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Nominal GDP versus Price Level Targeting: An Empirical Evaluation

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Abstract

In response to the ongoing discussion in the literature of the appropriate framework for monetary policy, we compare two of the most frequently discussed alternatives to inflation targeting—targeting either the level of nominal GDP or the price level—within the context of a simple vector autoregressive (VAR) model. Our approach can be considered a constrained-discretion approach. The model is estimated using quarterly data over the period 1979:4-2003:4, a period in which the economy was buffeted by substantial supply and demand shocks. The paths of the federal funds rate, nominal GDP, real GDP, and the price level under nominal GDP and price level targeting are simulated over the 2004:1-2006:4 period. We evaluate nominal GDP and price level targeting by computing the values of simple loss functions. The loss function values indicate that closely targeting the path of nominal GDP based on 4.5% desired growth in nominal GDP produces noticeably lower losses in the simulation period than either price level targeting or a continuation of the implicit flexible inflation targeting monetary policy that characterized the estimation period.

Keywords: Nominal GDP Targeting, Price Level Targeting, Central Bank Policies, Monetary Policy Objectives

JEL Codes: E31; E37; E52; E58

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1. Introduction

The Federal Reserve's monetary policy framework before and after the 2008 financial crisis has often been characterized as flexible inflation targeting, a policy of constrained discretion that, before the crisis, contributed to a low, stable rate of inflation around the target rate of 2 percent and to modest fluctuations of output around estimates of potential output. Unfortunately, this good macroeconomic performance was not sufficient to ensure financial stability. This fact, along with the slow recovery of the United States and other economies from the recession associated with the financial crisis, and inflation persistently below target for the last decade, has led to suggestions that the Fed should replace flexible inflation targeting with targeting the path of the level of nominal GDP or with targeting the path of the price level, policy approaches that their advocates argue would have been promoted a faster post-crisis recovery.[1]

Our objective in this paper is to analyze and compare targeting the path of the level of nominal GDP with targeting the path of the price level for a recent period, 2004 – 2006. We assess the statistical merits of both policies in the context of a single econometric framework, a simple vector autoregression (VAR) estimated using quarterly data over the 1979:4-2003:4 period of implicit inflation targeting by the Fed. Specifically, in the context of the policy planning process summarized by Blinder (1997), we use the VAR to conduct counterfactual experiments consisting of 1,000 trials—dynamic, stochastic out-of-sample simulations—in which we compute policy interventions needed to keep the targeted variable within specified tolerance bands, reflecting constrained discretion, for both nominal GDP and price level targeting.[2] For these alternative strategies, we compute a sequence of monetary policy innovations consistent with each strategy and then use these innovations along with representative historical shocks to

[1] Conceptual discussions of the implications of nominal GDP targeting and price level targeting for monetary policy aren't presented in this paper since our focus is purely empirical. General discussions of these types of targeting can be found in, among others, Bean (1983), Bradley and Jansen (1989), Hall and Mankiw (1994), Kahn (2009), Mester (2018), and Fackler and McMillin (2019). Bernanke (2017) discusses a variety of recent proposals for changing the monetary policy framework including a temporary price level target.

[2] Precedents in the literature that use counterfactual simulations in VARs to evaluate policy alternatives include Christiano (1998), Fackler and Rogers (1995), and Fackler and McMillin (2011). Kilian and Lütkepohl (2017) provide a thorough discussion of the use of counterfactual simulations in VARs.

the other variables to compute the simulations. For each experiment we seek answers to the following questions: (1) Which policy approach, targeting nominal GDP or targeting the price level, best achieves the Fed's dual mandate in terms of real GDP and the price level?[3] (2) How do the simulation results compare with results of a "continuation policy" consistent with a simple dynamic forecast over the simulation period? (3) Is the policy path needed to target nominal GDP or the price level "reasonable" or is the degree of interest rate variability implausible? In the extreme, is there instrument instability? (4) Do the changes in policy strategy lead to a perception by agents that a Lucas-type regime change has occurred? (5) Is either type of policy, a nominal GDP target or a price level target, obviously preferred to the other? Is either preferred to the continuation policy? We summarize our results using three variants of an ad hoc (but common) loss function with different weights on the squared deviations of real GDP and the price level from their specified target paths.[4]

Given the Federal Reserve's medium-to-long-run inflation target of 2%, we assume a 2% inflation rate underlies the price level target. For nominal GDP, we consider three targets based on growth rates of 4.5%, 5%, and 5.5%. A 2.5% rate of growth in real GDP underlies the 4.5% growth rate along with the 2% inflation rate, and rates of growth in real GDP of 3% and 3.5% underlie the 5% and 5.5% nominal GDP growth, respectively. We find that, for both 1% and 2% tolerance bands around the targets, nominal GDP targeting based on a desired 4.5% rate of growth in nominal GDP is superior to a policy aimed solely at the price level and to the "continuation policy." However, as detailed below, for higher desired rates of nominal GDP growth, the relative rankings of the policies reveal some ambiguity. In addition, while the policy instrument for attaining our targets, the federal funds rate, fluctuates within historical norms, adjustments to the funds rate needed to attain either the nominal GDP or the price level objective are, at the outset of the simulation periods, larger than the usual 25 basis point adjustments

[3] While the formal mandate is expressed in terms of maximum employment and stable prices, we adopt the common approach of focusing on real GDP in place of employment. Since the mandate does not explicitly state the relative weights on these objectives, we will experiment with several alternatives.
[4] Detailed below, the weighting schemes are characterized as representing the dual mandate, "Keynesian" preferences, and "Classical" preferences.

typical of monetary policy. Thus, the cost of attaining the nominal GDP or price level objective may be initially greater variability in market rates of interest.

In a growing literature, several recent papers stand out as particularly relevant to our work. Using a small variant of the FRB/US model, English, Lopez-Salido, and Tetlow (2015) compare the performance of the economy when the Fed follows a rule based on nominal income targeting to outcomes from an optimal commitment strategy to the performance based on an inertial Taylor rule. Under conditions similar to those faced by the Fed in the fall of 2012, their simulations suggest that the paths of the federal funds rate, core PCE inflation, the unemployment rate, and the output gap are closer to those associated with the optimal commitment strategy under nominal income targeting than with the inertial Taylor rule. However, they express concerns about the effects of data revisions on the effectiveness of nominal income targeting.

Benchimol and Fourçans (2019) evaluate a DSGE model using a variety of policy rules including Taylor rule variants, nominal GDP growth rate targets, and level nominal GDP targets. Their evaluation is in the form of a variety of loss functions for the central bank and household welfare measures. When using the central bank loss function, which is the weighted sum of the variances of inflation, the output gap, interest rate changes, and wage growth as the criterion, level nominal GDP targets generally perform best.

In two variants of a New Keynesian model, Garín, Lester, and Sims (2016) investigate the welfare implications of targeting rules for nominal GDP, inflation, and the output gap that are special cases of a standard Taylor rule. The targeting rules are compared with those for a standard Taylor rule. In virtually all cases for both models, output gap targeting does best, although nominal GDP targeting is a close second in most cases. They argue that successfully implementing an output gap rule is likely not feasible because of difficulties in accurately measuring the output gap in real time and difficulties in communicating the rule to the public. In a practical sense, their results suggest that nominal GDP targeting is a preferred alternative to inflation targeting or a standard Taylor rule.

Hendrickson (2012) argues that the stabilization of inflation in the U.S. in the 1980s was achieved by a commitment to low, stable rates of growth in nominal GDP. He embeds into two alternative DSGE models an interest rate rule in which the current value of the federal funds rate is a function of its lagged value and the rate of change in nominal GDP and finds that the volatility of both inflation and real GDP decline the stronger the response of the Fed funds rate to nominal income. Beckworth and Hendrickson (forthcoming) find that nominal GDP targeting is superior to use of the Taylor rule in real time.

Finally, Bodenstein and Zhao (forthcoming) utilize a medium-size DSGE model to compare a variety of policy strategies including inflation targeting, price level targeting, nominal GDP targeting, and Walsh's (2003) speed limit policy in which the policymaker is concerned with stabilizing inflation and the change in the output gap. They consider policymaking under commitment and under discretion and compute the welfare implications of each policy. Under commitment, inflation targeting is slightly preferred to the speed limit policy. These two policies are preferred to both price level targeting and nominal GDP targeting, but price level targeting dominates nominal GDP targeting. Under discretion, the speed limit policy is the best overall.

The literature just cited compares nominal GDP targeting, price level targeting, and inflation targeting by analyzing the macroeconomic effects of formal rules specific to each type of targeting that are embedded in a variety of DSGE models. A strong point of this approach is that it respects the Lucas critique and allows expectations endogenous to the model to adjust to the specific rule. However, although central banks often use the settings of their policy instrument implied by a variety of different rules as inputs to their policy deliberations, in practice no major central banks have yet adopted an explicit rule, and, arguably, none are likely to do so in the near future. Given that flexible inflation targeting, the strategy employed by many central banks today, is implemented in a constrained-discretionary way, it is plausible that, if adopted, nominal GDP targeting or price level targeting would be implemented in a similar way. Rather than follow the cited studies and use a variant of a DSGE model to evaluate nominal GDP and price level targeting, we follow the suggestion of McCallum (1988) that alternative strategies be evaluated within a variety of different types of models and employ a pure time series model in which we assume that the same type of constrained discretion that guides the Federal Reserve's flexible inflation targeting framework also would guide the implementation of either nominal GDP targeting or price level targeting.

Since we evaluate a change in policy strategy from implicit flexible inflation targeting to nominal GDP or price level targeting, the Lucas critique is potentially applicable. However, as noted by Leeper and Zha (2003) in their discussion of modest policy interventions, as long as the new strategies don't result in markedly different behavior by the Federal Reserve and hence don't significantly alter private agents' beliefs about the policy regime, counterfactual simulations using the VAR can be a viable way to evaluate these strategies. We compute the modesty statistic suggested by Leeper-Zha (2003), which analyzes the statistical properties of the policy innovations. Intuitively, relative to policy shocks in the historical regime, if the policy innovations needed to transition to the new policy regime are sufficiently large and persistent, agents in the economy are likely to perceive that a change in regime has occurred, obviating the usefulness of the historical data. To determine if the Lucas critique is applicable to the counterfactual policy innovations that attain our hypothesized objectives for nominal GDP or price level target, we compute the modesty statistics and find sufficiently small values to suggest that our results may not violate this critique.[5]

We proceed as follows. In section II, we present the VAR model to be estimated and discuss its impulse response functions. In section III, we provide an intuitive discussion of the counterfactual methodology employed to assess the relative merits of nominal GDP versus price level targeting; technical details are included in an appendix which is available on request. Empirical results are included in section IV, and section V concludes.

[5] As noted by Leeper and Zha (2003), small values of the modesty statistic are necessary, but not sufficient, to allow researchers to discount concern about the Lucas critique. This should be kept in mind in interpreting our results.

2. The Empirical Model

We estimate a six-variable vector autoregression (VAR) that includes typical macro activity variables, monetary policy variables, and a measure of bond financing costs for nonfinancial firms. Specifically, the data series used in the analysis are the log level of the Commodity Research Bureau spot market price index for all commodities, the log level of the GDP deflator, the log level of real GDP, the effective federal funds rate (FFR), a measure of the money stock represented by the log level of MZM, which comprises the components of money with zero maturity,[6] and the Gilchrist-Zakrajšek (2012) excess bond premium, a credit spread that in other work has been deemed important in explaining economic activity.

Commodity prices are included to help mitigate the well-known "price puzzle" often found in VAR models. In the spirit of the monetary economics of Friedman and Brunner and Meltzer, Nelson (2003, p. 1029) argues for the inclusion of money in macro models as a "proxy for the various substitution effects of monetary policy that exist when many asset prices matter for aggregate demand." The money supply measure thus potentially captures information about monetary conditions not fully reflected in FFR. In its policy decisions, the Fed is concerned not only about the state of the macroeconomy but also about the state of financial markets and their links to the real economy. Consequently, when identifying monetary policy shocks, it seems important to include a proxy for concern about financial markets in the model, and we include the excess bond premium as this proxy. Favara et al. (2016) note that the excess bond premium, which removes the default risk of individual firms from the Gilchrist-Zakrajšek corporate bond market credit spread, captures credit market sentiment toward the general level of corporate credit risk. The excess bond premium is a forward-looking variable that reflects investors' expectations about future corporate defaults, which in turn depend on expectations about future corporate profits, employment, investment, and aggregate economic activity. Favara et al.

[6] Specifically, MZM equals M2 less small time deposits plus institutional money market mutual fund deposits.

(2016) summarize evidence that indicates an important effect of this variable in explaining economic activity.[7]

Since our focal point is targeting nominal GDP or the price level, it is natural to use real GDP and the GDP deflator in our basic model. As noted, other than FFR and the excess bond premium that are included in levels, we estimate the model in log levels. We will either target the sum of the logs of real GDP and the GDP deflator or, alternatively, just the log of the deflator.[8] We recognize that recent policy has aimed more at the personal consumption expenditures index, but use of the deflator is appropriate for an initial investigation given its formal role in defining nominal GDP. In addition, in the original proposal of the Taylor rule (Taylor, 1993), the focus for the inflation variable was the deflator rather than narrower, consumer-focused indexes.

The model was estimated using quarterly data for the time period 1979:4–2003:4. The starting point corresponds to the period initiated by the special Saturday night FOMC meeting at which then-Federal Reserve chair Paul Volcker refocused monetary policy on reducing the inflation rate. Our ending date for estimation allows us to investigate counterfactual policies that begin in a low interest rate environment, the FFR target having been 1 percent between mid-2003 and mid-2004, much as current policy normalization began with short-term interest rates just above zero. Among other things, this setting

[7] Although the explicit measure of the excess bond premium was not introduced until after our estimation period ended, we employ it for three reasons. First, as revealed in minutes of FOMC meetings and public statements of Fed officials, there has been a long-standing concern among policy makers about the state of financial markets and the implications for the macro economy in general. Second, the detailed information needed for construction of the excess bond premium was available beginning in 1973; see Gilchrist-Zakrajšek (2012.) It is econometrically efficient to include a single measure as a proxy for the state of financial markets. Third, Favara et al. (2016) find that the excess bond premium helps predict future economic activity and serves as a leading indicator for recessions. They find that the predictive content of the Gilchrist-Zakrajšek corporate credit spread for economic activity stems solely from the excess bond premium; the default risk of individual firms has no explanatory content. Based on these results, we used the excess bond market premium rather than the Gilchrist-Zakrajšek corporate credit spread.

[8] Since an integral part of our exercise includes the dynamic forecast of the VAR, we estimate in log levels, noting the recommendation of Lin and Tsay (1996). They argue that while the best forecasts are those that include the correct unit roots and cointegrating relationships, "when applied to real data, the results change. . . . Because the available cointegration tests have low power in rejecting the unit root hypothesis when the time series has characteristic roots close to 1, the danger of mis-imposing unit root constraints is real" (p. 537). More recently, Gospodinov, Herrera, and Pesavento (2013) argue that "the unrestricted VAR in levels appears to be the most robust specification when there is uncertainty about the magnitude of the largest roots and the co-movement between the variables."

also allows us to see if the zero bound on the nominal rate is encountered in our counterfactual experiments. Ending the estimation in 2003:4 also allows us three years for out-of-sample simulations with which to form initial impressions of the relative advantages of nominal GDP and price level targeting before early signs of the financial crisis began to appear in 2007. Four lags of all variables were employed and were sufficient to whiten the residuals of the equations of the VAR.[9]

The Federal Reserve is assumed to respond contemporaneously to the variables directly related to its dual mandate, but only with a lag to variables it doesn't directly target. Monetary policy shocks are identified as innovations to FFR using a Choleski decomposition with the ordering listed earlier. Thus, in the identification scheme, a contemporaneous response by the Federal Reserve to movements in the macro variables (commodity prices, the inflation rate, and output) is allowed, but the Federal Reserve is assumed to respond only with a lag to movements in the monetary aggregate and the excess bond premium. We note that since the Fed paid little attention to monetary aggregates over the estimation period it seems reasonable to assume no contemporaneous response to MZM. Recall that, following Nelson (2003), MZM is included as a proxy for the effects of monetary policy on asset prices other than bonds. Efficient markets considerations also suggest ordering MZM after FFR. Ordering the excess bond premium after the fed funds rate assumes that the Fed responds only to sustained changes in credit market sentiment about corporate credit risk and not to perhaps transitory contemporaneous changes.[10]

[9] Lag length was determined in the following way. We started from Doan's (2014) recommendation that at least a year's worth of lags be included in the VAR and then used the degrees-of-freedom multiplier-corrected version of the AIC criterion to determine if longer lags of 5 or 6 quarters should be employed. The AIC suggested 4 lags was optimal. However, we also computed the point estimates of the impulse response functions for a shock to monetary policy for both 5 and 6 lags in the VAR. These point estimates were almost always within the confidence intervals for the 4-lag model; the few elements of the point estimates that weren't within the confidence intervals were barely outside the intervals. Consequently, we decided to focus on the 4-lag model. The impulse responses for the 5- and 6-lag models are available on request.

[10] Because commodity prices are largely determined in world commodity markets, shocks to U.S. monetary policy are constrained not to have any contemporaneous effect on commodity prices but are allowed to have possible lagged effects on them. In the commodity price equation in the VAR, the F-statistic for jointly significant effects of the lagged fed funds rate on commodity prices is 0.84 with a significance level of 0.5. In fact, the only set of lagged values that are significant in the commodity price equation are lagged commodity prices. Nevertheless, following a referee's suggestion, we estimated a structural VAR in which bi-directional contemporaneous effects between the fed funds rate and commodity prices were allowed. Adding a contemporaneous coefficient for the fed funds rate to the commodity price equation required eliminating a contemporaneous coefficient elsewhere, and we eliminated the direct contemporaneous effect of commodity prices on MZM. This constrains any contemporaneous effect of

The pattern of effects of monetary policy shocks is as expected. A contractionary monetary policy shock, a rise in the funds rate, persists for several quarters but weakens and dies out as expected if the Fed responds to the negative output and price level effects of the initial contractionary shock. MZM falls at first and then returns to its initial level, as do commodity prices. The contractionary monetary policy shock has a negative and long-lived, but ultimately transitory, impact on real GDP and a delayed and then persistent negative impact on the GDP deflator. As expected, contractionary monetary policy, which pushes the economy into a transitory but long-lived recession, leads to a deterioration in the credit market's assessment of general corporate credit risk and hence to a transitory increase in the excess bond premium. A plot of the impulse response functions with one standard deviation confidence intervals is presented in an appendix which is available on request.

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commodity prices on MZM to indirect contemporaneous effects through a contemporaneous effect of commodity prices on the fed funds rate and then from the funds rate on MZM. Not too surprisingly, given the F-test results and the fact that the coefficient on the contemporaneous shock to the funds rate in the commodity price shock equation was not significantly different from zero, the IRFs for this structural VAR system are essentially identical to the ones presented in the appendix. This appendix is available on request.

Although we believe the arguments in the text and earlier in this footnote justify ordering commodity prices first and the excess bond premium last, following a referee's suggestion, we also swapped the ordering of commodity prices and the excess bond premium. The IRFs for a contractionary monetary policy shock are within the confidence bands for the ordering in the paper except for the first several quarters for commodity prices.

The sensitivity of the results to the Choleski method of identifying monetary policy shocks was checked by imposing structural constraints similar to those imposed by Leeper and Roush (2003). Three different structural identification schemes were examined, and each differed from the Choleski method only for the MZM and FFR equations. In the first scheme, the MZM equation was interpreted as a real money demand function by imposing the following constraints: no contemporaneous effect of the commodity price shock or the excess bond premium shock on real money demand, a contemporaneous coefficient of –1.0 on the log GDP deflator shock (which converts the log nominal MZM shock to a real money demand shock), and nonzero coefficients on the real GDP shock and the FFR shock. Thus, real money demand is specified to be a function of real GDP and FFR. In addition, in this first scheme, all model variables except the excess bond premium shock were allowed to affect the FFR shock contemporaneously. This configuration of the FFR equation thus allows MZM to affect FFR contemporaneously. Maximum likelihood estimation of this first structural model found a positive effect of real GDP and a negative effect of FFR on real money demand. Positive contemporaneous effects of commodity prices, the GDP deflator, and real GDP on FFR were found, and the effect of MZM on FFR was negative.

The second structural identification scheme imposed the same constraints as the first scheme for the MZM equation, and, in the FFR equation, eliminated the contemporaneous effect of MZM on FFR. The third structural identification scheme differed from the second by imposing a Taylor-rule-like structure on the FFR equation: the effects of commodity prices, MZM, and the excess bond premium on FFR were set to zero and the only nonzero effects allowed were for the GDP deflator and real GDP. For both the second and third identification schemes, the signs of the effects of real GDP and FFR on real money demand were the same as in the first, and the effects of the included variables in the FFR equation were all positive. Shocks to the FFR equation were interpreted as monetary policy shocks in all three structural alternatives, and impulse response functions (IRFs) for all three were essentially the same as those reported in the text for the Choleski decomposition which, for simplicity, is used hereafter. The methodology described in Section III below can be adapted in a straightforward way for shocks from structural identification schemes.

3. Methodology

We determine the path for the nominal interest rate over a planning horizon that maintains average nominal GDP (the price level) within a desired range, a tolerance band around a target path specified by the policy maker. A byproduct of the policy path is that we also produce counterfactual paths for all system variables associated with the average nominal GDP (price level) target.

Our approach to finding the path for the nominal rate that achieves the desired outcomes for nominal GDP (the price level) and the implications for the rest of the variables in the estimated system is an application of the policy planning process described by Blinder (1997):

> First, you must plan an entire hypothetical path for your policy instrument from now until the end of the planning horizon, even though you know you will activate only the first step of the plan. It is simply illogical to make your current decision in splendid isolation from what you expect to do in subsequent periods. Second, when next period actually comes, you must appraise the new information that has arrived and make an entirely new multiperiod plan. If the surprises were trivial, that is, if the stochastic errors were approximately zero, step one of your new plan will mimic the hypothetical step two of your old plan. But if significant new information has arrived, the new plan will differ notably from the old one.

We expect this ‘first step’ to be especially interesting when considering adoption of a new policy approach, such as moving from an inflation target to a nominal GDP or price level target. Prior to such an adoption, the policy maker would like to know whether the proposed policy is acceptable when considering the implied paths and volatility of system variables, especially the variables included in the central bank objective function such as the Fed’s dual mandate. In addition, the policy maker would like to know whether there would be instrument instability in the policy tool as well as whether adoption of the alternative approach would encounter Lucas critique issues, which if present may render existing data uninformative in the evaluation process.[11]

We start with a generic structural model of the form:

$$Y_t = A_0 Y_t + A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + \mu_t$$

[11] Blinder’s “second step,” which occurs after the passage of a time period, is more likely informative within a policy regime rather than when considering adopting a new regime.

where Y_t is an nx1 vector of variables, the A_i are nxn matrices with A_0 including the contemporaneous structural components of the model, and u_t is the corresponding vector of structural shocks, which are mutually and serially uncorrelated and zero in expected value. Our objective is to find values for the structural shocks to the policy equation (the innovation in the federal funds rate in our application) which allow the policy maker to attain a chosen path for a target variable (either nominal GDP or the price level). In our application, as noted above, we use a Choleski decomposition as our structure, though our technique can be applied to linear structural models in general.

To develop intuition, consider a two-variable structural VAR identified with a Choleski decomposition. Let the first variable be the target and the second the policy variable. Following a common assumption in the literature that the policy variable affects target variables like nominal GDP or prices only with a lag but responds contemporaneously to these variables, the matrix A_0 is then

$$A_0 = \begin{bmatrix} 0 & 0 \\ a_{0,21} & 0 \end{bmatrix}.$$

Assuming for simplicity of illustration there is only one lag in the structural model (in the generic model above the $A_i = 0$ for i>1) and assuming the model is estimated through period t with the dynamic simulations beginning in period t+1, our equations are:

$$Y_{1,t+1} = a_{1,11}Y_{1,t} + a_{1,12}Y_{2,t} + \mu_{1,t+1}$$

$$Y_{2,t+1} = a_{0,21}Y_{1,t+1} + a_{1,21}Y_{1,t} + a_{1,22}Y_{2,t} + \mu_{2,t+1}$$

Note that the policy innovation $\mu_{2,t+1}$ has no impact on $Y_{1,t+1}$. However, through $Y_{2,t+1}$, this innovation will alter the target variable in period t+2; specifically, advancing to period t+2 the innovation of $\mu_{2,t+1}$ alters $Y_{1,t+2}$ through its impact on $Y_{2,t+1}$.

$$Y_{1,t+2} = a_{1,11}Y_{1,t+1} + a_{1,12}Y_{2,t+1} + \mu_{1,t+2}$$

A target value for $Y_{1,t+2}$ of $Y^*_{1,t+2}$ is achieved by finding the policy innovation, $\mu_{2,t+1}$, that sets the value of the policy instrument in t+1 to be $Y^*_{2,t+1}$ such that

$$Y^*_{1,t+2} = a_{1,11}Y_{1,t+1} + a_{1,12}Y^*_{2,t+1} + \mu_{1,t+2}$$

Solve for $Y^*_{2,t+1}$, the value of the policy variable that will achieve $Y^*_{1,t+2}$:

$$Y^*_{2,t+1} = \left(\frac{1}{a_{1,12}}\right)\left\{Y^*_{1,t+2} - a_{1,11}Y_{1,t+1} - \mu_{1,t+2}\right\}$$

But, in t+1, policymakers don't know $\mu_{1,t+2}$. If they assume shocks to Y_1 in the future will be similar to past shocks, they could randomly draw from past shocks to Y_1 as a proxy for $\mu_{1,t+2}$. Define the shock that is drawn as $\hat{\mu}_{1,t+2}$.

Thus,

$$Y^*_{2,t+1} = \left(\frac{1}{a_{1,12}}\right)\left\{Y^*_{1,t+2} - a_{1,11}Y_{1,t+1} - \hat{\mu}_{1,t+2}\right\}$$

From $Y_{2,t+1} = a_{0,21}Y_{1,t+1} + a_{1,21}Y_{1,t} + a_{1,22}Y_{2,t} + \mu_{2,t+1}$, we can write $Y^*_{2,t+1} = Y^{*\,sys}_{2,t+1} + \mu^*_{2,t+1}$ where $Y^{*\,sys}_{2,t+1} = a_{0,21}Y_{1,t+1} + a_{1,21}Y_{1,t} + a_{1,22}Y_{2,t}$ is the systematic response of the policy variable to current and past values of the model variables and $\mu^*_{2,t+1}$ is the innovation in monetary policy (i.e. the deviation above or below $Y^{*\,sys}_{2,t+1}$) required to achieve $Y^*_{2,t+1}$. Thus, $\mu^*_{2,t+1} = Y^*_{2,t+1} - Y^{*\,sys}_{2,t+1}$.[12] Under our assumptions about the structural shocks, solving for the optimal policy innovation will have no implications for the other structural shocks.[13]

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[12] We note that the systematic portion the policy variable, $Y^{*,sys}_{2,t+1}$, can be computed as the dynamic forecast or base projection of the reduced form of the structural model.

[13] In contrast, if the policy maker mistakenly solved for the reduced form shock consistent with an estimated reduced form VAR, there would be unwanted consequences for the other reduced form shocks due to the contemporaneous correlations between these reduced form disturbances. That is, imposing a policy "innovation" in this fashion would affect other system variables in a complicated manner.

Similarly, in period t+3, the value of the target variable will depend on $Y_{2,t+2}$. Using the computed value $Y^{*}_{2,t+1}$ as the own lag in the expression for $Y_{2,t+2}$ then incorporates the policy innovation from period t+1, $\mu^{*}_{2,t+1}$, which is in turn incorporated into the computation of $Y^{*}_{1,t+3}$ and hence $\mu^{*}_{2,t+2}$. Continuing in this fashion, conditional on using random draws from the structural residuals for the shocks to the target variable, the policy maker can compute the values of the policy innovations needed to achieve the 'entire hypothetical path for your policy instrument from now until the end of the planning horizon, even though you know you will activate only the first step of the plan' as suggested by Blinder. Furthermore, as emphasized by Blinder, computing the consequences of the policy over the entire horizon is necessary as '[i]t is simply illogical to make your current decision in splendid isolation from what you expect to do in subsequent periods.'

The example above implies that the 'entire path' for the policy innovation can be computed by taking a random draw of a vector shocks to the target variable sufficient to cover the planning horizon. Using this draw, we would have one trial for the system given the desired path of the target and the policy needed to achieve this path. Repeating this process by taking new random draws allows computation of similar paths, each consistent with the target path, leading to an average path for the economy along with volatility around this path, assuming that the estimated residuals will be representative of the economic shocks over the planning horizon.[14] In our actual application below, we will perform 1,000 such trials.[15]

The simplified presentation above assumes that there are only two variables and that the policy maker aims to attain the policy path period-by-period. In practice, a policy maker will take a longer-run view when considering policy, so the period-by-period analysis above, while offering useful intuition, is

[14] As noted earlier, if the policy maker plans on policy objectives different from those in the estimation period, agents in the economy may be alerted to a regime shift. The implication of the Lucas critique is that such simulations will not be valid since the evolution of the economy in the new regime will differ from the old, so that the residuals upon which we rely may not be representative. We address and test for this possibility below.

[15] In our empirical approach, rather than using the VAR directly, for computational reasons we instead transform the VAR to its moving average representation (MAR) and conduct our counterfactual experiments using that alternative framework. The results are, of course, identical to those implied by the VAR. Detail is included in an appendix which is available on request.

unrealistic to use in a real-world application assessing targets for nominal GDP or the price level. Rather, the policy maker in our analysis has a medium-term objective to be achieved on average rather than precisely each quarter.[16] Specifically, we assume the objective is to maintain nominal GDP (the price level) within a specified tolerance band around a target path, allowing quarterly GDP (the price level) to violate the band in the short run as long as any deviation is offset during another period(s) during the policy horizon.

Our application allows for a medium-run policy horizon and constrained discretion, roughly mimicking important portions of the current policy regime. We specify a desired path for the target variable beginning at the historical value at the end of the estimation period, along with a tolerance band around the path. For example, we could target the price level rising at 2 percent per year from the most recent historical value, and then construct a plus/minus 1 percent tolerance band around that path. For period t+1, using a draw from the estimated system residuals, including that for the policy variable, we construct the counterfactual path over a 12 quarter horizon (periods t+1 through t+12), and ask whether any of the computed 12 quarters violates the band without being offset during another quarter in the horizon.[17] Consistent with a policy maker tolerating temporary deviations from the target, if the violation is offset in other periods within the horizon, no policy intervention in period t+1 is undertaken; that is, the policy innovation from the random draw is retained. If, however, violations are not offset, we compute a policy innovation for period t+1 that will produce a path for the target variable so that any deviations over the twelve-period horizon are offset. The innovation for the policy instrument (either the residual from the

[16] For example, Federal Reserve officials have indicated a tolerance for temporary deviations from its inflation goal by declaring that its objective for inflation is "symmetric" around its goal of 2% inflation over the medium term.

[17] Two obvious alternatives to random draws from the estimated residuals deserve mention. One option is to set them to their expected values of zero. Of course, this option is not interesting if the policy maker would like to know about the inherent variability of the alternative policy path based on the estimated volatility of the equation disturbances. A second option is to assume a particular probability distribution for the shocks to each variable and take random draws from these distributions. This option requires a possibly arbitrary choice of a probability distribution from which to draw. The option used here, employing values drawn randomly from the estimated residuals (transformed to their structural values), being linear transformations of the reduced-form OLS residuals, are zero mean. They also have the advantage of reflecting the statistical characteristics of the data, avoiding misspecification that would likely occur with the selection of a probability distribution that may not reflect the data.

draw or the computed policy innovation as appropriate) will be retained for the next period in the analysis. For period t+2, we maintain the 12 quarter horizon that continues to reflect the medium term policy horizon (periods t+2 through t+13), and use the drawn shocks conditional on the policy shock for period t+1 (as above) for the system to again ask whether the tolerance band is violated by a sufficiently large amount to require a policy intervention. If not, then the drawn shock for the policy equation is retained; if a violation of the band occurs that is not offset elsewhere in the horizon, then we compute a policy shock that will achieve the objective. The final period in our planning horizon, period t+12 in our case, continues to use mix of policy innovations and drawn shocks for the prior periods in evaluating the final medium-term horizon, periods t+12 through t+23.

We monitor the simulations for violations of the zero-lower bound.[18] Specifically, in our experiments the policy evaluations begin in a period with a 1 percent fed funds rate, and we investigate the frequency of violations of the zero-lower bound. Our hope is to provide initial information about whether price level, nominal GDP targets, or both are feasible without violating a lower bound in light of the low levels of interest rates in the decade subsequent to the financial crisis of 2007-2009, a topic of interest given the *Fed Listens* events in the first half of 2019 and the conference at the Federal Reserve Bank of Chicago in June, 2019 examining policy tools and strategies.

A potential shortcoming of our approach arises when we replace policy shocks drawn from the estimated residuals with computed shocks needed to attain the policy objective. If the computed policy innovations are implicitly from some other probability distribution, they may lead agents to infer a change in the policy regime, an issue raised by the Lucas critique. If so, our estimated model might not be

[18] Until the financial crisis, many viewed zero as the lower bound (the ZLB) for the policy interest rate. Of course, during the crisis, some central banks found that the policy rate could be set somewhat below zero—the effective lower bound (ELB). In the U.S., the policy rate never fell below zero. Using simulations of two Fed models employing alternative interest rate rules (an estimated rule and the Taylor rule) and assuming a policy setting with low nominal and real interest rates along with low inflation, Kiley-Roberts (2017) find nontrivial probabilities (at most 20 percent) of hitting the ELB. Lubik, Matthes, and Price (2018) use simulations of a time-varying parameter VAR to estimate the probability of hitting the ZLB over a 40-quarter forecast horizon that begins in the third quarter of 2018. They find a 15 percent chance of the economy being at the ZLB in the long-run, and about a 25 percent chance that all forecasted paths of the funds rate hit the ZLB at least once over their forecast horizon.

relevant for the simulation period. To test for this possibility, we compute and report the "modesty statistic" introduced by Leeper and Zha (2003) to evaluate whether our policy interventions would have likely been viewed by agents as "modest" and hence unlikely to have led to an inference of a change in the policy regime. Technical details are in an appendix which is available on request.

4. Results

4.1 Overview of the Experiments

We conducted several different experiments each for nominal GDP targets and price level targets. These experiments reflect combinations of target rates and widths of the tolerance band for each targeted variable. We begin with a description of the targets and the tolerance band selections and then provide additional details on the loss function metrics used for evaluation and on monitoring for violations of the zero-lower bound. We also roughly mimic the policy makers' use of the Tealbook by evaluating a key comparison: rather than adopting either a nominal GDP or a price level target, what are the effects of a "continuation policy," where we never intervene and instead let the draws for the policy equation, which represent estimated policy innovations, determine the policy implemented each quarter. Without interventions, then, this policy is a continuation of existing policy conditional on the representative shocks to the policy equation.[19]

The selected targets for nominal GDP and the price level all show rising values over time. For a nominal GDP target, rising nominal GDP objectives reflect the desires for both rising real GDP and modest increases in the price level. A policy maker selecting a realistic nominal GDP target would do so against the backdrop of estimates of the path of potential GDP, reflecting a wide variety of factors such as projected productivity growth, demographic changes, and commitments on fiscal spending. In addition, the nominal GDP objective must at least implicitly incorporate an objective for increases in the price level. For a price level target, we expect that the rate of increase will be consistent with the recent

[19] Note that these simulations mimic the base projections since the residuals from which we sample are zero mean.

inflation target, with the additional commitment to offset inflation "misses" by returning the price level to the desired path rather than letting bygones be bygones.

For nominal GDP for our base case, we target a growth rate of 4.5 percent per year, consistent with slowing productivity growth and an aging population. Following Hatzius and Stehn (2011), this 4.5 percent rate of growth is based on an assumed potential real GDP growth rate of 2.5 percent and a 2.0 percent inflation target.[20] Furthermore, given current policy discussions about transitioning to a nominal GDP or price level target starting from a policy rate near zero, a relatively modest objective for the transition period seems reasonable. We have also investigated rates of nominal GDP growth of 5.0 percent and 5.5 percent as well, continuing to assume a 2.0 percent inflation objective, so by implication of the purposes of our loss function computations, real growth of 3.0 percent or 3.5 percent, respectively. The standard deviation for growth rates of nominal potential GDP reported by the Congressional Budget Office was 0.4 for the decade prior to the simulations, 0.8 for the 15-year period prior, and 2.2 for the estimation period. For this initial assessment, around each target path for nominal GDP, we use tolerance bands of ±1 percent or ±2 percent. Both bands aim at using policy to maintain nominal GDP growth above zero.

For the price level target, 2.0 percent has been a common target for inflation across the advanced economies, including the United States, and we use this value in defining the target path for the price level. However, targeting prices to grow at 2.0 percent usually corresponds to a measure of consumer prices. Here, consistent with nominal GDP targets, the GDP deflator is a natural alternative. The GDP deflator over the estimation period rose at a rate of about 3.3 percent. In the decade and a half prior to our simulation, it rose at a rate of 2.3 percent, and in the decade prior it rose at a rate of about 1.8 percent. Using 2.0 percent as the inflation rate that defines the price level target path is thus not only consistent with publicly stated objectives for consumer prices, it is also within the range of the rate of change in the

[20] We note that Kohlscheen and Nakajima (2019), using a time-varying parameter VAR model, estimate the current steady-state growth of U.S. real GDP as 2.4%, essentially the same value as we employ.

GDP deflator for the period leading to the simulation dates. We specify bands around the target path for the price level of ±1.0 and ±2.0 percent, avoiding an absolute decline in the price level.

To construct the target paths of nominal GDP the price level, we use the 2003:4 value of the relevant variable and then assume the target grows according to the growth rates discussed above.[21] We then measure for each trial the root mean squared deviation (RMSD) for real GDP and the price level around their specified trends. We compare and contrast nominal GDP targets versus price level targets in detail, first by comparing the RMSDs of the trials across the various target paths and tolerance bands. Since weighted averages of mean squared deviations (MSDs) of output and the price level around their specified growth paths are broadly consistent with loss functions employed in standard dynamic optimization problems, we also compute three alternative values for loss functions that are the weighted sum of the MSDs of output and the price level around their specified growth paths. We compute one with equal weights on the MSDs of real GDP and the price level (the "dual mandate weights"), one with weights of 0.75 on real GDP and 0.25 on prices (the "Keynesian weights"), and one with weights of 0.25 on real GDP and 0.75 on prices ("Classical weights").[22] We similarly compute MSDs for the continuation policy and the associated loss functions, where for purposes of comparison, the MSDs of this policy are computed relative to the trend values used for the various nominal GDP and price level targets. Finally,

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[21] We chose 2003:4 as the base for computing the target path of the price level and the level of nominal GDP since we wanted to focus on how monetary policy and economic activity would have differed in the immediate run-up (2004:1-2006:4) to the recent financial crisis if a new monetary policy strategy had been implemented several years before the crisis. However, as noted by Mester (2018), among others, the target path of the price level or the level of nominal GDP at a given moment in time can differ substantially depending on the starting point for computation of the target path.

[22] A referee suggested that the use of the mean squared deviation of the price level from its target path was inappropriate and that the loss function should instead have the mean squared deviation of the inflation rate from its target. However, we specified the model in levels, so a loss function that contained squared deviations of the level of price and output from target seemed natural to use, especially since two of the three policies we consider (and which are the primary focus of our analysis) are "level" policies—price level targeting and targeting the level of nominal GDP. Furthermore, although the Federal Reserve specifies a target for the inflation rate, it is straightforward to translate this target to a desired path for the price level. In addition, the Federal Reserve's dual mandate refers to stable prices so that a loss function that contains price level deviations from target may be closer in intent to the spirit of the dual mandate than one that contains deviations of inflation from target. Finally, we note that, for the case of price-level targeting, Svensson (1999; forthcoming) and Bodenstein-Zhao (forthcoming) specified the central bank loss function with the squared deviation of the price level, rather than the inflation rate, from target as an argument.

although negative policy rates became commonplace in some countries during and subsequent to the financial crisis, negative rates were not employed in the United States. To see whether our simulations evolving from FFR of 1 percent at the end of the estimation period entailed negative rates in the simulations, for each experiment we report the number of periods in which the interest rate must be set below zero to attain the objective for that experiment and, when this occurs, the minimum value for the target rate.

For each experiment, we conducted 1,000 simulations, evaluating both the average policy paths and the response of the economy to nominal GDP targets or price level targets. As noted in the introduction, we seek answers to the following questions. For each experiment: (1) Which policy approach, targeting nominal GDP or targeting the price level, best achieves the Fed's dual mandate in terms of real GDP and the price level? (2) How do the simulation results compare with results of a "continuation policy" consistent with a simple dynamic forecast over the simulation period? (3) Is the policy path needed to target nominal GDP or the price level "reasonable" or is the degree of interest rate variability implausible? In the extreme, is there instrument instability? (4) Do the changes in policy strategy lead to a perception by agents that a Lucas-type regime change has occurred? (5) Is either type of policy, a nominal GDP target or a price level target, obviously preferred to the other? Is either preferred to the continuation policy?

4.2 Targeting Nominal GDP

Our first experiment is an investigation of a nominal GDP target. We specify a target path for nominal GDP growth along with a tolerance band and examine the implications for real GDP and the price level of using monetary policy to attain the nominal GDP objective. In addition, we analyze the interest rate path needed to attain the nominal GDP path. The analysis is based on 1,000 trials, which allow us to compute the variabilities of nominal GDP, real GDP, the price level, and the interest rate. In addition, we ask whether the policy as implemented would have violated the Lucas critique.

Having estimated our model through 2003:4, for our base case we target average nominal GDP growth of 4.5 percent at an annual rate for 2004:1 through 2006:4. In the context of recent history, Figure 1 shows this target path along with tolerance bands that are 1 percent above and below target. This target path is approximately in line with nominal GDP movements prior to our simulation period. However, while unknown to a policy planner at the end of 2003, in retrospect, this target path would have been somewhat restraining over the simulation period.[23] What could have been computed, however, is the simulated path for the continuation policy, which will be included in the figures below, consistent with policy-making that compares current policy with an evaluation of alternatives.

[Figure 1 about here]

The solid line in Figure 2 (a) shows the results for average quarter-by-quarter nominal GDP based on 1,000 simulations in which policy is conducted to maintain average 12-quarter nominal GDP inside the prespecified bands. As indicated in the description of the methodology, the computed policy shocks may allow individual quarterly values of the targeted variable to move outside the specified band (the dashed lines in Figure 2 (a)), as is evident in the first four quarters of the simulation. After the first year of the simulation, on average nominal GDP lies within the tolerance bands and offsets the values of nominal GDP above the bands over the twelve-quarter policy horizon.[24] The dotted line shows the nominal GDP path for the continuation policy, which is above the upper tolerance band in every quarter in the simulation period. Thus, the continuation policy path suggests that, on average, the policy pursued over the model estimation period would not have kept nominal GDP within 1.0 percent of the 4.5 percent

[23] The target path relative to the actual evolution of the economy suggests that early and restrictive intervention in the simulation period will likely be needed. We present evidence on the pattern of interventions below.
[24] As speculated above, of the 1,000 trials in our base case, it was necessary to intervene 990 times in the first quarter of the simulations, 2004:1. Subsequently, there were 11 in the second quarter, with none again until 2005:3, when the number gradually rose to 179 in 2006:4. Total interventions in the base case were 1,413 of the 12,000 total quarters in the horizon.

nominal GDP target path. Since our methodology selects a path for the policy shocks that attains this objective, once we have computed the path for the policy innovations that satisfies the policy objective, along with the other shocks from the trial draw we can trace the paths of all system variables, including those in Figures 2 (b) – (d).

[Figure 2 about here]

The solid line in Figure 2 (b) shows the average path for FFR associated with the policy objective and the dotted line shows the average path for the continuation policy. Figures 2 (c) and 2 (d) show the real and price components of the nominal GDP path. As is evident from Figure 2 (b), attaining the specified nominal GDP target requires an immediate and relatively large increase in FFR. In the average simulation, FFR rises to over 6.5 percent during the first year and then gradually declines. In contrast, this was a period in which the Fed was raising the funds rate target "at a measured pace" from the prior floor of 1.0 percent. Furthermore, the rise in the computed average policy rate (though not its magnitude) is in the direction suggested by critics, often appealing to the Taylor rule, who argued at the time that rates were too low for too long during the 2003–2004 period. The range of the simulated fed funds rate is reasonably close to what transpired, though the pattern is quite different. We note that the average paths for FFR for both the continuation policy and the nominal GDP target are noteworthy for their large upward movements, inconsistent with the appearance of interest rate smoothing in the data. Whether policy makers would be willing to raise rates as aggressively as indicated in our experiments is an open question.[25]

The solid line in Figure 2 (c) shows average real GDP given the policy shocks needed to attain the nominal GDP target and the dotted line shows the average real GDP for the continuation policy. The

[25] The large initial increases of the federal funds rate shown in Figure 2 (b) (along with a similar pattern shown in Figure 4 (b) below for the case of price level targeting) may overstate the rise in the policy rate if a level target policy was adopted. A referee has pointed out that it is possible that credible establishment of nominal GDP or price level targeting may lead to a smaller likelihood of deviations of nominal GDP or the price level from target if the public believes monetary policymakers will do whatever is necessary to achieve the targets. These smaller deviations in turn may mean that monetary policymakers may not have to intervene by as much as our simulations suggest. Consequently, the simulation paths of the funds rate in Figures 2 and 4 may be upper bounds.

restraint needed to maintain nominal growth inside the tolerance range induces a shallow recession, with output falling between the fourth quarter of 2004 and the second quarter of 2005 at an annual rate of about 1.1 percent, and then exceeding the previous peak by the fourth quarter of 2005. From the trough in 2005:2 until the end of the simulation, annualized output growth is 2.4 percent.

In Figure 2 (d), the solid line shows the path for the GDP deflator implied by the policy shocks needed for the nominal GDP target and the dotted line shows the average path for the continuation policy. Annualized inflation implied by the path of the price level is 2.3 percent over the simulation period.

As noted earlier, the dotted line Figure 2 (a) shows the continuation policy path of nominal GDP. The targeted policy discussed above clearly restrains nominal GDP relative to the continuation policy path.[26] Consistent with the continuation policy path for nominal GDP being higher than the path with the explicit target value, the continuation policy path of the fed funds rate is substantially less contractionary over the initial two quarters than with nominal GDP targeting and then follows approximately the same path over the remainder of the horizon. Real GDP and the price level are persistently higher than with the nominal GDP target, as would be expected in light of the different initial paths of FFR. For the continuation policy case, real GDP falls at an annual rate of 1.4 percent between 2004:4 and 2005:2, with annualized growth until 2006:4 from the trough of 2.1 percent. The price level rises over the period at an annual rate of 2.5 percent. So, while the continuation policy case has a higher level of nominal GDP, it has a modestly deeper recession, grows less rapidly subsequently, and has moderately higher inflation.

Table 1 contains additional information about the base-case nominal GDP and the continuation policy (and other) experiments. Several characteristics of these experiments warrant comment. First, there is no apparent “instrument instability” in the funds rate. Specifically, for a nominal GDP growth target of 4.5 percent and the ± 1 percent tolerance band, the average standard deviation of the policy rate across the trials is just marginally higher (1.80) than the actual standard deviation (1.61) over the period. Nonetheless, among the 12,000 quarters across the 1,000 trials, the maximum and minimum values

[26] The alternative paths are identical over the first quarter due to the Choleski decomposition, which places the policy variable lower in the ordering than the target variables.

ranged from -0.10 percent to 8.57 percent. In contrast, the corresponding range for the continuation policy was 0.06 percent to 8.62 percent (and the historical range was 1.0 percent to 5.25 percent). Second, there is only one instance in these 12,000 quarters in which the funds rate was set below zero, just marginally with a value of -0.10 percent. Despite the actual funds rate being 1.0 percent at the outset of our simulations, these results appear to allow a transition to the nominal GDP targeting regime without sustained instances of negative policy rates. Third, panel A of Table 1 reports the absolute values of the maximum computed Leeper-Zha modesty statistics.[27] For our base-case nominal GDP analysis, there does not appear to be concern regarding the Lucas critique. Our intuition is that while the range of interest rates in our experiments is wider than actually experienced, with the standard deviation of our experiment being roughly the same magnitude as actually occurred, those outside the actual range were sufficiently rare that the Lucas concerns were not of importance.

[Table 1 about here]

Table 2 presents average RMSDs for real GDP and the price level and Table 3 presents the loss function results for the nominal GDP targeting base case as well as for the continuation policy and other experiments. We note that the average RMSD for real GDP for the nominal GDP targeting base case is essentially the same as for the continuation policy, but for the price level, the average RMSD is about 16% lower for the nominal GDP targeting base case compared to the continuation case. From Table 3 we see that for all three weighting schemes—Dual Mandate, Keynesian, and Classical—the base-case nominal GDP targeting produces a lower loss than the continuation policy.

[27] We make one adjustment to their computation. Specifically, we use the randomly drawn disturbances to the other equations, with our policy interventions conditional on these disturbances, rather than assuming that the shocks to the nonpolicy equations are all zero (though our estimation, equivalent to OLS equation by equation, implies expected values of zero for these shocks). We do so since our computed policy interventions are conditioned on the drawn residuals in each trial.

[Table 2 about here]

[Table 3 about here]

As noted earlier, we have also considered higher targeted growth paths for nominal GDP of 5.0 percent and 5.5 percent based on alternative assumptions about the growth rate of real potential GDP. The results for these higher nominal GDP growth paths are summarized in Tables 1, 2, and 3. From Table 1, we note that the average standard deviations of the funds rate for these alternatives are greater than for the base case of 4.5 percent growth, although the increases appear to be negligible. The range of interest rate values rises somewhat with an increase in the target growth rate, as does the number of quarters with a negative interest rate. The Leeper-Zha statistics for the higher growth rates remain less than 2.0 in absolute value, so again there do not seem to be substantial Lucas critique concerns for the interest rate changes associated with the higher growth rates. However, we see from Table 2 that the average RMSDs for both real GDP and the price level for target nominal GDP growth of 5.0 percent and 5.5 percent are greater than for 4.5 percent growth but are, with one exception, below those for the continuation policy. From Table 3, we see that the loss function values are substantially different. For 5.0 percent growth, across the different weight schemes, the loss function values are 36.0 percent to 38.0 percent higher than for 4.5 percent growth and are 42.0 percent to 57.0 percent higher for 5.5 percent growth than for 4.5 percent growth. Again, however, the loss function values for nominal GDP targets based on both 5.0 percent and 5.5 percent growth are less than the comparable continuation policy results.

We also considered a wider tolerance band of 2 percent. In Table 1, we see that the average standard deviations of the funds rate are lower for the wider 2 percent band than the 1 percent band, and the range of interest rate values is often smaller than for the 1 percent band since there are fewer policy interventions under the wider band. As would be expected for the wider band, there are fewer quarters with a negative interest rate; for 4.5 percent and 5.0 percent growth in nominal GDP, there are no quarters with a negative interest rate. The results presented in Table 2 reveal that the average RMSDs for real GDP and the price level for the different target growth rates of nominal GDP for the 2% tolerance band are in four instances higher and in two instances lower than for the 1% tolerance bands. For the 2% tolerance bands, the average RMSDs for the nominal GDP targets are comparable in magnitude to those for the continuation policy whereas for the 1% band, they were lower in all but one instance. However, the loss function values presented in Table 3 are always higher for the 2 percent tolerance band than for the 1 percent tolerance band across all weight schemes and nominal GDP growth rates. For 4.5 percent growth, the loss function values are 6.0 percent to 25.0 percent higher across the weight schemes for the 2 percent tolerance band than for the 1 percent band; for 5.0 percent growth, the range is 7.0 percent to 11.0 percent higher, and for 5.5 percent growth, the range is 9.0 percent to 51.0 percent higher. For the 2% tolerance band and for all weight schemes, the loss function values for 4.5 percent nominal GDP growth remain below those for the continuation policy whereas for 5.0 percent growth they are essentially equal to those for the continuation policy but are below those for the continuation policy for 5.5 percent growth.

The loss function values in Table 3 provide the most comprehensive evaluation of the nominal GDP targeting results and suggest that, for our estimation period, simulation period, and model, a 4.5 percent nominal GDP target growth rate with a 1 percent tolerance band around the target level of nominal GDP delivers better results than nominal GDP targets of 5.0 percent or 5.5 percent or a tolerance band of 2 percent and generally better results than a continuation over the simulation period of the type of policy that characterized the estimation period.

4.3: Targeting the GDP Deflator

Our second experiment analyzes a target path for the price level. Similar to the analysis of the nominal GDP target, we specify a target path for the GDP deflator along with a tolerance band and examine the implications of using monetary policy to attain the targeted price level objective. Specifically, we analyze the interest rate path needed to attain the price level goals along with the implications of this path for real GDP. The analysis again is based on 1,000 trial simulations. As before, we ask whether the policy as implemented would have violated the Lucas critique.

Consistent with 2 percent inflation targets at major central banks around the world for much of the past several decades, and having estimated our model through 2003:4, we target price level growth of 2 percent with tolerance bands, alternatively, of ± 1 percent and ± 2 percent. While unknown to a policy planner at the end of 2003, this target path, specified to be about the same pace as then-recent historical values, would have been somewhat restraining over the simulation period; Figure 3 shows the target path with ± 1 percent tolerance bands, which we refer to as the base case for price level targeting.

[Figure 3 about here]

Average results for the 1,000 trials are shown in Figures 4 (a) – 4 (c). We begin with Figure 4 (a), which shows the quarter-by quarter average path for the price level under our base case price level target (solid line) and under continuation policy (dotted line). We note that with the continuation policy, after three quarters, the price level rises above the upper tolerance band and remains above for the rest of the simulation. Price level targeting gradually lowers the price level to a value within the tolerance band. As noted earlier, under price level targeting, the 12-quarter average price level meets the criterion set out in the methodology discussion, and this criterion does allow the quarter-by quarter price level to move modestly outside the tolerance band, although in each quarter it is below the price level implied by the continuation policy. Given recent references by Fed policy makers to a "symmetric" goal for policy around the 2% objective, we expect that policy makers would tolerate such temporary, modest deviations of the price level from the tolerance band. Inflation over the simulation period is 2.2 percent, close to the 2.0 percent rate that defined the target path for the price level.[28]

[Figure 4 about here]

[28] As with nominal GDP, we again anticipated restrictive interventions early in the period to move the price level along its target path. For the base case, we intervened in each of the 1,000 trials in both 2004:1 and 2004:2, in 880 trials in 2004:3, and in 34 trials in 2004:4 with no interventions in later periods. So, the total interventions for the price level target were 2,914.

Figure 4 (b) shows that, as expected from the fact that price level targeting generates a price level path below that of the continuation policy, monetary policy is initially substantially tighter under price level targeting than with the continuation policy. In 2004:1, the value of FFR implied by price level targeting is approximately 6.5 percent compared to a value slightly below 3.0 percent for the continuation policy. In 2004:2, under price level targeting, FFR is raised to almost 8.0 percent, whereas it rises to slightly above 5 percent under the continuation-policy.[29]

The tight policy under price level targeting reduces real GDP with a slight lag (Figure 4 (c) and begins to restrain the rise in prices relative to the continuation policy (Figure 4 (a)). Under price level targeting, the initial decline is 1.3 percent, followed by growth in 2006 of 3.0 percent. The annualized rate of inflation for our price level target over the simulation period is 2.2 percent, somewhat below the 2.5 percent annualized inflation rate under the continuation policy.

The decrease in real GDP is followed by cuts to FFR for both the targeting and the continuation policy approaches. Under price level targeting, after rising initially, FFR is cut in 2004:3 and the cuts continue until 2005:1, when FFR approximately levels out at a value slightly above 2 percent. With the continuation policy, FFR is increased to about 6.5 percent in 2004:3 (which is about the same value FFR is reduced to under price level targeting) and is cut in 2004:4 and thereafter. From about 2005:3 to the end of the simulation, FFR under price level targeting is actually below the values implied by the continuation policy. Although FFR is higher for a longer period of time under continuation policy than under price level targeting, for the continuation policy the peak in FFR is lower, the downturn in real GDP is smaller and less long-lived (two versus four quarters), and the recovery, which begins in 2005:2 for both policies, is weaker than for price level targeting.

[29] For our base cases, visual comparison of Figures 2 (b) and 4 (b) shows that the price level target on average requires an interest rate over the first year of the simulation period about one percent higher than required for the nominal GDP target. Table 1, panel B, shows that the maximum interest rate across the trials is 100 basis points higher for the price level target for the base cases.

Table 1 also contains information about this policy experiment. First, as before, there is no apparent "instrument instability" in FFR. Specifically, for the ± 1 percent tolerance band, the average standard deviation of policy across the trials is higher (2.23) than the actual standard deviation (1.61) over the period and the standard deviation for the continuation policy (1.58). Among the 12,000 quarters across the 1,000 trials, the highest interest rate needed was about 9.6 percent compared with an actual maximum of 5.25 percent. Second, there are only three instances in the 12,000 quarters in which FFR was set below zero, and just marginally (-0.06 percent). Despite the actual FFR being 1 percent at the outset of our simulations, as with nominal GDP targets, these results appear to allow a transition to the price level targeting regime without worry of sustained instances of negative policy rates. Also consistent with the nominal GDP target, we note that the path of FFR differs substantially from the smooth rise in the actual value of FFR over the simulation period and again question whether policy makers would move from a policy of modest adjustments of 25 basis points in order to attain the price level target. The absolute values of the maximum computed Leeper-Zha modesty statistics in Table 1, panel A indicate that, as was the case for nominal GDP targeting, there does not appear to be concern regarding the Lucas critique.

As with nominal GDP targeting, we also considered a 2 percent tolerance band for price level targeting. For price level targeting, the average standard deviation of FFR (Table 1, panel A) falls sharply for a 2 percent tolerance band relative to the 1 percent band and is essentially the same as for nominal GDP targeting of 4.5 percent, with a 2 percent tolerance band. The range of values of FFR for a 2 percent price level targeting tolerance band is now less than the range for nominal GDP targeting with a 2 percent tolerance band, and there are no periods in which a negative interest rate is required. With the price level objective, the average RMSD for real GDP falls when the tolerance band is widened from 1 percent to 2 percent (Table 2), but it rises for the price level. In Table 3, the loss function value for price level targeting for a 2 percent band is substantially lower than for a 1 percent band for the dual mandate and Keynesian weights but is only slightly less for Classical weights. Regardless of the weight scheme or the size of the tolerance band, loss function values for price level targeting are greater than those for the continuation policy. For the 1% tolerance band, the loss function values for price level targeting are greater than those for nominal GDP targeting except for nominal GDP targeting associated with 5.5 percent growth and Classical weights. For all three~~s~~ weight schemes, the loss function values for price level targeting with a 2 percent band are greater than those for nominal GDP targeting of 4.5 percent with a 2 percent band and higher than the best results for the same nominal GDP target but with the 1 percent band for all weighting schemes. The results are mixed for the 2% tolerance band when price level targeting is compared with nominal GDP targeting of either 5.0 percent or 5.5 percent growth.

We have also experimented with higher targeted growth paths for the price level. Generally, since we are starting with a relatively low interest rate at the outset, these cases required a substantial number of negative interest rates to attain higher price level objectives. As an example, when the price level is targeted to grow at a 2.6 percent rate with a ± 1 percent tolerance band, 1,305 quarters of the 12,000 across the trials required a negative rate to attain the objective. With a target growth in the price level of 4 percent, 4,874 quarters required a negative rate.[30] In addition, these alternatives fare poorly in terms of the ability to implement them without raising substantial Lucas critique objections. Examples such as these raise the question, given the model specification, of whether policy can emerge from a low interest rate environment by raising the price level objective over time, as suggested by some in the current environment.

4.4: Should There Be a Preference?

As we saw in the previous section, qualitatively, the effects of nominal GDP and price level targeting are similar. There are, however, some quantitative differences for the simulated paths of the key variables, real GDP and the price level. Both policies generate a brief downturn in real GDP followed by a recovery, and both restrain the increase in the price level relative to the continuation policy. Under nominal GDP targeting, the downturn is only two periods in duration (2005:1-2005:2), and real GDP falls

[30] While inflation averaged 3.3 percent over the estimation period, we evaluate a 4.0 percent price level growth objective in light of some proposals to at least temporarily raise the inflation target above 2.0 percent. Our guess is that 4.0 percent is the likely upper bound policy makers would tolerate given the potential loss of credibility for policy of rates higher than this and given the costs of returning inflation to the longer-run 2.0 percent objective.

by $77.2 billion. Real GDP peaks in 2004:2 under price level targeting, and a trough is reached in 2005:2. Real GDP declines by $187.3 billion. Thus, under price level targeting, the recession is longer and deeper than with nominal GDP targeting. With the continuation policy, real GDP falls in 2005:1 and 2005:2 and the decrease in real GDP is $100.3 billion. Price level targeting generates a decrease in real GDP that is 2.4 times the decrease under nominal GDP targeting and 1.3 times the decrease with the continuation policy. Although both targeting policies generate a price level below that of the continuation policy, the price level at the end of the simulation period is somewhat lower for price level targeting than for nominal GDP targeting. However, the annualized rate of inflation over the simulation period is about the same for nominal GDP and price level targeting. Across trials, inflation averages 2.3 percent for nominal GDP targeting and 2.2 percent for price level targeting; the continuation policy generates a moderately higher rate of inflation of 2.5 percent.

Comparing Figures 2 (b) and 4 (b), we note that although the pattern of adjustment of the funds rate is similar under both types of targeting, policy is initially tighter under price level targeting than under nominal GDP targeting (a maximum funds rate of almost 8.00 percent in Figure 4 (b) vs. about 6.75 percent in Figure 2 (b)) and that both types of targeting generate initially tighter policy than for the continuation policy (a maximum funds rate of about 6.50 percent). We also note that the average standard deviation of FFR under price level targeting (2.23) is higher than under nominal GDP targeting (1.80), and both are moderately higher than for the continuation policy (1.58) or for the actual standard deviation (1.61). Over the simulations, the spread between the maximum and minimum values of the funds rate is comparable, although the range is somewhat wider for price level targeting than for nominal GDP targeting. The number of quarters with a negative funds rate is negligible for both types of targeting using the base case parameters for the targeting experiments. The Leeper-Zha statistics suggest that the Lucas Critique is not an issue for the base cases.

Table 2 shows the RMSDs for the various experiments, computed around trend values as specified earlier. Table 2 indicates that for the price level objective for the ± 1 percent tolerance band, the RMSDs are notably different than for the base case for nominal GDP targeting. In particular, the RMSD for real GDP is nearly twice as large as for the nominal GDP target example, while the price level RMSD is about 20 percent lower. The tighter control of the price level is not surprising, given that the price level is the objective of this experiment.

Table 3 presents the values of the loss functions associated with the dual mandate, Keynesian, and Classical preferences. In Table 3, a comparison of the loss function values across different policy strategies reveals that for both 1% and 2% tolerance bands around the targets, nominal GDP targeting based on a desired 4.5% rate of growth in nominal GDP is superior to a policy aimed solely at the price level and to the continuation policy. The smallest loss function value in Table 3 is for nominal GDP targeting based on a desired 4.5% rate of growth in nominal GDP and a 1% tolerance band. We also see that the loss function values for nominal GDP targeting for all weight schemes rise as the tolerance band width increases from 1% to 2%, and the performance of nominal GDP targeting relative to the price level and continuation policies deteriorates the higher the rate of growth in nominal GDP.[31] However, for a 1% tolerance band and 5% nominal GDP target, nominal GDP targeting is still preferred to both the price level target and the continuation policy, and, for a 1% tolerance band and 5.5% nominal GDP target, nominal GDP targeting is preferred to the price level target and the continuation policy except for Classical weights, where the nominal GDP target is tied with the price level target, but is still preferred to the continuation policy. For a 2% tolerance band and 5% nominal GDP target, the nominal GDP target, price level target, and continuation policy are essentially tied for all weight schemes. For the 2% tolerance band and 5.5% nominal GDP target, the price level target is preferred for all weight schemes to both the

[31] Higher rates of nominal GDP growth allow for greater variability in inflation and output. To understand the contributions of output and price variability to total loss, we computed the separate contributions to total loss of the weighted squared deviations of output and price from their respective targets for each weight scheme and tolerance band. These separate contributions were derived from the RMSDs by squaring the RMSDs and applying the relevant weights to the sum of the squared deviations of output and price from their respective targets. The results are presented in an expanded Table 3, found in the appendix which is available on request. Not surprisingly, it shows that as the specified target growth on nominal GDP rises, the squared deviations of both real GDP and the price level rise. However, for the 1% tolerance band, within a given weighting scheme, the relative contributions of real GDP and the price level are approximately stable. For the 2% tolerance band, the relative contribution of output variability rises and the relative contribution of inflation variability falls by either 19 percentage points (dual mandate weights) or by 14-15 points (Keynesian and Classical weights) as target nominal GDP growth rises from 4.5% to 5.5%.

nominal GDP target and the continuation policies, but the nominal GDP target is preferred to the continuation policy.

Overall, our results suggest that a constrained-discretionary implementation of a level nominal GDP target based on 4.5% nominal GDP growth achieved with tighter rather than looser precision is preferred to a continuation of the implicit flexible inflation targeting of the period before the recent crisis or to price level targeting. We reach this conclusion since (1) the lowest value of the loss function is found for the level nominal GDP target based on 4.5% nominal GDP growth with a 1% tolerance band, (2) the assumption about the rate of growth in real GDP of 2.5% underlying the 4.5% nominal GDP target is more in line with recent estimates of a sustainable rate of growth in real GDP than the assumptions about real GDP growth of 3% and 3.5% that underlie the 5% and 5.5% nominal GDP targets, (3) that with the exception of one tie, nominal GDP targeting is preferred to the continuation policy of implicit flexible inflation targeting, (4) that policy credibility is more likely to be established when consistently hitting a tighter tolerance band than a looser one, and (5) that price level targeting is preferred to nominal GDP targeting only when the tolerance band is 2% and real GDP growth that underlies the nominal GDP target is a very optimistic 3.5%.

4.5: Was the Fed Implicitly Targeting Nominal GDP?

Our results in Table 3 are broadly consistent with the hypothesis and empirical results of Hendrickson (2012) to the effect that the Federal Reserve under Paul Volcker adopted policy consistent with controlling inflation and inflation expectations "by maintaining low, stable rates of nominal income growth." His supporting evidence includes both reduced form estimation and analysis of two DSGE models, each of which embeds a rule that sets the fed funds rate as responsive to anticipated nominal GDP growth as measured by Greenbook forecasts. In our analysis, we note that the loss function values for the continuation policy evaluated against a 2% inflation rate and a 3% real GDP growth rate are essentially the same as for our nominal GDP targets with a nominal GDP growth rate objective of 5% and our wider tolerance bands. Even for 4.5% nominal GDP growth and the wide tolerance bands, the loss function values for this implementation of nominal GDP targeting and for the continuation policy are of comparable magnitude. So, while our model suggests that policy would have produced better results with a smaller tolerance band, the results for 4.5%-5% nominal GDP targeting with wide tolerance bands are consistent with a correspondence between the continuation policy and a loose implementation of nominal GDP targeting.[32]

5. Concluding Comments

This paper takes a different approach to evaluating nominal GDP and price level targeting than the extant literature. Previous literature compares alternative policy rules mainly within New Keynesian models. Following an earlier suggestion of McCallum (1988) that alternative strategies be evaluated within a variety of different models including time series models, this paper evaluates nominal GDP and price level targeting within a policy framework of constrained discretion using a vector autoregressive model. Constrained discretion, rather than adherence to a formal rule, best describes the implementation of policy today, and, in our view, is most likely to characterize policy implementation in the future. Concerns about the applicability of the Lucas critique to our approach are mitigated by the low values of the Leeper-Zha (2003) modesty statistics which analyze the statistical properties of the policy innovations required to achieve either the nominal GDP or price level target.

Although we use a very different approach to evaluating nominal GDP and price level targeting, our results are generally complementary to those in the literature we cited earlier. Our results suggest a preference for a nominal GDP targeting strategy that closely rather than loosely targets a path of the level of nominal GDP based on a 2.5% long-run rate of growth in real GDP and a desired inflation rate of 2%. Alternatives considered included price level targeting, a continuation of the implicit flexible inflation targeting that characterized the period over which we estimated our model, and path targets for the level of nominal GDP associated with higher rates of nominal GDP growth. However, we do note some

[32] We are grateful to the editor for pointing out to us this feature of the results.

ambiguity in the rankings of the nominal GDP and price level strategies when price level targeting is compared to nominal GDP targets that are based on higher and perhaps less realistic growth rates of real GDP and wider tolerance bands around the target path for nominal GDP or prices.

The evidence from our study that nominal GDP targeting, and to a lesser extent price level targeting, outperforms a continuation of the implicit flexible inflation targeting of the period preceding the most recent financial crisis in conjunction with evidence from earlier studies suggests that central bankers should seriously consider nominal GDP and price level targeting as alternatives to flexible inflation targeting as they periodically evaluate their policy strategies. In particular, the accumulating evidence suggests that nominal GDP and price level targeting deserve careful evaluation in the Federal Reserve's current review of its monetary policy framework.

References

Bean, C. R. (1983). Targeting nominal income: An appraisal. *The Economic Journal, 93,* 806-19.

Beckworth, D. & Hendrickson, J. R. (Forthcoming). Nominal GDP targeting and the Taylor rule on an even playing field. *Journal of Money, Credit, and Banking*.

Benchimol, J. & Fourçans, A. (2019). Central bank losses and monetary policy rules: A DSGE investigation. *International Review of Economics and Finance, 61,* 289-303.

Bernanke, B. S. (2017, October 12). Monetary policy in a new era. Presented at the conference on Rethinking Macroeconomic Policy, Peterson Institute for International Economics, Washington DC. Available at https://www.brookings.edu/research/monetary-policy-in-a-new-era/.

Blinder, A. S. (1997). What central bankers could learn from academics – and vice versa. *Journal of Economic Perspectives, 11,* 3–29.

Bodenstein, M. & Zhao, J. (Forthcoming). On targeting frameworks and optimal monetary policy. *Journal of Money, Credit, and Banking*.

Bradley, M. D. & Jansen, D. W. (1989). Understanding nominal GDP targeting. Federal Reserve Bank of St. Louis *Review, 71*, 31-40.

Christiano, L J. (1998). Discussion of Christopher A. Sims' The role of interest rate policy in the generation and propagation of business cycles: What has changed since the 1930s? In J. C. Fuhrer & S. Schuh (Eds.), *Beyond shocks: What causes business cycles* (pp.161-70). Boston: Federal Reserve Bank of Boston.

Doan, T. (2018). *RATS version 10 user's guide*. Evanston, IL: Estima, (Chapter 7).

English, W. B., Lopez-Salido, J. D., & Tetlow, R. J. (2015). The Federal Reserve's framework for monetary policy: Recent changes and new questions. *IMF Economic Review, 63,* 22-70.

Fackler, J. S. & Rogers, J. (1995). Output, inflation, and stabilization: A counterfactual analysis. *Journal of International Money and Finance, 14*, 619-40.

Fackler, J. S. & McMillin, W. D. (2011). Inflation forecast targeting: An alternative approach to estimating the inflation-output variability tradeoff. *Southern Economic Journal,* *78*, 424-51.

Fackler, J. S. & McMillin, W. D. (2019). An evaluation of nominal GDP versus price-level targeting. Mercatus Center *Policy Brief* (May 14). Available at: https://www.mercatus.org/publications/monetary-policy/evaluation-nominal-gdp-versus-price-level-targeting.

Favara, G., Gilchrist, S., Lewis K. F., & Zakrajšek, E. (2016). Recession risk and the excess bond premium. *FEDS Notes* (April 8). Available at: https://www.federalreserve.gov/econresdata/notes/feds-notes/2016/recession-risk-and-the-excess-bond-premium-20160408.html.

Garín, J., Lester, R., & Sims, E. (2016). On the desirability of nominal GDP targeting. *Journal of Economic Dynamics and Control, 69,* 21–44.

Gilchrist, S., & Zakrajšek, E. (2012). Credit spreads and business cycle fluctuations. *American Economic Review, 102,* 1692–1720.

Gospodinov, N., Herrera, A. M., & Pesavento, E. (2013). Unit roots, cointegration and pre-testing in VAR models. In T. B. Fomby, L. Kilian, & A. Murphy (Eds.), *Advances in econometrics: VAR models in macroeconomics—new developments and applications: Essays in honor of Christopher A. Sims*, 32 (pp. 81–115). Bingley, UK: Emerald Group.

Hall, R. E. & Mankiw, N. G. (1994). Nominal income targeting. In N. G. Mankiw (Ed.), *Monetary Policy* (pp. 71-94). Chicago: University of Chicago Press.

Hatzius, J., & Stehn, S. J. (2011). The case for a nominal GDP target. *US Economics Analyst* (October 14). Available at: https://www.goldmansachs.com/insights/archive/archive-pdfs/case-for-nominal-gdp-level-target.pdf.

Hendrickson, J. R. (2012). An overhaul of Federal Reserve doctrine: Nominal income and the great moderation. *Journal of Macroeconomics, 34,* 304–17.

Kahn, G. A. (2009). Beyond inflation targeting: Should central banks target the price level? Federal Reserve Bank of Kansas City *Economic Review*, *94* (Third Quarter), 35-64.

Kiley, M. T. & Roberts, J. M. (2017). Monetary policy in a low interest rate world. *Brookings Papers on Economic Activity* (Spring), 317–96.

Kilian, L. & Lütkepohl, H. (2017). *Structural Vector Autoregression Analysis*. Cambridge: Cambridge University Press.

Kohlscheen, E. & Nakajima, J. (2019). Steady-state growth. Bank for International Settlements Working Paper 812. Available at: https://www.bis.org/publ/work812.htm.

Leeper, E. M., & Roush, J. E. (2003). Putting 'm' back in monetary policy. *Journal of Money, Credit, and Banking, 35* (December, Part 2), 1217–56.

Leeper, E. M., & Zha, T. (2003). Modest policy interventions. *Journal of Monetary Economics, 50*, 1673–1700.

Lin, J.-L., & Tsay, R. S. (1996). Cointegration constraint and forecasting: An empirical examination. *Journal of Applied Econometrics*, *11*, 519–38.

Lubik, T. A., Matthes, C., & Price, D. (2018). How likely is a return to the zero lower bound? Federal Reserve Bank of Richmond *Economic Brief* EB18-09 (September). Available at: https://www.richmondfed.org/publications/research/economic_brief/2018/eb_18-09.

McCallum, B. T. (1988). Robustness properties of a rule for monetary policy. *Carnegie-Rochester Conference Series on Public Policy*, *29*, 173-203.

Mester, L. J. (2018, January 5). Monetary policy frameworks. Presentation at the Allied Social Sciences Association Annual Meeting, Philadelphia, PA. Available at: https://www.clevelandfed.org/newsroom-and-events/speeches/sp-20180105-monetary-policy-frameworks.

Nelson, E. (2003). The future of monetary aggregates in monetary policy analysis. *Journal of Monetary Economics*, *50*, 1029–59.

Svensson, L. E. O. (1999). Price level targeting versus inflation targeting: A free lunch? *Journal of Money, Credit, and Banking*, *31* (part 1), 277–95.

Svensson, L. E. O. (forthcoming). Monetary policy strategies for the Federal Reserve. *International*

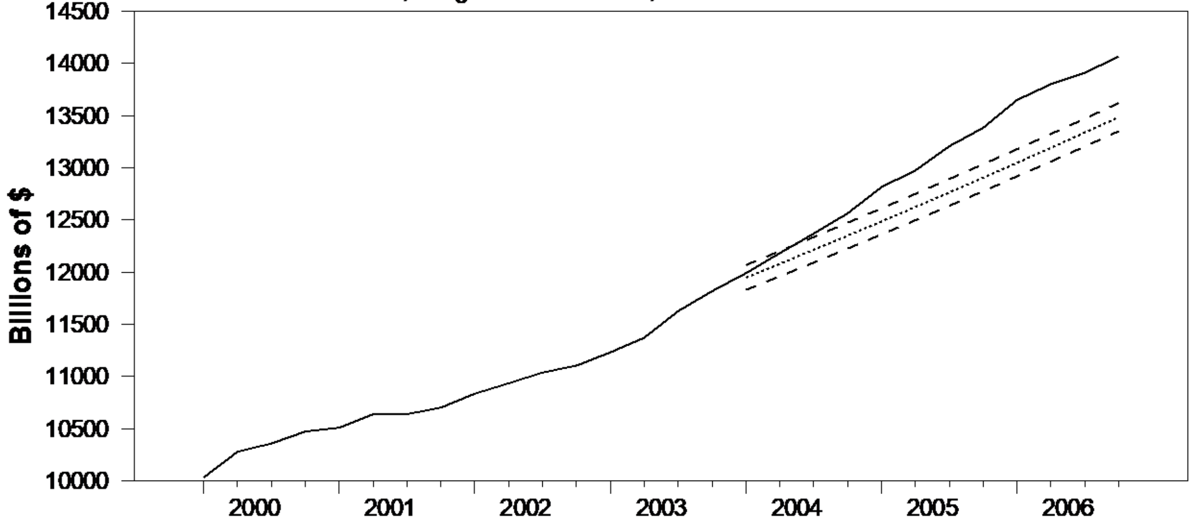
Journal of Central Banking.

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy, 39,* 195–214.

Walsh, C. E. (2003). Speed limit policies: The output gap and optimal monetary policy. *American Economic Review, 93*, 265-78.

Figure 1: Nominal GDP Targeting

Nominal GDP, Target Nominal GDP, and 1% Tolerance Bands



Solid Line = Nominal GDP; Dots = Target Nominal GDP; Dashes = 1% Tolerance Bands

Figure 2: Nominal GDP Targeting

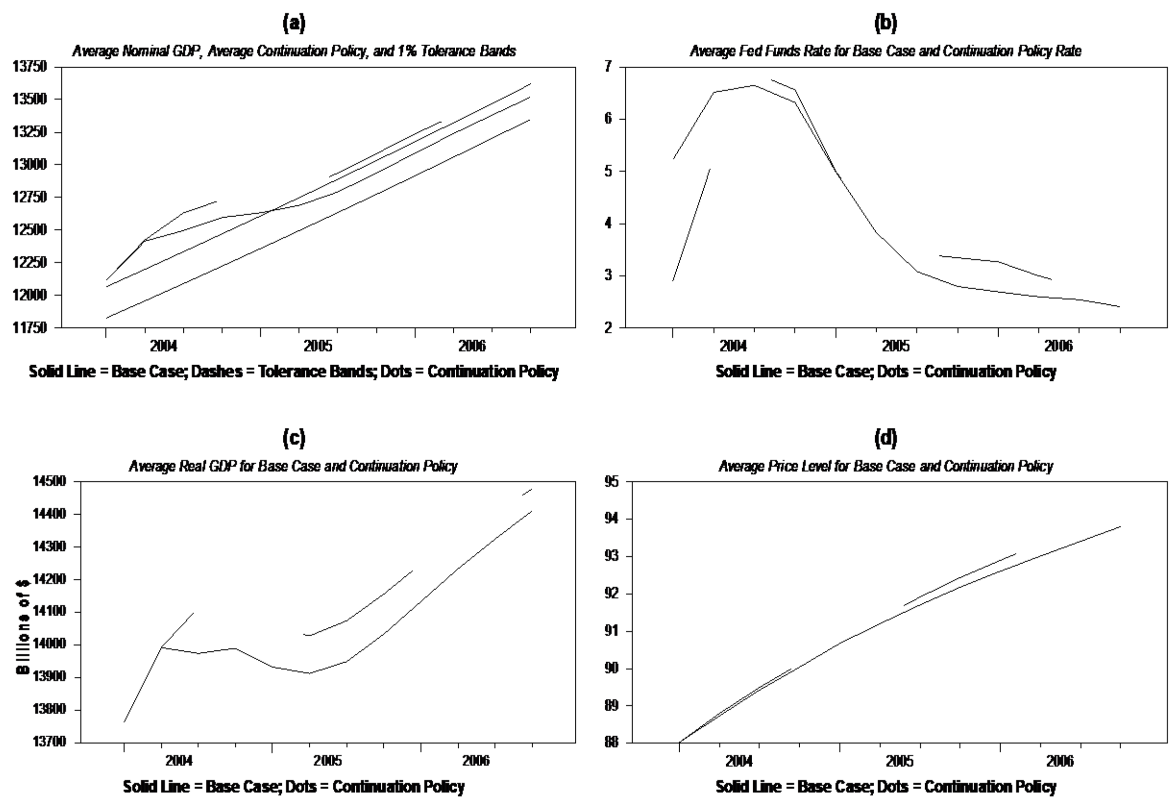
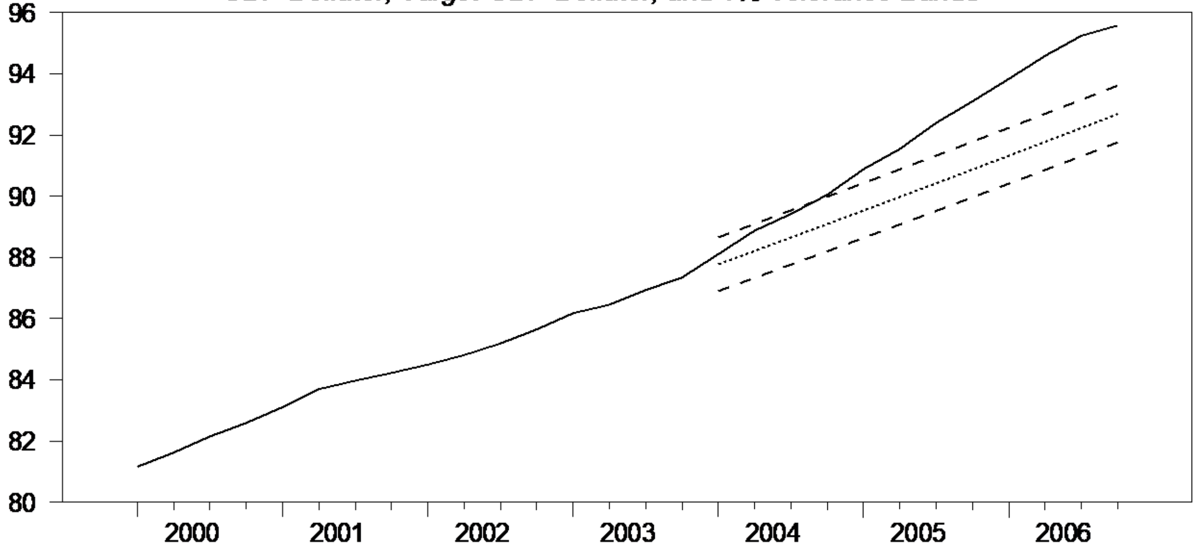


Figure 3: Price Level Targeting

GDP Deflator, Target GDP Deflator, and 1% Tolerance Bands



Solid Line = GDP Deflator; Dots = Target GDP Deflator; Dashes = 1% Tolerance Bands

Figure 4: Price Level Targeting

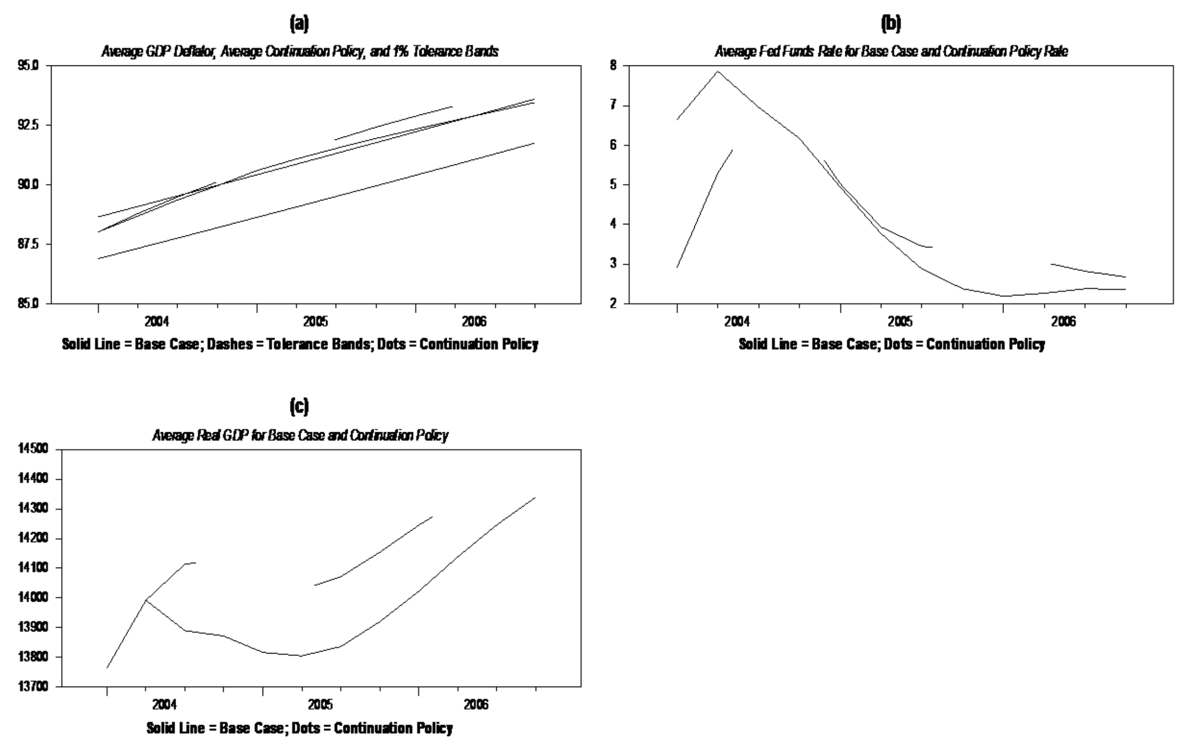


Table 1: Select Interest Rate Statistics, 1,000 Trials

A. Average Standard Deviation*†

Target Variable	% Rate of Change	Tolerance Band Width		Leeper-Zha Statistic
		± 1%	± 2%	± 1% / ± 2%
1. Level NGDP	**4.5**	1.80	1.58	1.65 / 1.54
2. Level NGDP	**5.0**	1.83	1.64	1.58 / 1.52
3. Level NGDP	**5.5**	1.92	1.64	1.97 / 1.91
4. Price Level	**2.0**	2.23	1.57	1.59 / 1.48

* **Actual:** 1.61
† **Continuation Policy:** 1.58

B. Minimum / Maximum Values*†

Target Variable	% Rate of Change	Tolerance Band Width	
		± 1%	± 2%
1. Level NGDP	**4.5**	-0.10 / 8.57	0.06 / 8.62
2. Level NGDP	**5.0**	-0.29 / 8.62	0.06 / 8.62
3. Level NGDP	**5.5**	-0.62 / 8.47	-0.67 / 8.62
4. Price Level	**2.0**	-0.06 / 9.57	0.22 / 8.42

* **Actual:** 1.0 / 5.25
† **Continuation Policy:** 0.06 / 8.62

C. Number of Quarters with Negative Rate*†

Target Variable	% Rate of Change	Tolerance Band Width	
		± 1%	± 2%
1. Level NGDP	**4.5**	1	0
2. Level NGDP	**5.0**	3	0
3. Level NGDP	**5.5**	13	9
4. Price Level	**2.0**	3	0

* **Actual: 0**
† **Continuation Policy: 0**

Table 2: Average Root Mean Squared Deviations (RMSD), 1,000 Trials*†			
RMSDs for Nominal GDP and Price Level Targets	**±1% band**	**±2% band**	**Continuation Policy‡**
Nominal GDP Target Growth: 4.5%			
RMSD: Real GDP	1.23	1.21	1.26
RMSD: Price Level	1.18	1.37	1.40
Nominal GDP Target Growth: 5.0%			
RMSD: Real GDP	1.45	1.54	1.55
RMSD: Price Level	1.37	1.40	1.40
Nominal GDP Target Growth: 5.5%			
RMSD: Real GDP	1.43	1.88	2.20
RMSD: Price Level	1.51	1.44	1.40
Price Level Target Growth: 2.0%			
RMSD: Real GDP	2.38	1.56	1.56
RMSD: Price Level	0.99	1.39	1.35

* All values multiplied by e-02.

† RMSDs are computed around the following trends. Target price level growth is always 2%, based on the actual value in 2003:4. Also, starting from the actual 2003:4 value, real GDP growth trends are 2.5% for target nominal growth of 4.5%, 3% for target nominal growth of 5%, and 3.5% for target nominal growth of 5.5%.

‡ RMSDs for the continuation policy experiment calculated around trends used for the growth targets in the corresponding row.

Table 3: Loss Functions				
Type Loss Function/ Policy Objective	**% Rate of Change[a]**	**Loss Function Value[*]**		
		Tolerance Band Width		**Continuation Policy[**]**
		±1%	**±2%**	
A. Dual Mandate Weights[b]				
1. Level NGDP	4.5	1.45	1.67	1.76
2. Level NGDP	5.0	1.99	2.16	2.17
3. Level NGDP	5.5	2.17	2.80	3.39
4. Price Level	2.0	3.33	2.18	1.76
B. Keynesian Weights[c]				
1. Level NGDP	4.5	1.48	1.57	1.67
2. Level NGDP	5.0	2.04	2.27	2.28
3. Level NGDP	5.5	2.11	3.17	4.11
4. Price Level	2.0	4.50	2.31	1.67
C. Classical Weights[d]				
1. Level NGDP	4.5	1.41	1.77	1.86
2. Level NGDP	5.0	1.93	2.06	2.06
3. Level NGDP	5.5	2.22	2.43	2.67
4. Price Level	2.0	2.15	2.06	1.86

[*] All values should be multiplied by e-04.
[**] Under the continuation policy, the loss function values for price level targeting with 2% inflation and NGDP targeting with 4.5% growth are the same since these share common trends of 2% growth for prices and 2.5% growth for real GDP around which the MSDs are computed. For Level NGDP targets based on 5.0% and 5.5% growth, the loss functions are based on a price path with 2% growth and real GDP growth of 3.0% and 3.5%, respectively.

[a] The desired rate of change employed in computing the target path of the level of the variable over 2004:1–2006:4. The 2003:4 value is projected forward as the target value at the indicated rate of change.

[b] Dual Mandate Weights: 0.5 on the variance of both output and the price level from target.

[c] Keynesian Weights: 0.25 on the variance of the price level from target and 0.75 on the variance of the output from target.

[d] Classical Weights: 0.75 on the variance of the price level from target and 0.25 on the variance of the output from target.