC deliberations following the 1993 decision to release full transcripts, with members more reluctant to offer dissenting opinions following the increase in transparency (see Meade and Stasavage, 2008; Hansen et al., 2017). For this reason, it is perhaps better to model the frequency of dissent as a discrete dummy variable rather than as the fraction of votes. Therefore, in Table 5 we look at an alternative set of specifications where the dependent variable is a binary variable indicating if there has been at least one dissent vote for the current quarter. Three different specifications of the dependent variable are considered: $DIS_t > 0$, $DT_t > 0$ and $DE_t > 0$.

Despite having dependent variables which are discrete, the regressions are estimated using a linear model. We do this because estimating a limited dependent variable model would preclude the inclusion of year fixed effects, which have been shown to improve substantially the model's fit. In particular, given the clustering of dissent described earlier, on occasions the year fixed effect predicts dissent perfectly and those observations need to be dropped unless we estimate a linear model. Finally, given the previous results we consider only the contribution of the supply and non-supply shocks to inflation volatility ($|\pi_t^{\text{sup}}|$ and $\left|\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\right|$).

The results for $DIS_t > 0$ as the dependent variable are shown in the first column of Table 5. Inflation volatility attributed to supply shocks is again found to raise the frequency of dissent, while inflation volatility attributed to non-supply shocks lowers dissent (the coefficients are statistically significant at the 5% and 1% level respectively). Despite the inclusion of year fixed effects, unemployment is still found to affect FOMC dissent. Curiously the coefficient of unemployment is now negative and precisely estimated, indicating FOMC members are more united when the economy is weaker. This is the opposite of what we obtained in column (a) of Table 5 and to what Thornton and Wheelock (2014) obtained when using the fraction of votes for dissent (DIS_t) as the dependent variable. Thus, conclusions about how unemployment affects FOMC deliberation ad the occurrence of dissent appears to be very much sensitive to how dissent is measured.

To better understand the relationship between the structural shocks and the frequency of dissent, we distinguish between dissents for tighter (second column of Table 5) and dissents for easier (third columnn of Table 5). We find that non-supply shocks (which combines demand and monetary shocks) lower the frequency of dissent for both tighter and easier, while supply shocks matter mostly by raising the frequency of dissent for easier.

Finally, we consider the role of individual members' disagreement about macroeconomic conditions, as a possible channel to explain our findings. This is important, since recent studies have found that committee members' different assessments of the economy affect votes after controlling for individual policy preferences.[14] Therefore, we explore if our structural shocks can explain FOMC dissent beyond differences in members expectations for inflation and unemployment. We do this by using the information in the Monetary Policy Reports (MPRs) submitted to Congress by the Federal Reserve Board since 1979. The MPRs are submitted semi-annually in June and in December. The MPRs include the range of FOMC member forecasts for nominal GDP, real GDP, Consumer Price Index (CPI) and unemployment.

We use the MPRs to construct measures of disagreement in expectations of inflation (π_t^D) and disagreement in expectations of unemployment (u_t^D) of FOMC members by subtracting the lowest projection from the highest projection. From the range of FOMC member forecasts of the June MPRs we calculate π_t^D and u_t^D for the second and third quarters. From the range of FOMC member forecasts of the December MPRs we calculate π_t^D and u_t^D for the fourth quarter and the first quarter of the subsequent year. We then introduce π_t^D and u_t^D in our time series OLS regressions of the fraction of votes for dissent, as follows

$$DIS_t = \theta_0 + \theta_1 \pi_t + \theta_2 u_t + \theta_3 \pi_t^D + \theta_4 u_t^D + \theta_5 \left|\pi_t^{\text{sup}}\right| + \theta_6 \left|\pi_t^{\text{dem}}\right| + \theta_7 \left|\pi_t^{\text{mon}}\right| + F_t + T_t + \varepsilon_t. \quad (12)$$

[14]See Hansen et al. (2014) who analyse voting records from the Bank of England's Monetary Policy Committee and find that private assessments are an important driver of individual votes. Also, Eichler and Lähner (2014) using data on FOMC members own forecasts, find that higher individual inflation and real GDP growth forecasts relative to the Committee's median raise the probability of dissent in favor of tighter monetary policy, while higher individual unemployment rate forecasts significantly lowers it.

The estimates are reported in Table 6. For the regression without the structural shock variables, see column (a), none of the variables are statistically significant. When controlling for disagreement among FOMC members about future macroeconomic conditions, we find that inflation volatility attributed to supply shocks still raises dissent. This is statistically significant at the 1% level, see columns (b) and (c). We also confirm the previous findings that inflation volatility attributed to demand shocks lowers dissent (an effect statistically significant at the 5% level) and the same occurs for non-supply shocks (an effect statistically significant at the 1% level) see respectively columns (b) and (c).

In summary, the time series regressions support the theory exposed in Section 3.1. We find that inflation volatility attributed to supply shocks raises dissent in FOMC deliberations, while that attributed to demand and monetary shocks lowers dissent.

4.3 Panel data regressions

We now study the determinants of dissent using individual members' data, at the meeting level. We consider again several different measures of dissent as the dependent variable ($V_{i,t}$) in our panel data regressions. Specifically, $DIS_{i,t}$ which is the number of votes for dissent of member i at quarter t, $DIS_{i,t} > 0$ which is a dummy variable for whether member i voted dissent at quarter t, $DT_{i,t} > 0$ which is a dummy variable for whether member i voted dissent for tighter at quarter t, and $DE_{i,t} > 0$ which is a dummy variable for whether member i voted dissent for easier at quarter t. The regression equation we estimate is the following

$$\begin{aligned} V_{i,t} = \theta_0 + \theta_1 \pi_t + \theta_2 u_t + \theta_3 \left|\pi_t^{\text{sup}}\right| + \theta_4 \left|\pi_t^{\text{dem}}\right| + \theta_5 \left|\pi_t^{\text{mon}}\right| \\ + \theta_6 D_{i,t} + \theta_7 N_{i,t} + \theta_8 N_t^C + M_i + F_t + T_t + \varepsilon_{i,t}, \end{aligned} \tag{13}$$

where $D_{i,t}$ is a dummy variable that takes a value of 1 if the dissenting member is a governor and 0 if the dissenting member is a bank president, $N_{i,t}$ is the number of previous meetings attended by FOMC member i at time t, N_t^C is the number of previous meetings attended by the Chair at time t and M_i are individual FOMC member fixed effects.

The other control variables are defined as above. We estimate the model in (13) by OLS, with observations on each FOMC member voting record over the period 1957-2018. All the regressions have fixed effects for individual FOMC members and for the Chair in charge of each meeting.[15]

Table 7 shows the results of OLS estimates of (13) with member fixed effects, when the dependent variable is $DIS_{i,t}$. In column (a) we estimate a specification of (13) without the structural shocks. The specification in column (b) includes our main set of explanatory variables: the absolute value of the contribution of supply, demand and monetary shocks to inflation (respectively, $|\pi_t^{\text{sup}}|$, $\left|\pi_t^{\text{dem}}\right|$ and $|\pi_t^{\text{mon}}|$). Finally, specification (c) considers demand and monetary shocks jointly (that is, we impose the restriction that $\theta_4 = \theta_5$).

In the regression without the structural shocks, see column (a), we find that only the coefficient for N_t^C is statistically significant. The coefficient is positive which indicates that dissent increases with the number of previous meetings attended by the Chair (N_t^C). We find a similar effect in the regressions with structural shocks, see columns (b) and (c). This suggests that members who disagree from the adopted policy by the FOMC are less likely to dissent in the earlier stages of the Chair's term (maybe because at that stage they hope to persuade the Chair of their views). As with the time series regressions, we find that the contribution to inflation variability of supply shocks ($|\pi_t^{\text{sup}}|$) increases dissent, while the inflation volatility attributed to demand shocks ($\left|\pi_t^{\text{dem}}\right|$) and non-supply shocks ($\left|\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\right|$) decreases dissent. These results are reported in columns (b) and (c).

The results shown in Table 8, correspond to the regressions specified with the dissent dummies as the dependent variable. This time, we consider demand and monetary shocks jointly (the specification in Table 7 with the highest R^2). Once again, we find that the contribution to inflation volatility of supply shocks raises the frequency of dissent, while

[15]The OLS model (which can be applied to binary or categorical variables) is special among models with fixed effects, because it is robust to the incidental parameters problem and, thus, yields consistent estimates of θ even if the estimated coefficients associated with the vector of fixed effects are inconsistent in finite samples. See Wooldridge (2001) for a discussion of the incidental parameter problem. This problem occurs in non-linear models, when one wants to estimate a vector of coefficients Θ (the coefficients of the variables of interest) but needs to add other controls including fixed effects.

the inflation volatility attributed to non-supply shocks lowers dissent. We also find that non-supply shocks lower dissent for tighter and dissent for easier. Supply shocks increase dissent for easier but the coefficient is only statistically significant at the 10% level.

In summary, the panel data regressions using individual voting records confirm our main hypothesis that inflation volatility originating from supply shocks increases the frequency of dissent, while volatility attributed to demand and monetary shocks lowers dissent. As explained in Section 3 this is consistent with a model in which members of the FOMC have heterogeneous preferences across the dual mandate of inflation and output stabilization, and the FOMC faces a trade-off between the two objectives conditional on supply shocks.

5 Additional empirical results

In this Section, we consider additional empirical exercises. First, we consider a different method (a structural VAR model) to identify the structural shocks and their contribution to inflation variability. Second, we examine the relationship between the shocks' contribution to inflation variability and private sector forecast uncertainty. Finally, we discuss other robustness exercises relegated to the Online Appendix.

5.1 Structural shocks based on a proxy SVAR

We have so far worked with structural shocks obtained from the Smets and Wouters (2007) medium-scale DSGE model, widely used by central banks. But, another popular approach to identify macroeconomic shocks and their propagation relies on the use of structural VAR models (Ramey, 2016). In this Section we consider a structural VAR to obtain an alternative historical decomposition of inflation volatility. To identify the supply, demand and monetary shocks we use the proxy variable method, in which narrative-based proxy variables are used as instruments to identify how the structural shocks propagate across the economy.[16]

[16]Pioneering applications of the proxy VAR method are found in Stock et al. (2012) and Mertens and Ravn (2013). We explain briefly the method in the Appendix A.

Using the VAR model we obtain historical decompositions of the inflation volatility attributed to the supply shocks ($|\pi_t^{\text{sup}}|$) and the volatility attributed to the demand and monetary shocks ($\left|\pi_t^{\text{dem}}\right|$ and $|\pi_t^{\text{mon}}|$) analogous to the the measures constructed for the DSGE model in the previous Section. The proxy variables used to obtain the structural historical decompositions are based on narrative evidence obtained from various sources. In particular, the supply shock is identified using the Ramey and Vine (2011) shortage adjusted index for the real price of gasoline as external instrument, the demand shock is identified using the Ramey (2011) narrative measure of defense expenditure and the Aaa/Baa corporate bond yield spread, and the monetary shock is identified using the Romer and Romer (2004) narrative measure of monetary policy shocks (updated until 2012 by Breitenlechner, 2018).

Using the proxy VAR based historical decompositions, we estimate the baseline regression model in (11), where the dependent variable is the fraction of dissent votes, DIS_t. The sample period, from 1970:1 to 2011:4, is determined by the availability of the external instruments. The results are shown in Table 9, and are entirely consistent with our findings in Section 4 based on the DSGE model. In particular, inflation volatility attributed to supply shocks is again found to increase the frequency of dissent in the FOMC, and this effect is precisely estimated. Since the supply shock is identified using a proxy variable for the cost of automobile fuel, disagreement is directly attributable to volatility from oil shocks. In turn, inflation volatility caused by demand and monetary shocks is found to lower disagreement. Although the effect of demand shock is not found to be statistically significant, that of the monetary policy shock is. Moreover, the inflation volatility attributed to the combined demand and monetary shock is again found to lower dissent.

We conclude that our baseline results for the structural determinants of monetary policy committee disagreement are robust in relation to the shock identification methodology. In particular, when we use narrative-based measures of macroeconomic shocks to construct historical decompositions of inflation based on a structural VAR model, we still find that the volatility attributed to supply shocks raises dissent, while the volatility attributed to demand and monetary shocks lowers it.

5.2 Dispersion in expectations of monetary policy

In Section 4 we provide compelling evidence that dissent at the FOMC meetings is associated with inflation volatility attributed to supply shocks. We have also shown that this result is not explained away after controlling for dispersion in FOMC members' beliefs about the future path of inflation and unemployment. Next, we investigate if the inflation volatility attributed to different structural shocks drives higher private sector uncertainty regarding the direction of monetary policy.

This hypothesis is important given the finding by Baker et al. (2016) that economic policy uncertainty is detrimental to business investment. The recent result by Madeira and Madeira (2019) that FOMC dissent negatively affects stock market prices may be explained in part by the association between FOMC disagreement and inflation volatility associated with supply shocks. Moreover, if Committee dissent raises uncertainty (as recently explored by Husted et al., 2017) it undermines the ability by the central bank to control private sector expectations which could be detrimental for stabilization.[17]

We measure private sector uncertainty using survey expectations data on future interest rate obtained from the Survey of Professional Forecasters (SPF) by the Federal Reserve Bank of Philadelphia. The expectations dispersion measure for interest rates we use from the SPF data, $s_t(r_{t+k})$, is the surveys' interquartile range (IQR) for the k quarter horizon forecast of the 3 month Treasury bill. The SPF provides data for $k = \{0, 1, 2, 3, 4\}$. The sample period for the SPF data is 1981:3 – 2018:1.

The regression equation we estimate is the following

$$s_t(r_{t+k}) = \theta_0 + \theta_1 \pi_t + \theta_2 u_t + \theta_3 \left|\pi_t^{\text{sup}}\right| + \theta_4 \left|\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\right|. \quad (14)$$

The results are shown in Table 10. We find that both higher inflation and higher unemployment lead to increased dispersion in expectations of interest rates by professional forecasters at all horizons (although for the current quarter horizon the coefficient for unemployment is

[17]Coibion et al. (2018) study how central bank communication strategies should be designed to achieve better control over private sector expectations.

only statistically significant at the 10% level). We also find that supply shocks increase the dispersion of expectations of interest rates by professional forecasters at all horizons. Non-supply shocks reduce dispersion of expectations of interest rates at all horizons (but the coefficient is not statistically significant with $k = 3$ and with $k = 4$).

Moreover, we find that including the absolute value of the contribution of supply and non-supply shocks to inflation increases substantially the fit to the data at all forecast horizons. In the regressions without the shock variables the R^2 varies between 40.9% (with $k = 0$) to 49.8% (with $k = 2$). In the regressions with the shock variables the R^2 varies between 53.6% (with $k = 0$) to 65.7% (with $k = 2$).

These results suggest that the ocurrence of supply shocks makes it harder for agents to predict how Commitee members will choose to respond to economic developments, which results in increased uncertainty in interest rate expectations. This echoes well with the finding by Belden (1989) that periods of greater uncertainty about the impact of policy actions are associated with heightened dissent.

5.3 Other robustness exercises

In the Online Appendix we show that our main results (shown in Table 4 and Table 5) are robust to using other variables instead of the unemployment rate (u_t) to control for economic conditions, such as a model based measure of the output gap (obtained from the estimated DSGE model), a data based measure of the output gap (the Hodrick-Prescott, hence HP, filtered output), and an alternative unemployment gap measure (the HP filtered civilian unemployment rate). We also show that the results in Table 6 are robust to constructing in a different way the measures of FOMC members disagreement in expectations of inflation and unemployment.[18] In relation to the panel data results, we estimate the same model without

[18]The MPRs also include the range for the central tendency (which excludes the three highest and three lowest projections for each variable). We use the MPRs to construct measures of disagreement in expectations of inflation (π_t^{DCT}) and disagreement in expectations of unemployment (u_t^{DCT}) of FOMC members by subtracting the lowest projection for the central tendency from the highest projection for the central tendency. In the Online Appendix we re-estimate (12) but using π_t^{DCT} and u_t^{DCT} instead of π_t^D and u_t^D. Note that only the median, lowest projections, highest projections, lowest projections for the central tendency and highest projections for the central tendency are included. Therefore, it is not possible to consider say the

the individual fixed effects but using random-effects, and found the results to be very similar regarding all the macroeconomic variables.[19]

6 Conclusion

This paper has shown that the source of inflation volatility is an important and robust predictor of disagreement in the FOMC deliberations. In particular, making use of an estimated medium-scale DSGE model to identify structural shocks and their contribution to inflation volatility, we have found that inflation volatility attributed to supply shocks raises the frequency of dissent and, instead, inflation volatility attributed to demand shocks lowers dissent. This result is obtained both in the aggregate time-series on FOMC voting records, and with longitudinal data based on individual member's voting records.

Through the lenses of the three equations NK model, we show that our empirical finding for the structural predictors of FOMC dissent can be explained if individual Committee members have heterogeneous preferences over inflation and output stabilization and, thus, assign different weights to the two different objectives in their individual policy rules. Since supply shocks yield a trade-off between inflation and output stabilization, volatility emerging from these shocks uncovers preference disagreement across FOMC members and, thus, predicts dissent votes in the FOMC.

The ability of supply and demand shocks to predict dissent is shown not to be affected by whether or not one controls for the FOMC members' dispersion in beliefs about the future path for inflation and unemployment. Our results are not an artifact of the DSGE identification

standard deviation of FOMC members forecasts as a measure of disagreement in expectations.

[19]When comparing the model with member fixed effects to the models without member fixed effects, the interpretation of some individual coefficients may change. For example, in the OLS regression without fixed effects, the coefficient for the governor dummy ($D_{i,t}$) gives the average voting difference between governors and regional bank presidents. However, this interpretation changes once one includes fixed effects for FOMC members, since in this case the coefficient is given not by the difference between the two groups of members (because most governors and regional bank presidents do not switch positions) and therefore the coefficient must be interpreted as the difference in voting behavior when members switch from bank president to governor (of course only a handful of members experience such transitions–for example, Janet Yellen) or from governor to Chair (such as Janet Yellen and Ben Bernanke) over the course of their career.

of the structural shocks. In particular, we obtain similar results if narrative-based shocks and a structural VAR model are used to construct historical shock decompositions of inflation.

Finally, we show that inflation volatility due to supply shocks raises private sector uncertainty over the future path of interest rates (and inflation), using a measure of uncertainty based on the survey of professional forecasters.

Appendix

A Proxy VAR model

The structural VAR model in Section 5 is identified using external instruments, following the methodology by Stock et al. (2012) and Mertens and Ravn (2013). In what follows we explain carefully how this method is implemented, following the approach in Lunsford (2015).

The VAR specification includes six macroeconomic time-series: the GDP deflator, real GDP, real consumption, real investment, real wage, hours worked, and the federal funds rate. The vector of macroeconomic time-series is assumed to follow a reduced-form VAR model with $p = 4$ lags of the form

$$x_t = \sum_{i=1}^{p} \mathbf{A}_i x_{t-i} + \eta_t, \tag{A.1}$$

where η_t denotes the reduced form errors. The corresponding structural shocks are given by e_t such that $\eta_t = \mathbf{B}e_t$, with $\mathbf{B}$ an $n \times n$ square matrix, $E\left(e_t e_t'\right) = \mathbf{I}_n$ the n-dimensional identity matrix and, thus, $E\left(\eta_t \eta_t'\right) = \mathbf{B}\mathbf{B}'$, the covariance matrix of the reduced form errors.

Suppose we have an instrument z_t for the structural shock $e_{1,t}$ that satisfies the two conditions:

1. $E\left(e_{1,t} z_t\right) = \psi \neq 0$;

2. $E\left(e_{s,t} z_t\right) = 0, \ \forall \ s \neq 1$.

Let $\mathbf{B}^{\bullet}$ denote the first column of $\mathbf{B}$, so that $\mathbf{B} = [\mathbf{B}^{\bullet}, \mathbf{B}^{\bullet\bullet}]$. Then, from the two conditions above, we have that $E\left(\eta_t z_t\right) = \mathbf{B}^{\bullet}\psi$. We further assume that $\mathbf{B}$ is invertible, with the upshot that $\mathbf{B}^{-1}\mathbf{B}^{\bullet} = [1, 0 \ldots 0]' \equiv \mathbf{i}$. Making use of these conditions we obtain identification of ψ

up to a sign (which we assume is known), as follows

$$\begin{aligned} (\mathbf{B}\mathbf{B}')^{-1} &= [E(\eta_t\eta_t')]^{-1}, \\ \psi\mathbf{B}^{\bullet\prime}(\mathbf{B}\mathbf{B}')^{-1}\mathbf{B}^{\bullet}\psi &= E(z_t\eta_t')[E(\eta_t\eta_t')]^{-1}E(\eta_t z_t), \\ \psi\mathbf{i}'\mathbf{i}\psi &= E(z_t\eta_t')[E(\eta_t\eta_t')]^{-1}E(\eta_t z_t), \\ \psi &= \text{sign}(\psi)\sqrt{E(z_t\eta_t')[E(\eta_t\eta_t')]^{-1}E(\eta_t z_t)}. \end{aligned} \tag{A.2}$$

This in turn yields identification of the vector $\mathbf{B}^{\bullet}$, as follows

$$\mathbf{B}^{\bullet} = \text{sign}(\psi)\,E(\eta_t z_t)\left\{\sqrt{E(z_t\eta_t')[E(\eta_t\eta_t')]^{-1}E(\eta_t z_t)}\right\}^{-1}. \tag{A.3}$$

Moreover, projecting the reduced form residuals η_t onto the instrumental variable z_t allows the construction of the historical decompositions used to obtain $|\pi_t^{\text{sup}}|$, $\left|\pi_t^{\text{dem}}\right|$, and $|\pi_t^{\text{mon}}|$.

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Tables

Table 1: Dissent vote in the FOMC

Chair	Sample period	Votes of dissent (%)				Quarters with dissent (%)			
		DIS_t	DT_t	DE_t	DO_t	$DIS_t > 0$	$DT_t > 0$	$DE_t > 0$	$DO_t > 0$
Martin	1957:1 – 1970:1	5.6	2.5	2.6	0.6	64.2	41.5	45.3	7.5
Burns	1970:2 – 1978:1	5.0	2.6	2.0	0.4	71.9	50.0	37.5	9.4
Miller	1978:2 – 1979:3	17.6	13.5	4.1	0.0	100.0	100.0	66.7	0.0
Volcker	1979:4 – 1987:3	10.2	5.2	4.8	0.2	84.4	62.5	53.1	6.3
Greenspan	1987:4 – 2006:1	4.7	2.5	1.4	0.7	51.4	33.8	23.0	10.8
Bernanke	2006:2 – 2014:1	7.1	5.1	0.8	1.2	68.8	56.3	12.5	18.8
Yellen	2014:2 – 2018:1	6.7	3.1	2.0	1.6	68.8	37.5	25.0	12.5
Overall	1957:1 – 2018:1	6.4	3.5	2.2	0.7	65.7	46.1	33.5	10.2

The first panel (votes of dissent, %) reports the the frequency of each dissent category across sub-samples. The categories considered are DIS, denoting overall votes of dissent, DT denoting dissent for tighter, DE denoting dissent for easier, DO denoting other forms of dissent. The second panel (quarters with dissent, %) reports the percentage of quarters in which dissent occurs, across categories and for each sub-sample. Each sub-sample corresponds to a different Chair tenure. The overall sample period runs from 1957:1 to 2018:1.

Table 2: Number of FOMC members who dissented

Chair	# Meetings per quarter	# DIS	# DT	# DE	# DO
Martin	4.2	22	15	13	8
Burns	3.2	15	10	11	2
Miller	3.2	4	3	1	1
Volcker	2.3	13	7	9	5
Greenspan	2.1	17	12	9	3
Bernanke	2.1	5	4	2	3
Yellen	2.0	5	3	3	1
Overall	2.7	81	54	48	23

The table reports the average number of meetings per quarter and the total number of dissents of each type, split across each Chair tenure. DIS is dissent, DT is dissent for tighter, DE is dissent for easier, DO is dissent for other.The overall sample period runs from 1957:1 to 2018:1.

Table 3: Probability of dissent vote (percentiles of FOMC members who dissented)

	Percentile 25				Percentile 50				Percentile 75			
Chair	DIS	DT	DE	DO	DIS	DT	DE	DO	DIS	DT	DE	DO
Martin	2.6	1.7	1.4	1.2	4.9	3.6	2.4	1.6	7.9	7.0	5.1	3.0
Burns	4.8	3.0	1.6	1.2	7.3	4.9	3.7	1.5	11.1	8.8	7.1	3.0
Miller	5.6	4.0	1.9	0.8	8.3	7.6	4.3	2.3	17.6	16.2	5.6	3.7
Volcker	4.8	4.3	1.9	1.8	8.7	7.6	3.3	3.6	17.6	14.3	6.2	4.5
Greenspan	4.5	4.5	1.5	3.6	11.3	12.9	2.8	9.4	20.0	18.8	4.3	12.9
Bernanke	5.7	8.1	4.2	8.0	15.2	12.5	6.8	12.7	30.1	20.0	6.9	15.8
Yellen	10.3	12.0	6.8	8.0	28.5	13.3	6.9	12.7	37.5	31.3	12.5	15.8
Overall	4.5	3.7	1.7	1.5	8.1	7.6	3.3	3.6	17.6	14.3	6.9	9.4

The table reports the 25^{th}, 50^{th} and 75^{th} percentiles of the distribution of the frequency of dissent across members of the FOMC, conditioning on the member dissenting at least once. The dissent types considered are: overall dissent (DIS); dissent for tighter (DT); dissent for easier (DE); other types of dissent (DO). Each sub-sample corresponds to a different Chair tenure. The overall sample is from 1957:1 to 2018:1.

Table 4: FOMC dissent (fraction of dissent votes)

	(a)	(b)	(c)	(d)	(e)
π_t	0.013	−0.008	0.017	−0.012	−0.010
	(0.010)	(0.019)	(0.011)	(0.019)	(0.018)
u_t	0.007*	0.002	0.012**	−0.004	−0.008
	(0.004)	(0.016)	(0.005)	(0.015)	(0.014)
$\lvert\pi_t^{\text{sup}}\rvert$			0.040***	0.065***	0.060***
			(0.015)	(0.023)	(0.023)
$\lvert\pi_t^{\text{dem}}\rvert$			−0.051	−0.189***	
			(0.034)	(0.062)	
$\lvert\pi_t^{\text{mon}}\rvert$			−0.078**	−0.067	
			(0.036)	(0.085)	
$\lvert\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\rvert$					−0.234***
					(0.074)
R^2	15.3%	42.3%	19.7%	46.5%	47.3%
Observations	245	245	245	245	245

The dependent variable is the fraction of dissent votes, DIS_t. Constant included but not reported. All specifications include Chair fixed effects. The regressions in columns (b), (d) and (e) also have year fixed effects. Robust standard errors are shown in parenthesis. * , ** and *** denote respectively 10%, 5% and 1% significance. The data sample is from 1957:1 to 2018:1.

Table 5: FOMC dissent (discrete dependent variable)

	$DIS_t > 0$	$DT_t > 0$	$DE_t > 0$
π_t	-0.103	0.120	-0.176
	(0.131)	(0.143)	(0.128)
u_t	-0.222^{***}	-0.014	0.166^{*}
	(0.073)	(0.086)	(0.095)
$\lvert\pi_t^{\text{sup}}\rvert$	0.318^{**}	0.226	0.403^{**}
	(0.152)	(0.171)	(0.162)
$\left\lvert\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\right\rvert$	-1.947^{***}	-1.316^{**}	-0.954^{*}
	(0.482)	(0.528)	(0.552)
R^2	51.3%	54.7%	48.3%
Observations	245	245	245

Constant included but not reported. $DIS_t > 0$ if there has been dissent; $DT_t > 0$ if there has been dissent for tighter; $DE_t > 0$ if there has been dissent for easier. All specifications include Chair fixed effects and year fixed effects. Robust standard errors are shown in parenthesis. * , ** and *** denote respectively 10%, 5% and 1% significance. The data sample is from 1957:1 to 2018:1.

Table 6: FOMC dissent and expectations disagreement

	(a)	(b)	(c)
π_t	-0.024	0.004	0.018
	(0.035)	(0.033)	(0.032)
u_t	0.005	0.001	-0.002
	(0.023)	(0.021)	(0.020)
$\lvert\pi_t^{\text{sup}}\rvert$		0.093^{***}	0.105^{***}
		(0.034)	(0.033)
$\lvert\pi_t^{\text{dem}}\rvert$		-0.195^{**}	
		(0.079)	
$\lvert\pi_t^{\text{mon}}\rvert$		-0.024	
		(0.123)	
$\lvert\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\rvert$			-0.233^{**}
			(0.093)
π_t^D	-0.025	-0.020	-0.014
	(0.025)	(0.025)	(0.024)
u_t^D	-0.017	0.002	0.001
	(0.038)	(0.040)	(0.040)
R^2	42.4%	46.9%	47.5%
Observations	155	155	155

The dependent variable is the fraction of dissent votes, DIS_t. Constant included but not reported. All specifications include Chair fixed effects and year fixed effects. Robust standard errors are shown in parenthesis. * , ** and *** denote respectively 10%, 5% and 1% significance. The data sample is from 1979:2 to 2018:1.

Table 7: Panel regressions ($DIS_{i,t}$ as dependent variable)

	(a)	(b)	(c)
π_t	-0.006	-0.016	-0.013
	(0.019)	(0.019)	(0.019)
u_t	-0.008	-0.014	-0.019^{*}
	(0.010)	(0.010)	(0.011)
$\lvert\pi_t^{\text{sup}}\rvert$		0.068^{***}	0.057^{***}
		(0.021)	(0.021)
$\lvert\pi_t^{\text{dem}}\rvert$		-0.161^{**}	
		(0.073)	
$\lvert\pi_t^{\text{mon}}\rvert$		0.032	
		(0.083)	
$\lvert\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\rvert$			-0.205^{***}
			(0.063)
$D_{i,t}$	0.063	0.063	0.063
	(0.055)	(0.056)	(0.056)
$N_{i,t}$	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
N_t^C	0.003^{***}	0.002^{**}	0.002^{**}
	(0.001)	(0.001)	(0.001)
R^2	15.5%	15.8%	15.9%
Observations	7,236	7,236	7,236

Constant included but not reported. The variable $D_{i,t}$ is a dummy variable for whether the member is a governor; $N_{i,t}$ is the number of previous meetings attended by member i at time t; N_t^C is the number of previous meetings attended by the Chair at time t. All specifications include Chair fixed effects, member fixed effects and year fixed effects. Robust standard errors are shown in parenthesis. * , ** and *** denote respectively 10%, 5% and 1% significance. The data sample includes all the FOMC meetings from 1957:1 to 2018:1.

Table 8: Panel regressions (discrete dependent variable)

	$DIS_{i,t} > 0$	$DT_{i,t} > 0$	$DE_{i,t} > 0$
π_t	-0.013	0.0028	-0.005
	(0.019)	(0.011)	(0.012)
u_t	-0.019^{*}	-0.009	-0.008
	(0.011)	(0.009)	(0.006)
$\lvert\pi_t^{\text{sup}}\rvert$	0.057^{***}	0.018	0.028^{*}
	(0.021)	(0.012)	(0.016)
$\left\lvert\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\right\rvert$	-0.205^{***}	-0.092^{**}	-0.091^{**}
	(0.0627)	(0.044)	(0.038)
$D_{i,t}$	0.063	0.010	0.032^{*}
	(0.056)	(0.059)	(0.017)
$N_{i,t}$	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
N_t^C	0.002^{**}	0.000	0.001^{***}
	(0.000)	(0.000)	(0.000)
R^2	15.9%	18.7%	10.6%
Observations	7,236	7,236	7,236

Constant included but not reported. $DIS_t > 0$ if there has been dissent; $DT_t > 0$ if there has been dissent for tighter; $DE_t > 0$ if there has been dissent for easier. All specifications include Chair fixed effects, member fixed effects and year fixed effects. Robust standard errors are shown in parenthesis. * , ** and *** denote respectively 10%, 5% and 1% significance. The data sample includes all the FOMC meetings from 1957:1 to 2018:1.

Table 9: Structural shocks from SVAR

	(a)	(b)
π_t	-0.005	-0.005
	(0.021)	(0.020)
u_t	0.002	0.006
	(0.021)	(0.021)
$\lvert\pi_t^{\text{sup}}\rvert$	0.023^{**}	0.028^{***}
	(0.010)	(0.011)
$\lvert\pi_t^{\text{dem}}\rvert$	-0.029	
	(0.021)	
$\lvert\pi_t^{\text{mon}}\rvert$	-0.107^{**}	
	(0.048)	
$\lvert\pi_t^{\text{dem}} + \pi_t^{\text{mon}}\rvert$		-0.039^{*}
		(0.022)
R^2	48.3%	47.0%
Observations	168	168

The dependent variable is the fraction of dissent votes, DIS_t. Constant included but not reported. All specifications include Chair fixed effects and year fixed effects. Robust standard errors are shown in parenthesis. * , ** and *** denote respectively 10%, 5% and 1% significance. The data sample is from 1970:1 to 2011:4.

Table 10: Disagreement in interest rate expectations

	$s_t(r_t)$		$s_t(r_{t+1})$		$s_t(r_{t+2})$		$s_t(r_{t+3})$		$s_t(r_{t+4})$	
π_t	0.408***	0.436***	0.769***	0.810***	0.846***	0.917***	0.950***	1.062***	1.045***	1.149***
	(0.104)	(0.010)	(0.155)	(0.141)	(0.150)	(0.130)	(0.183)	(0.159)	(0.209)	(0.191)
u_t	0.017*	0.032***	0.041***	0.070***	0.035**	0.064***	0.035**	0.057***	0.055***	0.081***
	(0.010)	(0.012)	(0.015)	(0.016)	(0.014)	(0.015)	(0.015)	(0.016)	(0.017)	(0.016)
$\lvert\pi_t^{\text{sup}}\rvert$		0.319***		0.564***		0.687***		0.794***		0.811***
		(0.077)		(0.114)		(0.114)		(0.132)		(0.158)
$\left\lvert\pi_t^{\text{dem}}+\pi_t^{\text{mon}}\right\rvert$		−0.156**		−0.324***		−0.244**		−0.057		−0.135
		(0.071)		(0.111)		(0.114)		(0.139)		(0.166)
R^2	40.9%	53.6%	49.4%	62.8%	49.8%	65.7%	46.2%	61.5%	46.1%	58.5%
Obs	147	147	147	147	147	147	147	147	147	147

Constant included but not reported. Robust standard errors are shown in parenthesis. * , ** and *** denote respectively 10%, 5% and 1% significance. The sample period is 1981:3 to 2018:1.

Figures

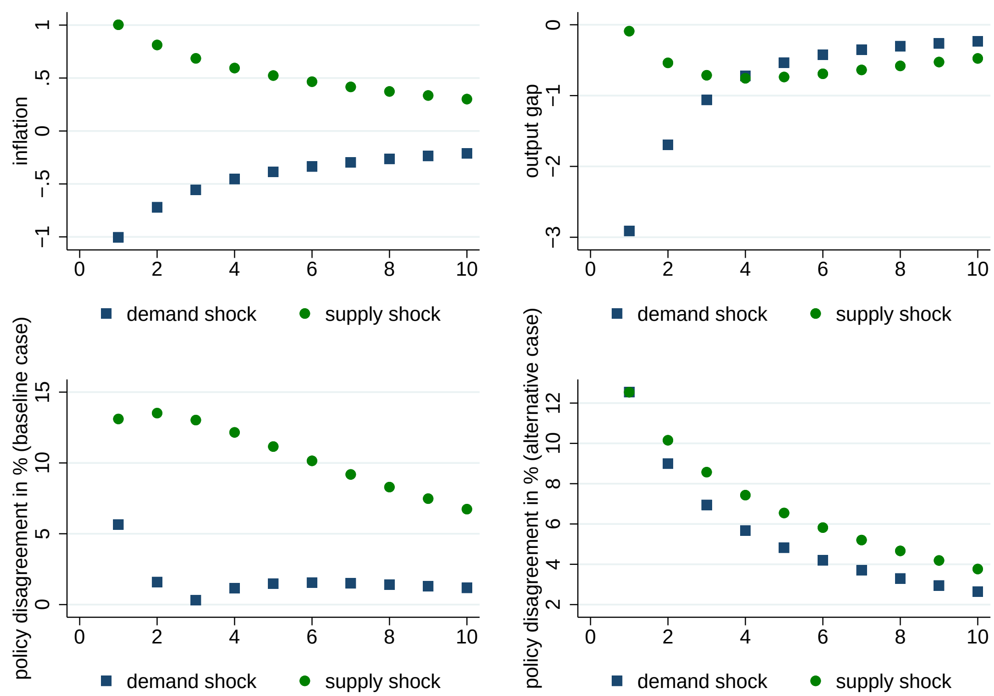

Figure 1: Dissent in the three equations NK model. Notes: the upper panels show IRFs for inflation and the output gap in response to demand and supply shocks that move inflation away from target by 1 percentage point. The lower panels show the implied absolute difference between the interest rate favored by hawk and dove committee members and that favored by the Chair in response to demand and supply shocks (policy disagreement). We consider the baseline case (lower-left panel), where committee members disagree over the response weights to inflation and the output gap, and an alternative case (lower-right panel), where committee members assign a different weight only to inflation. Each unit in the horizontal axis corresponds to one calendar quarter.

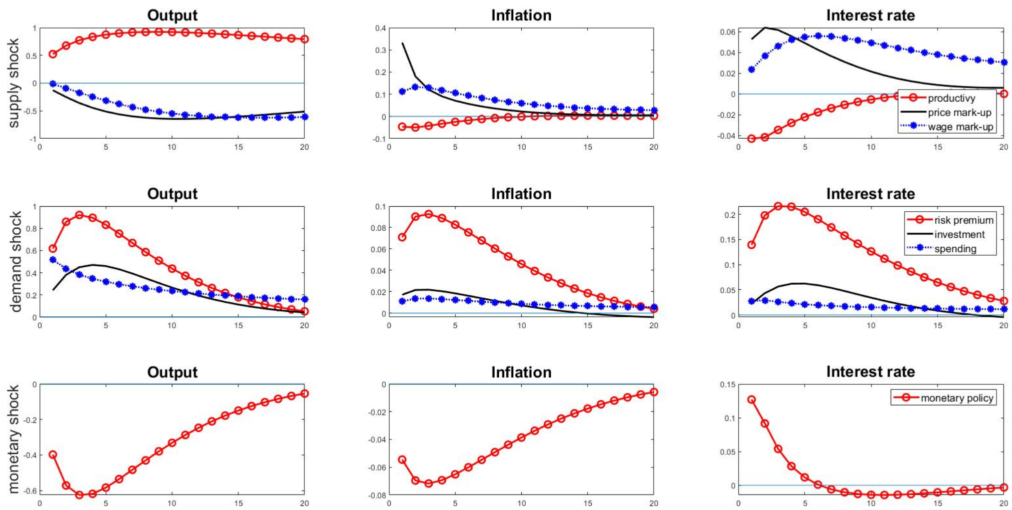

Figure 2: Estimated mean IRFs of the DSGE model. Notes: Each unit in the horizontal axis corresponds to one calendar quarter.

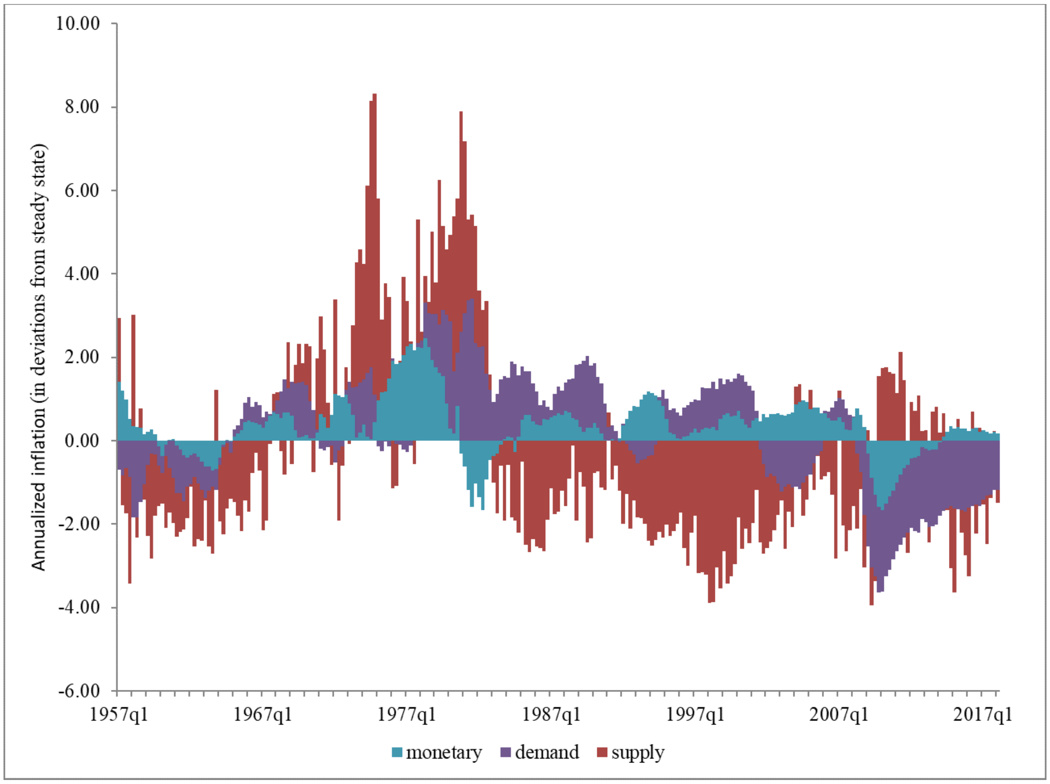

Figure 3: Historical shock decomposition of US inflation. Notes: Values were annualized by multiplying by 4. The data sample is from 1957:1 to 2018:1.

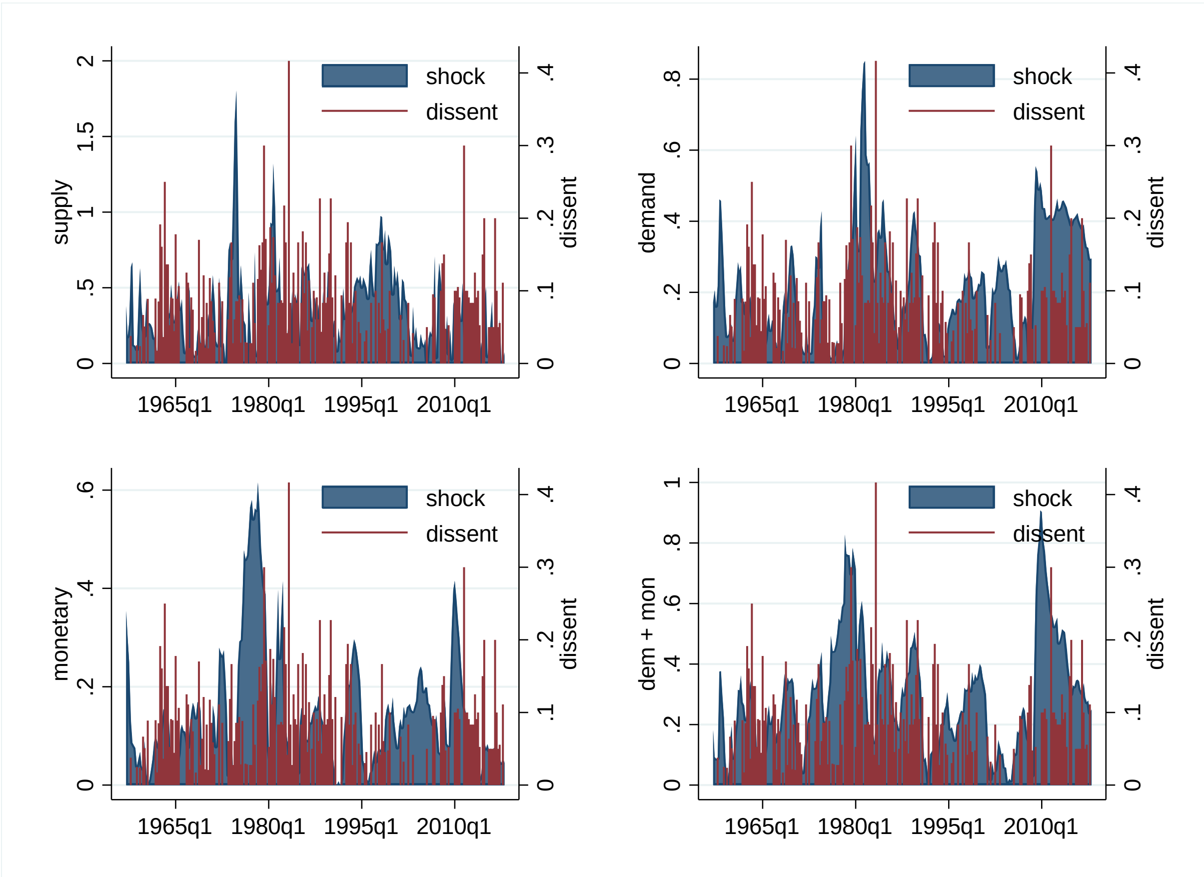

Figure 4: Sources of inflation volatility and FOMC dissent. Notes: The data sample is from 1957:1 to 2018:1.