A Divisia Measure of the Money Supply for Mexico*

Luis Fernando Colunga-Ramos† Victor J. Valcarcel‡

This Draft: September 05, 2020

Abstract

Currently, Banco de México measures money as a simple sum of the different monetary assets included at four levels of aggregation: M1, M2, M3, and M4. Seminal work by Barnett (1980) and many who followed since have amply demonstrated simple-sum aggregation is highly problematic. A wealth of monetary literature has shown Divisia indices of monetary aggregates are both theoretically and empirically superior to their simple-sum counterparts. While Divisia indices are available for the U.S., the U.K, the Euro area and a few other developed economies, no similar measure currently exists for Mexico.

This paper produces the first measure of Divisia money for the Mexican economy under the *Banco de México's Methodological Redefinition of 2018* of its monetary aggregates. Under standard and time-varying constructs of well-accepted structural VAR identifications, we find that Divisia M4 as an indicator of monetary policy yields responses of industrial production and prices that are in every case at least as sensible as (and often an improvement over) their counterpart specifications with a short-term offer rate as the indicator. Importantly, we find the resolution of the price puzzle in our Divisia specifications do not require expanding the information set of the VAR with commodity prices. We reach similar conclusions for Mexico to those Keating et al. (2019) arrive at for the U.S. economy.

Keywords: DIVISIA, money supply, user costs, monetary policy shocks, VAR

JEL classification codes: E3, E4, E5

*Acknowledgments deferred for review.

†Economics Political and Policy Sciences, University of Texas at Dallas, LuisFernando.ColungaRamos@utdallas.edu

‡University of Texas at Dallas, victor.valcarcel@utdallas.edu

1 Introduction

The central bank of Mexico—Banco de México—defines money as: "the set of assets of an economy that people are regularly willing to use as a means of payment to buy and sell goods and services." Many central banks, including Banco de México, measure money by simply adding up different monetary assets. An implicit assumption of the methodology is that all monetary assets included in the aggregate—irrespective of their associated yields—are perfect substitutes.

Given that the array of monetary assets typically included in monetary aggregates have varying degrees of "moneyness," adding them up with equal weights may lead to measurement error. Foundational work in Barnett (1978) and Barnett (1980) first highlights this important concern. Chrystal and MacDonald (1994) dubbed the essential message of Barnett's work—that simply summing monetary assets imposes, unrealistically, that they are perfect substitutes for each other even when they render different yields—as the "Barnett Critique." Belongia and Ireland (2014) emphasize the Barnett Critique is *"...as relevant today as it was 30 years ago."* Furthermore, Belongia (2000) notes that:

"Central banks continue to publish simple-sum measures of the money stock and draw policy inferences from their behavior even though it has been demonstrated conclusively that these data violate basic principles of economic and index number theory. As such, any in-sample results based on simple sum data must be spurious."

There has been an upsurge in empirical monetary research in the U.S.—particularly in the aftermath of the zero-lower-bound period that began in 2008—that has shown how a correct measure of money, such as the Divisia index, can be useful in the identification and estimation of the impact of monetary policy shocks. For example, in an investigation of the long-run relationship between nominal and real macroeconomic variables, Serletis and Gogas (2014) find persuasive evidence that Divisia monetary aggregates play an important role in money demand theory. In another recent paper, with a comprehensive investigation of Divisia aggregates, Belongia and Ireland (2019) show convincingly that money demand in the U.S. is more stable than previously thought. Finally, Keating et al. (2019) give compelling and robust evidence that the Divisia index is an appropriate indicator of U.S. monetary policy shocks during normal conditions and financial crises.

Most of this work focuses on the U.S. and, to a lesser extent, other countries where Divisia monetary data is available. No such measure exists for aggregate money balances in Mexico. This paper fills that void.

We build a Divisia index for each of the monetary aggregates that the Banco de México produces. The source material and all pertaining information on monetary assets included in each of the four major aggregates are obtained exclusively from the Banco de México.

The rest of this paper is structured as follows: Section 2 presents a brief literature review and details the methodology to construct each Divisia Index. Section 3 outlines the monetary assets that the Banco de México utilizes in the production of their official simple-sum measures. Section 4 expands on detail of our construction of the Divisia indices and describes the behavior of Divisia measures of M1, M2, M3, and M4 for Mexico. Section 5 identifies monetary policy shocks with our Divisia indicators that we produce and compares them to benchmark VAR specifications with a short-term offer rate as the policy indicator. Section 6 extends the analysis to a time-varying-parameter (TVP) approach and elaborates on the robustness of our results. Section 7 provides some final remarks.

2 Divisia Background

The landmark work in Barnett (1978) and Barnett (1980) establishes the methodology underlying the aggregation of monetary assets. This foundational work inspired a large literature on the benefits of Divisia aggregates that spans the last four decades. For example, Anderson et al. (1997) indicate that the methodology for the aggregation of monetary assets requires making some necessary—but not sufficient—assumptions such as: 1) existence of a theoretical aggregate function defined on a block of decision variables, 2) efficient allocation of resources over the block that can be factored from the decisions of the agents, 3) no rationing of quantities within the block, and 4) the existence of a representative agent if the information is to be aggregated among agents.

There are other assumptions about the micro foundations of the aggregation of monetary assets, such as: a representative individual price taker that maximizes an inter-temporal utility function in which monetary assets are weakly separable from other consumer goods and leisure subject to a set of restrictions. These assumptions can be understood through the seminal model of Barnett (1980) as adapted by Anderson et al. (1997).

The simple-sum measure of money published by Banco de México ($\bar{M}_t$) adds up N-arbitrary different components (implicitly imposing equal weights) were:

$$\bar{M}_t = \Sigma_{i=1}^{N}(M_{it}) \tag{1}$$

where M_{it} denotes the level of the i_{th}-monetary asset. We define $\delta_{j,t}$ as the share of the j_{th}-component in the monetary aggregate:

$$\delta_{j,t} = \frac{M_{jt}}{\Sigma_{i=1}^{N}(M_{it})} \tag{2}$$

As Barnett et al. (1992) noted, the simple sum aggregation in equation (1) implies that all components are perfect substitutes, where all indifference curves and isoquants over those components must be linear with slopes of minus one. The perfect substitutability condition is problematic when aggregating over monetary assets with widely different yields, such as are found in the Banco de México's M4 aggregate.

Therefore, we turn to the derivation of Divisia monetary aggregates for Mexico. The production of the index is firmly embedded in microeconomic theory. Consider a decision problem for a representative household over monetary assets. Let m_t' be the vector of real balances of monetary assets in time period t and r_t denote the vector of holding-period yield for those assets. The one-period holding yield of a benchmark asset is denoted as R_t. The monetary service this benchmark asset provides is strictly associated with investment returns and it otherwise generates negligible liquidity services. R_t is typically referred to as the benchmark rate that corresponds to a notional maximum holding yield available to households and firms during time period t. The decision problem features the maximization of utility from monetary assets subject to a restriction of total planned expenditure in monetary services y_t.

$$\begin{gathered} \text{Max } u(m_t) \\ \text{subject to } \pi_t' m_t = y_t \end{gathered}$$

Barnett (1978) shows the real user cost for each weakly separable group of monetary assets is calculated by

$$\pi_{it} = \frac{R_t - r_{it}}{1 + R_t} \tag{3}$$

The solution to this microeconomic problem shows that the exact monetary aggregate (DM_t) should equal the utility generated from an optimal allocation of monetary assets m_t^* to a representative agent. The real user cost in (3) and the quantity of a given monetary asset jointly determine the expenditure share of the asset relative to the total expenditure of monetary services. The growth rate of the monetary aggregate (and its price dual) is determined by the growth in its underlying monetary assets (and their own real user costs) weighted by their respective expenditure shares, which are themselves functions of real user costs of the form described in (3). The following describes the aggregate quantity index and its associated aggregate user cost:

$$\frac{d\log DM_t}{dt} = \sum_i s_{it}\frac{d\log m^*_{it}}{dt} \tag{4}$$

$$\frac{d\log \Pi_t}{dt} = \sum_i s_{it}\frac{d\log \pi_{it}}{dt} \tag{5}$$

where s_{it} is the expenditure share of each monetary asset in the total expenditure.

$$s_{it} = \frac{\pi_{it}m^*_{it}}{y_t} \tag{6}$$

The real user cost dual satisfies Fisher's factor reversal in continuous time

$$\Pi_t M_t = \pi'_t m_t \tag{7}$$

While the microfoundations for the construction of a Divisia index describe the continuous service flow rendered by monetary assets, accounting standards of many central banks—including Banco de México—require a discrete-time approximation. Barnett (1980) proposed the following Tornquist-Theil Divisia index:

$$\frac{DM_t}{DM_{t-1}} = \prod_{i=1}^{N}\left(\frac{m^*_{it}}{m^*_{it-1}}\right)^{\frac{1}{2}(s_{it}+s_{i,t-1})} \tag{8}$$

With a log transformation of equation (8), it is straightforward to see that the growth rate (log difference) of the Divisia index is the share-weighted average of the growth rate of the components quantities, which is a discrete-time approximation of equation (4)

$$\log DM_t - \log DM_{t-1} = \sum_{i=1}^{N}\bar{s}_{it}(\log m^*_{it} - \log m^*_{i,t-1}) \tag{9}$$

where

$$\bar{s}_{it} = \frac{1}{2}(s_{it} + s_{i,t-1}) \tag{10}$$

This formulation has been used by the Federal Reserve in its production of money-zero-maturity as well as the Center for Financial Stability (CFS) to construct Divisia indices for the U.S.

Hancock (2005) describes the slightly different formulation that the Bank of England employs as follows:

$$\frac{\Delta DM_t}{DM_t} = \sum_{i=1}^{N} \left(\frac{1}{2}\right) (\omega_{i,t} + \omega_{i,t-1}) \left(\frac{\Delta m_{it}^*}{m_{it-1}^*}\right) \tag{11}$$

where the weights are defined by

$$\omega_{i,t} = \frac{(R_t - r_{it})\, m_{it}^*}{\sum_{j=1}^{N} (R_t - r_{jt})\, m_{jt}^*} \tag{12}$$

Due to a cancellation of the $\frac{1}{1+R_t}$ terms in the definition of the user cost (π_{it}) it can be shown that $\omega_{i,t} = s_{it}$. Thus, the single difference between equation (9) and equation (11) is that the former is in log differences and the latter in growth rates.

3 The Banco de México (BOM) Monetary Aggregates

The Center for Financial Stability (CFS) in New York (a think tank), produces an array of Divisia indices for the United States. Similarly, the Bank of England produces and maintains up-to-date Divisia money balances for the United Kingdom. These are the two best-known institutions that construct and freely disseminate officially released Divisia data.[1] Otherwise, there has been a dearth of officially released measures of Divisia money balances for other countries. However, many Divisia measures for various countries have been produced at one time or another by academics. These tend to occur within academic works that once published are seldom updated.

The CFS categorizes a number of academic studies that, in the past, have produced Divisia data. These academic works have at some point generated Divisia indices for nearly 50 countries.[2] Most of these works were conducted in the first decade of the 2000s, with the United States, the United Kingdom and the European Union receiving the most attention. Some more recent constructions include: Barnett et al. (2013), Binner et al. (2009), and Darvas (2015) among others. Although the CFS lists a single work that produced a Divisia index for Mexico, that particular study was conducted nearly 30 years ago by Musi (1990) as part of a doctoral thesis at the University of Texas at Austin. The data gathering and

[1] There has been some conjecture that the European Central Bank also produces a Euro-area measure. However, this cannot be corroborated. If they produce a measure, it is not generally released to the public.

[2] These include: Australia, Austria, Bahrain, Barbados, Belgium, Brazil, Bulgaria, Canada, Chile, China, Denmark, European Monetary Union, Finland, France, Germany, Hungary, India, Indonesia, Iran, Israel, Italy, Japan, Kuwait, Malaysia, Mexico, Myanmar, Nepal, Netherlands, Oman, Pakistan, Peru, Poland, Qatar, Saudi Arabia, Singapore, South Korea, Spain, Sri Lanka, Switzerland, Taiwan, Thailand, Turkey, United Arab Emirates, United Kingdom, United States, and Uruguay.

production was discontinued at the conclusion of the thesis. Furthermore, the Banco de México has undertaken significant reforms in their data collection and classification since then. Thus, our purpose is to construct Divisia indices for the four major aggregates that Banco de México produces. We plan to update the indices in the future and make them publicly available.

The main source of information on monetary aggregates and interest rates is Banco de México.[3] Central Bank data is a recurrent measure in other studies that build Divisia indices, and it is generally desirable as it generates confidence and certainty because it is widely transparent.

Banco de México presents information on monetary aggregates under two methodologies, one implemented in 1999 and another one in 2018. The main differences between the 2018 methodology and the 1999 methodology are associated with greater precision and availability of financial instruments that enter into the consideration as constituting money in the broad sense.[4] Banco de México notes that these modifications adhere to the standards that the International Monetary Fund (IMF) made available in 2016 in its Manual of Monetary and Financial Statistics. Thus, statistics from the 2018 methodology render a more direct international comparison with other central banks.

Given that the data from the 2018 methodology are considered the better statistics—in that such information is aligned to the highest international standards—we employ this vintage in our construction of the Divisia index.[5].

Banco de México officially produces four major aggregates of the money supply. Table 1 gives a detailed description on the stocks (in billion pesos) of each of the extant components in M1, M2, M3, and M4 for January 2019 under the 2018 methodology.

As the table outlines for January 2019, M1 is the narrowest aggregate, which comprises currency and demand deposits in both commercial banks and other popular thrift and credit entities. Demand deposits in Mexican banks are typically decoupled into current account deposits—which are non-interest bearing—and checking accounts, which have typically yielded interest. It can be noted that narrow-money M1 as a proportion of the broadest aggregate

[3]We sought other sources of interest rate information (i.e. Comisión Nacional Bancaria y de Valores (CNBV) and Comisión Nacional para la Protección y Defensa de los Usuarios de Servicios Financieros (CONDUSEF)) through requests for public information from the Instituto Nacional de Transparencia, Acceso a la Información y Protección de Datos Personales (INAI), but these requests were unfortunately unsuccessful. Consequently, only public information available on the Central Bank's website was utilized.

[4]In addition, another classification for financial instruments that do not serve as broad money was also produced. Furthermore, under the 2018 methodology some other changes were made to the measurement of internal financial assets and bank financing.

[5]For more details on the changes in Methodology 2018, see the Bank of México's online document (Spanish text): Redefinicion de los Agregados Monetarios y Medicion de los Activos Financieros Internos emitidos por el Banco de México en 2018. https://www.banxico.org.mx/apps/sie

available for Mexico (M4) represents 35.1 percent, which is distributed mainly in deposits of immediate enforceability in banks (23.2 percent) and currency (11.7 percent).

M2 adds savings in banks and other loan institutions, as well as Money-Market Mutual Funds shares (MMMFs) and repurchase agreements to balances included in M1. Altogether, these assets included in M2 that are not reflected in M1 constitute about 35.3 percent of M4. The most important component is savings in banking institutions held by residents (15.3 percent of M4), next are MMMFs, which represent 12.5 percent of M4, leaving repurchase agreements in third place representing 6.2 percent of M4.

M3 adds public securities held by residents to the balances included in M2, which comprise 11.1 percent of M4—with the public securities issued by the federal government representing the lion's share at 9.6 percent of M4. Finally, M4 includes all assets in M3 adding many of the same monetary instruments that appear at lower degrees of aggregation, but this time only those held by non-residents of México. All told these represents 18.5 percent of the total sum of money balances in M4 and this difference refers mainly to public securities issued by the federal government in the hands of non-residents.

All these percentages hold for January 2019; thus, as such, they constitute a snapshot in time. For a more comprehensive view, Figure 1 provides an evolution of the contribution of various monetary assets to simple-sum M4. Currency and demand deposits comprised 28 percent of the total M4 balances in 2001, slowly rising to 34 percent by 2019. Conversely, the share of M4 accounted for by savings (both at commercial banks and thrift institutions) decreased dramatically from over 30 percent of M4 in 2001 to just below 15 percent by 2019. At 10 percent of M4, government securities held by residents remained essentially flat over the sample. While all deposits held by non-residents have been negligible over the sample, government securities held by non-residents experienced the largest increase in its contribution to M4 over the period. Between 2001 and 2003 these government securities accounted for a very small portion of about one percent of M4. In 2004, they began a sustained and protracted increase, peaking around 2014 at about 23 percent of M4. Subsequently, this protracted increase moderated somewhat, culminating in a share of about 18 percent of M4 at the end of our sample.

Figure 2 shows levels of the four official monetary aggregates the Banco de México produces: M1, M2, M3, and M4. The northwest panel in Figure 2 shows balances for M1. Demand deposits come in two forms in Mexico: current accounts—which do not bear interest—and checking accounts; which are interest-bearing deposits. Interest-bearing checking deposits account for the largest, and fastest growing component since 2012. The northeast panel shows M2 balances. While the fastest growing component over the sample has been money market mutual fund shares (MMMFs), savings are the largest component over most of the sample in comparable magnitudes to demand deposits. M3 adds government securities to the balances included in M2. The southwest panel shows that securities issued by the Federal Government of Mexico vastly outweighs balances of other government securities. Finally, M4 includes many of the same components reflected in M2 and M3 that are instead held by non-residents. The magnitudes of these deposits are all negligible when compared with balances in M2 and M3. However, the balance of government securities held by non-residents is too large—relative to the assets shown in the southeast panel of the figure—to include in the same chart. Thus we show those balances separately in Figure 3. Between 2011 and 2015 government securities held by non-residents quadrupled, reaching nearly twice the balance of government securities held by residents.

4 Divisia Indices for Mexico

The work of Barnett (1978) and Barnett (1980) outlined in Section 2 shows that Divisia aggregation requires calculation of the expenditure shares (s_{it}) for each component, which themselves are functions of the user costs (π_{it}) for each asset. As equation (3) shows, selecting a benchmark rate (R_t) is requisite for the determination of user costs, expenditure shares, and the eventual construction of the index. The benchmark rate is commonly understood to be the rate of return on a referent asset whose monetary service does not provide liquidity but strictly renders investment returns.

A complicating issue is that any benchmark asset is unobservable and, therefore, any selection of a benchmark rate is necessarily arbitrary. The most commonly used approximation involves adding a spread to the maximum return of some observed assets. The selection of the maximum return (at each point in time) is called the "*upper envelope*" approach and, in most cases, only the components included in the simple-sum measure are considered.

Stracca (2004) proxies the benchmark rate for the Euro area by adding 60 basis points to the rate on marketable instruments (defined as the sum of three components that differentiate European Central Bank's M2 and M3: repurchase agreements, money market funds, and debt securities up to 2 years). El-Shagi and Kelly (2013) adopted two proxies: (1) adding 100 basis points to the return on the maximum return of the components of the money stock, and (2) adding a variable premium to the maximum return of the components amounting to the spread between the ten-year and one-year government bond yields. In the past, the Bank of England has proxied the benchmark rate as the interest rate on three-month Local Government bills plus a 200 basis point spread, but after 2005, it switched to an envelope approach, whereby the benchmark asset is the M4 component that pays the highest interest rate. The CFS uses an envelope approach applied to all components of the money stock plus a loan rate.[6]

We follow the 'upper envelope' methodology employed by the Bank of England. Given our benchmark rate and own rates of each component allows us to generate measures of the real user costs of M1, M2, M3, and M4. The top panel of Figure 4 shows the real user costs for each aggregate and the bottom panel shows their respective implied rates. Both the user costs and the implied interest rates of all four aggregates were at relatively high levels in 2001. This was a period of relatively high interest rates in Mexico. In 2008, there was a second peak in user costs and in implied rates. Subsequently, there was a substantial moderation in the volatility—and reduction in the levels—of the real user costs and implied levels in the period between 2010 and 2016. Beginning in 2016, both user costs and implied rates began a steady climb through to the end of the sample.

Once real user costs are calculated, we construct a Divisia index counterpart for each of the four simple-sum aggregates that the Banco de México officially releases. The first observation available to us—December 2001—receives a value of 100 as the start of each of the four indices. Figure 5 compares annualized growth rates of the Divisia measures that we construct and their respective simple-sum counterparts.

The northwest panel of Figure 5 for simple-sum M1 and Divisia M1 seems intuitive. Given the narrowness of this first aggregate, it is not surprising that the Divisia index more closely resembles the simple-sum measure of M1 than that of any other aggregate. It is only for the narrowest aggregates composed of the fewest components that the assumption of perfect substitutability between assets is perhaps palatable. The northeast panel shows higher growth rates of Divisa M2 than simple-sum M2 for most of the sample except for the 2006-2009 period. The period of largest discrepancy is the 2014-2017 period where Divisia M2 suggests a much higher rate of expansion than the simple-sum M2. This phenomenon is also evident for Divisia M3 and simple-sum M3—shown in the southwest panel. Finally, the most stark difference between simple-sum and the Divisia counterpart occurs for M4 (shown in the southeast panel). This is sensible given that M4, as the broadest aggregate Banco de México produces, encompasses nearly 20 assets. Thus, the perfect substitutability assumption inherent in the simple-sum construction is highly problematic. The growth rate of simple-sum M4 seems to exhibit high variability averaging around seven percent between 2001 and 2006, doubling that between 2006 and 2015, before a marked contraction in the money supply after 2015. By comparison, the long-run average of Divisia M4 is relatively more stable. A common feature in M2, M3, and M4 is that the Divisia indices for those

[6] From 1997, the date when this loan rate becomes available. For earlier years, 100 basis points are added to the yield on the highest yielding asset of M4 (see Barnett et al. (2013)).

aggregates imply higher rates of money supply expansion after 2015 than what the problematic simple-sum measures show. Given that the gap in this period arises when aggregating beyond M1—but is otherwise similar across M2, M3, and M4 aggregates, suggests savings deposits might be what account for these substantial differences over this period.

5 The Effects of Monetary Policy Shocks in Mexico

Since the 1990s—and following particularly influential papers such as Bernanke and Blinder (1992) and Taylor (1993)—there have been myriad models of monetary policy shocks identified from innovations in a short-term nominal interest rate. More recently, there has also been an important, yet smaller, subset of papers in the monetary literature that identified policy shocks from innovations in nominal money balances.

We consider a structural VAR scheme that can accommodate indicators of monetary policy from short-term interest rates. We then compare it to similar specifications by replacing the short-term nominal interest rate with nominal money balances as the monetary policy indicator. Our approach closely resembles that of Keating et al. (2019), which identified monetary policy for the U.S. with Divisia monetary aggregates.[7] Keating et al. (2019) specifications operate on quarterly data. Data availability for Mexico motivates our use of monthly data instead. Exclusion restriction schemes that bind at quarterly frequencies will generally be more palatable, or at least less constraining, at higher (monthly) frequencies.

We begin with a reduced-form vector autoregression (VAR):

$$z_t = B_1 z_{t-1} + ... + B_q z_{t-q} + u_t \tag{13}$$

where q is the number of lags and $Eu_t u_t' = V$ is the covariance matrix for residuals.[8] Correspondingly, a linear structural model may be written as:

$$A_0 z_t = A_1 z_{t-1} + \ldots + A_q z_{t-q} + \varepsilon_t \tag{14}$$

where $\mathrm{E}\varepsilon_t {\varepsilon_t}' = \mathrm{D}$ is the diagonal covariance matrix for structural shocks.

[7]The identification in Keating et al. (2019) is similar in spirit to Christiano et al. (1999), which was once the standard model of empirical analysis of monetary policy. An important distinction is that, unlike Keating et al. (2019), Christiano et al. (1999) included simple-sum monetary aggregates as policy indicators or informational variables. We reject the validity of simple-sum measures of the money supply and therefore we eschew those in favor of Divisia measures whenever possible.

[8]In all of the VAR specifications of this section, $q = 5$.

Identification of these (ε_t) structural shocks can be accomplished in a number of ways. We opt for imposing restrictions on the A_0 matrix in accordance to a block-Cholesky identification scheme similar to the one investigated by Keating et al. (2019) and outlined below.

5.1 Money Balances v. Short-Term Rates as Monetary Policy Indicators

In a highly influential paper, Christiano et al. (1999) advanced what became a widely used method for identifying monetary policy shocks. Their empirical findings substantiated the identifying assumption that central banks adjust short-term rates (the federal funds rate in the case of the U.S.) in response to changes in output and prices but affect these variables with a lag.

In addition to the federal funds rate, Christiano et al. (1999) considered money balances as a possible alternative policy indicator. Their comprehensive investigation seemingly put to bed such specifications due to the puzzling responses of output, prices, interest rates, or other monetary aggregates in response to monetary policy shocks identified when simple-sum M1 or simple-sum M2 was considered the U.S. monetary policy indicator. However, our approach here employs our newly developed Divisia measures of the money supply for Mexico. Our Divisia measures do not suffer from the measurement error that pollute their simple-sum counterparts, and they are quite broad.

We sub-classify the variables in the model (eq. 13) into three blocks: an economic activity block (X_{1t}), a block containing a monetary policy indicator (X_{2t}), and an information block (X_{3t}).

$$z_t = (X_{1t}', X_{2t}', X_{3t}')' \tag{15}$$

Each block may consist of multiple variables; however, in our specification, X_{2t} is a single policy indicator.[9] The structure is assumed to take on the following form:

$$A_0 = \begin{bmatrix} A_{11} & 0_{12} & 0_{13} \\ A_{21} & A_{22} & 0_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \tag{16}$$

where A_{ij} is an $n_i \times n_j$ matrix of parameters and 0_{ij} is an $n_i \times n_j$ zero matrix. The vector of structural shocks is given by: $\varepsilon_t = (\varepsilon_{1t}{}' , \varepsilon_{2t}{}' , \varepsilon_{3t}{}')'$. Christiano et al. (1999) prove that

[9] For our purposes, given that X_{2t} is a single variable, we only require that D take on a *block-diagonal* form. This condition is sufficient to make the policy shock uncorrelated with the other structural shocks.

under these assumptions the Cholesky factor of V will identify the effects of shocks to the structural equation for X_{2t}.[10]

This identification assumes that the policy variable, X_{2t}, responds contemporaneously to X_{1t}, a set of economic activity variables that slowly adjust to policy and a variety of other nominal shocks. Throughout our analysis we follow a similar approach to Keating et al. (2019) and identify monetary policy shocks using a block-recursive formulation in which X_{1t} consists of a measure of industrial production and a measure of the consumer price index. We include them because of the assumption that the Banco de México may consider economic activity and prices in their formulation of a stance of monetary policy. When the policy variable is a short-term offer rate, a reaction to these two variables would be consistent with a Taylor Rule formulation. We follow Kamin and Rogers (1996) and De Mello and Moccero (2009), among others, in considering the treasury certificates with 28-day maturities (CETES-28 días) as a proxy for the short-term offer rate (henceforth, SOFR).

The third block, X_{3t}, consists of money market variables, such as the monetary base and the 1-year Mexican treasury rates. We assume they may respond immediately to disturbances in X_{1t} or X_{2t} but only affect these variables with a lag.

Panel (a) of Figure 6 shows responses of industrial production, the consumer price index, the SOFR, the monetary base, and the 1-year treasury rate (all variables are in log levels, except interest rates) to a one standard deviation increase in the SOFR. The responses of industrial production and that of the 1-year treasury rate seem sensible. The SOFR response to its own shock turns negative about seven months post shock. The monetary base moves in the same direction in response to this shock—it first increases with the hike in the interest rate and then turns negative when the rate response drops below zero. Thus, a liquidity effect interpretation (where interest rates and monetary balances are thought to move in opposite directions) seems to be rejected by this specification.

Perhaps more problematic is the response of the price level. The contractionary monetary policy shock leads the price level to a statistically significant increase in this specification—and once the SOFR response turns negative so does that of the price level (though not statistically significant). This perverse reaction is commonly known as the *price puzzle*, which has been a common empirical finding in many studies of monetary policy in the U.S. (see Balke et al. (1994) and Den Haan et al. (2007), among others), other developed economies (see Sims (1992) and Eichenbaum and Evans (1995), among others), as well as

[10] Keating (1996) generalizes Christiano et al. (1999), showing that if $n_2 > 1$ and A_{22} is a lower triangular matrix, the Cholesky factor of V will identify the effects of structural shocks for all n_2 shocks in ε_{2t}. Structures that take on this form are defined as partially recursive.

in the context of open economy models (Cushman and Zha (1997)) and in high dimensional VARs (Bernanke et al. (2005)).

The usual explanation for price puzzles is that the variables in the VAR do not sufficiently span the full information set available to central banks. Sims (1992), Bernanke and Mihov (1998), and Christiano et al. (1999), among others, argue that commodity prices serve as a good proxy for additional—more forward looking—information available to central banks.[11] Following Keating et al. (2019), we include a global commodity price index measure produced by the International Monetary Fund in third place of the economic activity block (X_{1t}.) A key identifying assumption is that monetary policy has no contemporaneous effect on X_{1t}. Panel (b) of Figure 6 shows responses of a VAR specification that includes commodity prices—where the SOFR is the policy indicator—do not improve the incidence of the price puzzle for Mexico.

We now turn to the Divisia specification by replacing the SOFR with DM4, the broadest Divisia measure we produce in the paper. Figure 7 shows the responses to the Divisia contractionary shock are more sensible than those of the SOFR specificaton. Where a contractionary hike in the SOFR expanded the monetary base in the previous specification, there is now a substantial contraction in the monetary base in response to an exogenous contraction of Divisia money balances. The 1-year treasury rate responds positively (although not statistically significant) in the first few months. More important, the price response is free of the puzzle that plagues the SOFR specification.

Overall, we focus on DM4 as the broadest measure we make available in this paper. The basis for considering a broad Divisia measure of money balances is two-pronged. First, there is overwhelming evidence that the *Barnett Critique*—that simple-sum monetary aggregates fail to account for the dual nature of monetary assets by incorrectly assuming perfect substitutability among them—holds for many developed economies. Barnett (1980) and others have long argued that use of simple-sum monetary aggregates is theoretically indefensible in developed economies. Belongia and Ireland (2014) persuasively argue for the desirability of Divisia as follows:

"...if pressed on this issue, virtually all monetary economists today would no doubt concede that the Divisia aggregates proposed by Barnett are both theoretically and empirically superior to their simple-sum counterparts."

[11] However, including commodity prices in monetary models has not been without detractors. Giordani (2004) and Hanson (2004) argue including commodity prices is an *ad hoc* solution with relatively little theoretical backing. Furthermore, Den Haan et al. (2007) shows commodity prices do not solve the incidence of the price puzzle in a modern sample of a VAR for the U.S. with the federal funds rate as the monetary policy indicator; and Keating et al. (2019) shows that, while inclusion of commodity prices lessens the virulence of the price puzzle for some postwar U.S. subsamples, they do not resolve its occurrence.

Second, the use of a broad index is desirable because a larger information set can, in principle, better encapsulate a wider amalgam of monetary shocks, particularly in economies with relatively high fluctuations in economic activity or substantial changes in monetary regimes or transmission mechanisms, both of which apply to the case of Mexico. Kelly et al. (2011) argue that narrowing the definition of money to include fewer assets is problematic as it arbitrarily ignores assets that provide monetary services. Keating et al. (2019) show the broadest Divisia aggregate currently available for the U.S. (DM4) can be used as an indicator of monetary policy that provides valuable signal both during financial crises and normal conditions.

While the results for DM4 are consistently sensible, we next explore whether narrower Divisia aggregates continue to be useful. Figure 8 shows responses to monetary policy shocks with DM2 as the policy indicator. The responses here display the expected dynamics. Industrial production declines in a hump-shaped fashion following a contractionary monetary policy. There is little evidence of a price puzzle that buffets the DM2 identification.

Finally, while commodity prices have been typically ascribed to as a potential—although often imperfect—solution to the price puzzle, we find they do not seem to help the SOFR specifications. The Divisia specifications that yield responses of Figures 7 and 8 that are free from puzzles do include a measure of commodity prices. This begs the question of whether commodity prices are a necessary factor for the resolution of the price puzzle in our Divisia specifications—even when they do not seem to help the SOFR specification. Figure 9 shows Divisia specifications that exclude commodity prices. Panels (a)-(c) consider DM1, DM2, and DM4 as policy indicators respectively. All three VARs yield sensible responses of economic activity. We conclude that correct monetary measurement (Divisia indexation) does the heavy lifting in the resolution of the price puzzle.

Our approach has been inspired by a similar analysis in Keating et al. (2019). While that paper considers sub-sampling to allow for the possibility of changes in regime or transmission in the U.S., their VARs assume constancy of parameters within each subsample. We set out to improve over this approach by relaxing the constancy or parameters assumption. The next section outlines an estimate of a VAR with time-varying drifts and volatilities over the whole sample, rather than estimating standard VARs across breaks presupposed a priori.

6 The Time-Varying Transmission of Monetary Policy Shocks in Mexico

Our sample begins in December 2001. This roughly corresponds with a period when Banco de México adopted an explicit CPI-based inflation target that eventually reached 3 percent.[12] This new targeting regime coincides with a substantial change in the time series properties of inflation. Chiquiar et al. (2010) provides persuasive evidence that inflation in Mexico seems to have switched from a nonstationary to a stationary process around 2001.

A consistent forward-looking policy objective does not necessarily guarantee uniformity in the responses of the economy. Thus, even if our sample does not encompass an apparent regime change in the conduct of monetary policy, we want to investigate the possibility of time variation in the transmission of monetary policy shocks. In an internal document, Banco de México advances a possible structural change in the monetary transmission mechanism may have taken place within the span of our sample.[13]

Thus, we maintain our structural identification outlined in Section 5.1 implied by the ordering of the variables in the system and a lower triangular impact matrix. However, our specification is now expanded by allowing both the parameters and the covariance matrix of the VAR to vary over time. Consider the following time-varying parameter TVP-VAR process:

$$\theta_t (L) z_t = e_t \tag{17}$$

where z_t is an n-vector of endogenous time t variables; $\theta_t = I_n - \theta_{1t} (L) - ... - \theta_{pt} (L^p)$ is a p-th lag polynomial in which each θ is a time-varying matrix of autoregressive coefficients and e_t is an n-vector of mean-zero VAR innovations. We allow for time variation in the variances of the shocks in the VAR model, all of which are summarized in the time-varying covariance matrix R_t. Let Θ_t represent the stacked vector of all coefficients in $\theta_t (L)$, and assume it evolves according to

$$\Theta_t = \Theta_{t-1} + u_t \tag{18}$$

where u_t is a Gaussian white noise process with zero mean and constant covariance Q, independent of e_t at all leads and lags. A seminal application of modern time-varying structural VARS by Cogley and Sargent (2005) and a comprehensive treatment by Primiceri

[12]See Bank of México online document (Spanish text): Régimen de Objetivos de Inflación y el Papel de los Pronósticos. https://www.banxico.org.mx/publicaciones-y-prensa/informes-trimestrales/recuadros/%7BF369E035-6C1D-B85F-AA5F-3193E68CE8B2%7D.pdf

[13]See Bank of México online document (Spanish text): Cambios Recientes en el Mecanismo de Transmisión de la Política Monetaria en México https://www.banxico.org.mx/publicaciones-y-prensa/informes-trimestrales/recuadros/%7B4E9CF0BE-8E0B-B599-6500-6553239FEF8B%7D.pdf

(2005) rely on the Bayesian single-move technique of Jacquier et al. (2002) to estimate stochastic volatilities. We follow a variant of the multi-move stochastic volatility construct of Kim et al. (1998) to allow for time variation in the underlying VAR model.[14] We decompose the covariance matrix of system (17) as follows:

Let $E(e_t e_t') \equiv F_t H_t F_t'$ where F is given by

$$F_t = \begin{bmatrix} 1 & 0 & \dots & 0 \\ f_{2t} & 1 & \dots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ f_{nt} & \dots & f_{nnt-1} & 1 \end{bmatrix}$$

and

$$H_t = \begin{bmatrix} h_{1t} & 0 & \dots & 0 \\ 0 & h_{2t} & \dots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & h_{nt} \end{bmatrix}$$

The diagonal elements of H_t are independent univariate stochastic processes that evolve according to the following:

$$ln(h_{jt}) = ln(h_{jt-1}) + \xi_t \qquad \forall j = 1, 2, \dots, n \tag{19}$$

Stacking all the off-diagonal elements of F_t^{-1} into a vector γ_t, we further assume that this vector evolves according to the following drift-less geometric random walk:

$$\gamma_t = \gamma_{t-1} + \zeta_t \tag{20}$$

where $\xi_t \sim iid(0, \Xi)$ and $\zeta_t \sim iid(0, Y)$. We assume $u_t \perp \xi_t \perp \zeta_t$ and the covariance matrix Y is assumed to be block-diagonal to prevent non-zero covariance of the coefficients among different equations. We assume the underlying structural shocks (ϵ_t) of the economy are a time-varying transformation of the reduced-form innovations (e_t) as follows:

$$e_t = P_t \epsilon_t \qquad \forall t \tag{21}$$

[14]Del Negro and Primiceri (2015) argue for an alternative algorithm that allows for a more efficient implementation of Kim et al. (1998) over Jacquier et al. (2002). It involves a reorganization of the steps in the Gibbs sampler where the history of the volatilities is sampled after—rather than ahead of—the mixing indicators for each parameter for every period t.

where P_t is a non-singular matrix that satisfies $P_t P_t' = R_t$. Given this mapping, changes in the contributions of different structural shocks to the volatility in innovations in the underlying variables of interest are captured by changes in P_t.

Let the companion form of (17) be given by:

$$Z_t = \Pi_t Z_{t-1} + De_t \tag{22}$$

where $Z_t = (z_t', z_{t-1}', \ldots, z_{t-p+1}')'$, $D = (I, 0, \ldots, 0)'$, and Π_t is the companion matrix containing the time-varying autoregressive coefficients in (17).

A standard local projection of (22) is given by:

$$\frac{\partial z_{t+h}}{\partial e_t} = s_{n,n}\left(\Pi_t^h\right) \qquad \forall t, h = 1 \tag{23}$$

where $s_{n,n} = D'\Pi_t^h D$ selects the upper left n-by-n sub-matrix from the larger matrix. A simple application of the chain rule obtains impulse responses at an arbitrary *h-th* horizon.

$$\frac{\partial z_{t+h}}{\partial \epsilon_t} = \frac{\partial z_{t+h}}{\partial e_t}\frac{\partial e_t}{\partial \epsilon_t} = s_{n,n}\left(\Pi_t^h\right) P_t \qquad \forall t, h = 1 \tag{24}$$

We follow here the same specifications as those described in Section 5.1. Therefore, in our specification n=5 and $X_t = [(\text{IP}); (\text{P}); (\text{SOFR or DM4}); (\text{MB}); (\text{TR})]'$, we use a training sample of 48 observations on a standard VAR to initialize the priors of the TVP-VAR. Thus, our monthly sample estimate is somewhat shorter than the VAR estimates of Section 5.1 spanning Nov. 2006 - Aug. 2019. The TVP-VAR is estimated with two lags.

The function described in equation (24) allows for an estimate of a selected response for each period and each horizon. For example, Figure 10 shows the time-varying price level responses—for a monthly sample between 2006 and 2019—for each month following a 1% standard deviation increase in the SOFR. Similarly, Figure 11 shows the time-varying responses of the price level to a 1% standard deviation reduction in Divisia M4 money balances. Both of these figures present a stark contrast in the response of the price level to a contractionary monetary policy shock. While the SOFR specification shows a significant price puzzle to a contractionary monetary policy shock at short horizons, the price response on the DM4 specification seems sensible throughout.

For simplicity of exposition, we summarize our time-varying responses around three horizons. Figures 12 - 19 contain three panels. The top panel in each figure shows the average response for the first three months post-shock. Each red triangle represents the average estimated response for the first three horizons for a given month in the sample that encompasses 2006 - 2019. The middle panels (in green dots) averages responses between six months and 12 months-post shock for each month. This represents the dynamics of these responses on the bottom half of the year, following the exogenous shock. The blue triangles in the bottom panels average the estimates of the responses between the 13th and the 24th month post shock. This constitutes a longer-term picture of the dynamic responses to the shocks of interest. The dashed lines comprise confidence bounds around the 16% - 84% credible set. The odd numbered figures between Figure 12 and Figure 19 correspond to the SOFR specification; while the even figures show responses from the specification that replaces the SOFR with DM4 money balances in each instance as the indicator of monetary policy.

Figure 12 shows puzzling responses of industrial production within the first quarter following an exogenous contractionary shock in the SOFR. Conversely, Figure 13 shows industrial production decreases with a lag in response to a contractionary shock in DM4 money balances. Figure 14 shows the price-level increases significantly in the first quarter following a contractionary shock in SOFR. However, Figure 15 shows a sensible response of the price level to a reduction in DM4 money balances. These dynamics are consistent with the VAR results of Section 5.1. Figure 16 shows a delayed contraction of the monetary base to a contractionary SOFR shock, whereas a contractionary shock in DM4 leads to an immediate reduction in the monetary base, as shown in the top panel of Figure 17. Finally, Figure 18 shows an increase in the 1-year treasury in response to an exogenous SOFR shock. Figure 19 shows the response of the 1-year treasury to a reduction in DM4 money balances is more muted.

Overall, both a structural Keating et al. (2019)-type identification as well as a TVP-VAR approach yield more sensible responses with a Divisia indicator of monetary policy shocks than with the SOFR.

7 Concluding Remarks

Twenty years ago, M4—the broadest measure of money balances available in Mexico—was just 29 percent of GDP. Today M4 constitutes over half of the economic activity of the country. Currently, Banco de México measures money as a simple sum of the different monetary assets included at four levels of aggregation: M1, M2, M3, and M4. Seminal work by Barnett (1980) and many who followed amply demonstrated simple-sum aggregation is highly problematic. Moreover, its virulence is greatly exacerbated at broader levels of aggregation. This presents significant complications for the information content of the money supply viz. monetary policy. A wealth of monetary literature has shown Divisia indices of monetary aggregates are both theoretically and empirically superior to their simple-sum counterparts. Our evidence here seems consistent with this assessment. While Divisia indices are available for the U.S., the U.K, the Euro area and a few other developed economies, no similar measure currently exists for Mexico. This paper produces the first modern measures of Divisia money, and their associated user costs, for the Mexican economy.

We estimate multiple specifications of a structural VARs for Mexico—similar to what has been used widely to identify the effects of monetary policy shocks on the economic activity of the U.S. In each of these models, we compare specifications that consider a short-term offer rate as the indicator of Mexican monetary policy—in the spirit of Taylor Rule approach—and contrast them with specifications that consider Divisia indices as policy indicators—consistent with a model advanced by Keating et al. (2019) for the U.S. Our findings include a perverse reaction of inflation or the price level to contractionary shocks in short-term interest rates. Similar conclusions have often been found in comparable VAR approaches for the U.S. Conversely, our Divisia specifications obtain sensible responses that are free from these price puzzles.

We then turn to a time-varying approach to allow for the possibility of structural change in our sample. Results of this approach largely complement those of the standard VAR. Importantly, we show the sensible responses monetary policy shocks to Divisia money balances need not rely on the *ad hoc* inclusion of commodity prices. These results suggest that the correct liquidity weighing encapsulated by the Divisia indices seems to do the heavy lifting.

Our Divisia measures of money balances for Mexico open the door for numerous elaborations of the characterization of the effects of monetary policy in that country. The availability of Divisia indices will generally be useful for any macroeconomic analysis that requires confidence in the measurement of money balances including, but not exclusive to, models of nominal income targeting, estimations of money demand shocks, long-run cointegrating relationships in money balances and other major economic aggregates.

References

Anderson, R.G., Jones, B., Nesmith, T., 1997. Monetary aggregation theory and statistical index numbers. Federal Reserve Bank of St. Louis Review 79.

Balke, N.S., Emery, K.M., et al., 1994. Understanding the price puzzle. Federal Reserve Bank of Dallas Economic Review, Fourth Quarter , 15–26.

Barnett, W.A., 1978. The user cost of money. Economics letters 1, 145–149.

Barnett, W.A., 1980. Economic monetary aggregate: an application of index number and aggregation theory. Journal of Econometrics 14, 11.

Barnett, W.A., Fisher, D., Serletis, A., 1992. Consumer theory and the demand for money. Journal of Economic Literature 30, 2086–2119.

Barnett, W.A., Liu, J., Mattson, R.S., van den Noort, J., 2013. The new cfs divisia monetary aggregates: Design, construction, and data sources. Open Economies Review 24, 101–124.

Belongia, M.T., 2000. Consequences of money stock mismeasurement: Evidence from three countries, in: Divisia Monetary Aggregates. Springer, pp. 292–312.

Belongia, M.T., Ireland, P.N., 2014. The barnett critique after three decades: A new keynesian analysis. Journal of Econometrics 183, 5–21.

Belongia, M.T., Ireland, P.N., 2019. The demand for divisia money: Theory and evidence. Journal of Macroeconomics 61, 103128.

Belongia, M.T., Ireland, P.N., et al., 2018. Targeting constant money growth at the zero lower bound. International Journal of Central Banking 14, 159–204.

Bernanke, B., Blinder, A.S., 1992. The federal funds rate and the transmission of monetary policy. American Economic Review 82, 901–21.

Bernanke, B.S., Boivin, J., Eliasz, P., 2005. Measuring the effects of monetary policy: a factor-augmented vector autoregressive (favar) approach. The Quarterly journal of economics 120, 387–422.

Bernanke, B.S., Mihov, I., 1998. Measuring monetary policy. The quarterly journal of economics 113, 869–902.

Binner, J.M., Bissoondeeal, R.K., Elger, C.T., Jones, B.E., Mullineux, A.W., 2009. Admissible monetary aggregates for the euro area. Journal of International Money and Finance 28, 99–114.

Carrillo, J.A., Elizondo, R., 2015. How robust are SVARs at measuring monetary policy in small open economies? Technical Report. Banco de Meixco Working Papers.

Chiquiar, D., Noriega, A.E., Ramos-Francia, M., 2010. A time-series approach to test a change in inflation persistence: the mexican experience. Applied Economics 42, 3067–3075. URL: https://doi.org/10.1080/00036840801982684, doi:10.1080/00036840801982684, arXiv:https://doi.org/10.1080/00036840801982684.

Christiano, L.J., Eichenbaum, M., Evans, C.L., 1999. Monetary policy shocks: What have we learned and to what end? Handbook of Macroeconomics 1, 65–148.

Chrystal, K.A., MacDonald, R., 1994. Empirical evidence on the recent behavior and usefulness of simple-sum and weighted measures of the money stock. Review-Federal Reserve Bank of Saint Louis 76, 73.

Cogley, T., Sargent, T.J., 2005. Drifts and volatilities: monetary policies and outcomes in the post wwii us. Review of Economic Dynamics 8, 262–302.

Cushman, D.O., Zha, T., 1997. Identifying monetary policy in a small open economy under flexible exchange rates. Journal of Monetary Economics 39, 433–448.

Darvas, Z., 2015. Does money matter in the euro area? evidence from a new divisia index. Economics Letters 133, 123–126.

De Mello, L., Moccero, D., 2009. Monetary policy and inflation expectations in latin america: Long-run effects and volatility spillovers. Journal of Money, Credit and Banking 41, 1671–1690.

Del Negro, M., Primiceri, G.E., 2015. Time varying structural vector autoregressions and monetary policy: a corrigendum. The Review of Economic Studies 82, 1342–1345.

Den Haan, W.J., Sumner, S.W., Yamashiro, G.M., 2007. Bank loan portfolios and the monetary transmission mechanism. Journal of Monetary Economics 54, 904–924.

Eichenbaum, M., Evans, C.L., 1995. Some empirical evidence on the effects of shocks to monetary policy on exchange rates. The Quarterly Journal of Economics 110, 975–1009.

El-Shagi, M., Kelly, L., 2013. Liquidity in the liquidity crisis: Evidence from divisia monetary aggregates in germany and the european crisis countries .

Giordani, P., 2004. An alternative explanation of the price puzzle. Journal of Monetary Economics 51, 1271–1296.

Hancock, M., 2005. Divisia money. Bank of England Quarterly Bulletin, Spring .

Hanson, M.S., 2004. The “price puzzle” reconsidered. Journal of Monetary Economics 51, 1385–1413.

Jacquier, E., Polson, N.G., Rossi, P.E., 2002. Bayesian analysis of stochastic volatility models. Journal of Business & Economic Statistics 20, 69–87.

Kamin, S.B., Rogers, J.H., 1996. Monetary policy in the end-game to exchange-rate based stabilizations: the case of mexico. Journal of International Economics 41, 285–307.

Keating, J., 1992. Structural approaches to vector autoregressions. Federal Reserve Bank of St. Louis Review 74.

Keating, J.W., 1996. Structural information in recursive var orderings. Journal of Economic Dynamics and Control 20, 1557–1580.

Keating, J.W., Kelly, L.J., Smith, A.L., Valcarcel, V.J., 2019. A model of monetary policy shocks for financial crises and normal conditions. Journal of Money, Credit and Banking 51, 227–259.

Kelly, L.J., Barnett, W.A., Keating, J.W., 2011. Rethinking the liquidity puzzle: Application of a new measure of the economic money stock. Journal of Banking and Finance 35, 768–774.

Kim, S., Shephard, N., Chib, S., 1998. Stochastic volatility: likelihood inference and comparison with arch models. The review of economic studies 65, 361–393.

Leeper, E.M., Roush, J.E., 2003. Putting” m” back in monetary policy. Journal of Money, Credit and Banking , 1217–1256.

Musi, A.S., 1990. Construction of new monetary aggregates: the case of Mexico. Colegio de México.

Primiceri, G.E., 2005. Time varying structural vector autoregressions and monetary policy. The Review of Economic Studies 72, 821–852.

Serletis, A., Gogas, P., 2014. Divisia monetary aggregates, the great ratios, and classical money demand functions. Journal of Money, Credit and Banking 46, 229–241. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/jmcb.12103, doi:10.1111/jmcb.12103, arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1111/jmcb.12103.

Sims, C.A., 1992. Interpreting the macroeconomic time series facts: The effects of monetary policy. European Economic Review 36, 975–1000.

Stracca, L., 2004. Does liquidity matter? properties of a divisia monetary aggregate in the euro area. Oxford Bulletin of Economics and Statistics 66, 309–331.

Taylor, J.B., 1993. Discretion versus policy rules in practice, in: Carnegie-Rochester conference series on public policy, Elsevier. pp. 195–214.

Appendix A: *An Alternative Non-Recursive Identification*

Much of the inference we draw in this paper is centered on addressing the price puzzle. However, for some purposes, central banks may be interested in collecting insight on inflation. We begin with a specification popularized by Keating (1992). Let $z_t = [\Delta p_t, \Delta IP_t, i_t, \Delta m_t]'$ where P_t denotes the log of the consumer price index, IP_t the log of industrial production, i_t the SOFR, and m_t the log of simple-sum M1.[15] The structure is assumed to take on the following non-recursive form:

$$A_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ A_{21} & 1 & A_{23} & A_{24} \\ 0 & 0 & 1 & A_{34} \\ A_{41} & A_{41} & A_{43} & 1 \end{bmatrix} \tag{25}$$

The structure in Keating (1992) recovers all structural shocks. The first equation suggests the price level may only respond to its own shock on impact—consistent with a horizontal short-run aggregate supply curve. The second equation suggests economic activity, as measured by industrial production rather than GNP or GDP, may respond to all other variables, suggestive of an IS curve. The third equation substantiates behavior for a monetary policy indicator, where the central bank adjusts the rate of interest in relation to the money balances. The fourth equation describes a money demand function in which short-run money balances are proportional income (or economic activity).[16] While this construct constitutes exact identification for all four shocks—in the original Keating (1992) the four disturbances were to *aggregate supply*, *IS*, *money supply*, and *money demand* shocks—entertained by this system, we focus on responses to (one-standard-deviation) shocks in the third variable, consistent with a contractionary monetary policy shock.

Figure A1 shows responses to an exogenous one-standard-deviation increase in the SOFR. Albeit somewhat muted, industrial production responds in the expected direction to a contractionary monetary policy shock. However, there is a perverse reaction of inflation which

[15]The original Keating (1992) model is estimated at quarterly frequencies with GNP as the second variable and simple-sum M1 as the fourth. Given our model is estimated at a monthly frequency, we replace GNP with industrial production. To remain as faithful as possible to the original, and despite our reservations on using simple-sum measures, we keep $M1$ in fourth place. Our results, however, are qualitatively robust to replacing simple-sum M1 with Divisia M1 in fourth place in the VAR ordering. We have also considered cyclical measures of output in place of industrial production with similar results. All the VARS under this specification consider five lags.

[16]A later paper by Leeper and Roush (2003) notes that when a monetary aggregate is also included in the list of variables used to estimate the model, as is the case here, a specification that orders the interest rate after prices and output but ahead of money balances may allow for a clear distinction between money supply and money demand

increases significantly following an increase in the short-term offer rate. Additionally, there is a statistically significant increase in M1 money balances for the first five months post shock before turning in the expected (negative) direction. In the short-run, this response is inconsistent with a strong liquidity effect.

We then turn to this same model under the assumption that our constructed Divisia for Mexico serves as the policy indicator. Given that the benchmark model contains a monetary aggregate (simple-sum M1) and a nominal interest rate (the short-term offer rate) we want to keep the same structure of including an interest rate and a money balance variable in the system. Figure A2 shows responses of the same identification scheme, with two major differences. We replace the short-term offer rate with DM4, the broadest measure of Divisia money we constructed. We, then, replace the simple-sum M1 balance in the fourth place, with the nominal three-year treasury rate. The benchmark specification modeled a hike in the nominal rate as a contractionary monetary policy shock. In this alternative specification contraction means a reduction in money balances. The inflation response displays a delayed reaction—consistent with a traditional New Keynesian prediction—before turning in the expected (negative) direction, and industrial production exhibits a more significant negative response as well.

We choose DM4 as the alternate indicator because it is the broadest Mexican Divisia aggregate we make available in this paper. Keating et al. (2019) suggest that a broad index might present some advantages as an indicator of monetary policy in an economy buffeted by a wide panoply of financial shocks in various money markets, such as that of the U.S. This implies that mitigating measurement error (with correct liquidity weights) and expanding information content (with broader indices) are both desirable. However, some of the more influential work on characterizing monetary policy shocks in the U.S. via Divisia measures, such as Belongia and Ireland (2014) and Belongia et al. (2018), champions the use of Divisia M2 for the U.S. even when the broader Divisia M4 is available.[17] Figure A3 shows responses from this specification where we replace DM4 with DM2. The responses are quite close to the DM4 specification. Overall, the Divisia specifications seem to give more sensible responses than that of the short-term offer rate.

[17]This suggests that a larger information set is of second order importance to correct measurement in our sample. Given that the M2 aggregate in the U.S. already includes the more important (and lion's share of) time deposits, it renders the DM2 profile as quite distinct from—and more useful than—its simple-sum counterpart.

Appendix B: *An Alternative Specification with Real Exchange Rates*

Price puzzles have been endemic in structural VARs for a long time. As mentioned in earlier sections of this paper, commodity prices have been typically ascribed to as a possible—albeit *ad hoc*—solution to the puzzle for the U.S. economy (see Christiano et al. (1999)) and for other open economies (see Cushman and Zha (1997)). However, evidence is mixed on the efficacy of commodity prices in the resolution of the price puzzle (see Sims (1992)).

Keating et al. (2019) find that commodity prices substantially moderate the incidence of the puzzle in a federal funds rate specification for a sample that ends in the mid 1990s (the original Christiano et al. (1999) sample). However, for a modern U.S. sample that ends in 2007, they find a much more muted role of commodity prices in the resolution of the puzzle. Importantly, they find that commodity prices are not required to resolve the puzzle in Divisia specifications. Our findings in this paper suggest that Divisia specifications do not require commodity prices to rule out price puzzles in Mexico. On the other hand, commodity prices do not seem to ameliorate the incidence of price puzzles in SOFR specifications.

The typical narrative for including commodity prices is that they are sensitive to changing information about expected future inflation, a significant concern for central banks. It could be argued that for the central banks of smaller open economies, exchange rates could play the role of expanding the more forward-looking information set that spans the central banks measures of interest. Thus, we replace commodity prices in our VAR specifications of Section 5.1 with the U.S.-Mexico real exchange rate. Figure A4 shows a price puzzle in a SOFR specification with the real exchange rate in place of commodity prices. Conversely, Figure A5 shows sensible responses of the price level to contractionary monetary policy shocks with DM4 money balances as the indicator. The evidence suggests that exchange rates do not improve over commodity prices in their ability to solve the price puzzle in SOFR specifications. On the other hand, inclusion of exchange rates or commodity prices in Divisia specifications yield sensible responses but, importantly, neither variable is required for the resolution of the price puzzle in DM specifications.

Finally, we consider a specification where the real exchange rate might work in conjunction with commodity prices. We estimate a Cholesky specification outlined by Carrillo and Elizondo (2015) with the real exchange rate ordered before the policy indicator and commodity prices ordered after as follows $z_t = [(\mathrm{IP}); (\mathrm{P}); (\mathrm{RXR}); (\mathrm{SOFR\ or\ DM4}); (\mathrm{MB}); (\mathrm{PCOM})]'$. Figure A6 shows that the incidence of price puzzle is now exacerbated for the SOFR specification, whereas Figure A7 shows no puzzling price-level responses in the DM4 specification.

Monetary aggregates (2018 methodology)	Monthly, Billions of Pesos, Stocks	Percentage with respect M4
● M1	4,342.6	35.1
○ Currency held by money holders 1/	1,442.7	11.7
○ Demand deposits in banks 2/	2,876.1	23.2
■ Checking accounts	2,148.5	17.4
■ Current account deposits	727.5	5.9
○ Demand deposits in saving and loan associations 3/	23.8	0.2
● M2 = M1 + monetary instruments held by residents	8,713.7	70.4
○ Monetary instruments held by residents 4/	4,371.1	35.3
■ Short-term deposits and securities	2,052.7	16.6
□ In banks 5/	1,895.6	15.3
□ In other non-banking institutions	157.1	1.3
● Credit unions	35.7	0.3
● Saving and loan associations 3/	121.5	1.0
■ Money-market mutual funds shares (MMMF)	1,550.0	12.5
■ Repurchase agreements 6/	768.4	6.2
● M3 = M2 + public securities held by residents	10,091.7	81.5
○ Public securities held by residents	1,378.0	11.1
■ Issued by the Federal Government	1,186.1	9.6
■ Issued by Banco de México (BREMS) 7/	0.0	0.0
■ Issued by IPAB 8/	192.0	1.6
● M4 = M3 + monetary instruments held by non-residents	12,379.1	100.0
○ Monetary instruments held by non-residents	2,287.4	18.5
■ Demand deposits in banks 2/	41.1	0.3
■ Short-term deposits and securities in banks 5/	45.7	0.4
■ Money-market mutual funds shares (MMMF)	9.8	0.1
■ Public securities held by non-residents	2,092.3	16.9
□ Federal Government securities	2,087.0	16.9
□ Banco de México's Bonds (BREMS) 7/	0.0	0.0
□ IPAB securities 8/	5.3	0.0
■ Repurchase agreements 6/	98.4	0.8

Notes: Methodological note.

Latest three months are preliminary. Totals may not add up exactly, due to rounding off.

1/ Excludes currency held by money-issuing and money-neutral sectors.

2/ Includes checking accounts and current account deposits.

3/ Includes figures of Savings and Loan Societies (SAPs), Popular Financial Companies (Sofipos) and Cooperative Savings and Loan Societies (SCAP).

4/ Excludes public securities.

5/ Includes deposits and debt securities of up to five-year residual maturity.

6/ Defined as the financial resources that banks receives in repurchase operations with the money-holding sector.

7/ In accordance with its law, Banco de México started to issue bonds (BREMS) to facilitate the conduction of monetary policy and its liquidity management in the money market.

8/ Institute for the Protection of Bank Savings (IPAB).

Table 1: Monetary Accounts of the Banco de México

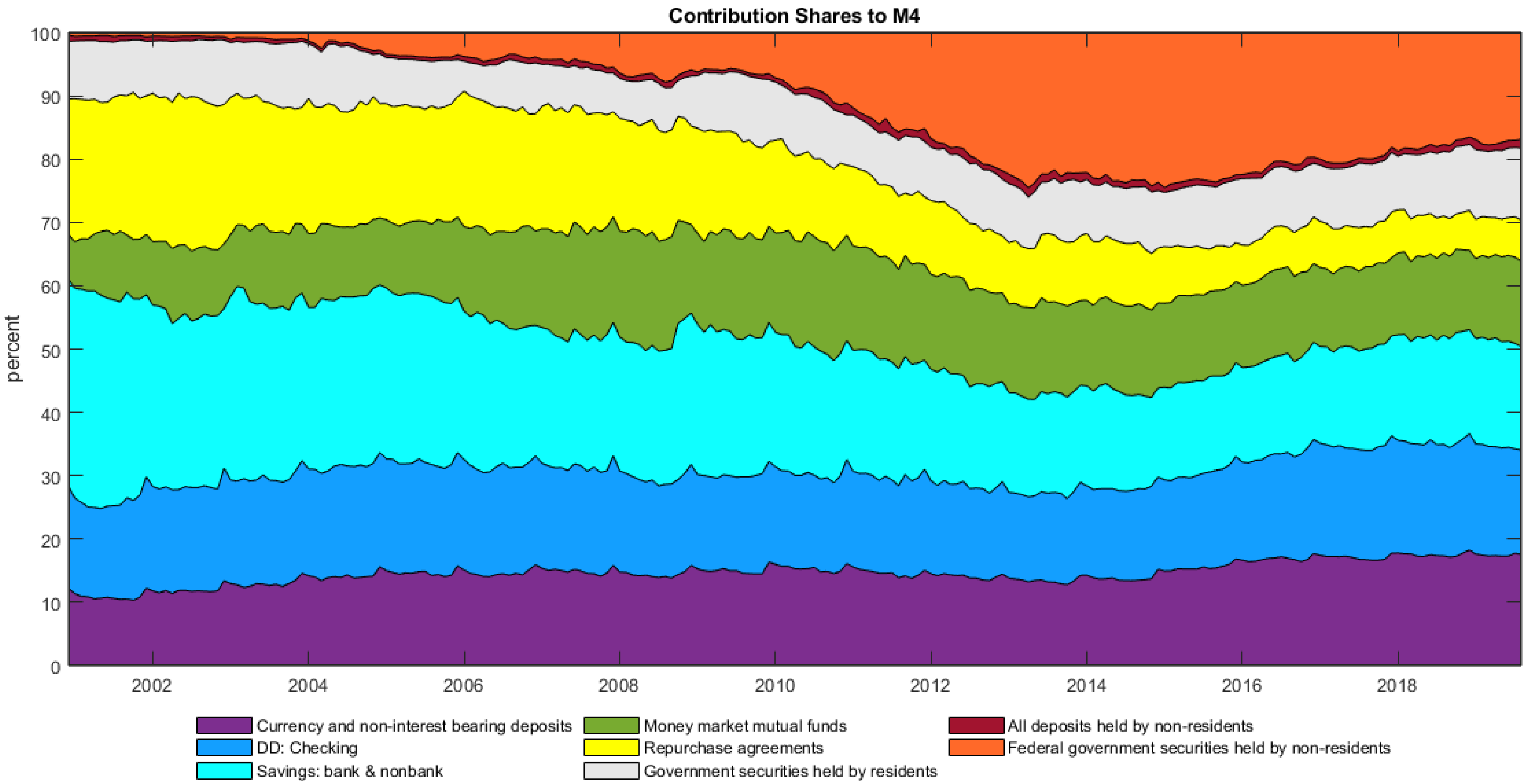


Figure 1: Component Contribution to Banco de México Simple-Sum M4

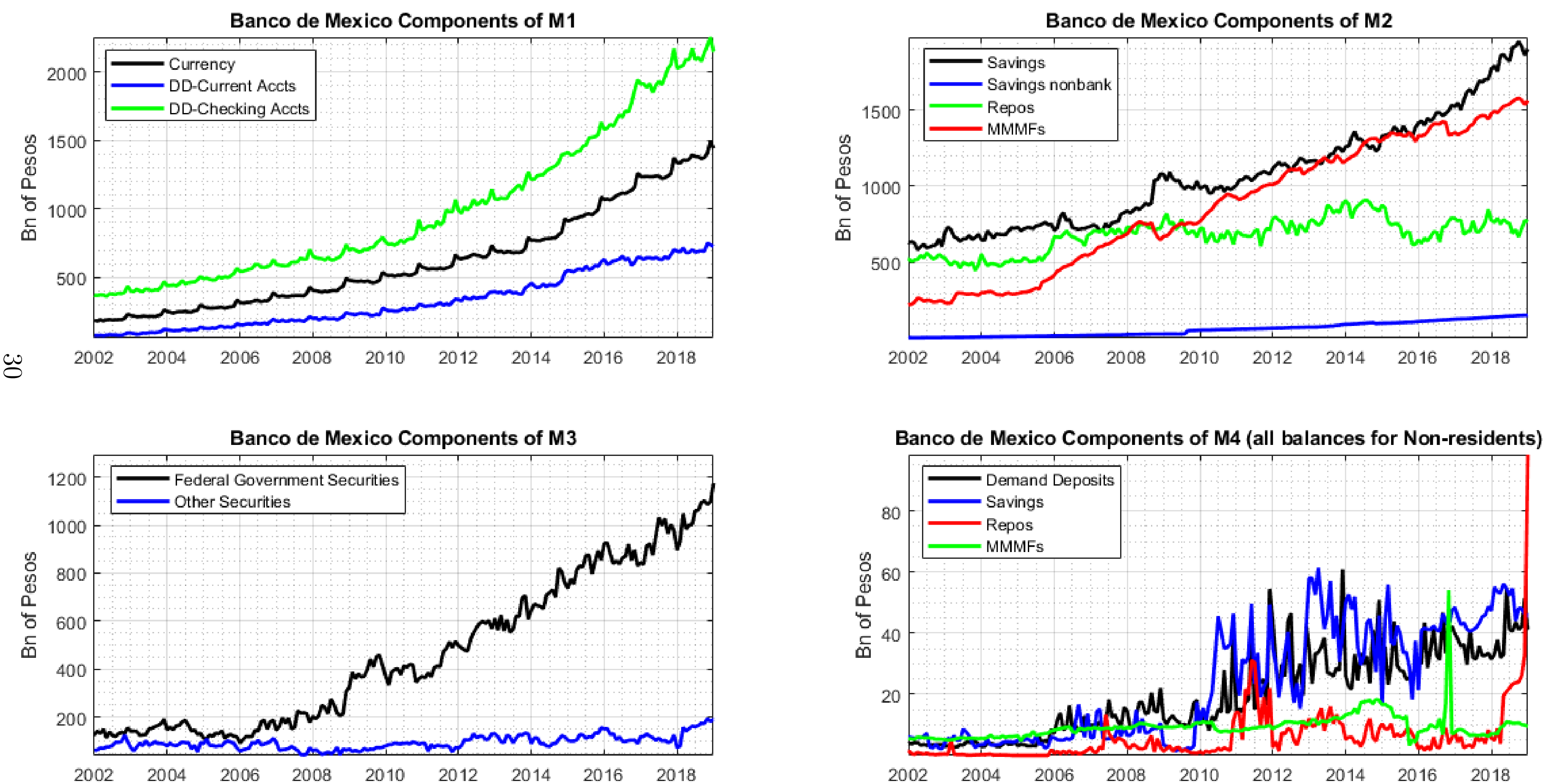


Figure 2: Simple-Sum Monetary Aggregates of the Banco de México

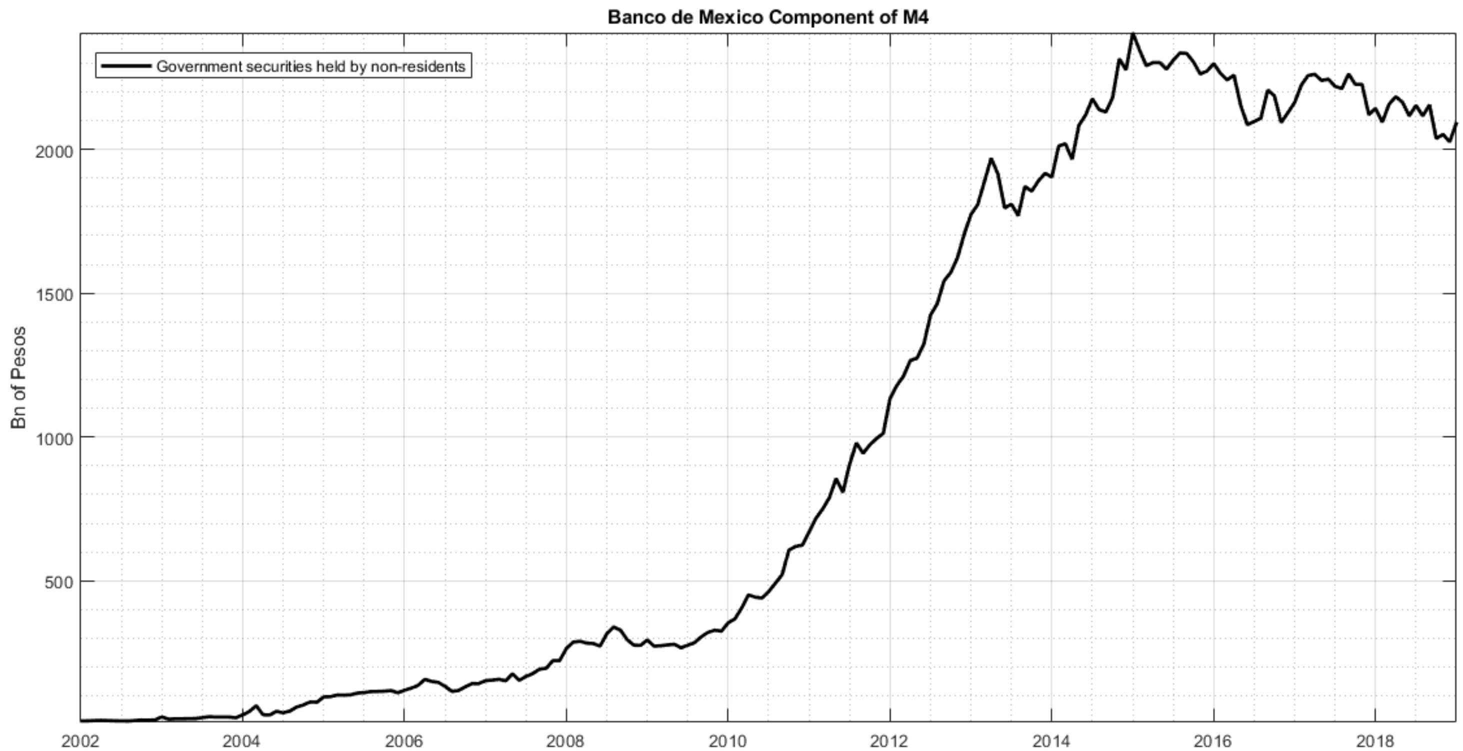


Figure 3: Government Securities Held by Non-Residents

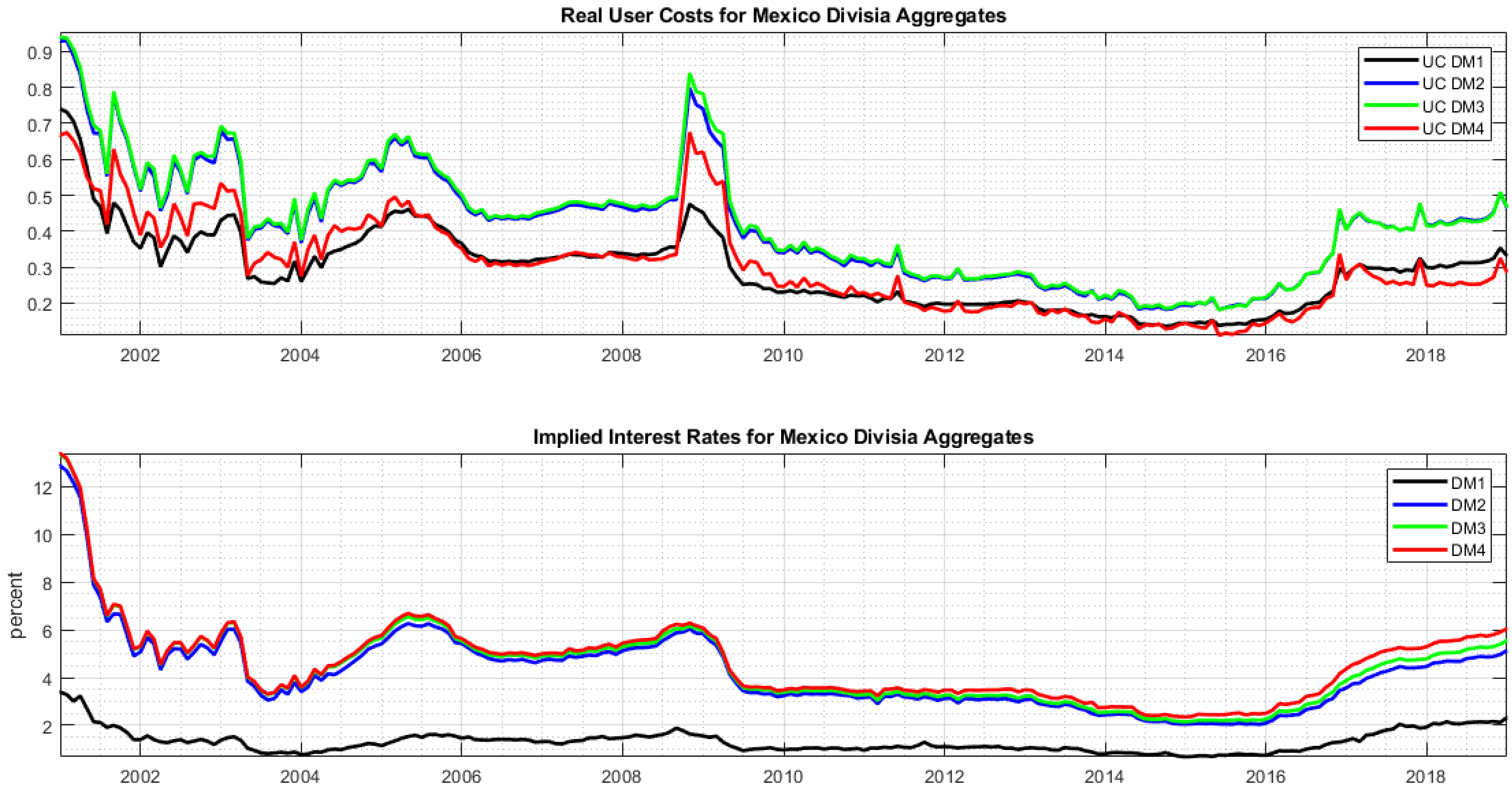


Figure 4: Relevant Interest Rates (price duals) for Various Mexican Monetary Aggregates

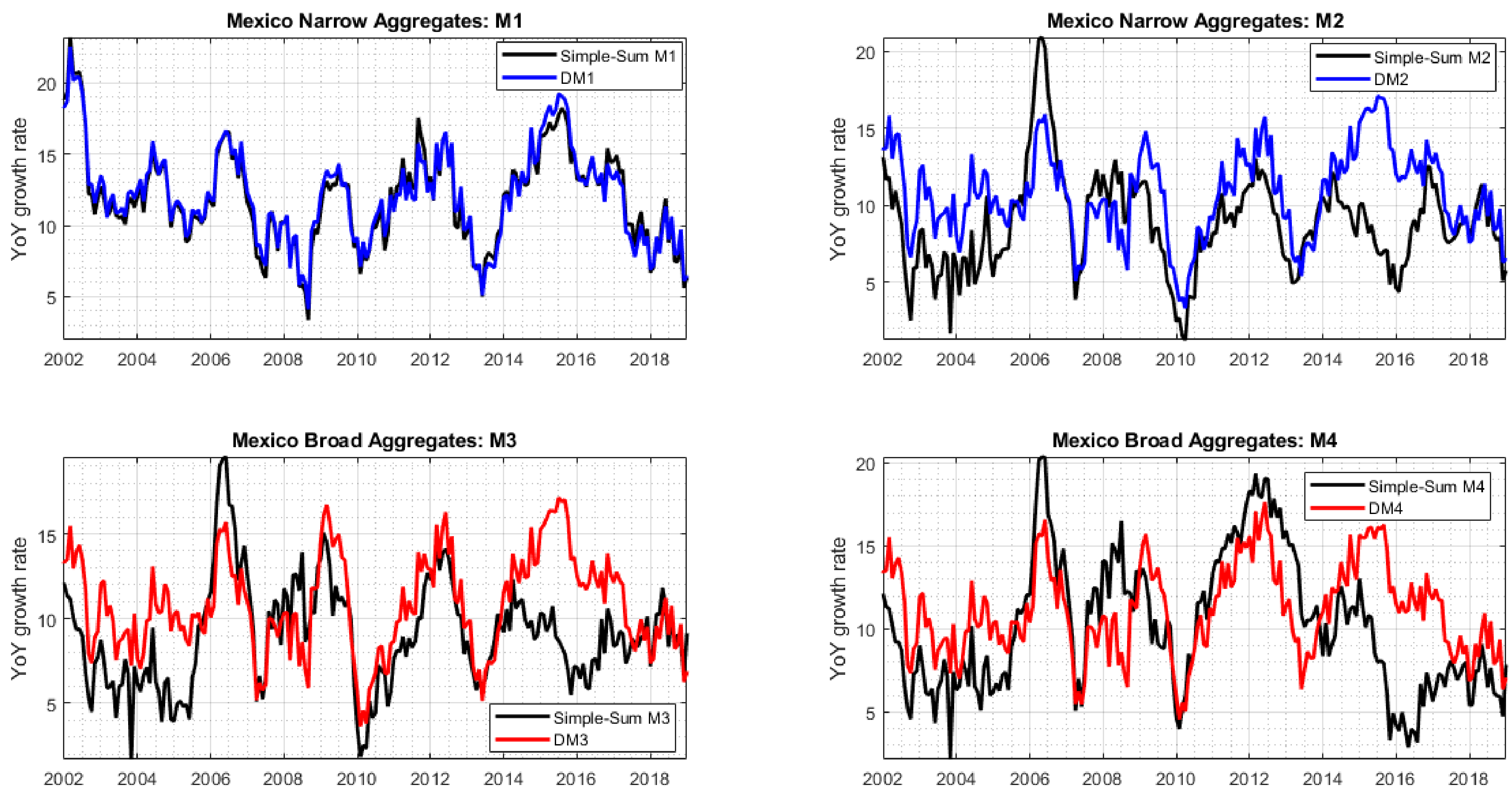
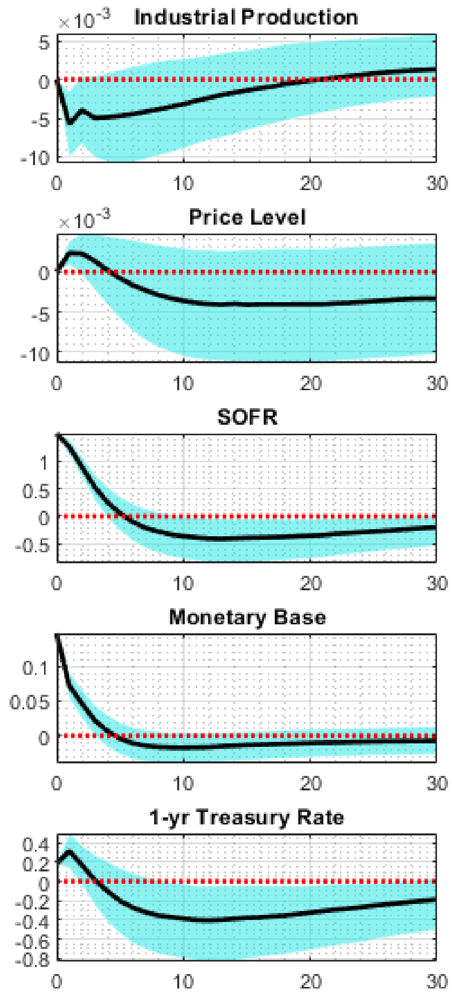


Figure 5: Annualized Money Growth Rates for Mexico

Panel (a)
SOFR
No Commodity Prices



Panel (b)
SOFR
With Commodity Prices

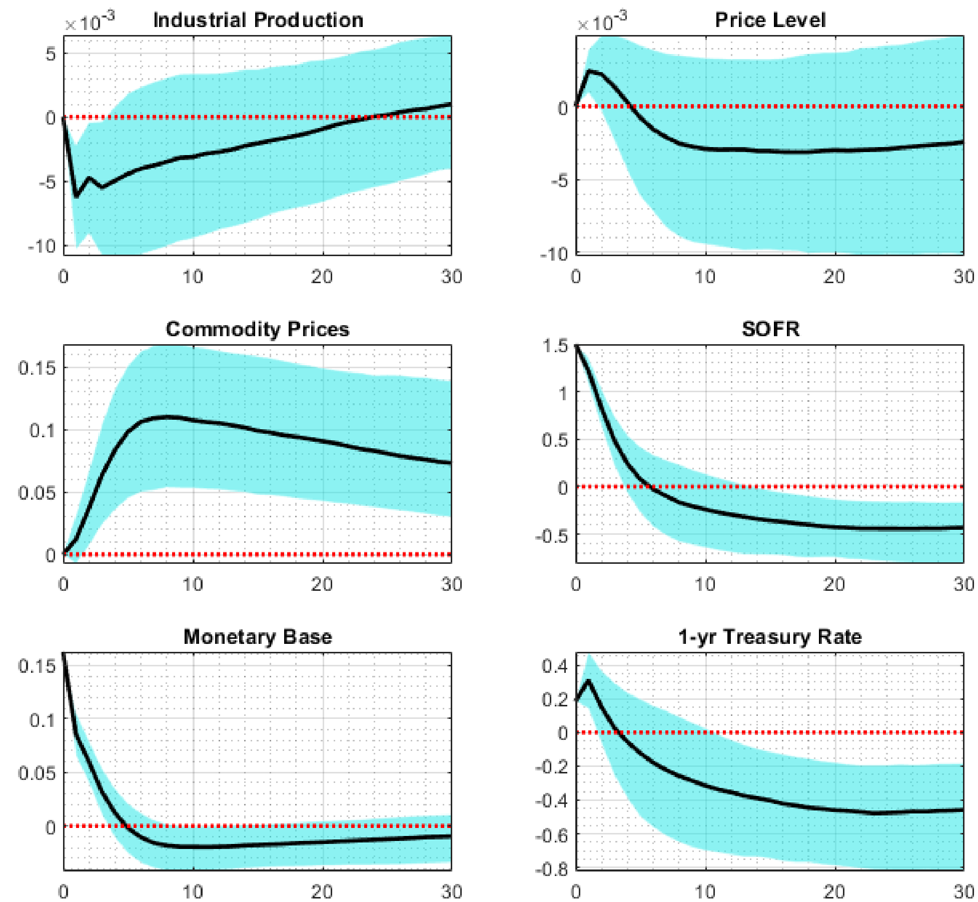


Figure 6: SOFR Specifications
Panel (a) shows a 5-variable Keating et al. (2019)-type specification. Panel (b) expands the X_{1t} block with the International Monetary Fund's Global Price Index of All Commodities in third place. All variables, except for the interest rates are in log levels.

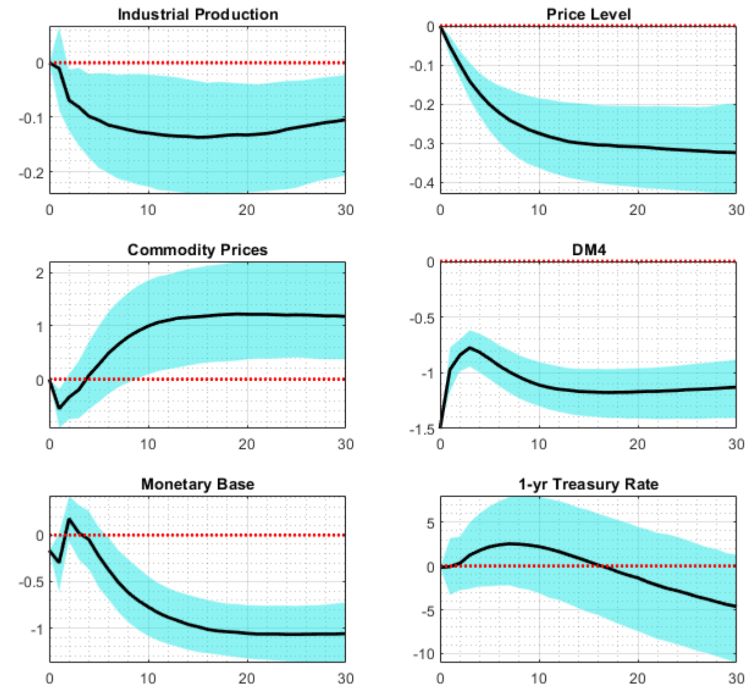


Figure 7: Responses to a One Standard Deviation Reduction in DM4 Money Balances. (*Keating et al. (2019)-type specification*)

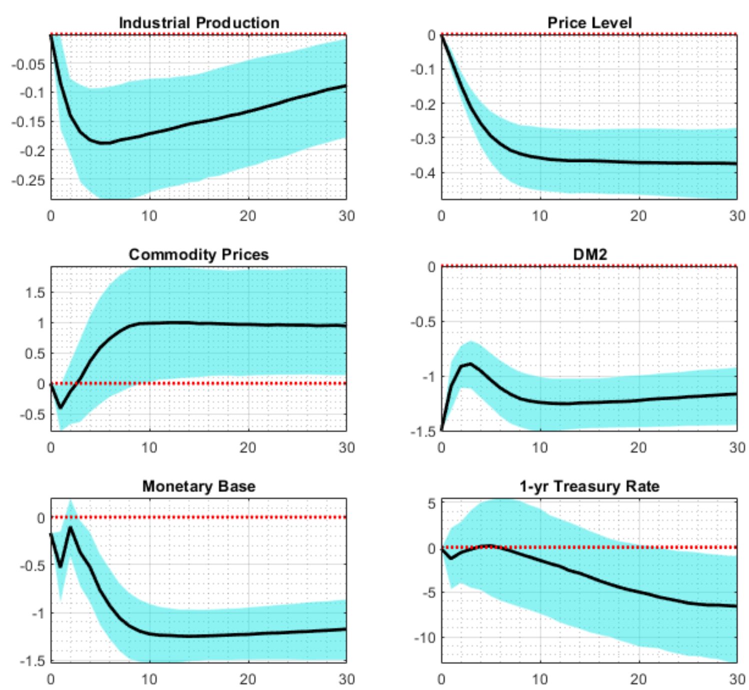


Figure 8: Responses to a One Standard Deviation Reduction in DM2 Money Balances. (*Keating et al. (2019)-type specification*)

Panel (a) **DM1** | **Panel (b)** **DM2** | **Panel (c)** **DM4**

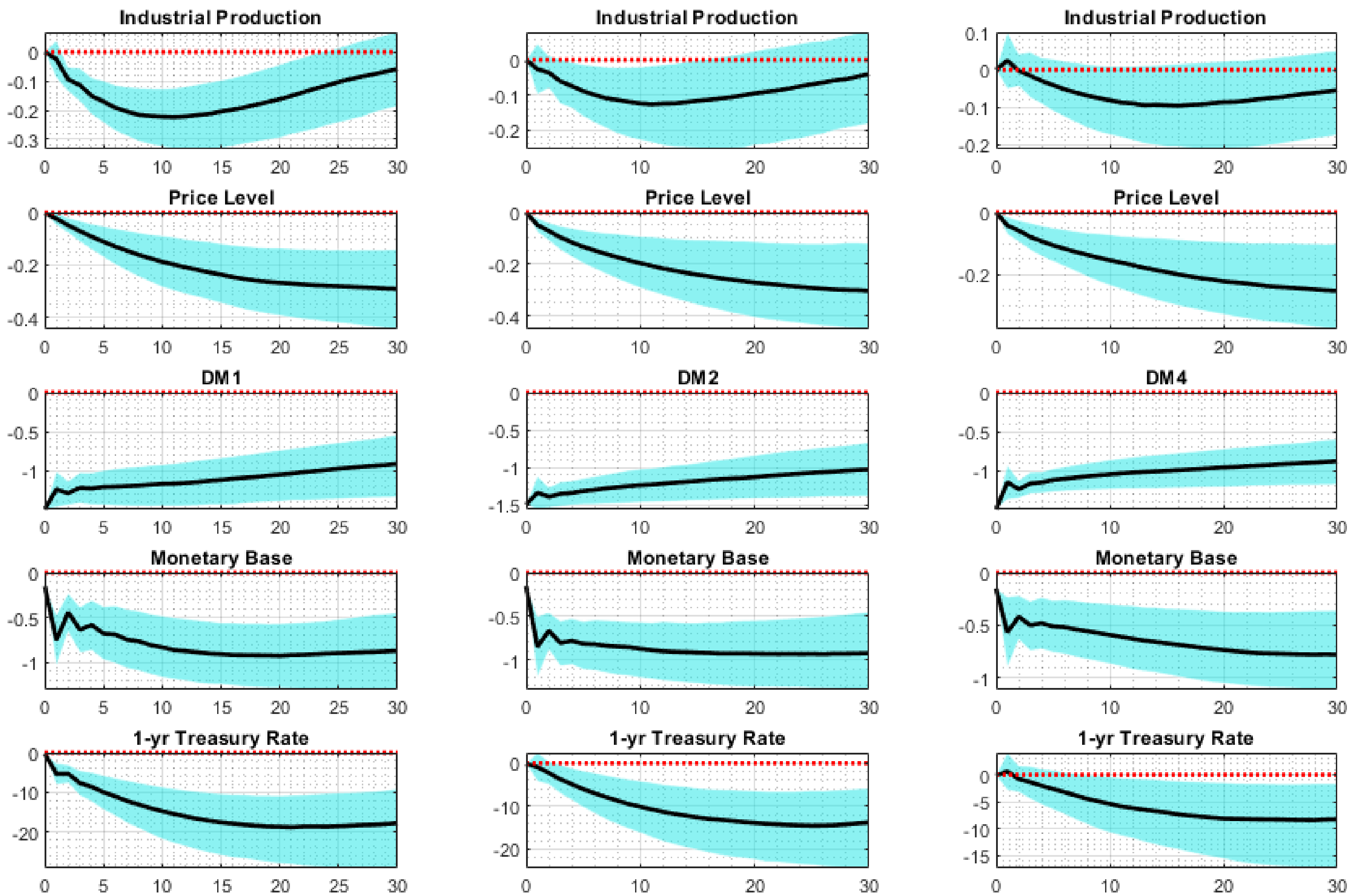


Figure 9: Divisia Specifications
These are Keating et al. (2019)-type specifications that exclude commodity prices for DM1, DM2, or DM4 as the policy indicator.

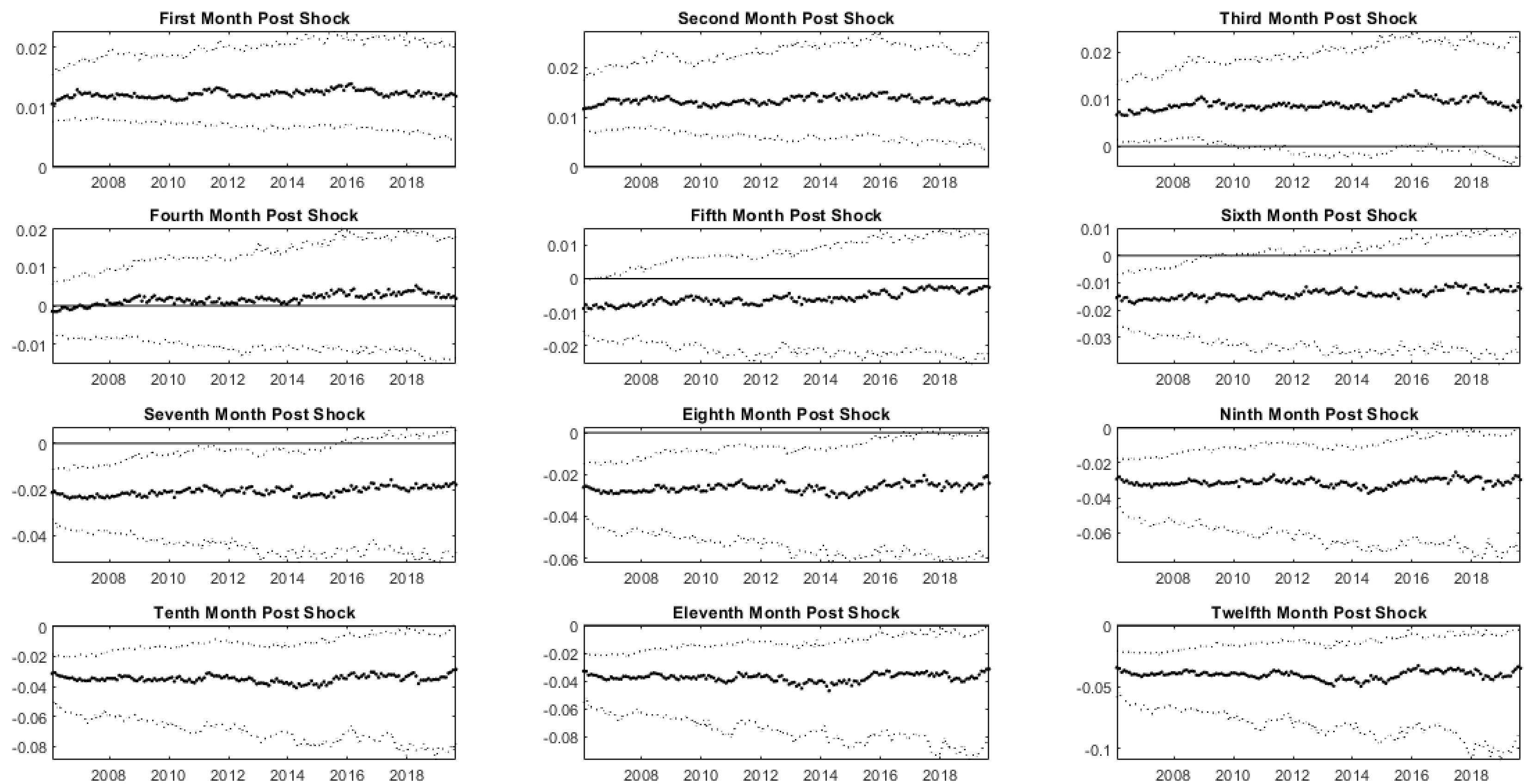


Figure 10: SOFR Specification: First Year Response of the Price Level to a Monetary Policy Shock
All variables (except the treasury and SOFR rates) enter the VAR in log-levels. Confidence bounds comprise the 16% - 84% credible set.

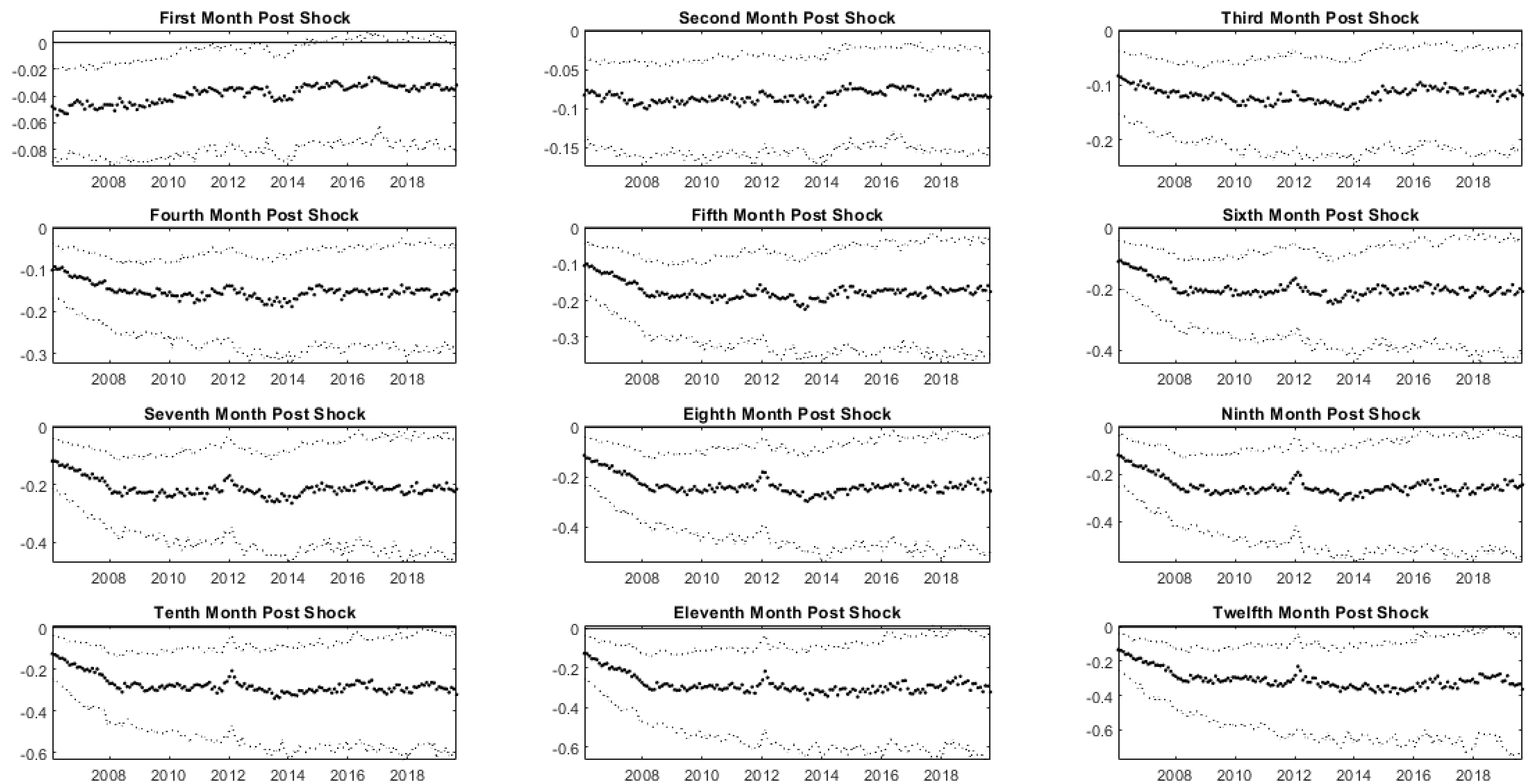


Figure 11: DM4 Specification: First Year Response of the Price Level to a Monetary Policy Shock
All variables (except the treasury rate) enter the VAR in log-levels. Confidence Bounds comprise the 16% - 84% credible set. This specification replaces the SOFR as the monetary policy indicator with Divisia Money M4

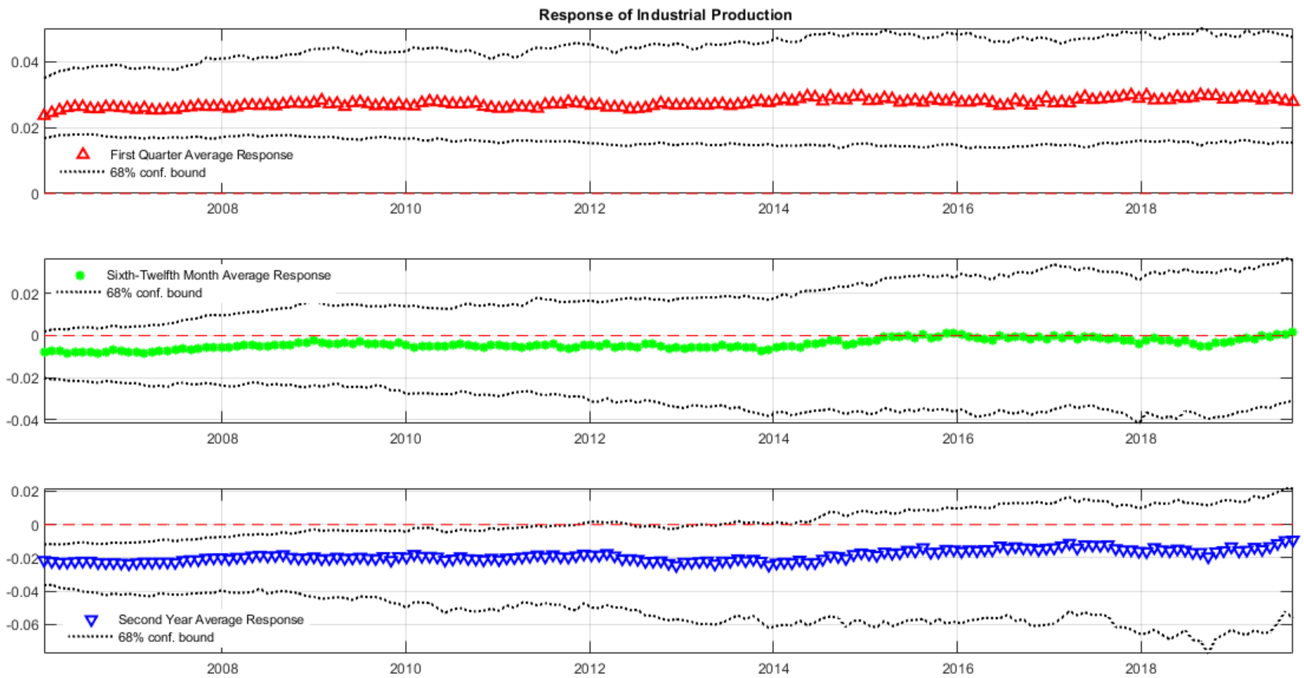


Figure 12: Industrial Production Time-varying Responses to a One Standard Deviation Increase in SOFR.

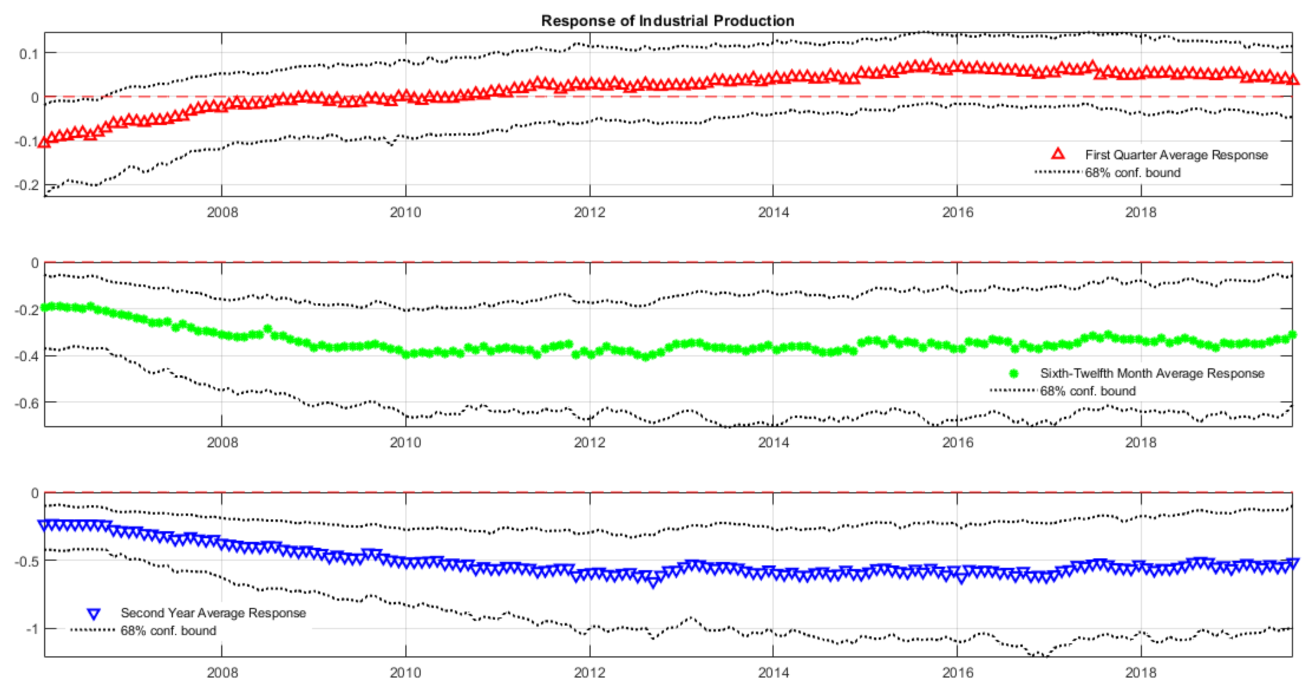


Figure 13: Industrial Production Time-Varying Responses to a One Standard Deviation Reduction in DM4 Money Balances.

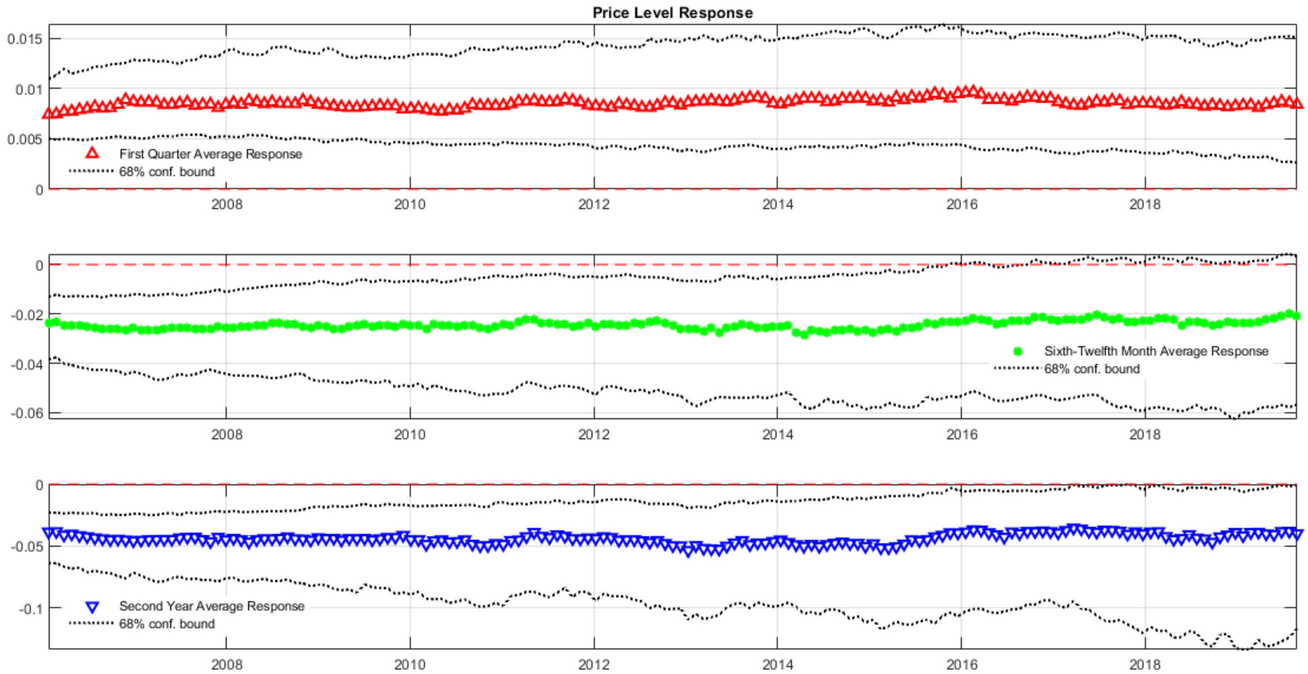


Figure 14: Price Level Time-varying Responses to a One Standard Deviation Increase in SOFR.

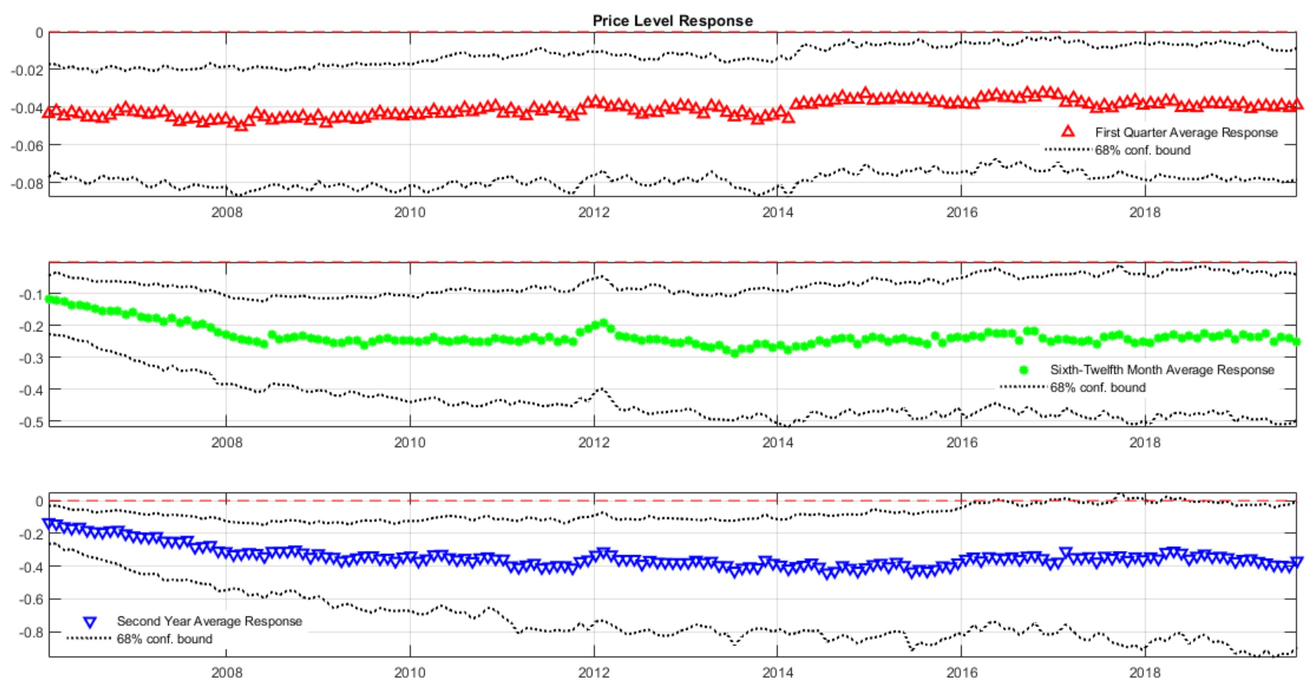


Figure 15: Price Level Time-Varying Responses to a One Standard Deviation Reduction in DM4 Money Balances.

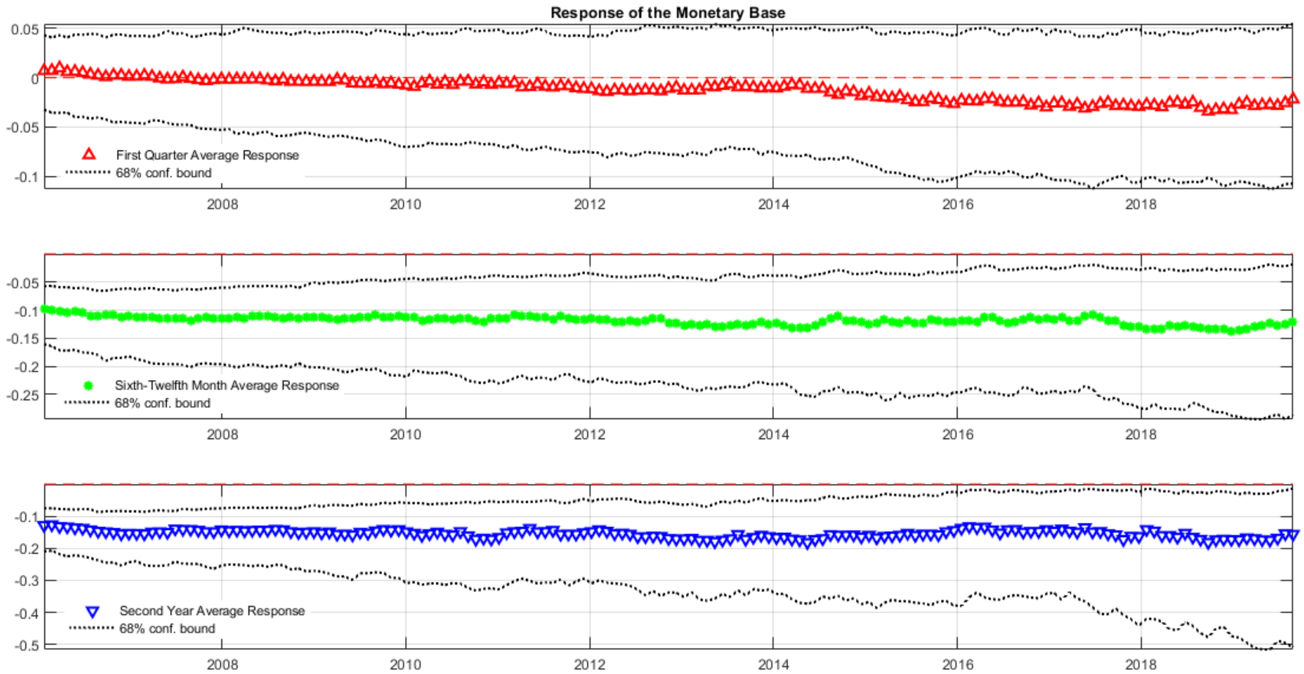


Figure 16: Monetary Base Time-varying Responses to a One Standard Deviation Increase in SOFR.

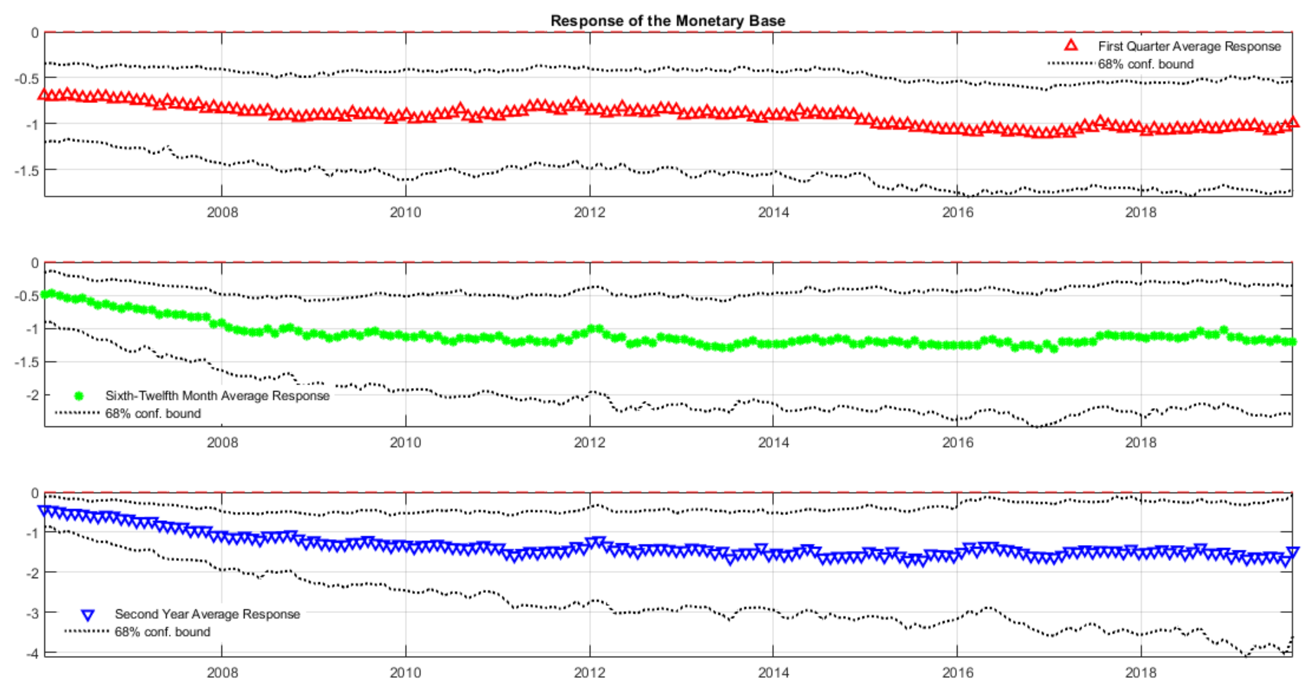


Figure 17: Monetary Base Time-Varying Responses to a One Standard Deviation Reduction in DM4 Money Balances.

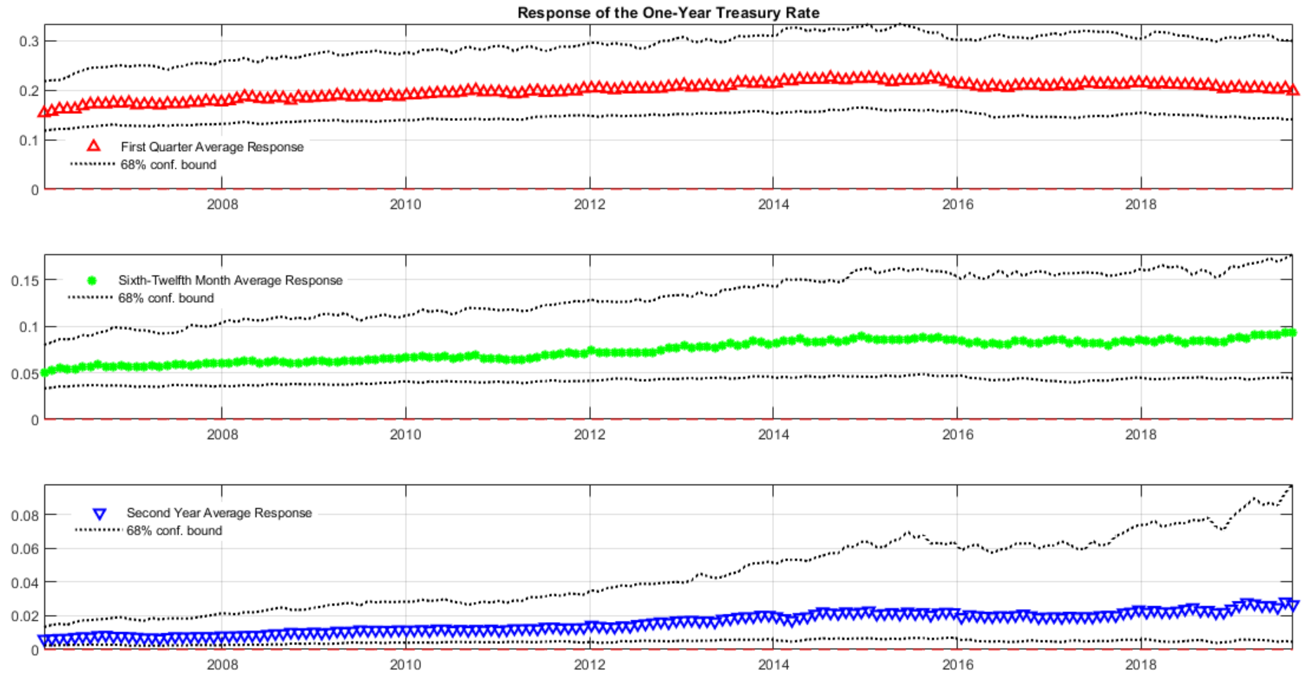


Figure 18: Monetary Base Time-varying Responses to a One Standard Deviation Increase in SOFR.

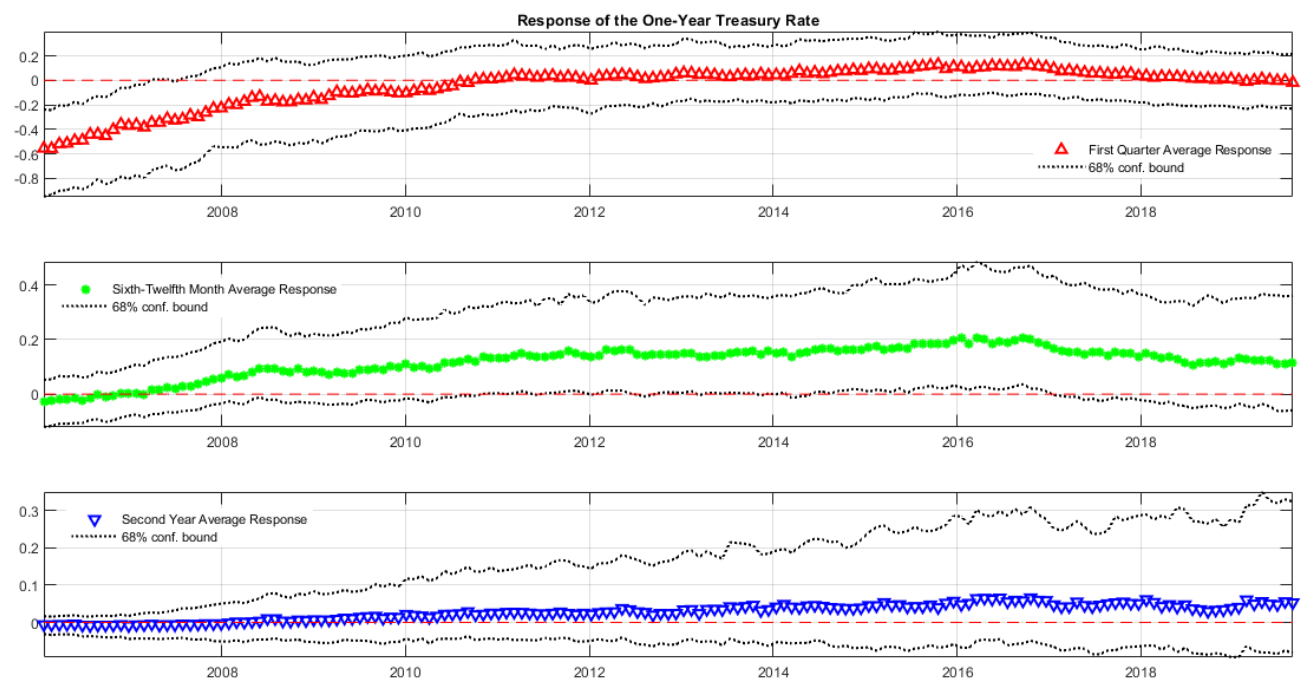


Figure 19: Monetary Base Time-Varying Responses to a One Standard Deviation Reduction in DM4 Money Balances.

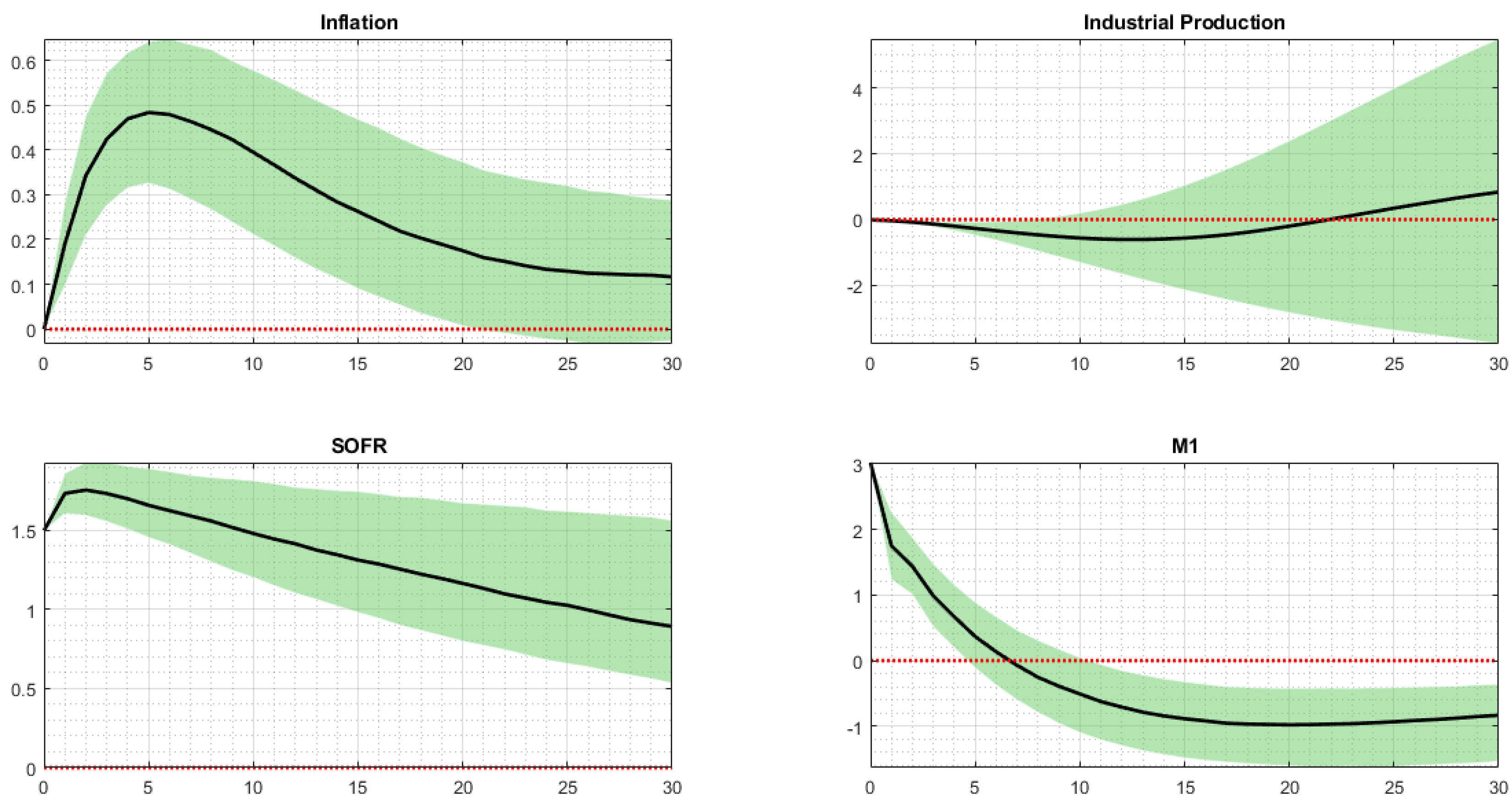


Figure A1: Responses to a One Standard Deviation Increase in the Short-Term Offer Rate (*Non-Recursive Identification*)

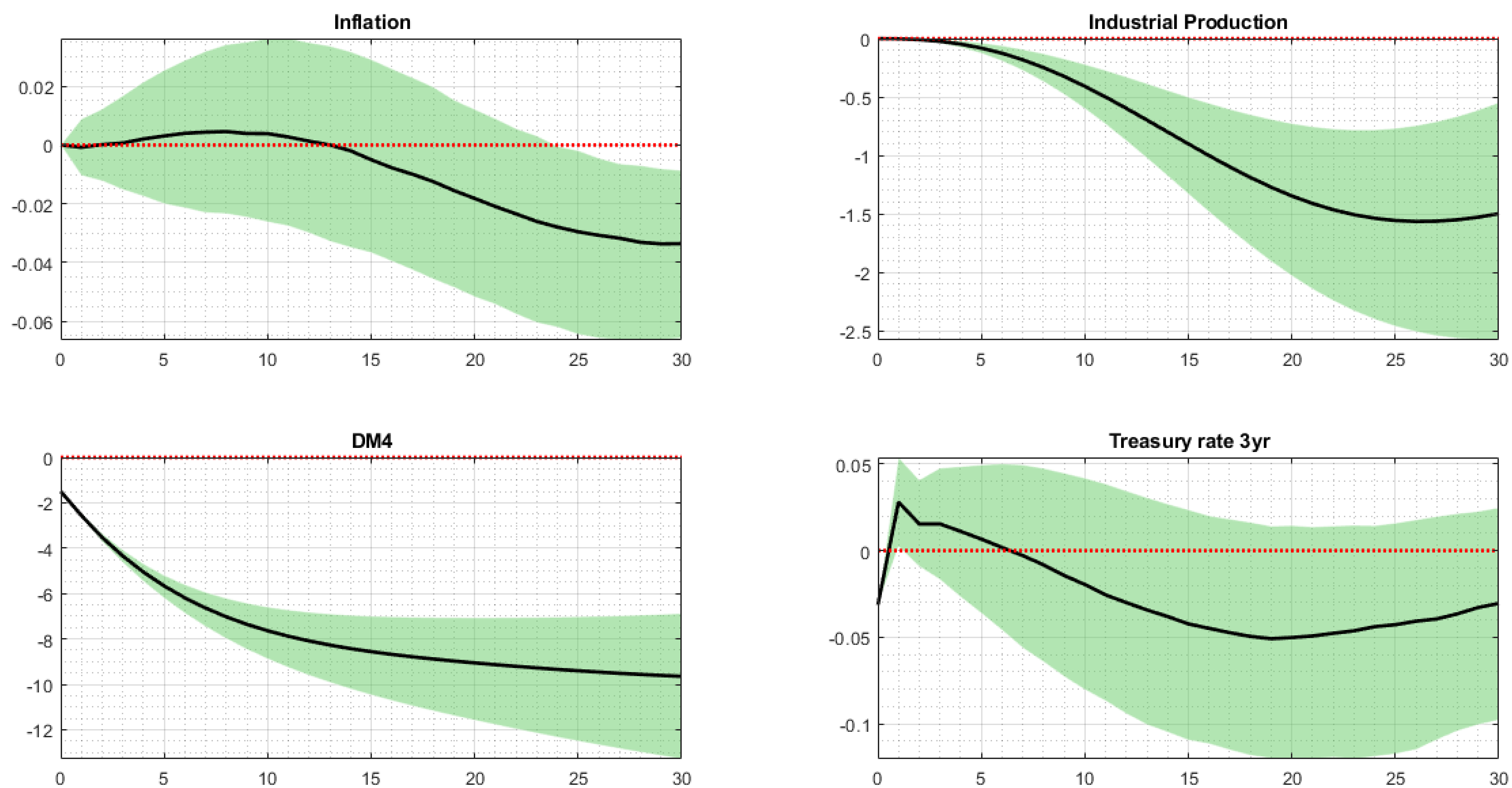


Figure A2: Responses to a One Standard Deviation Reduction in DM4 Money Balances (*Non-Recursive Identification*)

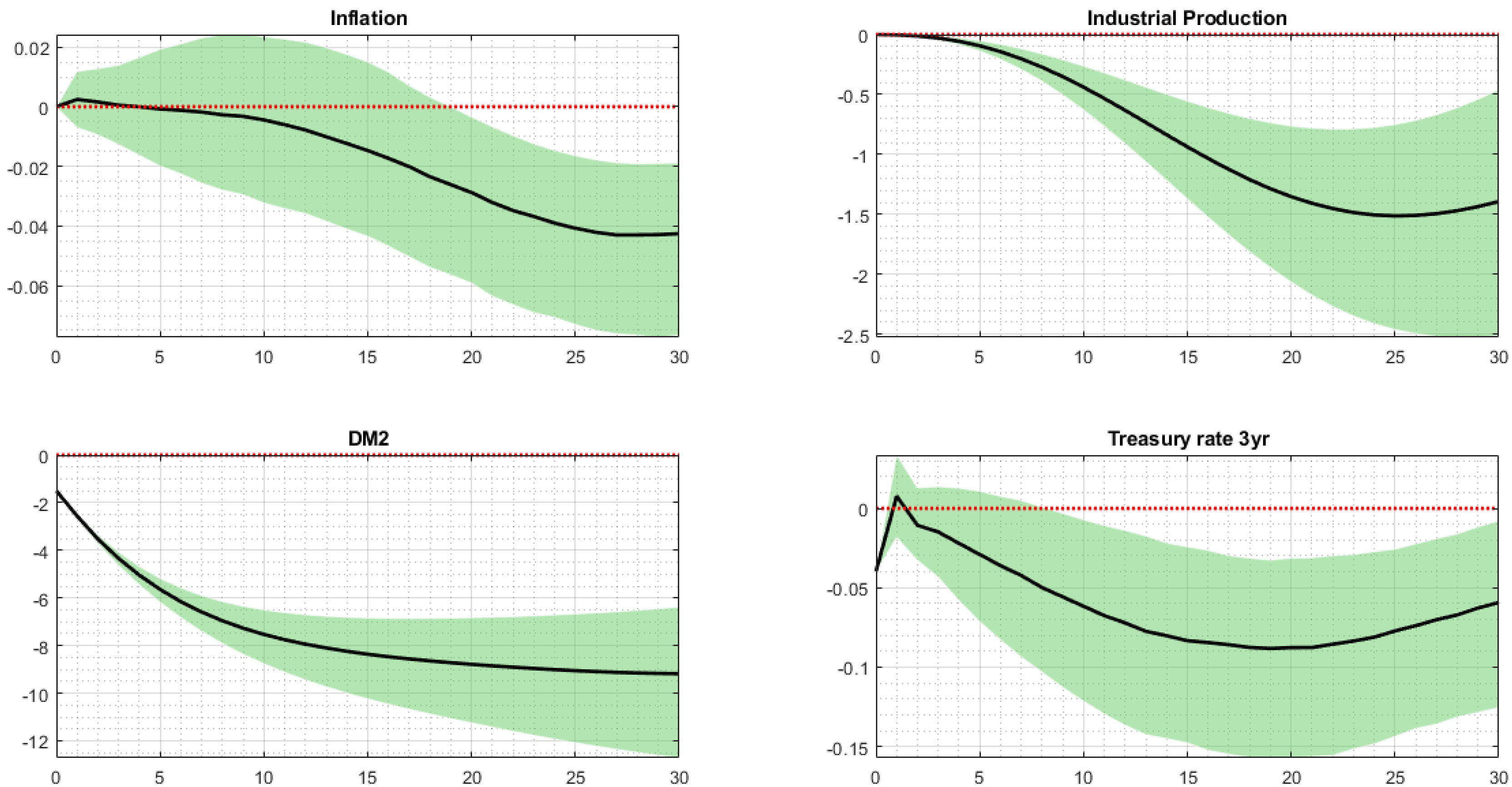


Figure A3: Responses to a One Standard Deviation Reduction in DM2 Money Balances (*Non-Recursive Identification*)

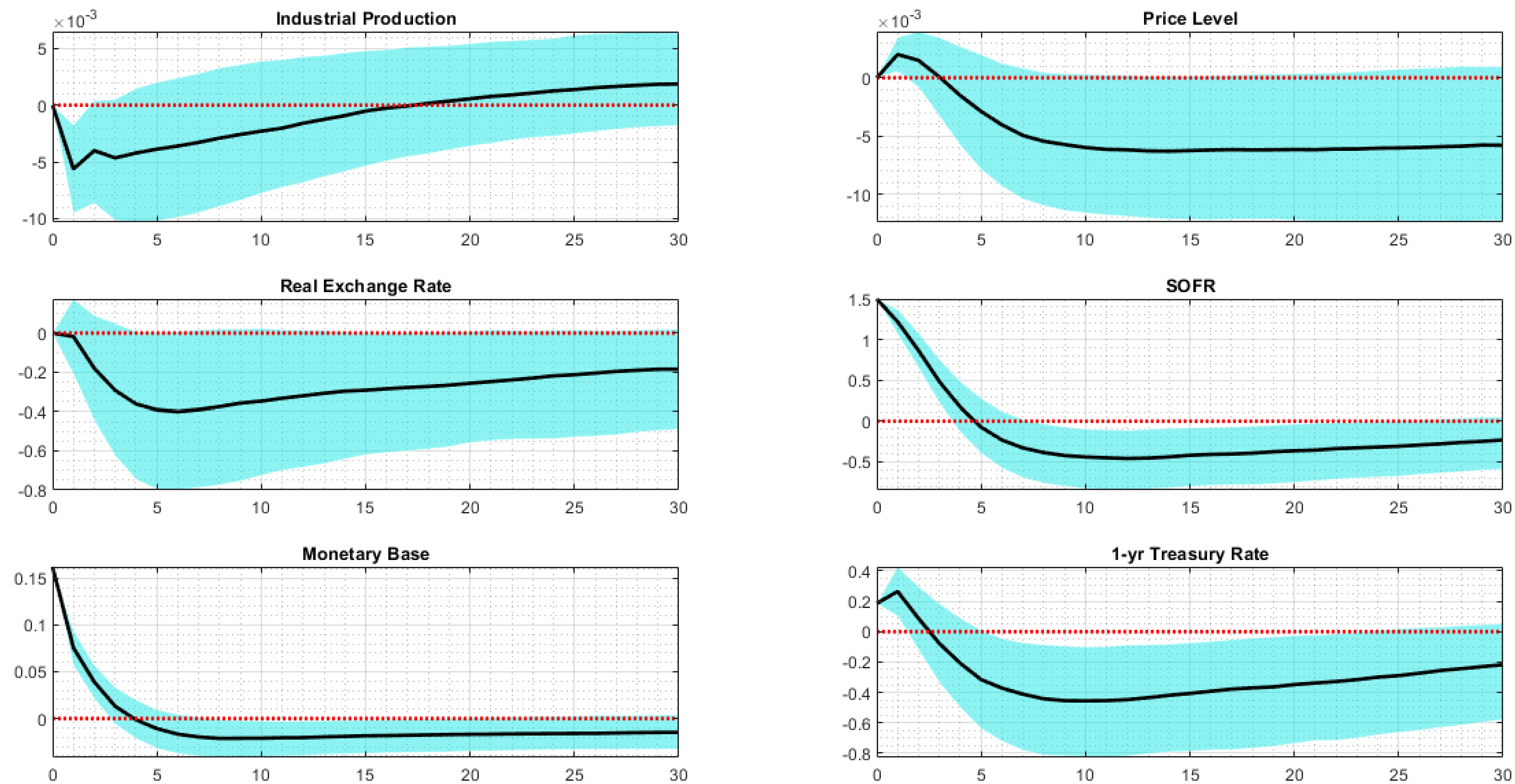


Figure A4: Responses to a One Standard Deviation Increase in the Short-Term Offer Rate (*Keating et al. (2019)-type specifications*)

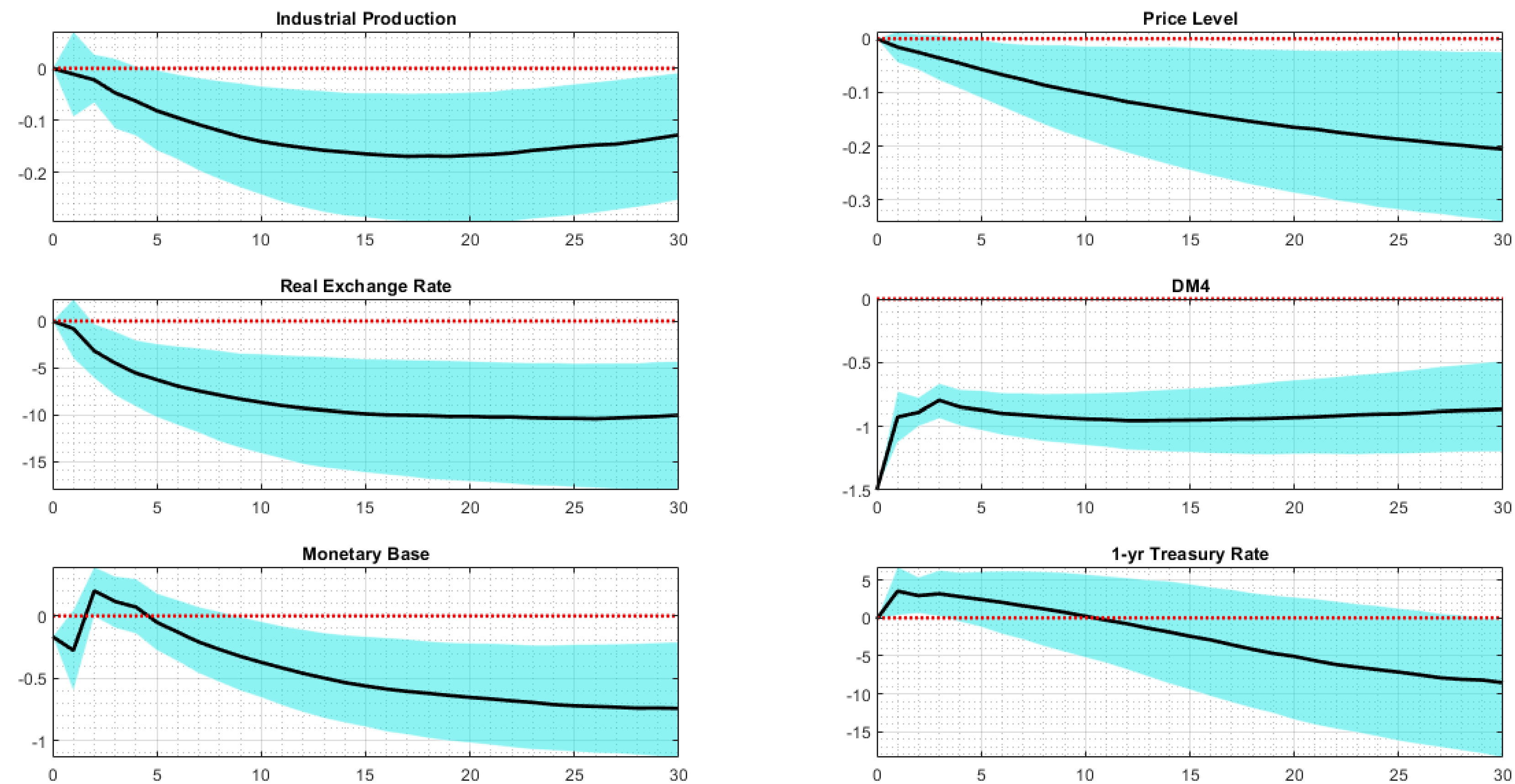


Figure A5: Responses to a One Standard Deviation Reduction in DM4 Money Balances (*Keating et al. (2019)-type specifications*)

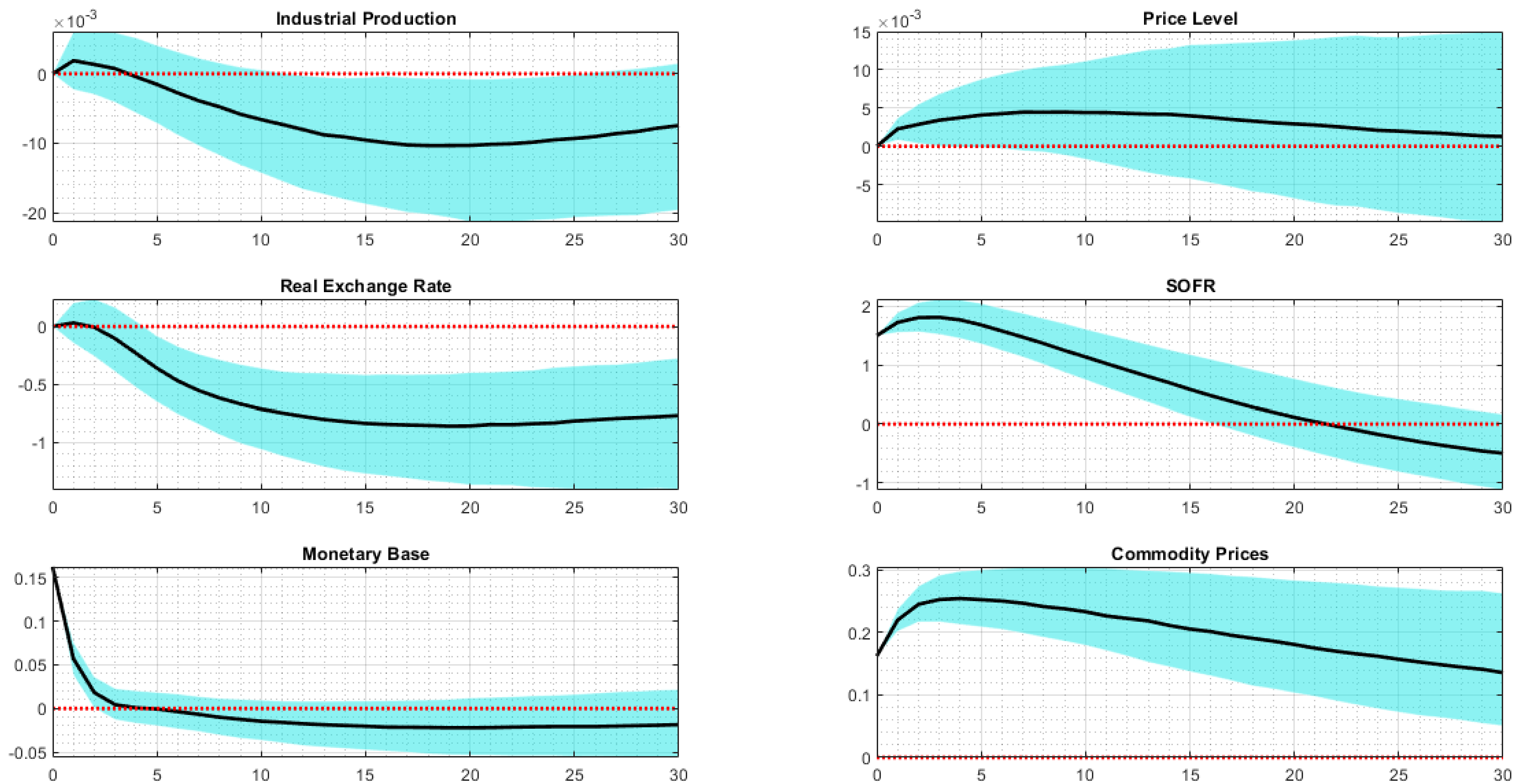


Figure A6: Responses to a One Standard Deviation Increase in the Short-Term Offer Rate (*Keating et al. (2019)-type specifications*)

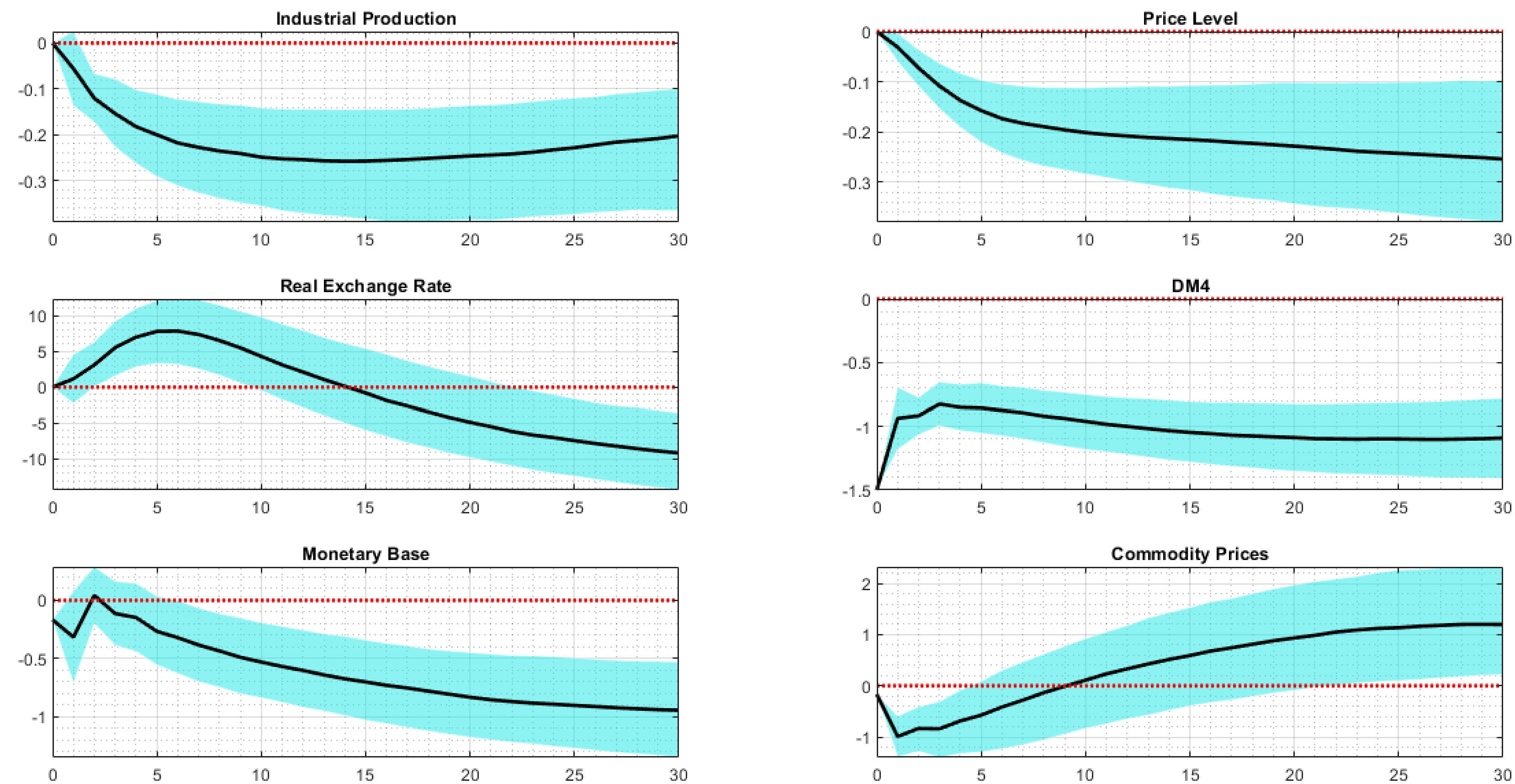


Figure A7: Responses to a One Standard Deviation Reduction in DM4 Money Balances (*Keating et al. (2019)-type specifications*)