

Circumventing the Zero Lower Bound with Monetary Policy Rules Based on Money

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Abstract: Discussions of monetary policy rules after the 2008-2009 recession highlight the potential impotence of a central bank's actions when the short-term interest rate under its control is limited by the zero lower bound. This perspective assumes, in a manner consistent with the canonical New Keynesian model, that the quantity of money has no role to play in transmitting a central bank's actions to economic activity. This paper examines the validity of this claim and investigates the properties of alternative monetary policy rules based on control of the monetary base or a monetary aggregate in lieu of a short-term interest rate. The results indicate that rules of this type have the potential to guide monetary policy decisions toward the achievement of a long run nominal goal without being constrained by the zero lower bound on a nominal interest rate. They suggest, in particular, that by exerting its influence over the monetary base or a broader aggregate, the Federal Reserve could more effectively stabilize nominal income around a long-run target path, even in a low or zero interest-rate environment.

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Circumventing the Zero Lower Bound with Monetary Policy Rules Based on Money

The Federal Reserve Act, as amended in 1977, directs the Fed to pursue “goals of maximum employment, stable prices, and moderate long-term interest rates.” From one perspective, the Act can be viewed as directing the central bank to follow a targeting rule because it specifies that the Fed is to achieve a particular set of objectives. Examples of targeting rules include proposals that would have the central bank stabilize nominal income [e.g., Bean (1983), Sumner (1989), Feldstein and Stock (1994) and Woodford (2012)] or the price level [e.g., Svensson (2003)]. Moreover, in the language of Debelle and Fischer (1994), the Act can be interpreted as preserving “instrument independence” in the sense that it allows the Fed to pursue these goals by using whatever monetary policy tools are available to it.¹

Monetary policy also can be implemented by adoption of an instrument rule. In this case, the policy rule gives guidance as to how a central bank’s instrument or intermediate target should be set to accomplish the ultimate objective of central bank actions. In contrast to a targeting rule, an instrument rule gives the central bank “goal independence” because it allows the central bank to determine the specific objective(s) of monetary policy; the well-known Taylor (1993) Rule, the monetary base rules outlined by Meltzer (1987) and McCallum (1988), and Milton Friedman’s (1960) k-percent rule are examples instrument rules. To be fair, these rules are constructed with the goals of the Federal Reserve Act in mind but set specific numerical values for policy objectives where the Act itself is silent on this issue.

Apart from questions about the relative merits of targeting rules and instrument rules, recent discussions of monetary policy rules have been forced to deal with a different issue. Because most central banks implement monetary policy by influencing the behavior of a short-

¹ From a different perspective, the omitted portion of the Federal Reserve Act quoted above may not offer as much latitude as it is interpreted conventionally. The full quote reads: “The Board of Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates” (emphasis added). Because virtually all modern monetary policy rules are based on a setting for a short-term interest rate, it is possible that they violate this overlooked portion of the Fed’s mandate.

term interest rate and an interest rate rule is part of the standard New Keynesian model, both practice and theory imply that monetary policy can lose its ability to stimulate economic activity when that short-term interest rate reaches its zero lower bound. As central bank actions after the market crash of 2008 made this apparent constraint a reality, much of the recent discussion about monetary policy rules has turned to “unconventional” tools that might allow monetary policy to escape this “liquidity trap.”²

In what follows, we describe an alternative approach to the specification of a targeting rule by focusing on the central bank’s ability to set a path for the quantity of money and exploiting the connection between variations in the quantity of money and other nominal magnitudes. The general approach taken is due to Working (1923) and is in the same spirit as a modified version of the P-star model due to Orphanides and Porter (2000). Finally, because discussions like those in Svensson (2003, 2005) and McCallum and Nelson (2005a, 2005b) explain the difficulties associated with any effort to determine whether one type of rule is superior to the other, we use this general framework to investigate how the behavior of nominal income or the price level is related to rule-based paths for the money supply.³ If a rule of this type is shown to be tractable it will offer a policy framework in which the zero lower bound constraint is irrelevant, or at least less important than it is popularly thought to be. In fact, our statistical results draw particularly tight links between the path of nominal GDP and those of several Divisia monetary aggregates and, especially, an adjusted measure of the monetary base due to Tatom (1994). These statistical links appear consistently throughout a sample of data running from 1967:1 through 2015:4 and show little or no signs of weakening in shorter and more recent subsamples dominated by the financial crisis and Great Recession of 2007 through 2009 and the slow recovery that followed. We interpret these results as evidence that, even working within existing institutional arrangements, the Fed could effectively adopt and

² Apart from issues about the potential effects of any change in interest rates on economic activity, a rule based on the federal funds rate also depends on the Federal Reserve’s ability to control that rate, a proposition questioned in recent work by Fama (2013).

³ Gartner (2008) examines monetary policy rules from a public choice perspective and also concludes that there appears to be no clear criterion by which one type of rule could be judged to be superior to an alternative.

follow a targeting rule for nominal income, using its power to influence the monetary base or one of the broader monetary aggregates, even when short-term interest rates are at or near their zero lower bound.

Motivation for a Rule Based on a Monetary Aggregate

After previously close connections between money and both nominal income and prices were questioned by influential papers due to Friedman and Kuttner (1992) and Bernanke and Blinder (1988, 1992), the focus of monetary policy research turned to the federal funds rate both as the tool used by central banks to implement monetary policy actions and the variable that transmitted the effects of policy actions to aggregate activity.⁴ In keeping with the spirit of these empirical findings, John Taylor altered the original version of his monetary policy rule [Taylor (1979)], which was based on controlling the money supply, to the more recognized rule based on settings for the federal funds rate [Taylor (1993, 1999)]. When the interest rate version of a Taylor Rule was embedded in the canonical New Keynesian model, any role for money was omitted and, by assumption, all effects of central bank actions on aggregate activity were left to be transmitted via changes in the federal funds rate. Together, these developments led to the conclusion that an economy could enter a “liquidity trap” when the short-term interest rate reached its zero lower bound and that, pending alternative monetary policy strategies, aggregate activity could become pinned at a low level.

Laidler (2004) questions this line of reasoning and, if his criticisms are valid, it would be worth re-examining whether the quantity of money can serve as an important policy lever. First, Laidler explains that the General Theory’s concept of a “liquidity trap” was not given that

⁴ Despite their influence on subsequent research, it is not clear that the results reported in these studies are robust. For example, Belongia (1996) and Hendrickson (2014) both replicated portions of these papers and found that qualitative conclusions were reversed when the Federal Reserve’s official monetary aggregates were replaced by a comparable Divisia monetary aggregate. The sensitivity of inference to choice of monetary aggregate influences the empirical choices made in this paper. Beckett and Morris (1992) and Thoma and Gray (1998) make more general comments on the robustness of the results reported by Friedman and Kuttner and by Bernanke and Blinder. Finally, Belongia and Ireland (2015b, 2015c) present evidence that money appears to contain information beyond that represented by an interest rate in isolation.

name until discussed and defined by Robertson (1940). And although Robertson may have had in mind a concept that differed slightly from that discussed by Keynes, the basic idea in either case involves a relationship between the demand for money and a long-term interest rate. Specifically, if the demand for money is infinitely elastic at some level of the long-term rate, a central bank's ability to stimulate spending is impeded because further increases in the quantity of money relative to wealth fail to induce further reductions in the relevant long rate. In this case, the quantity of money can be expanded but doing so will be of little consequence. While possible conceptually, the question is whether the phenomenon is important empirically and both Robertson and Keynes had reservations about the significance of this effect.⁵ And, for modern discussions of a "liquidity trap," it is important to note that the implied theoretical relationship is silent on the role of a short-term interest rate.

Rather than discuss a severe economic contraction in terms of a liquidity trap, Laidler notes that Hawtrey (1931, 1932) expressed the situation in terms of a "credit deadlock."⁶ Whereas a decline in interest rates might be sufficient to recover from a moderate downturn, a credit deadlock could arise if the public becomes sufficiently pessimistic about the future that they "abstain from enterprise and do not borrow." Thus, low interest rates observed during a prolonged contraction are "merely the outward reflection of the unprofitableness of business and the unwillingness of traders to borrow There is a deadlock which can best be broken by injecting money into the system" [Hawtrey (1932), p. 172]. Note that this situation is not about the demand for money but, instead, it describes highly inelastic schedules for the demand and supply of loans with respect to a short-term rate interest rate. Moreover, interest rates are low not because monetary policy has been excessively expansionary: Interest rates are low because monetary policy has been restrictive.

⁵ For example, Keynes (1936) wrote that: "whilst this limiting case might become practically important in the future, I know of no example hitherto." (p. 207).

⁶ Sandilands (2010) also discusses these topics at length and then illustrates the distinctions between modern notions of a liquidity trap and the lesser-known credit deadlock by comparing the experience of the United States during the Great Depression to the experience of Japan during the 1990s. Boianovsky (2004) provides an extensive discussion of how the concept of a liquidity trap has evolved "from Hicks to Krugman."

The basic problem in a credit deadlock, therefore, is not that increases in the quantity of money will have no effect on economic activity but rather that the public's reluctance to borrow prevents money from being created in the first place. Hawtrey (1931, pp. 30-31) describes the situation and a solution to it as follows:

[I]f the depression is very severe, enterprise will be killed. It is possible that no rate of interest, however low, will tempt dealers to buy goods. Even lending money without interest would not help if the borrower anticipated a loss on every conceivable use that he could make of the money. In that case the purchase of securities by the Central Bank, which is otherwise no more than a useful reinforcement of the low Bank rate, hastening the progress of revival, becomes an essential condition of the revival beginning at all. By buying securities the Central Bank creates money, which appears in the form of deposits credited to the banks whose customers have sold the securities. The banks can thus be flooded with idle money, and given a new and powerful inducement to find additional borrowers.

Thus, if modern understanding of what constitutes a liquidity trap differs from the original concept but modern downturns are analyzed from this perspective, the zero lower bound problem will, indeed, appear to constrain the central bank's efforts to initiate a recovery. If, however, a reluctance to borrow and its negative effects on money growth better explain a protracted downturn, it is possible to see how a central bank can affect aggregate spending through means other than manipulation of an interest rate. In particular, a role for money can be seen as an important omission from the New Keynesian model under conditions of a credit deadlock. This alternative interpretation of economic relationships motivates our return to policy rules based on money rather than a short-term interest rate.

A General Framework for a Rule Based on Money

All that follows is based on the standard quantity theory expression, $MV = PY$ and, in this form, the central bank is focused on a target level for its goal variable. Alternatively, a central bank could set its objective in terms of the inflation rate or the growth rate of nominal income. A disadvantage of setting a target in terms of growth rates is that accumulated deviations from a growth rate path can lead to "base drift," a widening and uncorrected gap between the target variable and a constant growth rate desired in the long run. Moreover, if base drift is persistent, the credibility of a central bank's commitment to its target may be

undermined. Conversely, an objective specified in terms of the level of prices or income will bring the target variable back to its long run trend but doing so may at times require excessively sharp contractions to offset disturbances that move the target variable above its trend. In the aftermath of a substantial downturn, however, a levels target will require more stimulus to return to the objective's trend path whereas a growth rate target can be resumed without ever returning the objective to its pre-disturbance level.⁷ The discussion below focuses on monetary policy objectives based on the level of a goal variable but does so only to illustrate strategies unconstrained by the zero lower bound on interest rates.

The basic quantity theory relationship can be manipulated in a variety of ways to generate policy rules directed to different objectives.⁸ For example, Belongia and Ireland (2015a) recently returned to this general framework to examine proposals for targeting nominal income. However, some empirical choices must be made if a rule for targeting nominal is to become operational. In particular, because the proposed rule is designed to keep nominal income on a smooth, long-run path, a value for trend velocity must be found. Towards this end, the quantity equation can be re-written as

$$(1) X_t = M_t V_t,$$

where X_t denotes nominal income, M_t is the money stock, and V_t is the velocity of money. Given data on nominal income and the money stock, (1) suggests that a series for trend velocity can be constructed by passing the series through the one-sided version of the Hodrick-Prescott filter described by Stock and Watson (1999). With the trend value of velocity V^*_t in hand, the target value for nominal income X^*_t can be expressed as:

⁷ It is this failure to return to the trend level of nominal spending after the Great Recession that has led economists known as "Market Monetarists" to focus on both a levels target and a target for nominal spending rather than prices alone. Because nominal income has been persistently below its trend value since 2007, this group has judged monetary policy as being too restrictive throughout the post-crash recovery.

⁸ Humphrey (2001) discusses proposals for this type of rule made in the 1920s and compares them to the monetary policy strategy, based on a version of the Real Bills Doctrine, employed by the Fed in that era. One implication of the discussion is that interest rates can be a very misleading indicator of the stance of monetary policy. Hetzel (1985) also reviews the debate between monetary rules and discretion that occurred in the 1920s.

$$(2) X_t^* = M_t V_t^*.$$

Thus, for a given level of the money stock M_t , X_t^* is the value to which actual nominal income X_t should converge as velocity V_t gradually returns to its long-run value V_t^* .⁹ By extension, the central bank can achieve its desired target for nominal income through the appropriate choice of the money stock M_t ; and since V_t^* is constructed with a one-sided filter, this procedure can be implemented in real time. Next, letting x_t and x_t^* denote the natural logarithms of X_t and X_t^* , the gap between the trend and actual value of nominal income is computed as $x_t^* - x_t$. In this case, as well as in the case of a target for the aggregate price level target discussed below, this gap indicates whether the growth rate of the variable being targeted will have to increase or decrease to bring it back to the calculated trend path. And because both nominal income and prices share a positive relationship with the quantity of money, the value of this gap will indicate whether the money supply will need to expand or contract as well.¹⁰

The same general framework can be used to derive a monetary policy rule in which the central bank uses a monetary aggregate to keep the price level close to a target path.¹¹

Following earlier work on this same question, research that includes, among others, Working (1923), the P-star model of Hallman, Porter, and Small (1991), and an updated version of the P-

⁹ The goal here is to compensate for the slow-moving trends in velocity, an issue that seems to have undermined the performance of rules based on some concept of money. For example, Dueker (1993a, 1993b) found that the performance of McCallum's (1988) monetary base rule was improved if time-varying parameter estimation was used to estimate the coefficients that determine a path for velocity. Similarly, Orphanides and Porter (2000) found the P-star model to forecast inflation well if velocity were allowed to vary rather than held constant as in the original formulation of that model.

¹⁰ Although the comparison is not exact, a policy strategy of this type bears some resemblance to the "twin pillars" approach adopted by the European Central Bank: While evaluating the behavior of actual spending or prices relative to the goal value, behavior of the money supply serves as a "cross check" on whether the stance of monetary policy is consistent with achievement of its ultimate objective. Woodford (2007) questions whether the quantity of money adds any useful information about the stance of monetary policy and, in doing so, concludes that this second pillar leads the ECB to monitor an irrelevant or redundant variable. This conclusion, however, assumes that the standard New Keynesian model captures all parts of the monetary transmission mechanism, an assumption questioned by, e.g., Nelson (2003). Also see Bergevin and Laidler (2010) for a discussion of the potential role for a monetary aggregate as a twin pillar, or cross-check, for the Bank of Canada and its inflation targeting strategy.

¹¹ Ambler (2009) surveys the literature on price level targeting and stabilization policy.

Star model due to Orphanides and Porter (2000), we return to the quantity equation in its original form

$$(3) P_t Y_t = M_t V_t,$$

which now breaks nominal income X_t down into its two components: the price level (P_t) and real GDP (Y_t). After rearranging (3) and replacing velocity with the same low-frequency trend V_t^* constructed using (2) above, actual GDP (Y_t) can be replaced by the Congressional Budget Office's estimate of potential Y_t^* . These empirical proxies provide an estimate of a smooth long run path for the price level,

$$(4) P_t^* = M_t V_t^* / Y_t^*,$$

towards which the actual price level P_t will gradually converge. They also provide an estimate of the associated price gap ($p_t^* - p_t$), which is defined as the difference between the logarithms of the two series. The expression in (4) differs from Hallman, Porter, and Small's (1991) P-star model only by allowing for slow-moving changes in velocity whereas HPS assumed, instead, that long-run velocity was constant and equal to its sample mean.¹² Specifying long-run velocity as a constant led to an eventual empirical breakdown of the relationship that Hallman, Porter, and Small had identified. In a later re-examination of the P-star model, however, Orphanides and Porter (2000) used recursive methods to estimate a flexible path for velocity and, after this modification of the original model, found that the model forecast inflation well.

The specification in (4), however, reveals one potential drawback of using the monetary aggregate M_t to set and achieve a target for the price level: The influence of errors associated with estimates of potential GDP in real time. Orphanides and van Norden (2002) have shown these estimates to be subject to large errors and Orphanides (2001) found that the behavior of the federal funds rate under the Taylor Rule was substantially different when actual values for the output gap were replaced with the real-time values available to the FOMC when policy

¹² Working (1923) dealt with this issue by assuming that velocity and the volume of transactions evolved at similar rates, an assumption that eliminated them from his analysis. After fitting the price level to a trend and extrapolating future values from it Working plotted (on a log scale) values for M/P to identify paths for money that would be consistent with the calculated trend path for prices.

decisions were made. This, by itself, provides a reason for preferring a nominal GDP targeting strategy built around (1) and (2) to a price-level targeting strategy based on (3) and (4).¹³ We will, nevertheless, proceed with our analysis under the assumption that accurate real-time measures of potential real GDP are available to the central bank, although we will experiment, later, with alternative measures of trend output Y^*_t constructed using the same one-sided Hodrick-Prescott filter used to compute the long-run value of velocity V^*_t .

Choosing a Value for the Quantity of Money

The Federal Reserve's official monetary aggregates contain inherent measurement errors because they are created by the method of simple sum (unweighted) aggregation. Errors arise because this approach to aggregation allows the measure to change in response to a substitution effect when an aggregate should change only in response to an income effect. The potential for measurement error associated with simple sum aggregation is particularly important to aggregate measures of money as the public shifts funds from, for example, demand deposits to savings accounts, CDs, or other alternatives. This issue and its effects on measurement are discussed at length in Barnett (e.g., 1980, 1982, 2012) and Barnett, Serleitis, and Fisher (1992). The Federal Reserve's official monetary aggregates fail to adjust, as well, for the effects of computerized sweep programs through which, in the 1990s, banks began reclassifying funds held in their customers' deposit accounts as funds held in the form of other highly liquid assets not subject to statutory reserve requirements. As noted by Cynamon, Dutkowsky, and Jones (2006), these programs operate in ways that remain largely invisible to customers themselves and thereby cause the official monetary statistics to grossly understate the public's perception of its holdings of monetary assets.

In recognition of these measurement issues, we employ Divisia indexes of the money stock as calculated by Barnett, et al. (2013) and provided by the Center for Financial Stability.

¹³ In this same spirit, Beckworth and Hendrickson (2016) found that welfare is improved if the separate price and output terms in the standard Taylor Rule are replaced with a single expression for nominal income.

However, even though superlative indexes of this type address measurement error induced by the Fed's use of a fixed weight aggregation method, and correct for the effects of sweep programs as well, they do not provide a clear answer to the question of narrow versus broad measures of money. We address the issue of robustness in the empirical section by providing results based on alternative aggregates ranging from narrow to broad concepts of money. For compactness, however, much of the discussion in the main text draws from benchmark results based on a Divisia measure of the MZM monetary aggregate.¹⁴ Extended results for other aggregates are reported in the Appendix.¹⁵

These choices can be avoided by following McCallum (1988) and using a measure of the monetary base, rather than a monetary aggregate, to represent the thrust of monetary policy actions. Doing so, however, has been complicated by the Federal Reserve's decision in 2008 to begin paying interest on reserves, a policy that has led to holdings of large volumes of excess reserves by the banking system; whereas excess reserves now represent approximately sixty percent of the monetary base, they were only two percent of the base prior to the Fed's policy change. A distortion of this magnitude has shifted focus away from a quantity theoretic policy rule that would use the monetary base as the Fed's policy instrument.

Tatom (2014) has suggested that a consistent series for the base can be constructed by subtracting excess reserves. After doing so, he illustrated that traditional associations between the base and nominal magnitudes still appear in the data once this adjustment has been made.¹⁶ To investigate the properties of a monetary base rule we use Tatom's "adjusted" version of the base. To be clear, however, we are not examining the performance of McCallum's rule, which expresses a strategy for determining a path for the monetary base. Instead of his

¹⁴ The MZM grouping was called "non-term M3" by Motley (1988) in his investigation of an aggregate composed of monetary assets that could be used immediately for transactions purposes. Thus, it excluded the small-time deposit component of M2 but included, among other assets, the institutional money market mutual fund component of M3. Poole (1991) subsequently named this aggregate "MZM" – money, zero maturity.

¹⁵ Available at <http://irelandp.com/papers/mrules-appendix.pdf>.

¹⁶ Ireland (2014) shows that the payment of interest on reserves does not sever the relationship between monetary policy actions and the price level.

instrument rule, we use Tatom's adjusted measure of the base in a rule designed to target a path for nominal income or the price level.

Overview of the Data

We begin by presenting, in the top panels of figure 1, plots of year-over-year growth in the two measures of money that serve, as described above, as the basis for our benchmark results: Tatom's (2014) adjusted monetary base and Barnett, et al.'s (2013) Divisia MZM monetary aggregate. In these two panels, recession dates identified by the National Bureau of Economic Research are shaded, in order to highlight the tendency for both measures of money growth to decline sharply before cyclical downturns, including the three most recent in 1990-1991, 2001, and 2007-2009. The bottom panels, meanwhile, compare the behavior of the income velocities of these same two measures of money to the trend components, isolated as is also described above, with the same one-sided Hodrick-Prescott filter used by Stock and Watson (1999). Base and Divisia MZM velocities both trend upward during the period of rising inflation and interest rates before 1980 and downward during the period of falling inflation and interest rates since then. Moreover, both measures of velocity continue to decline even after short-term interest rates reached their zero lower bound in 2008; Anderson et al. (2016) attribute these most recent movements to flight-to-quality shifts in the public's demands for assets and describe how similar dynamics also appear in monetary velocity series during the Great Depression. Despite their considerable long-run variability, however, the one-sided HP filter succeeds in tracking these movements in real time, so that deviations of velocity from trend appear small and short-lived.

Tables 1 and 2 go further in quantifying links between our measures of money and the business cycle by reporting correlations between the cyclical components of nominal GDP and the GDP price deflator and various lags of the cyclical components of the adjusted monetary base and Divisia MZM, computed by passing each variable, measured in logarithms, through the band-pass filter described by Baxter and King (1999). This filter is designed specifically to focus on fluctuations taking place at frequencies between 8 and 32 quarters. All data are

quarterly, to match the frequency with which the GDP quantity and price series are available, and the full sample runs from 1967:1, when the series for Divisia money start, through 2015:4. Tables A1-A6 in the Appendix present similar correlations when the GDP price deflator is replaced by the price index for personal consumption expenditures and the core (excluding food and energy) PCE price index and when the Divisia MZM aggregate is replaced by Divisia measures of M1, M2, and M4.¹⁷

For the full sample period, panel A of table 1 shows modest correlations between nominal GDP and the two measures of money, peaking at 0.36 when the adjusted monetary base is lagged by 5 quarters and 0.32 when Divisia MZM is lagged by 9 quarters. Peak correlations between the GDP deflator and the measures of money are found at even longer lags: 0.26 when the adjusted monetary base is lagged by 8 quarters and 0.51 when Divisia MZM is lagged by 13 quarters.

The remaining panels show that these modest full sample correlations mask substantial changes that occur across subsamples.¹⁸ In particular, the correlations for the pre-1980 subsample running from 1967:1 through 1979:4 shown in panel B of both tables point to stronger links, occurring at shorter lags, for both measures of money, nominal income, and prices during that earlier period. Panels C and D show that the correlations resemble their more modest, full-sample values when re-computed from samples running from 1980:1 through 2015:4 and from 1990:1 through 2015:4. Panel E, however, shows that when the sample is narrowed to include only the most recent observations from 2000:1 through 2015:4, the peak correlations return to levels seen in the pre-1980 data, while the lags at which those maximum correlations occur lengthen still further. The correlation between the cyclical

¹⁷ The monetary assets included in Divisia M1 and M2 are the same as those included in the Federal Reserve's official simple-sum M1 and M2 aggregates. As noted above, Divisia MZM excludes the small time deposit component of M2 but adds funds held in institutional money market mutual funds. Divisia M4, the broadest aggregate compiled by Barnett et al. (2013), includes all of the assets in M2, plus institutional money market funds, large time deposits, overnight and term repurchase agreements, commercial paper, and US Treasury bills; this collection of assets resembles those included in the Federal Reserve's discontinued L series.

¹⁸ Belongia and Ireland (2015c) report and discuss similar patterns in correlations between the cyclical components of Divisia money and real GDP.

components of nominal GDP and the adjusted monetary base lagged by 7 quarters, for example, is 0.58 when computed with data from the most recent period, while the correlation between the cyclical components of the GDP deflator and the monetary base lagged 11 quarters is 0.55. And the correlations become even stronger still for Divisia MZM: with nominal GDP, its peak correlation equals 0.70 when lagged by 12 to 14 quarters, and with the GDP deflator, its peak correlation equals 0.85 when lagged by 16 quarters. Thus, far from disappearing, as popular discussions of the “liquidity trap” might suggest, the statistical relationships between Divisia measures of money and key macroeconomic aggregates appear to have strengthened in recent years.

The four panels of figure 2 plot series for the nominal GDP gap ($x_t^* - x_t$) and the GDP price gap ($p_t^* - p_t$), computed using the adjusted monetary base and the Divisia MZM aggregate. Periods when these gaps are positive correspond to episodes where observations on money indicate that monetary policy is exerting upward pressure on nominal income or the aggregate price level; periods when the gaps are negative correspond to episodes where money is pulling nominal income or the price level downwards. Reassuringly, all four gap measures suggest that monetary policy was working to slow nominal income growth and inflation during the late 1970s and early 1980s. And all four gap variables indicate that the stance of monetary policy shifted from highly expansionary to highly contractionary in the years leading up to the financial crisis and recession of 2007 through 2009, an observation consistent with arguments made by Barnett (2012), Hetzel (2012), and Tatom (2014) that overly restrictive monetary policy, reflected in slow growth in various measures of money, was partly to blame for these events. Finally, while all four gap variables indicate that monetary policy once again became expansionary during the financial crisis itself, these money-based indicators suggest that this stimulus was withdrawn in 2010, and the two price-gap measures even go further to indicate that monetary policy began contributing to strong deflationary pressures from that point forward. These signals sent by quantity-theoretic measures of monetary policy aggregates stand in marked contrast to those drawn from interest rates alone: With its funds rate target at or near its zero lower bound throughout this period, popular interpretations suggest that

Federal Reserve policy was consistently expansionary throughout the recession and slow recovery. The data indicate, however, that “quantitative easing” was often “quantitative tightening” instead.

The correlations from tables 1 and 2 and visual impressions from figure 1, though suggestive, are no substitute for more formal statistical results that systematically compare estimates of the effects that money may have on nominal income or prices to standard errors summarizing the degree of uncertainty that surrounds those estimates. Thus, we turn next to regression-based analysis to sharpen the comparison between alternative targeting rules based on money.

Empirical Results

Variations in the Quantity of Money and the Nominal Income Gap

The hypothesis behind both of our targeting rules is that, whenever the money stock M_t implies a target for nominal income (X_t^*) through (2) or a target for the price level (P_t^*) through (4) that lies above the actual value of the variable being targeted, the growth rate of the actual variable will increase to close the gap. Hallman, Porter, and Small (1991) test this same hypothesis for their own, P-star model by estimating a regression of the form

$$(5) \Delta^2 p_t = a + b_1 \Delta^2 p_{t-1} + b_2 \Delta^2 p_{t-2} + b_3 \Delta^2 p_{t-3} + b_4 \Delta^2 p_{t-4} + c(p_{t-1}^* - p_{t-1}) + e_t,$$

where $\Delta^2 p_t$ is the change in the inflation rate and $p_{t-1}^* - p_{t-1}$ is the quarterly lag of the price gap defined earlier. In terms of this regression, the null hypothesis is whether the coefficient on the lagged price gap is zero. Rejection of this null implies that changes in the rate of inflation are associated with the price gap in the previous period; as such, changes in the inflation rate put pressure on the gap to close. The same strategy can be applied to nominal income by regressing the change in nominal income growth on a constant, four lags of itself, and the nominal income gap from the previous quarter:

$$(6) \Delta^2 x_t = a + b_1 \Delta^2 x_{t-1} + b_2 \Delta^2 x_{t-2} + b_3 \Delta^2 x_{t-3} + b_4 \Delta^2 x_{t-4} + c(x_{t-1}^* - x_{t-1}) + e_t.$$

Turning first to questions about the efficacy of nominal income targeting, table 3 displays results from estimating (6) when the adjusted monetary base serves as our measure of

money; table 4 does the same when Divisia MZM is used instead. And because the correlations presented in tables 1 and 2 exhibit shifts across periods, tables 3 and 4 repeat the regression analysis for the full sample, subsamples ending in 1979:4 and beginning in 1980:1, and shorter subsamples covering the periods from 1990:1 through 2015:4 and 2000:1 through 2015:4. For the full sample spanning 1967:1 through 2015:4, the positive and highly significant coefficient on the lagged gap term associates a positive nominal income gap with a subsequent acceleration of nominal income. The coefficient on the lagged nominal income gap continues to be highly significant when the sample is split in two, the main difference being that the coefficients estimated with data from 1967:1 through 1979:4 are larger than those estimated with data from 1980:1 through 2015:4. This comparison implies that nominal income growth adjusted more quickly in the earlier period compared to the later, and is therefore consistent with the shorter lags required to find, in table 1, the maximum correlations between both measures of money and nominal income in pre-1980 data.

When the sample is limited to focus on the most recent periods, beginning either in 1990:1 or 2000:1, the estimated coefficient on the lagged nominal income gap computed using the adjusted monetary base continues to be highly significant; the results for Divisia MZM are slightly weaker, but the adjustment coefficients remain significant at the 90 percent confidence level. Table A7 in the Appendix confirms that all of these results are robust to the level of monetary aggregation, except that in the two most recent subsamples, the nominal income gap constructed with Divisia M4 loses its statistical significance for predicting changes in nominal income. On the other hand, Table A7 also shows that for all five sample periods, the significance of the coefficient on the lagged income gap becomes even stronger when either Divisia M1 or M2 replaces MZM as the measure of money.

The implications appear clear. Consistently over the period since 1967, growth in the adjusted monetary base or any of the Divisia monetary aggregates that is excessive, relative to the slow-moving trends in velocity that are accounted for in (2), is followed, with a lag, by acceleration in the rate of nominal income growth. The lag between changes in money and nominal income has lengthened, but a statistically significant relationship continues to be

captured by the estimated coefficient on the lagged nominal income gap, when one focuses on data from the post-1980 period. Finally, the relationship remains significant, appearing only slightly weaker in the case of MZM, when the coefficient is estimated with data covering 2000:1 through 2015:4, an episode dominated by the financial crisis, the Great Recession, and an extended period of zero nominal interest rates and sluggish nominal income growth.

Variations in the Quantity of Money and the Price Gap

Tables 5 and 6 report estimates of the regression equation (5) for changes in inflation and the price gap, again for our two benchmark cases using the adjusted monetary base and Divisia MZM as measures of money. In these tables, the GDP deflator is used to measure the aggregate price level and the Commerce Department's estimate of potential real GDP is employed in constructing P^*_t via (4). Over both the full sample period, 1967:1 through 2015:4, and the early subsample ending in 1979:4, the coefficients on the lagged price gaps are positive and statistically significant. For these periods, the results associate a positive price gap with accelerating inflation in the same way that the regressions in table 3 indicate that a positive nominal income gap presages accelerating growth in nominal GDP.

Tables 5 and 6 also show, however, that after changing the sample period to begin in 1980:1, 1990:1, or 2000:1, the estimated coefficients on the lagged price gaps become quantitatively small, lose their statistical significance, and for Divisia MZM even take the "wrong" (negative) sign for the most recent two periods. Table A8 in the Appendix verifies that these results do not depend sensitively on the choice of monetary aggregate: whether P^*_t is constructed with M1, M2, or M4, the price gap has statistically significant forecasting power for changes in GDP price inflation for the full sample and pre-1980 subsample. For the post-1980 subsample, the price gap constructed with Divisia M1 does, like the adjusted monetary base, enter (5) with a coefficient that is positive and significant at the 90 percent confidence level, but otherwise for the recent periods the price gap coefficients are insignificant and often estimated to be negative.

If, in choosing between alternative monetary policy rules based on the strength of the statistical relations between a Divisia monetary aggregate or the monetary base and the macroeconomic aggregate being targeted as they appear in the most recent data, the regression results point clearly to nominal income over the price level. The remaining tables in the Appendix highlight the robustness of this conclusion by experimenting with a range of alternative specifications for the measures of price inflation and the price gap that appear in the P-star-style regression model (5). Table A9, for example, continues to use the GDP deflator to measure inflation, but employs the one-sided Hodrick-Prescott filter to construct an alternative to the Congressional Budget Office's estimate of potential output as the measure of Y^*_t in (4). Although the series for output Y_t itself that serves as input to the filtering algorithm corresponds to the most recent vintage of historical data on US real GDP, the one-sided trend constructed in this way would, in principle, be available to the Federal Reserve in real time, making this approach to price-level targeting operational. The table shows, however, that price gaps constructed in this way have even weaker predictive power for changes in inflation. Tables A10 and A11 return to using nominal GDP and the CBO's estimate of potential real GDP to measure P^*_t using (4), but then use this measure of the price gap to forecast changes in either PCE price inflation (table A10) or core PCE price inflation (table A11); the results offer little or no improvement over our benchmarks. Finally, tables A12 and A13 use nominal personal consumption expenditures or nominal core personal consumption expenditures (PCE excluding food and energy) to compute the trend V^*_t in velocity, as well as the one-sided H-P trend component of real personal consumption expenditures or real core personal consumption expenditures to compute the level of potential real spending Y^*_t ; again, the forecasting power of the resulting price gap measures falls short of what we found for our benchmark.

Interpreting the Results

To help identify the source of the differences in the regression results for nominal income and the price level, figure 3 superimposes the behavior of nominal GDP growth and GDP price inflation themselves on the benchmark series for the nominal GDP and price gaps,

constructed with the adjusted monetary base and Divisia MZM and displayed earlier in figure 2. Each of the graph's two panels smooths the quarterly series for nominal income growth and inflation by presenting year-over-year percentage changes in either the level of nominal GDP or the GDP deflator.

The lower panels of figure 3 highlight why Hallman, Porter, and Small (1991) expressed their original regression equation (5) in terms of changes in inflation, rather than inflation itself: Consistently throughout our entire sample, but especially for the pre-1980 period when the predictive power of the price gap is strongest, high levels of the price gap are followed by periods of rising inflation and low levels of the price gap by periods of falling inflation. These same dynamics appear in the figure's upper panels, where high levels of the nominal income gap presage accelerating nominal GDP growth and low levels of the nominal income gap presage decelerating nominal GDP growth. But whereas the relation between the level of the price gap and changes in inflation seems strongest in the pre-1980 data, and appears to be considerably weaker over more recent decades, the analogous link between the level of the nominal GDP gap and changes in nominal income growth remains strong throughout the entire sample period.

It is tempting to explain the breakdown of our price-level targeting regressions by appealing to the "thermostat hypothesis" described and discussed by Nelson (2007, pp.169 – 171): If the Federal Reserve followed an inflation-targeting strategy, implicitly before 2012 and more explicitly thereafter, the lack of correlation between any indicator of the stance of monetary policy and the inflation rate would be implied by its success in stabilizing prices. But while this story provides a potential explanation of the regression results from tables 5 and 6, it fails to account for the correlations between both measures of money and prices shown previously in table 2, which appear as strong for the period since 2010 as they do in the pre-1980 subsample. More likely, the lags between shifts in money growth and changes in inflation, which are also reflected in the correlations shown in table 2, have become too long

and variable to be adequately captured with regressions of the form originally suggested by Hallman, Porter, and Small (1991).¹⁹

Interestingly, Milton Friedman (1968, p.15) rejected the price level as an appropriate target for monetary policy, arguing that

The link between the policy actions of the monetary authority and the price level, while unquestionably present, is more indirect than the link between the policy actions of the authority and any of the several monetary totals. Moreover, monetary action takes a longer time to affect the price level than to affect the monetary totals and both the time lag and the magnitude of effect vary with circumstances. As a result, we cannot predict at all accurately just what effect a particular monetary action will have on the price level and, equally important, just when it will have that effect.

Our regression results, particularly for the period since 1980, point to the continued validity of Friedman's concerns over a regime of price-level or inflation targeting. At the same time, however, our results also point to nominal income as an alternative aggregate that the Fed can reliably target by exercising its more direct influence over the monetary base or the broader monetary aggregates.²⁰ These relationships between Divisia money and nominal GDP growth appear stable over the entire period since 1980 and even when estimated over shorter subsamples that focus heavily on the episode of financial crisis, recession, and zero nominal interest rates since 2008.

Regarding the choice between the monetary base and broader measures of money as intermediate targets for use within a nominal income-targeting regime, our results suggest that Divisia M1, M2, or MZM would all serve reliably as indicators of the influence that monetary policy is having on nominal GDP. Our results for the adjusted monetary base, however, appear even stronger, suggesting that even under current institutional arrangements, where the Federal Reserve's interest on reserves policy has generated an enormous expansion in the quantity of excess reserves demanded, this alternative measure of base money, designed by

¹⁹ Reynard (2007) argues, similarly, that lags between movements in money and prices in data from the US, Euro Area, and Switzerland, are too long to be captured by conventional, regression-based forecasting models.

²⁰ Hetzel (2015) discusses potential pitfalls for nominal GDP targeting as well as several ways such a target could enhance the conduct of monetary policy.

Tatom (2014) to specifically account for the shift in reserves demand, might still work best as an intermediate target for nominal GDP.

Conclusions

If recovery from the Great Recession is interpreted through the lens of a liquidity trap, it is clear that the zero lower bound places a constraint on the usual tools a central bank might employ to initiate recovery from a severe downturn and it is this perspective that has prompted widespread discussions of “unconventional” monetary tools that might circumvent this constraint. This standard interpretation, however, appears to be based on a conception of the liquidity trap that varies from the original idea described by Keynes. If, however, a severe and persistent downturn has its roots in a “credit deadlock” – a general reluctance to borrow or lend, with the attendant consequences on money growth – the zero lower bound problem should pose no limits on the ability of a central bank to stimulate aggregate spending by standard open market operations that increase the quantity of money. This alternative suggests that monetary policy rules based on the money supply, rather than the federal funds rate, may be worth further examination.

This paper developed targeting rules directed to keeping the level of nominal GDP or the aggregate price level on a smooth path by controlling the money supply or the monetary base. Similar in spirit to monetary policy rules developed in the 1920s and the P-star model inspired by them, the rules use trend values for velocity, values for nominal GDP (or its components), and a measure of the money stock to create target paths for the monetary policy goal. The actual value of nominal GDP or the price level then is compared to its implied target path to discern whether any gap between the two exists and how the stance of monetary policy should be adjusted if the gap is to be closed.

The results indicate that shorter lags between money and nominal spending as well as stronger statistical associations between these variables may justify a preference for targeting the level of nominal GDP; problems with estimates of potential GDP, a necessary input to price level targeting, also appear as they have in studies of a Taylor Rule and this, too, argues in

favor of a nominal GDP target. These results are robust to choice between the adjusted monetary base and several broader, Divisia monetary aggregates and continue to hold even when the sample is limited to the most recent period, dominated by the financial crisis, Great Recession, and slow recovery that has followed. This robustness highlights that quantity variables – the base or some broader measure of money – can serve reliably as indicators of the stance of monetary policy even while short-term interest rates are at or near their zero lower bound. And, given the Fed’s continued ability, documented in Belongia and Ireland (2015a), to use open market operations to influence these measures of money, any one could serve effectively by policymakers to keep nominal GDP close to a desired target path.

Because economic theory has yet to offer clear guidance on criteria that would judge one type of policy rule to be preferred to its alternatives, it appears as if the question becomes one of identifying a policy rule that “works.” The type of rule proposed in this paper is transparent because the public can monitor whether and how the behavior of the goal variable differs from its target value. Moreover, the public understands how the central bank is implementing its policy decisions. The rule also provides for accountability once the legislative body that exercises oversight of central bank operations has set tolerances for how large any gap between actual and desired values of the goal variable can become before the central bank is asked to explain the source of the problem and describe actions intended to close the observed gap. Finally, because the rule is based on the Fed’s ability to influence the behavior of the monetary base or the money stock, the central bank is not constrained by the zero lower bound problem found in rules based on a short-term interest rate.

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Table 1. Correlations Between The Cyclical Components of Nominal GDP and Lagged Money

A. Full Sample: 1967:1 – 2015:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	-0.04	-0.06	-0.07	-0.05	-0.02	0.03	0.09	0.16	0.23	0.29	0.34	0.36	0.32	0.24	0.12	-0.01	-0.13
MZM	-0.04	0.01	0.07	0.15	0.21	0.27	0.31	0.32	0.30	0.27	0.22	0.17	0.10	0.02	-0.07	-0.17	-0.27
B. Pre-1980 Subsample: 1967:1 – 1979:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	0.54	0.26	-0.01	-0.23	-0.41	-0.53	-0.59	-0.57	-0.49	-0.35	-0.19	-0.03	0.12	0.24	0.35	0.44	0.49
MZM	-0.43	-0.47	-0.44	-0.37	-0.27	-0.13	0.05	0.25	0.45	0.61	0.73	0.81	0.85	0.86	0.83	0.74	0.58
C. Post-1980 Subsample: 1980:1 – 2015:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	-0.04	-0.06	-0.06	-0.04	0.01	0.07	0.14	0.22	0.30	0.37	0.41	0.40	0.35	0.24	0.08	-0.09	-0.23
MZM	0.01	0.05	0.10	0.16	0.21	0.26	0.28	0.28	0.24	0.19	0.12	0.04	-0.05	-0.16	-0.28	-0.38	-0.46
D. Post-1990 Subsample: 1990:1 – 2015:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	0.03	0.03	0.04	0.07	0.12	0.17	0.21	0.26	0.30	0.34	0.37	0.37	0.31	0.19	0.03	-0.13	-0.25
MZM	0.21	0.24	0.27	0.29	0.31	0.31	0.28	0.22	0.14	0.05	-0.03	-0.11	-0.19	-0.27	-0.34	-0.40	-0.42
E. Post-2000 Subsample: 2000:1 – 2015:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	0.11	0.16	0.23	0.30	0.38	0.45	0.51	0.55	0.57	0.58	0.56	0.49	0.36	0.18	-0.02	-0.21	-0.35
MZM	0.65	0.69	0.70	0.70	0.70	0.66	0.55	0.40	0.22	0.04	-0.13	-0.28	-0.42	-0.54	-0.62	-0.66	-0.62

Note: Each entry shows the correlation between the cyclical component of nominal GDP in quarter t and the cyclical component of either the adjusted monetary base (AMB) or the Divisia MZM monetary aggregate (MZM) in quarter $t-k$.

Table 2. Correlations Between The Cyclical Components of the GDP Deflator and Lagged Money

A. Full Sample: 1967:1 – 2015:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	-0.09	-0.03	0.03	0.09	0.15	0.20	0.23	0.25	0.26	0.24	0.20	0.14	0.07	-0.02	-0.10	-0.17	-0.23
MZM	0.43	0.48	0.51	0.51	0.49	0.43	0.35	0.25	0.12	-0.03	-0.18	-0.32	-0.45	-0.54	-0.59	-0.59	-0.55
B. Pre-1980 Subsample: 1967:1 – 1979:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	-0.52	-0.39	-0.26	-0.14	-0.02	0.10	0.22	0.35	0.46	0.56	0.61	0.63	0.61	0.55	0.43	0.25	0.03
MZM	-0.05	0.25	0.51	0.68	0.78	0.80	0.74	0.60	0.41	0.18	-0.05	-0.27	-0.45	-0.58	-0.65	-0.67	-0.63
C. Post-1980 Subsample: 1980:1 – 2015:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	-0.02	0.02	0.08	0.14	0.19	0.24	0.25	0.25	0.23	0.18	0.11	0.02	-0.09	-0.19	-0.28	-0.34	-0.37
MZM	0.38	0.39	0.39	0.37	0.32	0.24	0.14	0.03	-0.08	-0.20	-0.30	-0.40	-0.48	-0.55	-0.59	-0.58	-0.53
D. Post-1990 Subsample: 1990:1 – 2015:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	-0.09	-0.01	0.10	0.21	0.30	0.37	0.42	0.43	0.41	0.36	0.26	0.12	-0.04	-0.19	-0.31	-0.37	-0.38
MZM	0.46	0.53	0.57	0.57	0.53	0.45	0.32	0.17	0.01	-0.14	-0.28	-0.40	-0.50	-0.55	-0.55	-0.49	-0.37
E. Post-2000 Subsample: 2000:1 – 2015:4																	
k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AMB	0.20	0.27	0.36	0.44	0.51	0.55	0.54	0.50	0.44	0.35	0.22	0.06	-0.12	-0.30	-0.43	-0.49	-0.48
MZM	0.85	0.84	0.79	0.72	0.62	0.47	0.28	0.07	-0.13	-0.31	-0.46	-0.59	-0.69	-0.72	-0.68	-0.55	-0.36

Note: Each entry shows the correlation between the cyclical component of the GDP deflator in quarter t and the cyclical component of either the adjusted monetary base (AMB) or the Divisia MZM monetary aggregate (MZM) in quarter $t-k$.

Table 3. Estimated Forecasting Equations for Changes in Nominal GDP Growth Using the Adjusted Monetary Base

Dependent variable: Change in nominal GDP growth (Δ^2x_t)				
Independent variables: Constant, four quarterly lags of changes in nominal GDP growth, and lagged nominal GDP gap ($x^*_{t-1} - x_{t-1}$) constructed with the adjusted monetary base				
A. Full Sample: 1967:1 – 2015:4				
	coefficient	<i>t</i> stat (<i>p</i> value)		
constant	-0.000	-0.789 (0.43)		
Δ^2x_{t-1}	-0.626	-8.951 (0.00)		
Δ^2x_{t-2}	-0.376	-4.734 (0.00)		
Δ^2x_{t-3}	-0.264	-3.319 (0.00)		
Δ^2x_{t-4}	-0.040	-0.576 (0.57)		
$x^*_{t-1} - x_{t-1}$	0.112	4.326 (0.00)		
	$\bar{R}^2 = 0.34$	<i>DW</i> = 2.00		
B. Pre-1980: 1967:1 – 1979:4		C. Post-1980: 1980:1 – 2015:4		
	coefficient	<i>t</i> stat (<i>p</i> value)	coefficient	<i>t</i> stat (<i>p</i> value)
constant	0.001	0.761 (0.45)	-0.001	-1.020 (0.31)
Δ^2x_{t-1}	-0.810	-5.318 (0.00)	-0.502	-6.236 (0.00)
Δ^2x_{t-2}	-0.569	-3.133 (0.00)	-0.292	-3.312 (0.00)
Δ^2x_{t-3}	-0.466	-2.608 (0.01)	-0.159	-1.789 (0.08)
Δ^2x_{t-4}	-0.125	-0.864 (0.39)	-0.035	-0.432 (0.66)
$x^*_{t-1} - x_{t-1}$	0.313	2.202 (0.03)	0.098	4.020 (0.00)
	$\bar{R}^2 = 0.50$	<i>DW</i> = 1.97	$\bar{R}^2 = 0.25$	<i>DW</i> = 2.01
D. Post-1990: 1990:1 – 2015:4		E. Post-2000: 2000:1 – 2015:4		
	coefficient	<i>t</i> stat (<i>p</i> value)	coefficient	<i>t</i> stat (<i>p</i> value)
constant	-0.000	-0.455 (0.65)	-0.001	-0.907 (0.37)
Δ^2x_{t-1}	-0.555	-5.788 (0.00)	-0.578	-4.792 (0.00)
Δ^2x_{t-2}	-0.283	-2.671 (0.01)	-0.239	-1.766 (0.08)
Δ^2x_{t-3}	-0.204	-1.903 (0.06)	-0.091	-0.660 (0.51)
Δ^2x_{t-4}	0.012	0.120 (0.90)	0.076	0.617 (0.54)
$x^*_{t-1} - x_{t-1}$	0.067	3.068 (0.00)	0.091	3.196 (0.00)
	$\bar{R}^2 = 0.28$	<i>DW</i> = 1.96	$\bar{R}^2 = 0.30$	<i>DW</i> = 1.94

Table 4. Estimated Forecasting Equations for Changes in Nominal GDP Growth Using Divisia MZM

Dependent variable: Change in nominal GDP growth (Δ^2x_t)				
Independent variables: Constant, four quarterly lags of changes in nominal GDP growth, and lagged nominal GDP gap ($x^*_{t-1} - x_{t-1}$) constructed with Divisia MZM				
A. Full Sample: 1967:1 – 2015:4				
	coefficient	<i>t</i> stat (<i>p</i> value)		
constant	-0.000	-0.523 (0.60)		
Δ^2x_{t-1}	-0.644	-9.064 (0.00)		
Δ^2x_{t-2}	-0.397	-4.944 (0.00)		
Δ^2x_{t-3}	-0.280	-3.482 (0.00)		
Δ^2x_{t-4}	-0.048	-0.679 (0.50)		
$x^*_{t-1} - x_{t-1}$	0.065	3.703 (0.00)		
	$\bar{R}^2 = 0.33$	<i>DW</i> = 1.98		
B. Pre-1980: 1967:1 – 1979:4		C. Post-1980: 1980:1 – 2015:4		
	coefficient	<i>t</i> stat (<i>p</i> value)	coefficient	<i>t</i> stat (<i>p</i> value)
constant	0.001	0.825 (0.41)	-0.000	-0.650 (0.52)
Δ^2x_{t-1}	-0.937	-6.765 (0.00)	-0.506	-6.144 (0.00)
Δ^2x_{t-2}	-0.744	-4.474 (0.00)	-0.298	-3.313 (0.00)
Δ^2x_{t-3}	-0.636	-3.837 (0.00)	-0.159	-1.753 (0.08)
Δ^2x_{t-4}	-0.224	-1.647 (0.11)	-0.034	-0.418 (0.68)
$x^*_{t-1} - x_{t-1}$	0.228	3.072 (0.00)	0.053	3.148 (0.00)
	$\bar{R}^2 = 0.54$	<i>DW</i> = 2.02	$\bar{R}^2 = 0.22$	<i>DW</i> = 1.98
D. Post-1990: 1990:1 – 2015:4		E. Post-2000: 2000:1 – 2015:4		
	coefficient	<i>t</i> stat (<i>p</i> value)	coefficient	<i>t</i> stat (<i>p</i> value)
constant	-0.000	-0.382 (0.70)	-0.000	-0.463 (0.65)
Δ^2x_{t-1}	-0.543	-5.515 (0.00)	-0.537	-4.234 (0.00)
Δ^2x_{t-2}	-0.279	-2.554 (0.01)	-0.204	-1.412 (0.16)
Δ^2x_{t-3}	-0.201	-1.807 (0.07)	-0.060	-0.400 (0.69)
Δ^2x_{t-4}	0.018	0.175 (0.86)	0.102	0.770 (0.44)
$x^*_{t-1} - x_{t-1}$	0.033	1.868 (0.06)	0.044	1.781 (0.08)
	$\bar{R}^2 = 0.24$	<i>DW</i> = 1.95	$\bar{R}^2 = 0.22$	<i>DW</i> = 1.95

Table 5. Estimated Forecasting Equations for Changes in GDP Price Inflation Using the Adjusted Monetary Base

Dependent variable: Change in GDP price inflation ($\Delta^2 p_t$)				
Independent variables: Constant, four quarterly lags of changes in GDP price inflation, and lagged GDP price gap ($p^*_{t-1} - p_{t-1}$) constructed with the adjusted monetary base				
A. Full Sample: 1967:1 – 2015:4				
	coefficient	<i>t</i> stat (<i>p</i> value)		
constant	0.000	1.168 (0.24)		
$\Delta^2 p_{t-1}$	-0.405	-5.635 (0.00)		
$\Delta^2 p_{t-2}$	-0.235	-3.065 (0.00)		
$\Delta^2 p_{t-3}$	-0.088	-1.142 (0.25)		
$\Delta^2 p_{t-4}$	0.116	1.616 (0.11)		
$p^*_{t-1} - p_{t-1}$	0.027	3.249 (0.00)		
	$\bar{R}^2 = 0.18$	<i>DW</i> = 1.97		
B. Pre-1980: 1967:1 – 1979:4		C. Post-1980: 1980:1 – 2015:4		
	coefficient	<i>t</i> stat (<i>p</i> value)	coefficient	<i>t</i> stat (<i>p</i> value)
constant	0.001	0.935 (0.36)	0.000	0.015 (0.99)
$\Delta^2 p_{t-1}$	-0.464	-3.041 (0.00)	-0.413	-4.923 (0.00)
$\Delta^2 p_{t-2}$	-0.328	-2.008 (0.05)	-0.231	-2.553 (0.01)
$\Delta^2 p_{t-3}$	-0.225	-1.371 (0.18)	-0.040	-0.438 (0.66)
$\Delta^2 p_{t-4}$	0.072	0.466 (0.64)	0.098	1.178 (0.24)
$p^*_{t-1} - p_{t-1}$	0.062	2.560 (0.01)	0.013	1.662 (0.10)
	$\bar{R}^2 = 0.19$	<i>DW</i> = 1.92	$\bar{R}^2 = 0.15$	<i>DW</i> = 1.97
D. Post-1990: 1990:1 – 2015:4		E. Post-2000: 2000:1 – 2015:4		
	coefficient	<i>t</i> stat (<i>p</i> value)	coefficient	<i>t</i> stat (<i>p</i> value)
constant	-0.000	-0.379 (0.71)	-0.000	-0.081 (0.94)
$\Delta^2 p_{t-1}$	-0.555	-5.509 (0.00)	-0.544	-4.140 (0.00)
$\Delta^2 p_{t-2}$	-0.390	-3.461 (0.00)	-0.369	-2.463 (0.02)
$\Delta^2 p_{t-3}$	-0.222	-1.931 (0.06)	-0.226	-1.456 (0.15)
$\Delta^2 p_{t-4}$	-0.053	-0.518 (0.61)	-0.074	-0.543 (0.59)
$p^*_{t-1} - p_{t-1}$	0.001	0.145 (0.89)	0.001	0.066 (0.95)
	$\bar{R}^2 = 0.21$	<i>DW</i> = 1.97	$\bar{R}^2 = 0.17$	<i>DW</i> = 2.00

Table 6. Estimated Forecasting Equations for Changes in GDP Price Inflation Using Divisia MZM

Dependent variable: Change in GDP price inflation ($\Delta^2 p_t$)				
Independent variables: Constant, four quarterly lags of changes in GDP price inflation, and lagged GDP price gap ($p_{t-1}^* - p_{t-1}$) constructed with Divisia MZM				
A. Full Sample: 1967:1 – 2015:4				
	coefficient	<i>t</i> stat (<i>p</i> value)		
constant	0.000	0.334 (0.74)		
$\Delta^2 p_{t-1}$	-0.371	-5.138 (0.00)		
$\Delta^2 p_{t-2}$	-0.192	-2.498 (0.01)		
$\Delta^2 p_{t-3}$	-0.041	-0.533 (0.59)		
$\Delta^2 p_{t-4}$	0.160	2.219 (0.03)		
$p_{t-1}^* - p_{t-1}$	0.010	1.944 (0.05)		
	$\bar{R}^2 = 0.15$	<i>DW</i> = 2.00		
B. Pre-1980: 1967:1 – 1979:4		C. Post-1980: 1980:1 – 2015:4		
	coefficient	<i>t</i> stat (<i>p</i> value)	coefficient	<i>t</i> stat (<i>p</i> value)
constant	0.000	0.753 (0.46)	-0.000	-0.670 (0.50)
$\Delta^2 p_{t-1}$	-0.383	-2.573 (0.01)	-0.404	-4.791 (0.00)
$\Delta^2 p_{t-2}$	-0.204	-1.303 (0.20)	-0.224	-2.457 (0.02)
$\Delta^2 p_{t-3}$	-0.105	-0.667 (0.51)	-0.029	-0.313 (0.75)
$\Delta^2 p_{t-4}$	0.185	1.240 (0.22)	0.111	1.319 (0.19)
$p_{t-1}^* - p_{t-1}$	0.046	2.142 (0.04)	0.004	0.821 (0.41)
	$\bar{R}^2 = 0.15$	<i>DW</i> = 2.05	$\bar{R}^2 = 0.14$	<i>DW</i> = 1.97
D. Post-1990: 1990:1 – 2015:4		E. Post-2000: 2000:1 – 2015:4		
	coefficient	<i>t</i> stat (<i>p</i> value)	coefficient	<i>t</i> stat (<i>p</i> value)
constant	-0.000	-1.100 (0.27)	-0.000	-1.011 (0.32)
$\Delta^2 p_{t-1}$	-0.580	-5.708 (0.00)	-0.596	-4.496 (0.00)
$\Delta^2 p_{t-2}$	-0.425	-3.731 (0.00)	-0.444	-2.931 (0.00)
$\Delta^2 p_{t-3}$	-0.256	-2.202 (0.03)	-0.301	-1.924 (0.06)
$\Delta^2 p_{t-4}$	-0.077	-0.749 (0.46)	-0.120	-0.878 (0.38)
$p_{t-1}^* - p_{t-1}$	-0.007	-1.233 (0.22)	-0.013	-1.518 (0.13)
	$\bar{R}^2 = 0.22$	<i>DW</i> = 1.95	$\bar{R}^2 = 0.20$	<i>DW</i> = 1.99

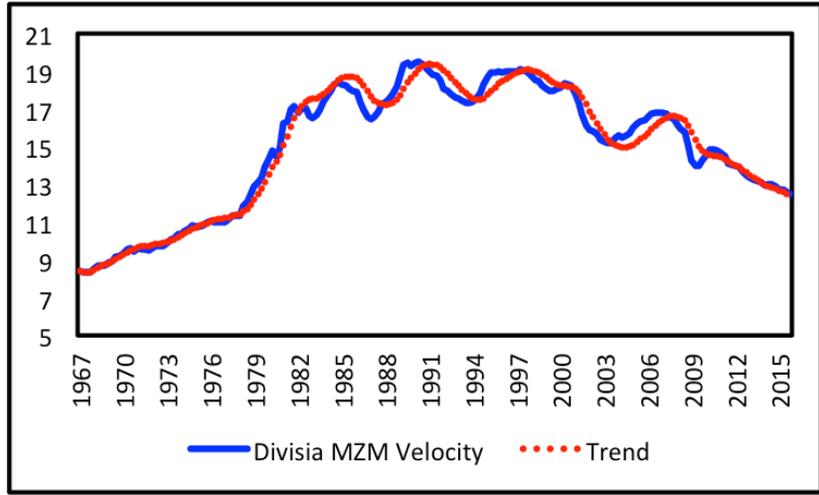
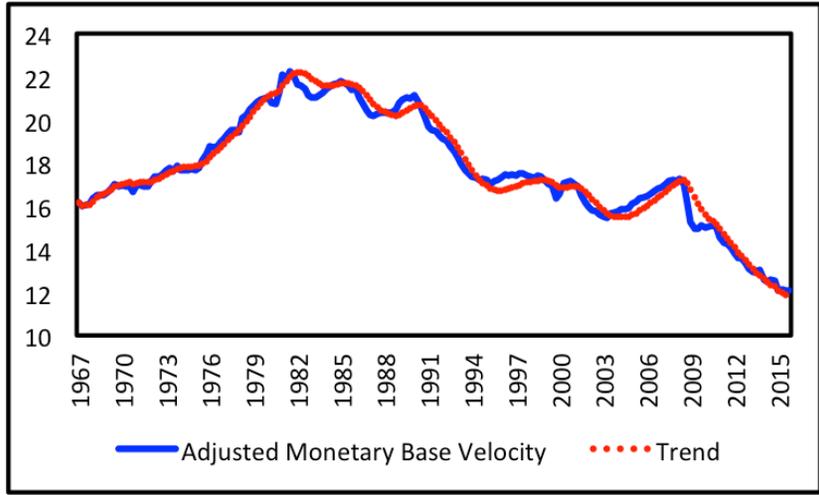
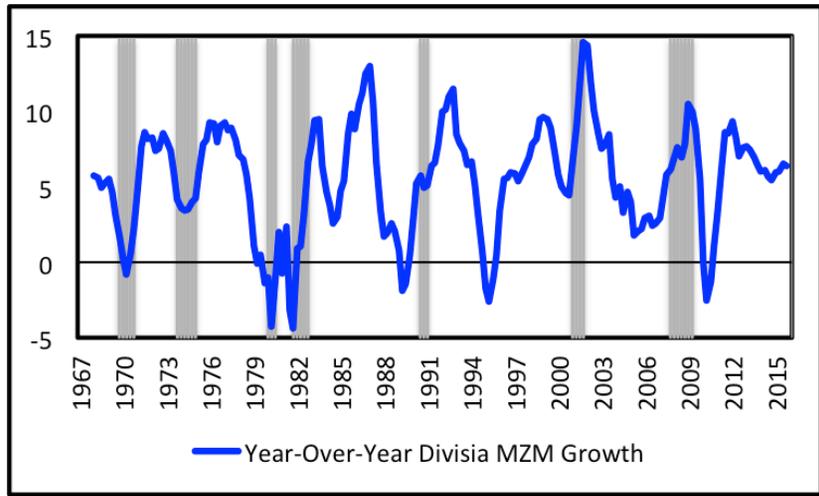
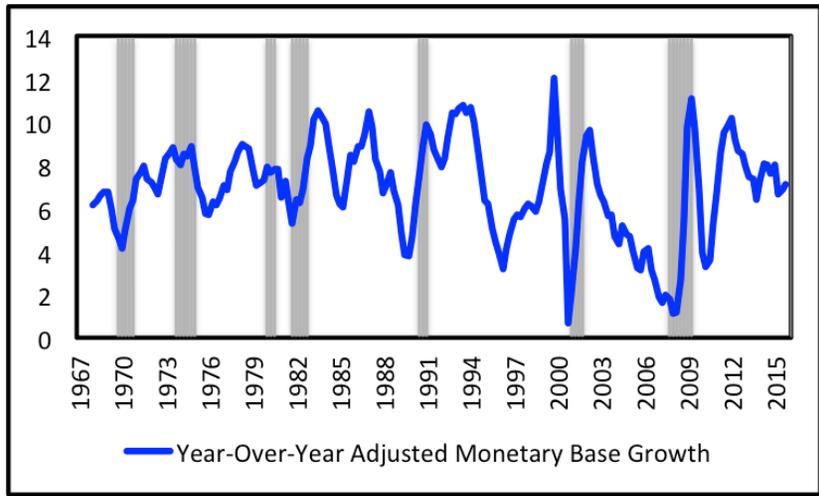


Figure 1. Monetary Growth and Velocity. The two top panels show year-over-year percentage changes in the adjusted monetary base and the Divisia MZM monetary aggregate, with shaded areas corresponding to NBER recession dates. The two bottom panels show the velocities of the adjusted monetary base and Divisia MZM (solid blue lines) together with their trend components (dotted red lines) computed with a one-sided Hodrick-Prescott filter.

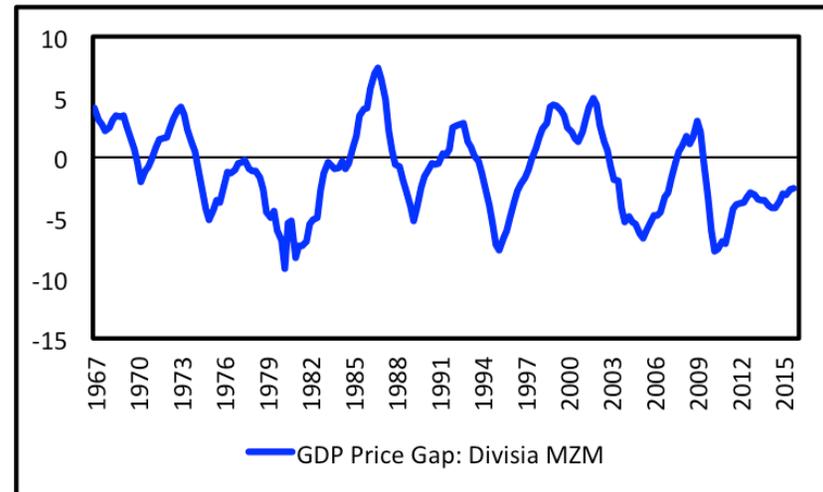
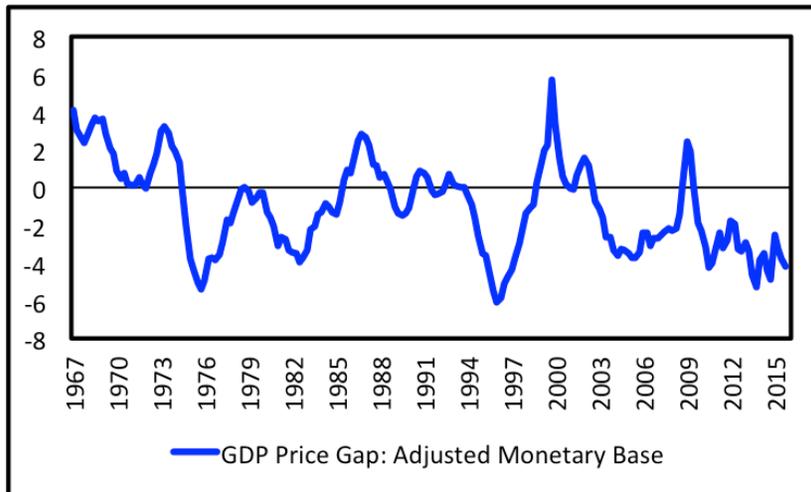
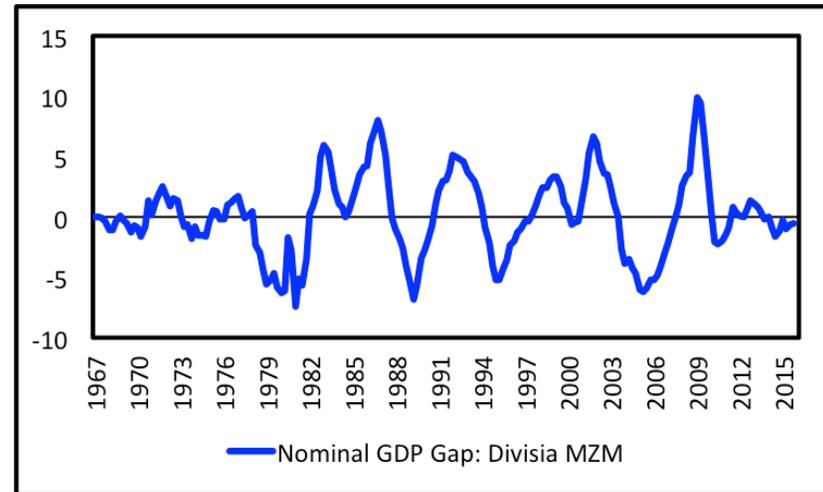
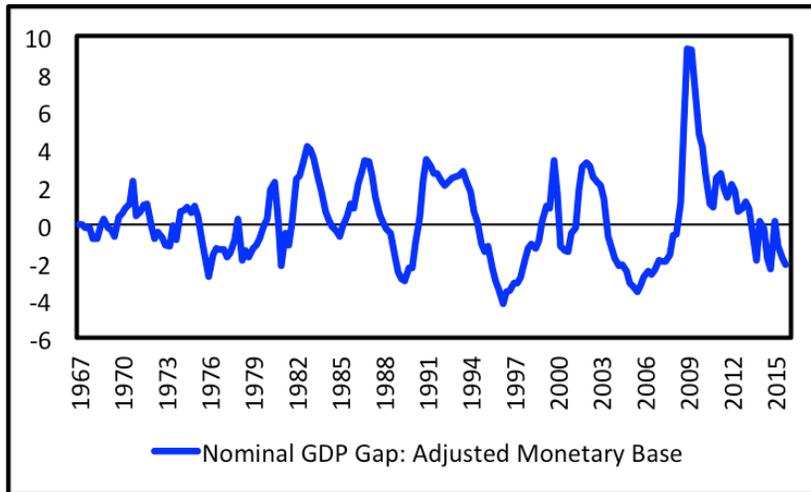


Figure 2. Nominal GDP and GDP Price Gaps. Constructed using the adjusted monetary base (left panels) and the Divisia MZM monetary aggregate (right panels). Each panel shows the percentage-gap between the target and actual level of the indicated variable, constructed as described in the text.

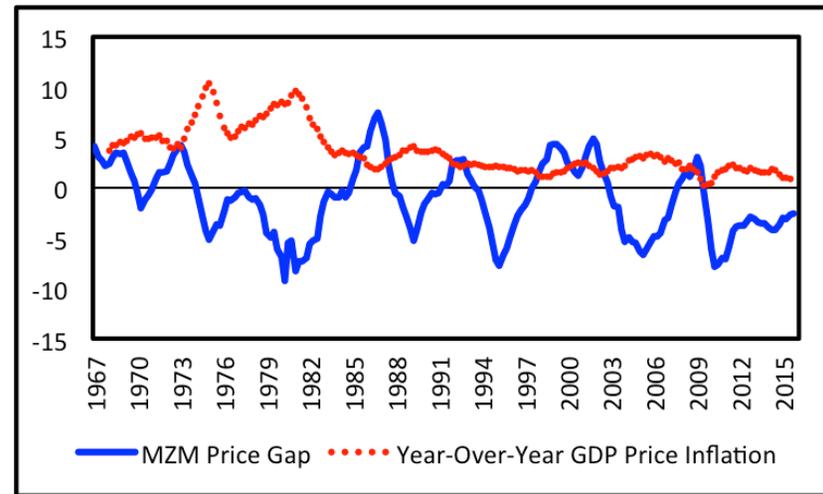
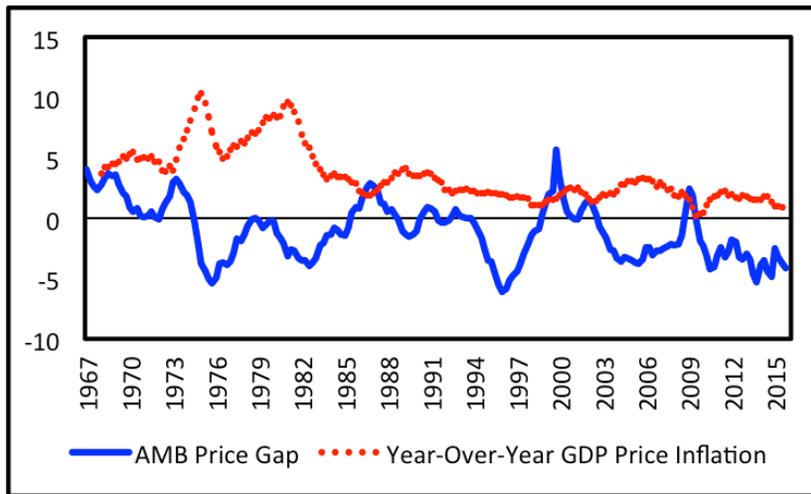
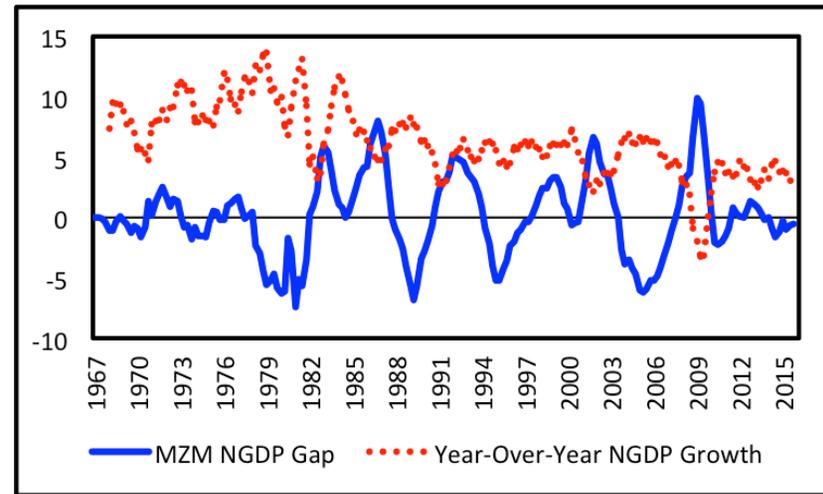
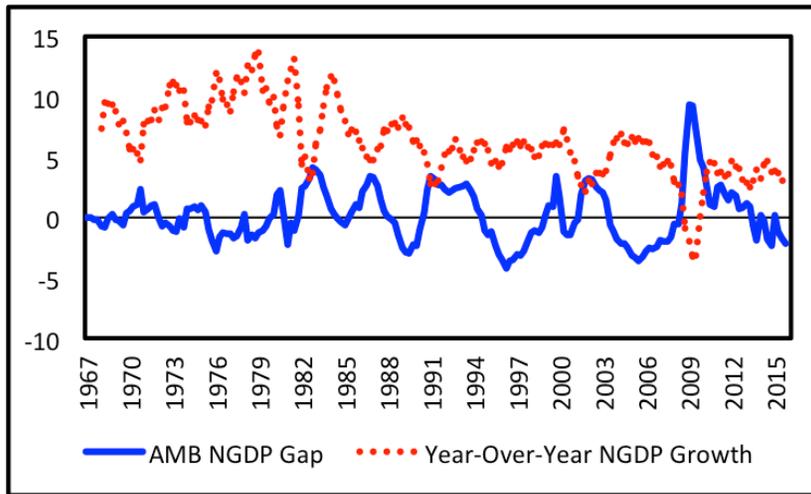


Figure 3. Nominal GDP and GDP Price Gaps and Growth Rates. Each panel compares the percentage-point gap between the target and actual level of the indicated variable (solid blue line) to the year-over-year growth rate in the actual value of the same variable (dotted red line).