A CLASSICAL VIEW OF THE BUSINESS CYCLE

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ABSTRACT

In the 1920s, Irving Fisher extended his previous work on the Quantity Theory to describe, through an early version of the Phillips Curve, how changes in the money stock could be associated with cyclical movements in output, employment, and inflation. At the same time, Holbrook Working designed a quantitative rule for achieving price stability through control of the money supply. This paper develops a structural vector autoregressive time series model that allows these "classical" channels of monetary transmission to operate alongside the now-more-familiar interest rate channel of the New Keynesian model. Even with Bayesian priors that intentionally favor the New Keynesian view, the United States data produce posterior distributions for the model's key parameters that are consistent with the ideas of Fisher and Working. Changes in real money balances enter importantly into the model's aggregate demand relationship, while growth in Divisia M2 appears in the estimated monetary policy rule. Contractionary monetary policy shocks reveal themselves through persistent declines in nominal money growth instead of rising nominal interest rates and account for important historical movements in output and inflation.

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1. Introduction

The New Keynesian model used for much of modern business cycle analysis consists, at its core, of three equations: forward-looking Phillips and IS Curves, together with an interest rate rule for monetary policy. A central element of this model is some form of administrative cost or information rigidity that prevents firms from adjusting their output prices fully and immediately in response to shocks that hit the economy. As well, households exhibit a willingness to rearrange their spending patterns in response to changes in the real interest rate as an intertemporal price. In this model, the effects of monetary policy actions on output and inflation are transmitted exclusively through the central bank's manipulation of the short-term nominal interest rate. Temporary rigidity in goods prices allows these nominal interest rate movements to affect real interest rates. These changes in turn generate adjustments in household spending that affect the output gap and feed back into firms' pricing decisions via the Phillips Curve. Notably missing from the model is any separate role for variations in the quantity of money.[1]

Approximately ninety years ago, Irving Fisher (1923, 1925, 1926) and Holbrook Working (1923, 1926) developed an alternative view of the monetary transmission mechanism that is associated here with a "classical" school of thought. Quite unlike modern real business cycle models, this older classical view does not deny the importance of nominal price rigidities and the resulting monetary non-neutralities in shaping business cycle dynamics. For example, as explained in more detail below, Fisher (1926) discovered a statistical relationship between inflation and employment that resembles closely what would later become known as the Phillips Curve.[2] And Fisher's (1923, 1925) description of the "so-called business cycle" as a

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[1] More precisely, changes in the real and nominal quantities of money play no independent role in determining the dynamics of inflation, the output gap, and the short-term nominal interest rate in the standard New Keynesian model. However, one can still view the central bank's choice for the average rate of nominal money supply growth as important for the determination of the model's steady-state rate of inflation. See Ireland (2004) and Nelson (2008) for more detailed discussions of this distinction.

[2] In fact, Fisher (1926) was republished as Fisher (1973) under the alternative title "I Discovered the Phillips Curve."

product of the "dance of the dollar" singles out nominal impulses as the primary driver of aggregate fluctuations.

Missing from Fisher's analyses was a full explanation of how this nominal instability could be traced back to the effects of monetary policy itself. Based on Fisher's earlier research, however, Laidler (2013) argues that Fisher must have seen variations in the quantity of money as the more fundamental source of what today would be labeled as a "monetary policy shock." Along those lines, Fisher (1925) refers to Holbrook Working's then-forthcoming 1926 paper, which found that movements in bank deposits tended to lead movements in the aggregate price level. In related research, Working (1923) uses a Quantity Theory framework complementary to Fisher's to characterize a path for the money stock that would be consistent with long-run price stability and, by extension, enhanced real stability as well.

After reviewing in greater detail the original work behind this classical view of the monetary business cycle, this paper proceeds to sharpen both its points of similarity to and its departures from the more contemporary, New Keynesian perspective. The paper then conducts an empirical exercise aimed at discovering whether classical channels of monetary transmission, working through Quantity-Theoretic interactions between money supply and demand, might operate alongside of the now much more familiar interest rate channels.[3]

Adapting methods outlined by Baumeister and Hamilton (2015, 2018), the econometric study begins by estimating a structural vector autoregression (VAR) for inflation, the output gap, and the federal funds rate under Bayesian priors that reflect the mainstream, New Keynesian view of the cycle. Next, the VAR is expanded to include a Divisia monetary aggregate and its associated user-cost index, using both of these new variables to help distinguish fluctuations in money supply from those in money demand. Although the Bayesian priors selected for this expanded model are deliberately chosen to reflect the New Keynesian view that any additional, classical channels of monetary transmission are of limited importance, quarterly data for the United States turn out to speak strongly in favor of their

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[3] Laidler (1973) develops a model similar in spirit to investigate the same question and finds significant associations between money and aggregate activity. This early paper, however, does not embed a monetary policy rule.

existence. Posterior distributions tilt heavily towards specifications that allow terms involving

real and nominal money growth to enter the IS and monetary policy equations that, according

to the strict New Keynesian view, ought to involve real and nominal interest rates alone.

Contractionary monetary policy shocks appear, in this more general framework, to be triggered

mainly by persistent reductions in nominal money growth that are followed by declines in

inflation, the output gap, and the short-term nominal interest rate. The expanded, "classical"

VAR points, in addition, to a larger role for monetary policy disturbances in shaping historical

fluctuations in inflation and the output gap. The paper's conclusion discusses the implications

of these findings for business cycle theory because, at a minimum, they seem to call for a new

class of models capable of capturing a wider range of channels through which monetary policy

affects the economy. The results also suggest that, even today, monetary aggregates could play

a useful role in the Federal Reserve's policymaking strategy.

2. A Classical View of the Monetary Business Cycle

A. Intellectual Origins

Long before the development of real business cycle and New Keynesian theories, Irving

Fisher (1923, 1925) published his own ideas on what forces might be behind aggregate

fluctuations. In these papers, Fisher conjectured that unanticipated movements in inflation

would alter expectations of future profits because prices received by producers for their output

adjusted more quickly than prices paid by firms for their inputs. Under these conditions,

unanticipated variations in the inflation rate represent a key component of the mechanism

generating "the cycle." Fisher also argued that movements in inflation would affect real

interest rates, potentially changing the cost of borrowing by firms. As bank loans were affected

by these changes in output and interest rates, the growth of bank deposits and, hence, the

quantity of money, would be altered as well. The effects following an inflation surprise on

output would end when input prices eventually adjusted and returned profits to normal levels.[4]

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[4] Laidler (2013) argues that this research can be seen as an effort by Fisher to confirm his
long-standing belief in the power of the Quantity Theory to explain aggregate fluctuations and

Missing from this analysis was any explicit treatment of a causal force that led to inflation variations in the first place but, based on his earlier research, it seems likely that Fisher believed that these variations could be traced to aggregate demand fluctuations that had a monetary origin.[5]

Fisher (1926) extended his work linking variations in inflation to the business cycle by outlining a relationship similar to what would later become known as the Phillips Curve. While his earlier papers explored the correlations between inflation and the volume of trade, his 1926 paper analyzed the association between inflation and employment.[6] Fisher now had found more evidence that variations in real activity were related to inflation but, as in his previous work, did not explain why prices varied. Nonetheless, based on his earlier (1911) investigations of the Quantity Theory and, specifically, that book's Chapter IV ("Disturbance of Equation [of Exchange] and of Purchasing Power during Transition Periods"), which connected variations in money to variations in the price level and, subsequently, to changes in the real rate of interest and output, it is again reasonable to infer that he saw variations in the quantity of money as an underlying source of aggregate fluctuations.[7]

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to support his advocacy of a rule that would direct the newly-created Federal Reserve to achieve price stability. This was his "compensated dollar" plan (see Fisher (1913, 1920)). Similar thinking was behind a significant effort at the International Labor Organization in the 1920s on mechanisms to achieve price stability (see Endres and Fleming (1998)). Simons (1936) later articulated similar logic for the adoption of a monetary policy rule.

[5] For example, Fisher treated the subject extensively in his (1911) *Purchasing Power of Money* and, for several years, he published forecasts of inflation in the *American Economic Review* (e.g., Fisher (1912)). These forecasts were derived from Quantity Theory relationships and based on regressions of the aggregate price level on the quantity of money. Fisher was not alone in making empirical investigations of Quantity Theory relationships in the early 20th century. For more background, see the retrospectives in Humphrey (1973) and Laidler (2013).

[6] Throughout the paper, Fisher refers to both employment and unemployment. His statistical evidence, however, is limited only to variations in employment. In a subsequent paper, Fisher (1936) revisited the question by investigating the relationship between the rate of change in wholesale prices and factory employment. The theoretical reasoning for this exercise remained the same as that articulated in Fisher (1925, 1926). Dimand (1993) discusses Fisher's ideas in greater detail. Loef and Monissen (1999) develop a formal model based on Fisher's discussion of the cycle.

[7] Although the focus in this paper is specifically on Fisher's work, it should be noted that others, notably Hawtrey (1913), also were developing monetary theories of the cycle at this time. While similar in many respects, however, the disturbances in these other models that

If variations in the quantity of money were, in fact, the cause of fluctuations in aggregate activity, it would be natural to ask if there was a mechanism by which price stability might be achieved and, indeed, Fisher (1913, 1920) had already proposed that price stability be adopted formally as the operating objective of the Federal Reserve. In this context, Working's contribution, discussed in more detail below, was to use the Quantity Theory to define a mechanism by which a value for the money supply consistent with long-run price stability could be identified. Moreover, Working recognized the role of lags between changes in the quantity of money and changes in the price level and embedded these lags in a policy framework based on a long-run simulated path for price stability. By comparing the current price level against the simulated long-run path, a central bank could then evaluate whether the stance of monetary policy was too accommodative or too restrictive.[8]

Although the details of these models are different, the foregoing discussion suggests that business cycle dynamics as viewed from a classical perspective reflect the operation of the same three relationships found in the New Keynesian model: a relationship between the output gap (or unemployment) and inflation, a relationship between monetary policy and the output gap, and a rule for the conduct of monetary policy. But, while both classical and New Keynesian theories depend on similar notions of the Phillips curve relation between output and inflation, the role of the money stock, both in transmitting monetary policy actions through the economy and in describing the stance of monetary policy itself, differs importantly across the two perspectives.

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initiated fluctuations in real activity were seen to originate from different sources. Fisher emphasized *exogenous* shocks to high-powered money that caused the price level to change and, if nominal interest rates did not adjust quickly enough, changes in the real rate would affect expected profits, output, and employment. Hawtrey's "model," summarized in a series of bullet points (Hawtrey (1913, pp.267-272)), tended to focus instead on *endogenous* changes in money and the money multiplier resulting from changes in expected profits and adjustments in credit markets. Thus, whereas Fisher focused on preventing exogenous changes in money, as in his "compensated dollar" plan, Hawtrey's analysis led him to emphasize control of commercial banks' behavior. A discussion of other work on monetary theories of the cycle during the early twentieth century can be found in Laidler (1991, Chapter 4).

[8] Humphrey (2001) conjectures that a Quantity Theoretic rule of this type would have indicated to the Fed that monetary policy was excessively tight in the late 1920s and early 1930s in contrast to the signal of monetary ease given by the Real Bills Doctrine that guided the Fed at that time.

The New Keynesian model includes a forward-looking IS curve derived as a log-linearized version of an optimizing household's Euler equation that links expected consumption growth to the *ex-ante* real interest rate. Therefore, the New Keynesian IS curve merely extends Fisher's (1930) theory of interest and intertemporal choice to the case of uncertainty and rational expectations.[9] The New Keynesian model, however, translates this Euler equation into the foundations of theory of short-run output determination by assuming, additionally, that monopolistically competitive firms sell output on demand at their pre-set nominal prices and that the central bank exploits the temporary rigidity of nominal goods prices to translate policy-induced movements in nominal interest rates into corresponding movements in the real interest rate. After imposing equilibrium conditions that link household spending to the output gap, the New Keynesian IS curve relates the output gap to the difference between the actual real interest rate and a corresponding measure of the natural real rate of interest.[10]

The body of classical thought discussed earlier pre-dates any notion of an IS curve that might be compared directly to the New Keynesian specification. Nonetheless, a contrast can be made by recalling that, for Fisher and Working, it was changes in money growth that set off the dynamics through which monetary policy affected output and inflation. This observation suggests a classical alternative to the New Keynesian IS curve in which real money balances appear, in addition to the real interest rate, as a summary statistic representing the channels through which monetary policy affects real economic activity. Ireland (2004) derives an IS curve of this form by assuming real money balances enter non-separably with consumption

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[9] Thus, scattered throughout Fisher's work appear variants of all the basic building blocks of contemporary macroeconomic models, including those that evolved into the New Keynesian IS and Phillips Curves. Tobin (1987, p.376) concludes: "Had Fisher pulled these strands together into a coherent theory, he could have been an American Keynes. Indeed the 'neoclassical synthesis' would not have had to wait until after World War II. Fisher would have done it all himself."

[10] See Woodford (2003, Chapter 4) for a derivation of this "Neo-Wicksellian" view of aggregate demand and Neiss and Nelson (2003) for further theoretical and empirical analysis. Laidler (1999), however, discusses how the same two interest rate model widely associated with Wicksell and the Stockholm School also can be interpreted in a manner that leads to money, rather than credit and interest rates, as the source of aggregate fluctuations.

into a representative household's utility function, so that the intertemporal optimality condition that forms the basis for the New Keynesian aggregate demand relation includes real balances as well as the real interest rate. Likewise, Nelson (2002) introduces adjustment costs of money demand into a New Keynesian model to derive a specification in which changes in real money balances reflect movements in long-term interest rates that are important in influencing aggregate demand; this model variant also motivates an empirical specification in which aggregate demand depends on changes in real money balances as well as the real short-term rate. In a similar spirit, Meltzer (2001) incorporates real money growth as well as interest rates into an empirical aggregate demand formulation, interpreting changes in real balances as proxies for the wider range of effects that monetary policy actions have on spending patterns. The classical specification outlined below takes the same approach, using the New Keynesian IS curve as its benchmark but allowing changes in real balances to enter that relationship as well so as to see, more broadly, which variables appear most important in transmitting the effects of monetary policy to output.

C. The Monetary Policy Rule

The New Keynesian model is closed by a third equation that represents a monetary policy rule for the central bank. With the path for the short-term interest as a key driver of output, the rule adopted for this purpose is focused on how the target value for that interest rate should be adjusted in response to prevailing economic conditions. Moreover, because the Federal Reserve's mandate specifies goals for two variables – stable prices and maximum employment – and because the output gap appears more frequently as the measure of resource utilization in the New Keynesian model, this rule naturally takes the same general form as Taylor's (1993) and prescribes a setting for the nominal interest rate with reference to movements in inflation away from the central bank's target and fluctuations in the output gap.

In a classical setting, however, the quantity of money is the focus of a rule for monetary policy and, in contrast to the joint objectives of full employment and price stability for the central bank in New Keynesian models, classical rules directed their attention only to price stability. To this end, Working (1923) used the basic Equation of Exchange and assumptions

about the behavior of velocity and the volume of transactions to focus on the value of real money balances. To determine a smooth path for prices, Working estimated a trend value using a regression of the logarithm of the price level on time, time squared, and time cubed and then identified targets for future values of the price level by extrapolating from this trend regression. With this information, Working could plot, on a log scale, values for M/P to illustrate the value of the money stock that would be consistent with the long-run trend path for the aggregate price level P.[11] And, in the same sense that the Taylor Rule directs the central bank to raise or lower its target for the short-term nominal interest rate as realized values for inflation and the output gap differ from their targets, the rule proposed by Working would have the central bank increase or decrease the quantity of money as the price level differed from its desired path.

The feedback rule proposed by Working (1923) can be interpreted as proscriptive, the outline of a strategy the Fed *would* follow if it used its influence over the money supply to stabilize inflation around a target path. Here, instead, the focus shifts to the role that money growth plays in describing the implications that Federal Reserve policy decisions *actually have had* over various historical periods extending from the late 1960s through the present. Accordingly, meant as a positive description of Fed behavior over these periods, the monetary policy rule in the classical variant of the model estimated below allows for contemporaneous links among the short-term nominal interest rate, the rate of nominal money growth, the output gap, and inflation. Then, in the special case where no separate role for money growth appears, this rule collapses to the standard Taylor Rule. More generally, however, the specification allows monetary policy shocks to manifest themselves in movements in interest rates, money growth, or some combination of the two. The model's expanded IS curve then allows movements in both interest rates and money growth to affect aggregate demand and, from there, inflation as well through the Phillips Curve.

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[11] The "P-star" model of Hallman, Porter, and Small (1991) was adapted from Working's (1923) framework. But whereas that study specified long-run equilibrium velocity, "V-star," as a constant, Orphanides and Porter (2000) and Belongia and Ireland (2015a, 2017) introduced time-varying measures of equilibrium velocity, a change that tightened the links between money and nominal objectives.

D. Money Demand and Supply

Leeper and Roush (2003) emphasize that a standard Taylor Rule describes part of a broader monetary regime in which Federal Reserve policy makes the supply of monetary assets infinitely elastic for any given target value for the short-term nominal interest rate. It is this infinite elasticity of money supply that implies that a money demand equation, if added to the New Keynesian model, serves only to determine the equilibrium stock of money, given the behavior of inflation, output, and interest rates. By contrast, a policy rule allowing for simultaneity between interest rates and money growth makes the money supply function less than fully elastic, and therefore requires an explicit consideration of money demand to pin down the dynamics of all other variables. Thus, the classical specification developed below must go beyond the three-variable New Keynesian one, not only by making the IS curve and monetary policy rules more flexible, but also by including entirely new relationships that clarify the distinction between money supply and money demand. The resulting description of monetary policy and its effects, working through the interactions between money supply and demand, highlights the deeper connections between the analysis conducted here and the classical ideas of Fisher and Working and, likewise, reveals a more fundamental departure from the standard New Keynesian approach.

3. The New Keynesian Benchmark

To demonstrate, first, that the empirical approach taken here is capable of producing results consistent with conventional New Keynesian theory as a benchmark, the analysis begins by focusing on a three-variable structural vector autoregression for inflation p_t, the output gap y_t, and the short-term nominal interest rate r_t. The quarterly data used to estimate this VAR begin in 1967:1, to match the availability of the monetary series used to extend the model later on, and run through 2017:4. In those data, inflation is measured by year-over-year percentage changes in the price index for personal consumption expenditures, and the output gap is measured as the percentage-point difference between real GDP and the

Congressional Budget Office's estimate of potential GDP. From the beginning of the sample period through 2008:4 and starting again in 2016:1, the short-term nominal interest rate is measured by the effective federal funds rate. From 2009:1 through 2015:4, it is measured instead using Wu and Xia's (2016) shadow federal funds rate, which provides a convenient one-dimensional index summarizing the full effects of the Federal Reserve's policies of forward guidance and quantitative easing on the entire term structure of interest rates over the interval when the federal funds rate itself was constrained by the zero lower bound.[12] All data come from the Federal Reserve Bank of St. Louis' FRED database, except for the shadow funds rate series, which was downloaded from Jing Cynthia Wu's website at the Booth School of Business, University of Chicago.

Collecting the data series in the 3x1 vector

$$x_t = \begin{bmatrix} p_t & y_t & r_t \end{bmatrix}'$$

allows the structural VAR to be written compactly as

$$Ax_t = \mu + \sum_{j=1}^{q} B_j x_{t-j} + \varepsilon_t, \tag{1}$$

where A is a 3x3 matrix of impact coefficients with ones along the diagonal, μ is a 3x1 vector of intercept terms, each B_j, $j = 1, 2, ..., q$, is a 3x3 matrix of autoregressive coefficients, and ε_t is a 3x1 vector of serially and mutually uncorrelated structural disturbances, assumed to be normally distributed with zero mean and diagonal 3x3 covariance matrix D. While (1) leaves the autoregression unconstrained, and thereby stops short of imposing all of the cross-equation restrictions implied by a fully-specified dynamic, stochastic, general equilibrium New

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[12] It should be noted that the term structure model used by Wu and Xia (2016) to estimate their shadow rate series allows for changes in bond risk premia that, strictly speaking, would not be captured by most New Keynesian models. However, the Wu-Xia model does share with New Keynesian theories the assumption that inferences about the stance of monetary policy can be gleaned from data on interest rates alone, without reference to changes in the stock of money. An alternative shadow rate series could be derived, instead, using Gust, Herbst, Lopez-Salido, and Smith's (2017) nonlinear estimates of a New Keynesian model.

Keynesian model, the matrix A of impact coefficients is parameterized with broader reference to New Keynesian theory to give each equation its structural interpretation.

More specifically, with

$$A = \begin{bmatrix} 1 & -\alpha_{py} & 0 \\ -\alpha_{yr} & 1 & \alpha_{yr} \\ -\alpha_{rp} & -\alpha_{ry} & 1 \end{bmatrix},$$
(2)

the first equation from (1) can be written as

$$p_t = \alpha_{py} y_t + \mu^{(1)} + \sum_{j=1}^{q} B_j^{(1)} x_{t-j} + \varepsilon_t^{as},$$
(3)

where, here and below, $\mu^{(i)}$ and $B_j^{(i)}$ refer to the elements from row $i = 1,2,3$ of the vector μ and the matrices B_j, $j = 1,2,...,q$. Equation (3), like the New Keynesian Phillips curve, describes a contemporaneous relationship between movements in inflation and the output gap. Likewise, the second equation from (1),

$$y_t = -\alpha_{yr}(r_t - p_t) + \mu^{(2)} + \sum_{j=1}^{q} B_j^{(2)} x_{t-j} + \varepsilon_t^{ad},$$
(4)

captures the essence of the New Keynesian aggregate demand relationship, linking the output gap to monetary-policy induced movements in the real short-term interest rate. The third equation,

$$r_t = \alpha_{rp} p_t + \alpha_{ry} y_t + \mu^{(3)} + \sum_{j=1}^{q} B_j^{(3)} x_{t-j} + \varepsilon_t^{mp},$$
(5)

is similar in spirit to the Taylor (1993) Rule and describes how the central bank adjusts the federal funds rate systematically in response to movements in inflation and the output gap. Under these interpretations, the structural disturbances in the vector

$$\varepsilon_t = \begin{bmatrix} \varepsilon_t^{as} & \varepsilon_t^{ad} & \varepsilon_t^{mp} \end{bmatrix}'$$

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correspond to aggregate supply, aggregate demand, and monetary policy shocks, which are assumed, by imposing the diagonal structure on their covariance matrix D, to be mutually uncorrelated.

The reduced form implied by the structural model (1) can be written as

$$x_t = v + \sum_{j=1}^{q} \Phi_j x_{t-j} + \zeta_t, \tag{6}$$

where $v = A^{-1}\mu$, $\Phi_j = A^{-1}B_j$ for $j = 1,2,...,q$, and $\zeta_t = A^{-1}\varepsilon_t$ is a 3x1 vector of reduced-form innovations that is normally distributed with zero mean and 3x3 covariance matrix $\Omega = A^{-1}D(A^{-1})'$. The reduced form (6) summarizes all of the information contained in the data, and the availability of only three distinct off-diagonal elements in the reduced-form covariance matrix Ω implies that the structural model as shown in (1) and (2) remains unidentified unless at least one more restriction is imposed on the four parameters entering into the matrix A. As an alternative, Baumeister and Hamilton (2015, 2018) outline methods for combining Bayesian prior distributions with information contained in the data, and therefore communicated through the likelihood function, to characterize the posterior distributions for the structural parameters. These methods do not solve the frequentist identification problem: within the Bayesian framework, the same problem manifests itself in the continued influence of the prior distribution in shaping the posterior, even as the number of observations in the data sample approaches infinity. Nevertheless, this Bayesian approach provides a coherent way of assessing how the information that *is* available in the data can be used to update optimally one's priors about the values of the structural parameters.

Thus, the analysis here follows Baumeister and Hamilton (2018) by using New Keynesian theory as a guide for calibrating prior distributions for the elements of A and, after characterizing the posterior distributions of the same parameters, asking whether the data provide any reason for doubting the statistical adequacy of that theory. Specifically, each of the four coefficients in (2) is assigned a Student t prior distribution with two degrees of freedom and scale parameter equal to 0.3. The location parameter determining the prior mean of the

Phillips Curve coefficient α_{py} is set equal to 0.5, consistent with the choice made by Lubik and

Schorfheide (2004). Meanwhile, the prior mean for the aggregate demand coefficient α_{yr} is set

at 1.0, as would be implied by a logarithmic utility function for the representative household in

a New Keynesian model. Finally, the original Taylor (1993) Rule assigns values of 1.5 and 0.5

to describe the policy responses of the federal funds rate to changes in inflation and the output

gap, but these response coefficients correspond most closely to the cumulative, or long-run,

effects of those variables on the funds rate in the general specification (5), which allows more

flexibility for interest rate smoothing behavior. Accordingly, values of 0.375 and 0.125 are

chosen for the prior means of the impact coefficients α_{rp} and α_{ry}. These settings are derived

by taking Taylor's original values 1.5 and 0.5 and multiplying each by 0.25, thereby assuming

that one-quarter of the gap between the actual funds rate and its long-run target gets closed

each period.

In contrast to Baumeister and Hamilton (2018), the prior distributions for all these

impact coefficients are not truncated at zero; this choice reflects a willingness to consider the

possibility that the posterior distributions assign non-negligible weight to negative values for

one or more of the structural parameters, which would then be interpreted as evidence against

the theory. Baumeister and Hamilton's (2018) specification also differs from the one used here

by allowing for separate impact coefficients on the nominal interest rate and inflation in the

aggregate demand equation (4); the hard restriction that these parameters are equal in

absolute value and opposite in sign is imposed here in order to emphasize the New Keynesian

model's implication that the effects of monetary policy on output are transmitted through the

effects of policy on the *real* interest rate.

After calibrating these Student t priors for the elements of A, the analysis continues by

forming priors first for the diagonal elements of the covariance matrix D for the structural

shocks and then for the coefficients in the intercept and autoregressive coefficients in (1) by

factoring the overall prior as

$$p(A, D, \mu, B_1, B_2, ..., B_q) = p(A)p(D)p(\mu, B_1, B_2, ..., B_q \mid D).$$

Specifically, the reciprocals of the three diagonal elements d_{ii}, $i = 1,2,3$, of D are assigned

independent Gamma prior distributions with parameters κ_i and τ_i such that κ_i / τ_i

represents its prior mean and κ_i / τ_i^2 its prior variance. Setting $\kappa_i = 2$ for $i = 1,2,3$ can be

interpreted as placing a weight on these priors equal to that provided by $2\kappa_i = 4$ observations

of data. The settings for each τ_i, $i = 1,2,3$ are then obtained by fitting univariate fourth-order

autoregressions to each of the three series, computing the covariance matrix

$$S = T^{-1} \sum_{t=1}^{T} e_t e_t', \tag{7}$$

where e_t denotes the 3x1 vector of residuals from these univariate models, and assigning to τ_i

a value equal to κ_i times the corresponding diagonal element of $\overline{A}S\overline{A}'$, where $\overline{A}$ is the matrix

formed by substituting into (2) the prior mean value for each of the unknown elements of A.

Finally, conditional on D, normal priors for the autoregressive parameters in the

matrices B_j, $j = 1,2,...,q$, are calibrated based on modifications to Litterman's (1986)

"Minnesota" prior introduced by Sims and Zha (1998) and Baumeister and Hamilton (2018).

With reference to the parameters of the structural model (1), this involves setting the prior

mean of each element of the matrix B_1 equal to a scalar ϕ times the corresponding element of

the matrix $\overline{A}$ defined above and the prior mean of each element of the matrices B_j,

$j = 2,3,...,q$, equal to zero. With $\phi = 1$, this specification would imply random walk behavior in

each variable according to the reduced form (6), consistent with Litterman's (1986) original

specification; the alternative setting $\phi = 0.75$ suggested by Baumeister and Hamilton (2018)

and adopted here as well reflects the fact that variables included in the VAR – inflation, the

output gap, and the federal funds rate – more likely follow persistent, but stationary, first-order autoregressive processes.

The prior covariance matrix for the elements of $B_1, B_2, ..., B_q$ considered jointly is diagonal, with variance of the coefficient on lag $j = 1, 2, ..., q$ for variable $h = 1, 2, 3$ in equation $i = 1, 2, 3$ given by

$$\frac{\lambda_0^2 \lambda_1^2 d_{ii}}{j^{2\lambda_2} s_{hh}},$$

where s_{hh} denotes the appropriate diagonal element of the covariance matrix S from (7). The three elements of the intercept vector μ are assigned independent normal priors, each with mean zero and variance $\lambda_0^2 \lambda_3^2$. Thus, as in Sims and Zha (1998), the hyperparameter λ_0 governs the overall weight on the Minnesota-style prior, λ_1 determines the weight on the belief that the reduced-form (6) describes first-order autoregressive behavior for each variable, λ_2 controls how the tightness of the prior increases on autoregressive coefficients for longer lags, and λ_3 applies specifically to the tightness of the prior on the intercept terms. Following Baumeister and Hamilton (2015), these hyperparameters are calibrated as $\lambda_0 = 0.2$, $\lambda_1 = \lambda_2 = 1$, and $\lambda_3 = 100$ after setting the lag length truncation parameter at $q = 4$.

Starting from these priors, the Metropolis-within-Gibbs sampling algorithm outlined by Baumeister and Hamilton (2015, p.1989) is used to draw from the posterior, factored as

$$p(A, D, \mu, B_1, B_2, B_3, B_4) = p(A \mid X_{1:T}) p(D \mid A, X_{1:T}) p(\mu, B_1, B_2, B_3, B_4 \mid A, D, X_{1:T}),$$

where $X_{1:T}$ denotes the sample of data on the three elements of x_t, $t = 1, 2, ..., T$. Draws for the reciprocals of the volatility parameters in D and the intercept and autoregressive parameters in μ and B_j, $j = 1, 2, 3, 4$, are taken directly from their conditional Gamma and Normal posterior distributions, whereas a random-walk Metropolis-Hastings step is required to

generate draws from the posterior for the elements of A.[13] After discarding the first one

million draws to allow for burn in, the next one million draws are used to produce the results

described below. Convergence and adequate mixing of this Markov Chain Monte Carlo

procedure is confirmed, informally, by checking that the results do not change when the

algorithm is initialized from different randomly chosen starting points and, more formally, by

monitoring the convergence diagnostic and relative numerical efficiency statistics described by

Geweke (1992).

Unlike the standard method of identifying structural disturbances from a VAR through

a Cholesky factorization of the covariance matrix of its reduced-form shocks, the Bayesian

approach to estimation taken here does not automatically produce time series for the fitted

structural disturbances that are completely uncorrelated. An informal test of the restriction,

imposed during estimation, that the covariance matrix D of the structural shocks is diagonal

can be performed by computing the correlations between the fitted values of those shocks to

confirm that they are small. In fact, median estimates of these correlations are all smaller than

0.10 in absolute value.

Table 1 summarizes the posterior distributions for the four coefficients in A by

reporting medians together with 16 and 84th percentiles; the graphs in the first column of

figure 1, meanwhile, compare in more detail the posterior density for each parameter, shown

with blue bars, to the prior density, traced out with red lines. But while the graphs in figure 1

focus on results when the model is estimated using the full sample of data running from

1967:1 through 2017:4, the table provides more detail in another way by reporting results

when the model is re-estimated over three subsamples corresponding to different episodes of

United States economic and monetary history. The "pre-1984" subsample, running from

1967:1 through 1983:4, spans the period of the Great Inflation and "stop-go" monetary policy

through the end of the Volcker disinflation. Meanwhile, the "post-1984" subsample, running

from 1984:1 through 2007:4, focuses on the Great Moderation. Finally, the "post-2000"

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[13] The tuning parameter $\xi = 1$ for this Metropolis step is chosen here, again following
Baumeister and Hamilton (2015), to target a 30 percent acceptance rate.

subsample, from 2000:1 through 2017:4, covers the period running up to, including, and since the financial crisis and Great Recession of 2007-2009.

For the full sample and across all subsamples, the top rows of table 1 and figure 1 show the posterior distribution of the Phillips Curve parameter α_{py} shifting noticeably to the left and tightening around a smaller median, relative to the prior. These smaller values for α_{py} correspond to longer intervals between individual price adjustments in the Calvo (1983) model and, hence, additional price rigidity in the aggregate. For the post-1984 subsample, in fact, the posterior distribution places heavy weight on negative values for this coefficient, suggesting that this variant of the Phillips Curve struggles to explain the dynamics linking inflation and the output gap during the Great Moderation. Although the posterior median values of the parameter α_{yr} measuring the real interest elasticity of aggregate demand also fall below the prior mean, they remain positive and sizeable across all sample periods.

In general, posterior estimates of the response coefficient α_{rp} on inflation in the monetary policy rule decrease, while estimates of the response coefficients α_{ry} to the output gap increase, compared to the corresponding priors. The estimated strength of the policy response to inflation relative to output increases, however, moving from the pre-1984 to the post-1984 subsample, consistent with the findings of Clarida, Gali, and Gertler (2000). The policy emphasis shifts strongly back towards output in the most recent, post-2000 subsample, confirming the view that the Federal Reserve has been unusually aggressive in its efforts to promote the recovery from each of the past two recessions in 2001 and 2007-2009.[14] Table 2 displays similar patterns in the long-run policy coefficients, computed by summing the values of parameters on the current and lagged values of each variable on the right-hand side of the policy rule (5). For the full sample and all subsamples, the posterior means for these long-run

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[14] Belongia and Ireland (2016*b*) characterize this recent shift towards output stabilization in more detail, using a three-variable Bayesian VAR that allows the parameters of the identified policy rule to drift continuously over time. Similarly, Reifschneider (2016) documents a stronger responsiveness of the Fed's interest rate target to movements in unemployment over the period from 2000 through 2008.

coefficients are consistent with a large degree of interest rate smoothing and, except for the post-1984 subsample that encompasses the Great Moderation, a stronger policy response to the output gap than inflation.

Graphs in the left-hand columns of figures 2 through 4 plot impulse responses to the aggregate supply, aggregate demand, and monetary policy shocks that appear in (3)-(5). Although the methods used here, which draw on prior information to help estimate the parameters of the aggregate supply, aggregate demand, and monetary policy equations directly, were proposed by Baumeister and Hamilton (2015) as alternatives to those that constrain the model's impulse responses using "sign restrictions," the impulse responses in the graphs generally display their expected patterns. In particular, the aggregate supply disturbance raises inflation and (with a lag) lowers the output gap, while calling forth a monetary policy tightening in the form of higher nominal interest rates. The aggregate demand shock increases inflation, the output gap, and the interest rate, while monetary policy shocks associate interest rate increases with reductions in inflation and output. The initial increase in the output gap that follows an aggregate supply shock in figure 2 and the small initial increase in inflation that follows a contractionary monetary policy shock in figure 4 appear as the only puzzles in these results, but each is followed by a more persistent movement in the relevant variable that is consistent with the predictions of the theory.

In general, therefore, this three-variable model appears successful in capturing the New Keynesian view of the business cycle, with parameter estimates and impulse responses that have the expected magnitudes and signs. Like the New Keynesian model itself, however, this three-variable model omits any consideration of the role that changes in nominal and real money growth may play in shaping how monetary policy affects the economy. Therefore, the results so far leave open the possibility that interactions between money supply and demand, unseen by the New Keynesian model with its deliberate exclusion of them, may also be affecting the dynamics of the United States economy. The analysis now turns to exploring this possibility.

4. A Classical Alternative

To detect evidence that classical channels of monetary transmission operate alongside the New Keynesian mechanisms highlighted above, the set of variables included in the VAR is enlarged to include two more: the year-over-year growth rate m_t of the Divisia M2 monetary aggregate and the associated monetary user cost index u_t. Use of a Divisia monetary aggregate, in place of one of the Federal Reserve's official simple-sum measures, offers two distinct advantages. First, as emphasized by Barnett (1980, 2012), Divisia monetary aggregates use economic aggregation theory to measure more accurately the flow of monetary services generated in an economy in which agents have the ability and willingness to substitute between various liquid assets paying interest at different rates.[15] Divisia aggregates do this by weighting individual components based on their expenditure shares, which depend in turn on their user costs, defined in terms of the spread between a market rate of interest on an illiquid asset and the lower rate of interest that consumers and non-financial firms will accept to obtain the liquidity services provided by each monetary asset. Second, as discussed originally by Barnett (1978) and more recently by Belongia (2006) and Belongia and Ireland (2015*b*, 2016*a*, 2018, 2019), the process of Divisia quantity aggregation yields, in the form of the price dual, a corresponding aggregate of the user costs of the individual monetary assets. Because this user-cost dual depends not on the level of market rates alone but rather on the spread between market rates and the "own rates" paid by monetary assets, it represents the own-price of money and, as such, is a variable that is likely to influence money demand but not money supply. Therefore, data on this variable can be put to good use in distinguishing movements in

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[15] Consistent with Barnett's (1980, 2012) theory, empirical studies, including Belongia (1996), Hendrickson (2014), and Belongia and Ireland (2015*b*, 2016*a*), find evidence of statistical links between Divisia monetary aggregates and key macroeconomic variables including inflation and output that are noticeably stronger than those between corresponding simple-sum measures and the same macroeconomic indicators.

money growth that reflect shocks to monetary policy from movements in money growth that have worked, instead, to accommodate shifts in money demand.[16]

Barnett, Liu, Mattson, and van den Noort (2013) describe in more detail the procedures behind the construction of the series for the Divisia M2 quantity and user-cost indices employed here, which are available through the Center for Financial Stability's website. With these series included, the data vector expands to become

$$x_t = \begin{bmatrix} p_t & y_t & r_t & m_t & u_t \end{bmatrix}'.$$

The descriptions of the structural VAR and its reduced form shown previously in (1) and (6) remain unchanged after all vectors and matrices are enlarged to accommodate the presence of the two additional variables. The autoregressive dynamics in (1) remain unconstrained, but the matrix of impact coefficients is again restricted to give the model its structural interpretation:

$$A = \begin{bmatrix} 1 & -\alpha_{py} & 0 & 0 & 0 \\ \alpha_{ym} - \alpha_{yr} & 1 & \alpha_{yr} & -\alpha_{ym} & 0 \\ -\alpha_{rp} & -\alpha_{ry} & 1 & -\alpha_{rm} & 0 \\ -1 & -\alpha_{my} & 0 & 1 & \alpha_{mu} \\ \alpha_{um} & 0 & -\alpha_{ur} & -\alpha_{um} & 1 \end{bmatrix}. \tag{8}$$

In this expanded system, the first equation implied by (1) and (8) retains the same form shown in (3), of a Phillips Curve relationship drawing a contemporaneous link between inflation and the output gap. The second equation, which represents an augmented version of the New Keynesian aggregate demand curve, can be written as

$$y_t = -\alpha_{yr}(r_t - p_t) + \alpha_{ym}(m_t - p_t) + \mu^{(2)} + \sum_{j=1}^{q} B_j^{(2)} x_{t-j} + \varepsilon_t^{ad}, \tag{9}$$

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[16] Belongia and Ireland (2006) show how the Divisia monetary user cost variable can be used, as well, to directly measure the inflation-tax effects that allow monetary policy shocks to be non-neutral even in models such as Cooley and Hansen's (1989) that provide a role for money as a medium of exchange while assuming that nominal goods prices and wages remain perfectly flexible.

where, here and below as before, $\mu^{(i)}$ and $B_j^{(i)}$ refer to the elements from row $i = 1, 2, ..., 5$ of the vector μ and the matrices B_j, $j = 1, 2, ..., q$. As discussed in Meltzer (2001), Ireland (2004), and Nelson (2008), this augmented aggregate demand curve incorporates the classical view that changes in nominal money growth, which translate into changes in the growth rate of real money balances over the interval during which nominal prices are slow to adjust, play a direct role in transmitting monetary policy actions to the real economy.

Likewise, the third equation, written as

$$r_t = \alpha_{rp} p_t + \alpha_{ry} y_t + \alpha_{rm} m_t + \mu^{(3)} + \sum_{j=1}^{q} B_j^{(3)} x_{t-j} + \varepsilon_t^{mp}, \tag{10}$$

can be interpreted as an expanded Taylor (1993) Rule that includes the contemporaneous rate of nominal money growth, as well as inflation and the output gap, on the short list of variables to which the Federal Reserve is assumed to respond in setting its target for the federal funds rate.[17] Alternatively, this monetary policy rule can be seen as taking the same general form as those used by Sims (1986), Leeper and Roush (2003), Leeper and Zha (2003), Sims and Zha (2006), Belongia and Ireland (2015b, 2016a, 2018), and Keating, Kelly, Smith, and Valcarcel (2019) to identify, within structural vector autoregressions, monetary policy shocks based on the contemporaneous effects those policy disturbances are allowed to have on both the federal funds rate and the rate of money growth. According to this interpretation, (10) associates a contractionary monetary policy shock – that is, a positive realization of ε_t^{mp} – with some combination of higher short-term interest rates and slower money growth, depending on the value of α_{rm}.

The fourth and fifth equations implied by (1) and (8) are entirely new and help distinguish movements in money growth triggered by monetary policy shocks from those reflecting shifts in the demand for monetary services by the non-bank public and in the

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[17] Ireland (2001) estimates an equation of this form within a dynamic, stochastic, New Keynesian model. Qureshi (2017) estimates the relationship using single equation methods.

behavior of the private banks that create deposits that contribute to broad measures of the money supply. The fourth equation takes the form of a money demand relationship,

$$m_t - p_t = \alpha_{my} y_t - \alpha_{mu} u_t + \mu^{(4)} + \sum_{j=1}^{q} B_j^{(4)} x_{t-j} + \varepsilon_t^{md}, \tag{11}$$

linking the growth rate of real money balances to the output gap as a scale variable and the user cost as an opportunity cost variable. As noted by Belongia (2006), besides their ability to track accurately movements in the non-bank public's demand for monetary services, Divisia monetary aggregates offer the additional advantage of having, in their corresponding price dual u_t, a theoretically-coherent measure of the user cost of real monetary services. By contrast, more conventional money demand specifications estimated for simple-sum aggregates typically use the short-term nominal interest rate to measure the opportunity cost of money, despite the fact that nominal interest rates reflect more closely the price of a money substitute (bonds) than the price of the liquidity services yielded by monetary assets themselves. Drawing on this distinction, (10) and (11) work to disentangle shocks to money supply from those to money demand in two ways. The first imposes the Quantity Theory's assumption that "money supply" refers to changes in the nominal quantity of money and "money demand" to changes in the real quantity of money. The second draws a sharper distinction between the role of the nominal interest rate as a variable that belongs only in the money supply function and the user cost of money as a variable that belongs only in the money demand equation.

Finally, the fifth equation implied by (1) and (8),

$$u_t = \alpha_{ur} r_t + \alpha_{um}(m_t - p_t) + \mu^{(5)} + \sum_{j=1}^{q} B_j^{(5)} x_{t-j} + \varepsilon_t^{ms}, \tag{12}$$

summarizes the behavior of the "monetary system" through which private banks create deposits that contribute to the broad money supply. Belongia and Ireland (2014) derive a theoretical relationship between the federal funds rate and the user cost of Divisia money by incorporating a competitive banking system into a dynamic, stochastic, general equilibrium New Keynesian model. In this extended model, banks hold reserves against the deposits they

issue to consumers. When the federal funds rate rises, increasing the opportunity cost of holding reserves, banks pass their higher costs along to consumers by lowering the interest rate paid on deposits. Through this channel, an increase in the federal funds rate r_t generates a simultaneous increase in the user cost of money u_t as captured by the parameter α_{ur} in (12). The additional parameter α_{mu} included here in (12) also allows u_t to rise as well in response to an increase the volume of real money balances created, as it would if banks' technology for creating deposits exhibits decreasing returns to scale.

Thus, in the expanded model, the five structural disturbances

$$\varepsilon_t = \begin{bmatrix} \varepsilon_t^{as} & \varepsilon_t^{ad} & \varepsilon_t^{mp} & \varepsilon_t^{md} & \varepsilon_t^{ms} \end{bmatrix}'$$

include the shock ε_t^{md} to money demand as well as the shock ε_t^{ms} to the monetary system that makes it more or less costly for banks to create deposits that, together with currency, provide monetary services to the non-bank public. Belongia and Ireland (2015b, 2016a, 2018) use frequentist statistical methods to identify the last three shocks, to monetary policy, money demand, and the monetary system, imposing the same structure shown here in (10)-(12) to help distinguish between money supply and money demand. The vector autoregressions in those previous studies were constrained further by hard zero restrictions on each of the non-diagonal elements of the first two rows of the matrix A shown in (8), except for the single element in the first column of the second row. These additional restrictions work to identify the model, in the frequentist sense, by imposing the stronger timing assumption that shocks to monetary policy, money demand, and the monetary system affect the aggregate price level and output only after a one-quarter lag. The Bayesian methods employed here allow these restrictions to be relaxed, while also distinguishing further between shocks to aggregate supply and aggregate demand via the specifications shown in (3) and (9). In addition, through the more flexible aggregate demand relation in (9), the Bayesian framework used here sheds light on the relative importance of the real interest rate versus real money balances in transmitting

monetary shocks to aggregate output and then, through the Philips Curve (3), to inflation as well, something that the previous studies with more restrictive assumptions were unable to do.

Student t prior distributions for the Phillips Curve parameter α_{py}, the aggregate demand elasticity α_{yr}, and the monetary policy response coefficients α_{rp} and α_{ry} are specified and calibrated exactly as before for the smaller New Keynesian model. Meanwhile, the new parameters that appear in the expanded aggregate demand relationship (9) and monetary policy rule (10) but not in their simpler New Keynesian counterparts (4) and (5) also are assigned Student t priors with two degrees of freedom and scale parameters equal to 0.3. However, both α_{ym}, measuring the direct impact of changes in real money balances on aggregate demand in (9) and α_{rm}, measuring the importance of changes in nominal money growth within the monetary policy rule (10), are assumed to have zero prior mean. These prior distributions are thereby centered so as to remain in alignment with the New Keynesian view that changes in real and nominal money play no role in shaping the dynamics of inflation, the output gap, and the short-term interest rate. But, at the same time, their large spread and fat tails leave ample opportunity for the data to either sharpen that New Keynesian perspective or shift it in favor of a more "classical" alternative.

Implementing this Bayesian exercise also requires the specification and calibration of prior distributions for the entirely new parameters that enter into the money demand and monetary system relationships (11) and (12). Belongia and Ireland (2019) specify cointegrating money demand equations for the Divisia M2 quantity aggregate, imposing a unitary income elasticity and estimating a semi-elasticity of 3.5 with respect to the Divisia M2 user cost. Interpreting these as long-run elasticities, each of these values is scaled by the factor 0.25 to fix prior means of 0.25 for α_{my} and 0.875 for α_{mu} in (11), thereby allowing for partial adjustment for real money demand. For the additional parameters in the monetary system equation (12), about which less is known, a prior mean of 3 for α_{ur} is set based on the simple

observation that, in the raw data, fluctuations in the Divisia M2 user cost appear to be about three times as large as those in the federal funds rate. And a prior mean of 0 for α_{um} is consistent with the simpler specification implied by the theoretical model in Belongia and Ireland (2014). All the Student t priors for these extra parameters have two degrees of freedom, but are assigned scale parameters equal to 10 to account for the larger amount of uncertainty that surrounds their hypothesized values. Priors for the elements of D, μ, and B_j, $j = 1,2,3,4$, meanwhile, are set and calibrated exactly as before for the three-variable New Keynesian specification, with the lag truncation parameter again set at $q = 4$.

The same procedure is used to generate draws from the posterior, except that a setting of $\xi = 0.6$ for the tuning parameter is now required to target an acceptance rate of 30 percent for the Metropolis step used to generate draws for the elements of A. And, also as before, evidence of convergence and adequate mixing of the Markov Chain is found by checking for consistent results across different randomly selected starting points and by computing the diagnostic statistics proposed by Geweke (1992). Finally, the success of the Bayesian estimation method in uncovering mutually uncorrelated structural disturbances can be assessed by examining the correlations between the fitted values of those shocks. Once again, median estimates of these correlations are typically smaller than 0.10 and never exceed 0.16 in absolute value.

Thus, this empirical exercise is designed to mimic the thought pattern of an observer of the United States economy who, while satisfied with the description that the benchmark New Keynesian model provides, stands willing to be persuaded that classical channels of monetary transmission are operative as well. The extent to which this persuasion occurs now hinges on the extent to which the posterior distributions shift in their locations away from the New Keynesian priors. And whatever dispersion may be left in the posterior distributions reflects uncertainty that remains, even after the data are analyzed carefully.

Table 3 and the second and third columns of figure 1 help communicate the results of this thought experiment. Table 3 retains the format of table 1, summarizing posterior distributions for the ten elements of the expanded matrix A from (8) by reporting medians together with 16 and 84th percentiles for the full sample period and the same three subsamples. Figure 1 again focuses on the full sample alone, but provides a more detailed comparison of the posterior (blue bars) and prior (red lines) densities for each coefficient.

Focusing first on the aggregate demand relationship, with the introduction of real balances into the expanded equation (9), the posterior distribution for the interest rate elasticity parameter again shifts to the left, placing additional weight on smaller values of α_{yr}, while the posterior for the new coefficient on real balances shifts to the right, favoring positive values of α_{ym}. These results are strongest when the model is estimated with data running back to 1967:1, but even for the post-1984 and post-2000 subsamples, the posterior distributions place heavy weight on positive values of α_{ym}. These results serve, therefore, as a first indication that classical channels of monetary transmission, working through changes in the money stock on aggregate demand, have been and continue to be important, despite their absence from the New Keynesian model.

Table 3 and figure 1 show, as well, that the data prefer a more classical version of the monetary policy rule (10), in which money growth enters with a sizeable median coefficient of $\alpha_{rm} = 1.2$ when estimated with the full sample of data and remains important relative to inflation and output growth across all subsamples. This result is consistent with previous findings by Ireland (2001) and Qureshi (2017) that point towards a continued role for money in estimated Taylor Rules, even in samples covering the Great Moderation. Table 4 expands on these results by reporting the sums of the coefficients on contemporaneous and lagged values of each of the five variables entering into the policy rule (10). These long-run response parameters, like those from table 2, suggest that Federal Reserve policy has always been characterized by a substantial degree of interest rate smoothing. And in table 4, just as in

table 2, the post-1984 period covering the Great Moderation appears as the only episode during which the funds rate responded more strongly to inflation than to the output gap. In table 4, however, Divisia money growth enters the policy rule in the full sample and across all subsamples. Moreover, while the median long-run coefficient on money growth declines, moving from the pre-1984 to the post-1984 subsamples, it rises again when estimated over the most recent, post-2000 subsample. Therefore, the results here, like those in Belongia and Ireland (2018), suggest that movements in money growth help capture some of the effects that the Fed's unconventional policy actions, especially its large-scale asset purchases, had on the economy while the federal funds rate was constrained by the zero lower bound.

For the model's remaining parameters, table 3 and figure 1 show that the Phillips Curve slope coefficient α_{py} generally appears larger when the VAR is expanded to include the additional monetary variables. Thus, by providing a more complete description of aggregate demand and monetary policy, the classical specification also works to link inflation more closely to the output gap through the aggregate supply relation. Table 3 and figure 1 also indicate that while all of the posterior distributions tighten considerably around median values of the expected sign, considerable uncertainty surrounds the coefficients appearing in the money demand curve (11) and the monetary system equation (12).

The right-hand column of figure 2, meanwhile, reveals that the incorporation of monetary variables into the expanded VAR "fixes" the positive response in the output gap that follows an adverse supply shock shown on the left for the smaller-scale, New Keynesian specification. Like the larger estimate of the Phillips Curve slope coefficient, this result suggests that, by helping to isolate disturbances to aggregate demand and monetary policy, the extra information in Divisia money growth also sharpens the model's inferences about aggregate supply. Meanwhile, in the second column of figure 3, all impulse responses to the expanded model's aggregate demand shock take their expected signs, with inflation, the output gap, and the nominal interest rate rising together after an expansionary disturbance. Real money balances, meanwhile, decline persistently following the shock, consistent with the

positive coefficients that appear on real balances in the estimated aggregate demand relationship (9). This persistent decline in real balances is, in fact, the main feature that distinguishes the effects of aggregate demand disturbances, shown in figure 3, from those of monetary policy shocks, shown in figure 4. The latter set of graphs implies that an expansionary monetary policy shock that raises inflation and the output gap works, instead, to increase the level of real balances.

Figure 4, in fact, provides the most striking evidence for the presence of distinctive, classical channels of monetary transmission not suggested by contemporary macroeconomic models. In the top two panels from the right-hand column, a contractionary monetary policy shock is followed consistently by persistent declines in both inflation and the output gap; here, as in Leeper and Roush (2003), the addition of a monetary aggregate to the information set also fixes the counterintuitive increase in the inflation rate that immediately follows the monetary shock in the smaller, New Keynesian model that uses interest rates alone. The view provided by figure 4 is, therefore, quite different from that provided by a real business cycle, or purely "neoclassical," perspective. On the other hand, as shown vividly the in the figure's third and fourth rows, a monetary tightening gets signaled in the expanded model as a persistent decline in the rate of nominal money growth. Although the fall in the nominal interest rate seems easy to explain. with reference to the Fisher (1930) effect, as a reflection of the declines in money growth and inflation that also follow this contractionary shock, it works against popular intuition, based partly on the New Keynesian view, that associates lower nominal interest rates with a monetary policy easing instead.

To what extent do these results corroborate Irving Fisher's (1923, 1925) description of the "so-called business cycle" as a product of the "dance of the dollar?" Figure 5 answers this question by using the classical specification to break historical movements in each variable over the full sample period down into components attributable to each of the model's five structural disturbances, placing posterior 16 and 84th percentile bands around the median estimates using the same methods outlined by Baumeister and Hamilton (2018). The graphs in column one show that, according to the estimated model, aggregate supply shocks have

contributed most importantly to high-frequency movements in inflation. Those in column two, meanwhile, assign an important role to aggregate demand disturbances, not only in driving business cycle fluctuations in output and inflation, but also to movements in interest rates and money growth as monetary policy has adjusted systematically to these shocks.

Figure 5 also reveals, however, that monetary policy disturbances have contributed importantly to historical volatility in inflation and the output gap. The top panel in the figure's third column indicates that from the late 1970s through the mid 1990s, monetary policy shocks generated a cumulative reduction in the inflation rate of nearly four percentage points. The second panel in the same column, meanwhile, attributes to monetary policy shocks significant declines in output during the Volcker disinflation of the early 1980s and the Great Recession of 2007-2009.[18] Figure 6 compares the five-variable model's implications along these lines to the corresponding implications of the benchmark, three-variable New Keynesian specification, to highlight further the consequences of incorporating money into the information set. The classical estimates show much larger effects of monetary policy shocks in explaining historical movements, especially in inflation but for the output gap as well. Again, these results point to the workings of additional channels of monetary transmission, captured by movements in the money stock above and beyond movements in interest rates.

5. Conclusion

Though based on New Keynesian priors, the expanded VAR estimated here provides a posterior view of monetary policy and its effects on the economy that is highly "classical" instead. Within this estimated model, changes in real money balances play a role, alongside movements in real interest rates, in transmitting the effects of monetary policy to aggregate output over the period during which nominal rigidities prevent prices from adjusting fully. Likewise, changes in nominal money growth signal, much more clearly than changes in

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[18] Figure 5 also reveals that, according to the estimated classical specification, unusually large money demand shocks hit the economy during the financial crisis, presumably reflecting flight-to-quality dynamics. This result reinforces the message from Belongia and Ireland (2018), that the Fed might have been able to provide additional monetary stimulus during and after the crisis by targeting even faster growth rates for the monetary aggregates.

nominal interest rates, whether monetary policy is expansionary or contractionary. The estimated model attributes sizable movements in inflation and the output gap to monetary policy disturbances, particularly during the disinflationary recessions of the early 1980s and the Great Recession of 2007-2009.

All of these results appear consistent with ideas expressed long ago by Fisher (1923, 1925, 1926) and Working (1923, 1926), that Quantity Theoretic interactions between money supply and money demand help shape the effects that Federal Reserve policy has on both inflation and output. None of these results, however, is easily reconciled with more recent theories of aggregate fluctuations. Real business cycle models, representing the latest stage in the evolution of "neoclassical" thought, cannot explain the interactions between nominal and real variables that appear to be as important today as they were in Fisher's time. New Keynesian models based on nominal price and wage rigidities do a better job, of course, at capturing the short-run relationships between output and inflation first noted by Fisher (1926) and later incorporated into the Phillips Curve.[19] On the other hand, the Bayesian priors that are updated here suggest strongly that, by focusing entirely on interest rates and excluding measures of money, the strict New Keynesian model provides an overly narrow view of channels through which monetary policy affects the economy.

These results call out for a new class of models, or at least substantial extensions of existing ones, that provide a richer and more realistic description of the monetary business cycle. They call out, as well, for a reconsideration of the role that measures of money play in the formation of Federal Reserve policy. Bernanke (2006) discusses the historical and intellectual trends that caused the Fed to gradually deemphasize the monetary aggregates in its policymaking process, beginning in the early 1980s. The results presented here and in Keating, Kelly, Smith, and Valcarcel (2019), however, reveal that valuable information is contained in Divisia monetary aggregates, both about monetary policy and its effects on the economy, even in data samples including the 1980s and running through the present. Perhaps, after a long hiatus, research focusing the classical channels of transmission

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[19] See Laidler (1978, 1990) and Taylor (2017) for more on this point.

discussed by Fisher and Working can contribute importantly to the design of effective monetary policy strategies.

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Table 1. Impact Coefficients: Three-Variable New Keynesian Specification

| | Prior Percentiles | | | Posterior Percentiles | | | | | | | | | | | |
| | | | | Full 1967:1 – 2017:4 | | | Pre-1984 1967:1 – 1983:4 | | | Post-1984 1984:1 – 2007:4 | | | Post-2000 2000:1 – 2017:4 | | |
	50	16	84	50	16	84	50	16	84	50	16	84	50	16	84
α_{py}	0.50	0.10	0.90	0.06	–0.00	0.11	0.17	0.10	0.23	–0.08	–0.19	0.03	0.13	–0.02	0.27
α_{yr}	1.00	0.60	1.40	0.50	0.35	0.68	0.77	0.56	0.99	0.47	0.27	0.70	0.39	0.22	0.57
α_{rp}	0.38	–0.02	0.77	0.26	0.12	0.38	0.53	0.28	0.83	0.29	0.20	0.38	0.07	–0.02	0.16
α_{ry}	0.13	–0.27	0.52	0.85	0.69	1.03	1.22	0.98	1.50	0.43	0.34	0.53	0.30	0.20	0.39

Note: Each impact coefficient has a prior Student t distribution with the indicated median and mean, scale parameter 0.3, and 2 degrees of freedom.

Table 2. Long-Run Monetary Policy Response Coefficients: Three-Variable New Keynesian Specification

| | Posterior Percentiles | | | | | | | | | | | |
| | Full 1967:1 – 2017:4 | | | Pre-1984 1967:1 – 1983:4 | | | Post-1984 1984:1 – 2007:4 | | | Post-2000 2000:1 – 2017:4 | | |
	50	16	84	50	16	84	50	16	84	50	16	84
p	0.14	0.09	0.18	0.22	0.10	0.35	0.14	0.08	0.20	0.02	–0.06	0.10
y	0.23	0.18	0.27	0.41	0.29	0.53	0.12	0.08	0.16	0.08	0.05	0.12
r	0.94	0.92	0.97	1.10	1.02	1.19	0.93	0.90	0.95	0.92	0.90	0.95

Note: The long-run coefficient for each variable corresponds to the sum of the impact and autoregressive coefficients on that variable in the estimated monetary policy rule.

Table 3. Impact Coefficients: Five-Variable Classical Specification

|	Prior Percentiles			Full 1967:1 – 2017:4			Pre-1984 1967:1 – 1983:4			Post-1984 1984:1 – 2007:4			Post-2000 2000:1 – 2017:4		
	50	16	84	50	16	84	50	16	84	50	16	84	50	16	84
α_{py}	0.50	0.10	0.90	0.25	0.18	0.33	0.27	0.18	0.36	0.17	0.05	0.30	0.29	0.16	0.42
α_{yr}	1.00	0.60	1.40	0.24	0.11	0.39	0.22	−0.04	0.57	0.51	0.27	0.79	0.43	0.23	0.66
α_{ym}	0.00	−0.40	0.40	0.40	0.24	0.59	0.87	0.27	1.41	0.36	0.21	0.56	0.19	0.06	0.36
α_{rp}	0.38	−0.02	0.77	0.83	0.55	1.22	0.62	0.28	1.14	0.56	0.40	0.76	0.28	0.13	0.46
α_{ry}	0.13	−0.27	0.52	1.32	0.95	1.71	1.49	1.03	1.96	0.80	0.59	1.04	0.66	0.42	0.96
α_{rm}	0.00	−0.40	0.40	1.23	0.97	1.57	1.08	0.66	1.73	0.32	0.21	0.47	0.47	0.33	0.68
α_{my}	0.25	−12.96	13.46	0.75	0.40	1.13	0.56	−0.58	2.25	0.75	0.11	1.40	0.64	−0.13	1.53
α_{mu}	0.88	−12.34	14.09	0.77	0.66	0.91	0.98	0.75	1.37	0.93	0.77	1.14	1.12	0.90	1.47
α_{ur}	3.00	−10.21	16.21	4.97	4.64	5.35	3.25	3.09	3.41	10.78	9.37	12.53	16.21	12.91	20.92
α_{um}	0.00	−13.21	13.21	0.73	0.49	0.98	0.11	−0.06	0.29	2.35	1.80	3.05	3.31	2.19	4.92

Note: Each impact coefficient in the aggregate supply, aggregate demand, and monetary policy equations has a prior Student *t* distribution with the indicated median and mean, scale parameter 0.3, and 2 degrees of freedom. Each impact coefficient in the money demand and monetary system equations has a prior Student *t* distribution with the indicated median and mean, scale parameter 10, and 2 degrees of freedom.

Table 4. Long-Run Monetary Policy Response Coefficients: Five-Variable Classical Specification

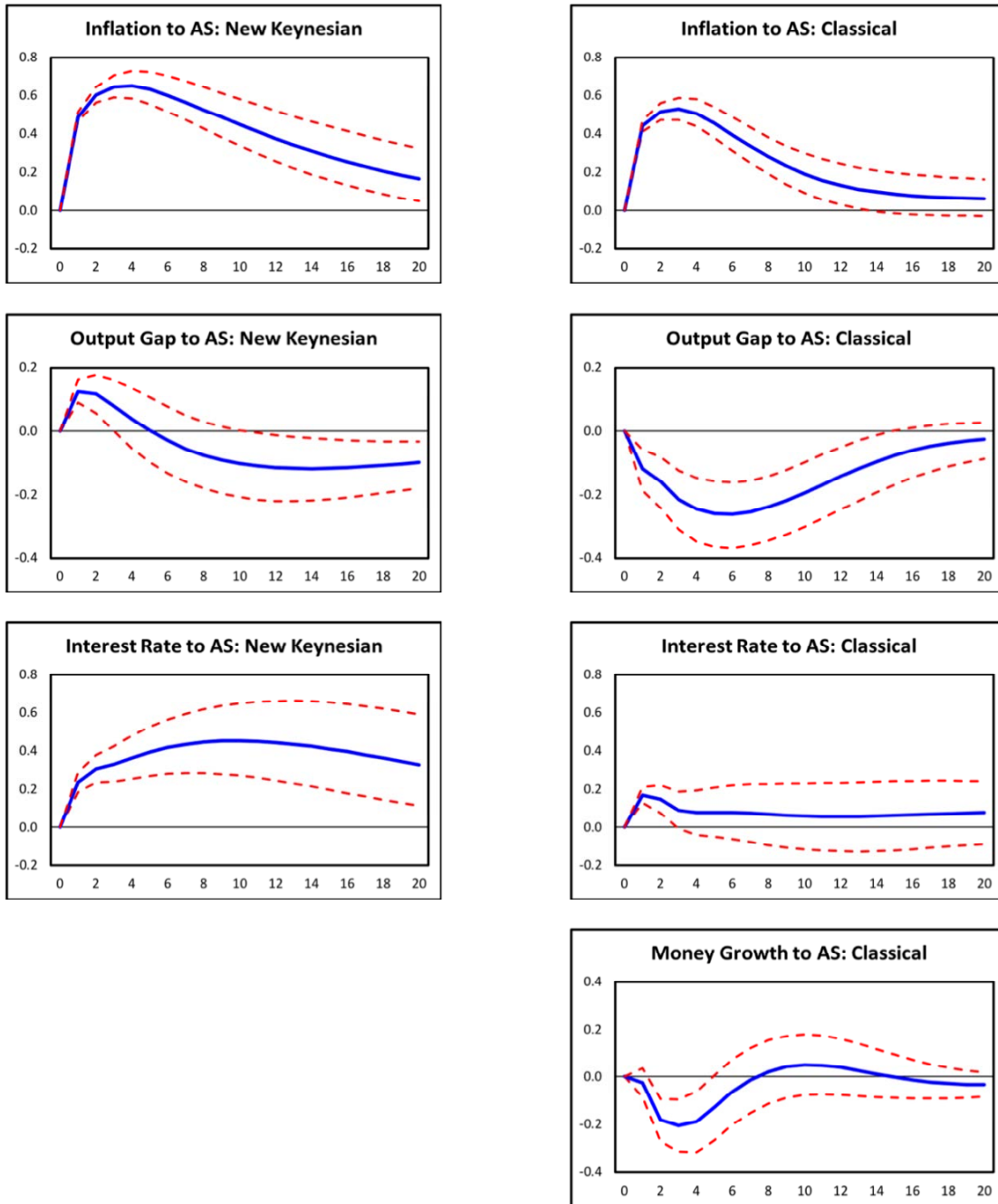|	Posterior Percentiles											
	Full 1967:1 – 2017:4			Pre-1984 1967:1 – 1983:4			Post-1984 1984:1 – 2007:4			Post-2000 2000:1 – 2017:4		
	50	16	84	50	16	84	50	16	84	50	16	84
p	0.12	0.03	0.21	0.12	−0.08	0.31	0.29	0.18	0.42	0.01	−0.14	0.16
y	0.12	0.02	0.21	0.65	0.47	0.88	0.11	0.01	0.20	0.11	0.04	0.19
r	0.93	0.85	1.02	1.36	1.10	1.68	0.91	0.86	0.96	0.96	0.88	1.04
m	0.25	0.15	0.36	0.32	0.10	0.64	0.10	0.05	0.17	0.17	0.09	0.27
u	0.05	0.02	0.08	0.05	−0.03	0.13	0.00	−0.02	0.02	0.00	−0.02	0.03

Note: The long-run coefficient for each variable corresponds to the sum of the impact and autoregressive coefficients on that variable in the estimated monetary policy rule.

Figure 1. Prior and Posterior Densities of Impact Coefficients
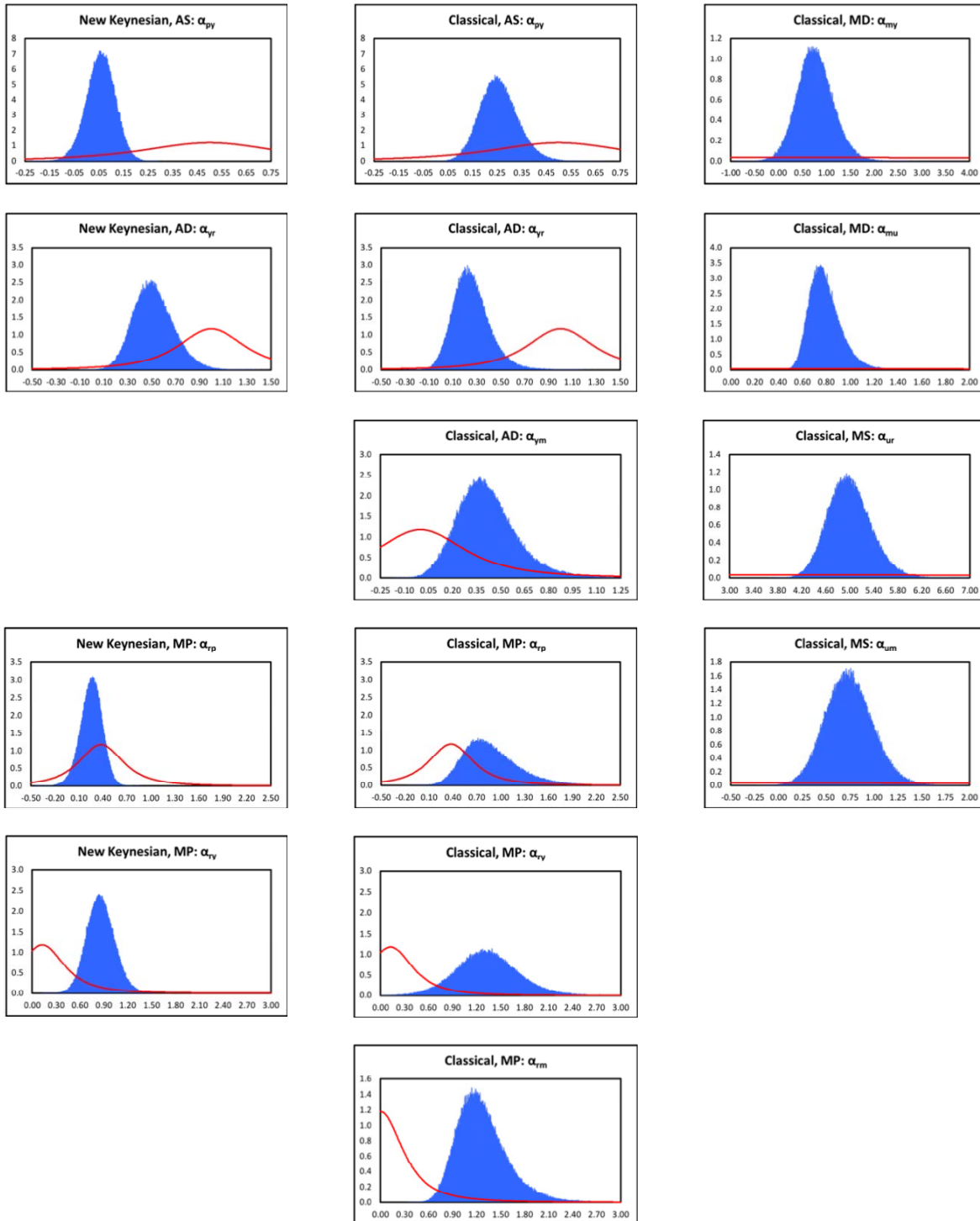
Note: Each panel illustrates the prior (red line) and posterior (blue bars) densities of the indicated parameter from the indicated specification.

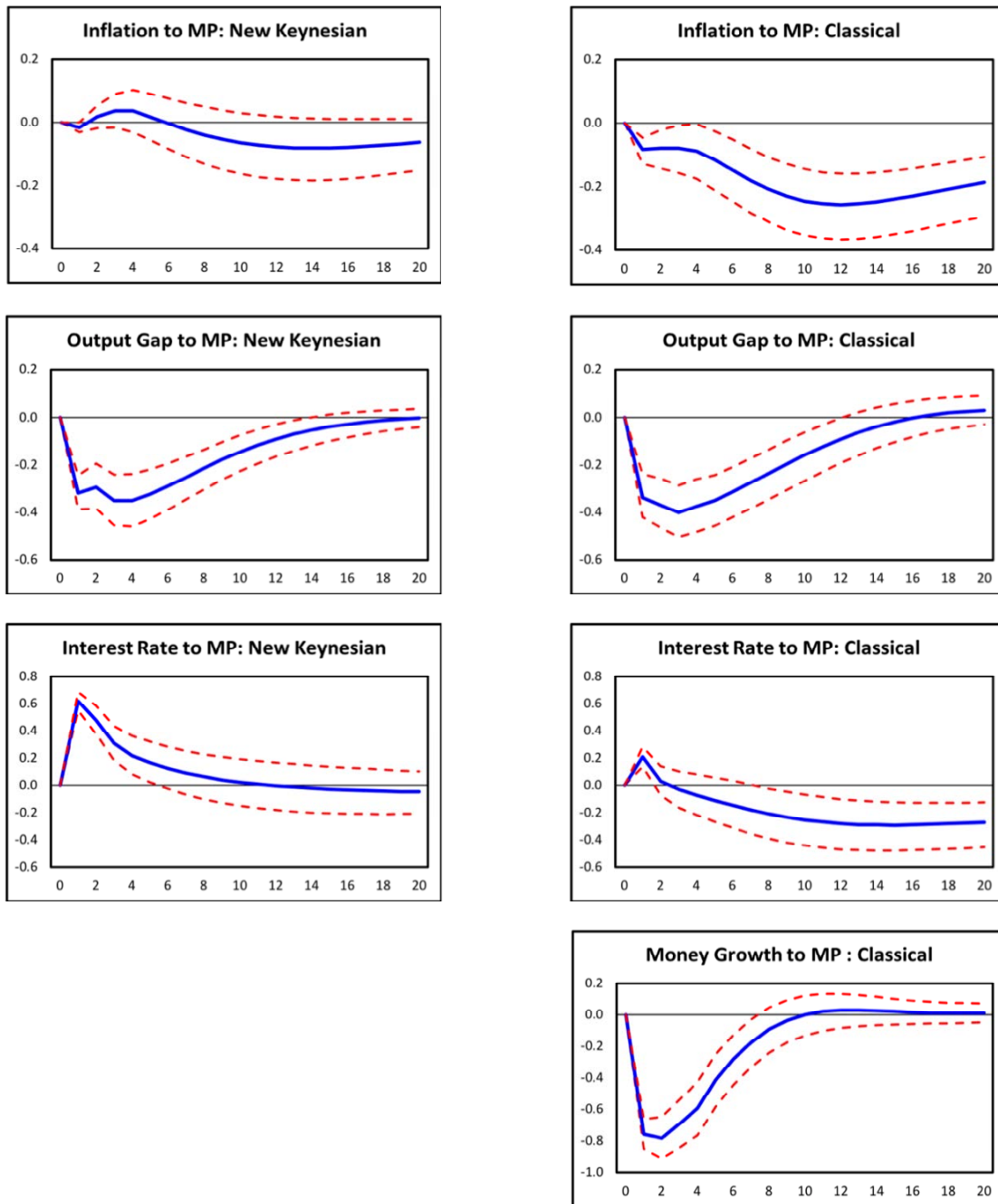Figure 2. Impulse Responses: Aggregate Supply Shock

Note: Each panel shows the median (solid blue line) and the 16th and 84th percentiles (dashed red lines) of the posterior distribution of the impulse response of the indicated variable to a one-standard deviation aggregate supply shock.
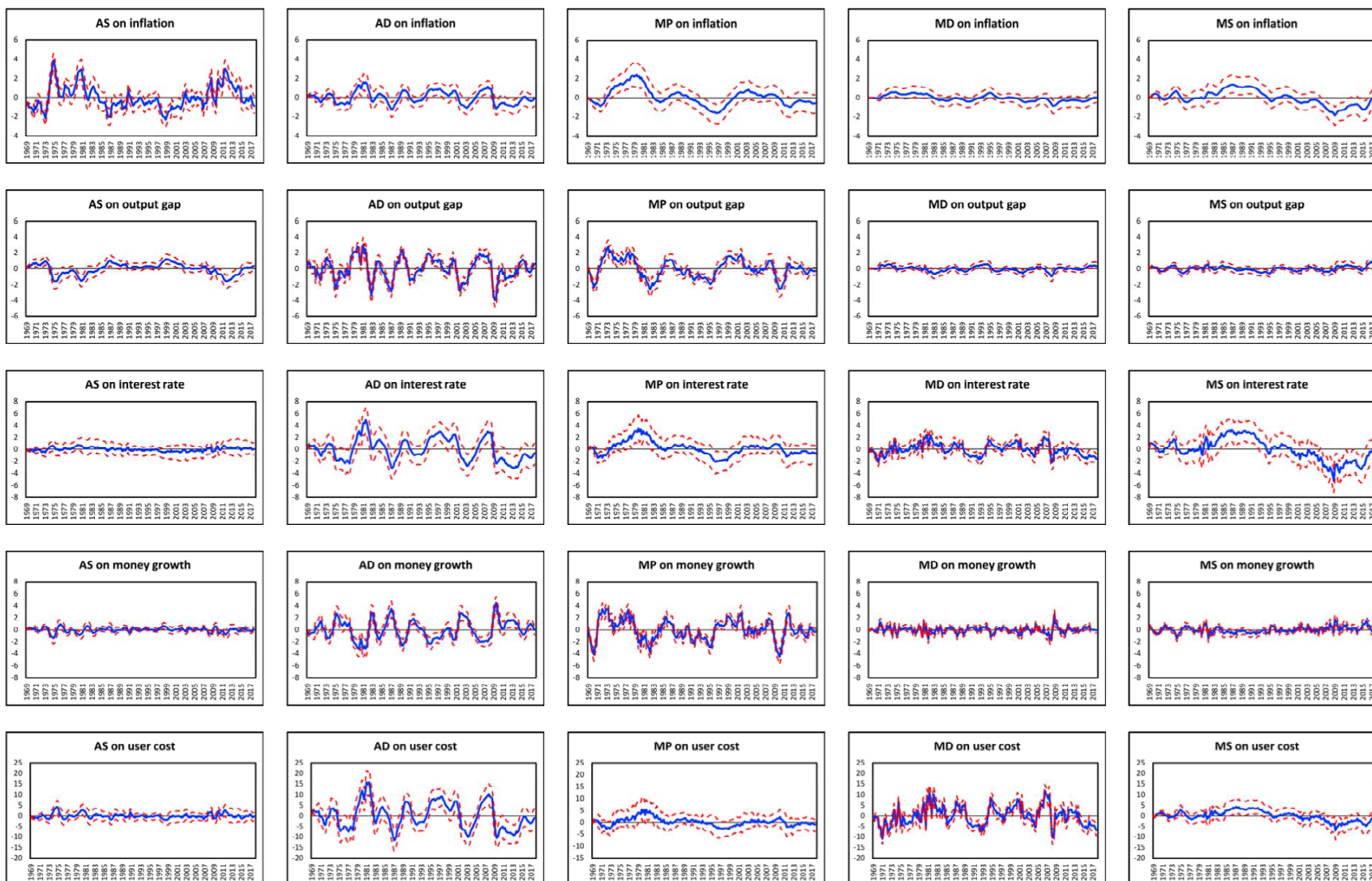
Figure 3. Impulse Responses: Aggregate Demand Shock
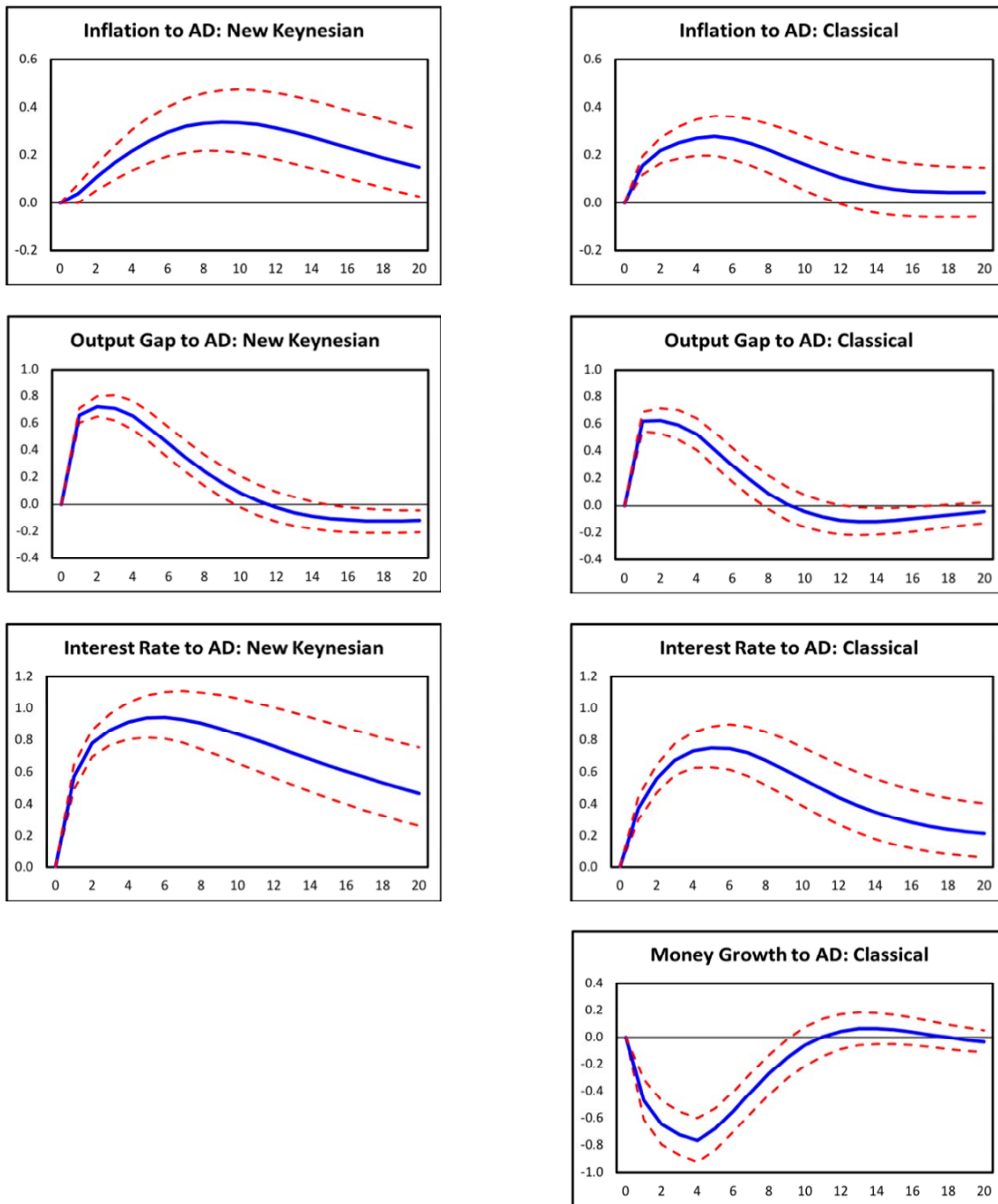
Note: Each panel shows the median (solid blue line) and the 16th and 84th percentiles (dashed red lines) of the posterior distribution of the impulse response of the indicated variable to a one-standard deviation aggregate demand shock.
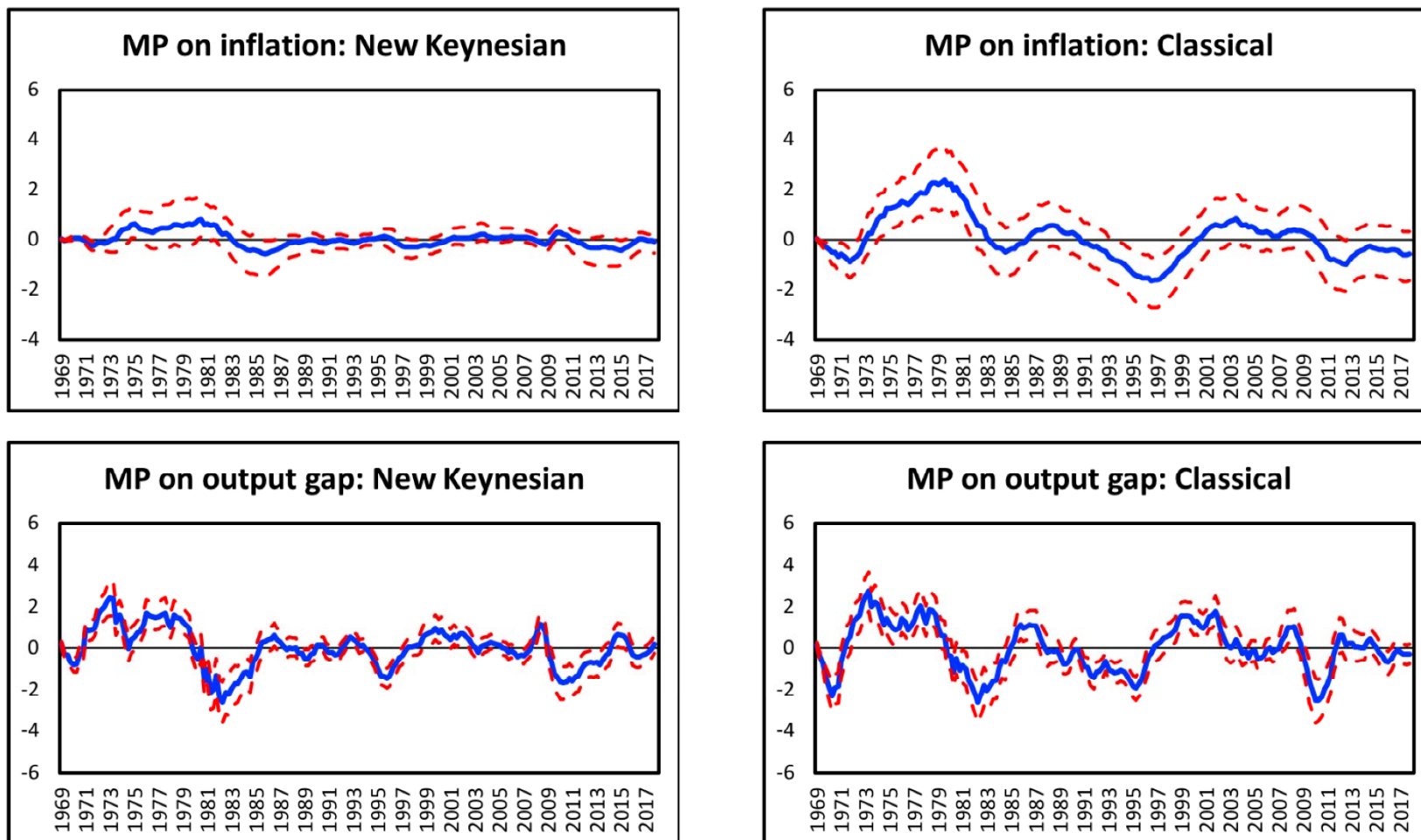
Figure 4. Impulse Responses: Monetary Policy Shock

Note: Each panel shows the median (solid blue line) and the 16th and 84th percentiles (dashed red lines) of the posterior distribution of the impulse response of the indicated variable to a one-standard deviation monetary policy shock.

Figure 5. Historical Decomposition: Five-Variable Classical Specification

Note: Each panel shows the median (solid blue line) and the 16th and 84th percentiles (dashed red lines) of the posterior distribution of the historical effects of aggregate supply (AS), aggregate demand (AD), monetary policy (MP), money demand (MD), and monetary system (MS) shocks.

Figure 6. Historical Contributions of Monetary Policy Shocks to Movements in Inflation and the Output Gap

Note: Each panel shows the median (solid blue line) and the 16th and 84th percentiles (dashed red lines) of the historical effects of monetary policy shocks, as implied by the three-variable New Keynesian specification (left column) and the five-variable Classical specification (right column).