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Nominal GDP targeting, real economic activity and inflation stabilization in a new Keynesian framework

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ABSTRACT

This paper examines a nominal GDP growth targeting (NGDP-GT) rule, two Taylor types of rules and a strict inflation targeting regime in a New Keynesian model with the assumption of a positive rate of trend inflation. The model adopts a trend total factor productivity (TFP) growth to compare monetary policies in both high and low growth environments. Policy rankings are affected by the level of trend growth, the level of partial indexation to inflation and different specifications of the Taylor rule. NGDP-GT either outperforms other regimes or is weakly dominated by a desirable policy. Specifically, from the stability perspective, NGDP-GT is preferred compared to a Taylor type of rule and a strict inflation targeting regime in stabilizing the economy. It reduces inflation volatility by 25% or more while performs almost as well in stabilizing output and consumption relative to the Taylor rule. It produces at least 27% less fluctuations in output and consumption, and is almost as well as inflation targeting in stabilizing inflation. From the welfare perspective, when the Taylor rule takes the simple form, inflation targeting is the least desirable framework and NGDP-GT is weakly dominated by the Taylor rule. The conclusions are not conditioning on the trend growth rate or the level of inflation indexation. However, if the Taylor rule takes the form that interest rate responds to deviations of inflation and output growth (TR-II), when a TFP shock hits the economy and trend growth rate $A = 1$, TR-II generates of the least welfare loss and NGDP-GT performs almost as well. When trend growth rate $A \neq 1$, NGDP-GT is the most desirable policy regime. When the economy is subject to a markup shock, and $A \geq 1$ and (or) partial indexation to inflation $\eta = 1$, TR-II dominates the other two regimes. For other cases, NGDP-GT is the desirable policy rule.

1. Introduction

Prior to the normalization of the federal funds rate, the past economic crisis and the nominal interest rate at the zero lower-bound (ZLB) revived economists' interest in the targeting of nominal GDP (or nominal income) as an attractive monetary policy option. Before 2008, the Taylor rule had kept its prevalence of nearly two decades by virtue of being both relatively simple to compute and practically implementable by the Federal Reserve while having great effectiveness in preventing the recurrence of high inflation. As pointed out by Sumner (2014), if the Great Moderation had continued, there would be few reasons to abandon the Taylor rule. The current study is motivated by the limitations of the Taylor rule due to the narrow operation room to the ZLB in recent years and its congenital defects in requiring the measurement of real economic activity and core inflation, and by the discussion on nominal GDP targeting. Since 2016, the Federal Reserve has been gradually raising the federal funds rate with the expectation of restoring it to the normal range. However, the financial market has been well ahead of the data, pricing in downside risks such as slow global growth, trade negotiations and expected contractionary monetary policy, leading to dramatic volatility recently, which is consistent with Alan Greenspan's opinion that traditional monetary policies are not critical at this stage. The current study is motivated by the non-implementability of the traditional monetary policy rules in the foreseeable future due to the ZLB, the normalization of the federal rates, and traditional monetary policy's congenital defects in requiring the measurement of real economic activity and core inflation.

Literature on NGDP targeting can be tracked back to the 1990's. McCallum (1987), McCallum (1989), and Hall and Mankiw (1994) found that nominal GDP targeting rule provides policy makers operability and robustness due to its favorable performance across a range of models. In response to the 'Ball-Svensson' instability conclusion of Ball (1997) and Svensson (1997), McCallum (1997) utilizes a model involving forward-looking rational expectations

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and alternative analysis of supply-side specifications where he ultimately shows that the result of Ball (1997) and Svensson (1997) is fragile. To examine these two competing results, Dennis (2001) considers the general case where inflation expectations are a mixture of backward-looking and forward-looking terms, which nests those of Ball (1997) and McCallum (1997) as special cases. This general case yields the result that nominal GDP growth targeting does not lead to instability. Henderson and Kim (2005) designs a model that features optimization and monopolistic competition in both product and labor markets where one-period nominal contracts signed before shocks are known. Qualitatively, nominal-income-growth targeting turns out to dominate inflation targeting for plausible parameter values.

In more recent literatures, Beckworth and Hendrickson (2015) amend a standard New Keynesian model to assume that the central bank has imperfect information about the output gap. Their simulations show that a nominal GDP targeting rule produces lower volatility in both inflation and the output gap in comparison with the Taylor rule under imperfect information. Garín, Lester, and Sims (2016) evaluates the desirability of NGDP targeting in a New Keynesian model with price and wage rigidities. They find that NGDP targeting significantly outperforms inflation targeting and it is associated a smaller welfare losses than a Taylor rule when the economy is subject to supply-side shocks and when wages are sticky relative to prices. Output gap targeting, however, tends to at least weakly outperforms NGDP targeting, but the differences in welfare losses associated with the two rules are small and there are instances when NGDP targeting is preferred. Frankel (2014) suggests that NGDP Targeting may be more appropriate for middle-sized middle-income countries as opposed to large advanced economies. The reason is that such countries often face supply shocks and terms of trade shocks, forcing the abandonment of inflation targets or exchange rate targets. Billi (2017) compares nominal GDP level targeting with strict price level targeting in a small New Keynesian model, with the central bank operating under optimal discretion and facing a zero lower bound on nominal interest rates. The paper shows that, if the economy is only buffeted by temporary inflation shocks, nominal GDP level targeting may be preferable. However, in the presence of persistent supply and demand shocks, strict price level targeting may be superior.

This paper evaluates a nominal GDP growth targeting (NGDP-GT) rule, the Taylor type of rules (TR and TR-II) and inflation targeting (IT) in a New Keynesian framework. The paper contributes to the literature on nominal GDP targeting in the following aspects. First, one of the critical differences relative to most other papers in the literature is that the paper assumes a positive rather than zero rate of trend inflation, which is consistent with the concept of optimal inflation rate from the Federal Reserve and the European Central Bank. Second, the paper introduces trend total factor productivity (TFP) growth into the nominal GDP scope, which allows to compare monetary policy rules in both high and low growth environments. Third, the paper comprehensively examines monetary policy rules from both the stability and welfare perspectives. From the stability viewpoint, while NGDP-GT performs almost as well in output and consumption stabilization, it surprisingly outperforms a Taylor rule in stabilizing inflation. Compared to the strict inflation targeting regime, NGDP-GT framework generates at least 27% less fluctuations in output and consumption, while NGDP-GT is almost as well as inflation targeting in stabilizing inflation. To summarize, nominal GDP growth targeting rule does better in stabilizing the economy relative to a Taylor rule and the strict inflation targeting rule. The paper explores the mechanism that contributes to that stability, and demonstrate to what extent this rule can smooth out fluctuations of the economy. These conclusions are not conditioning on the trend growth rate and the level of inflation indexation. From the welfare perspective, when Taylor rule takes the simple form, that is, interest rate responds to deviations of inflation and current output level, inflation targeting is the least desirable policy and NGDP-GT is weakly dominated by the Taylor rule. The conclusions are not conditioning on the trend growth rate or the level of inflation indexation. However, when the Taylor rule takes the form that interest rate responds to deviations of inflation and output growth (TR-II), the trend growth rate, the level of partial inflation indexation and the shock affect the rankings of policy regimes. Generally, NGDP-GT rule either outperforms TR-II and inflation targeting, or be weakly dominated by the TR-II.

The baseline setup of this paper is characterized by three sectors of the economy: households, monopolistically-competitive firms that face adjustment costs, and a monetary authority. The private-sector equilibrium is constituted by optimal paths of consumption, labor, interest rate, real marginal cost, output, and inflation. For the NGDP-GT rule, I keep the growth rate of nominal output between two consecutive periods constant. In the benchmark model, the growth rate of NGDP is set to the U.S. historical level.

The rest of this paper is organized in the following structure: Section 2 outlines the model and defines the private-sector equilibrium, Section 3 provides a description of the policy rules, Section 4 defines equilibrium, Section 5 presents the calibration of the model, Section 6 shows the quantitative results, Section 7 presents the welfare analysis, Section 8 is the robustness analysis and Section 9 concludes.

2. The model

2.1. Modeling trend growth in DSGE models

The paper models productivity growth as characterized by a deterministic linear trend[1] . In particular, the trend-stationary model follows the specification:

$$
\begin{aligned}
Z_t &= z_t A^t \\
\log(z_t) &= (1-\rho_z)\log(\mu_z) + \rho_z \log(z_{t-1}) + \nu z_t
\end{aligned}
\tag{1}
$$

in which the trend growth rate A is a primitive parameter and z_t generates stationary fluctuations of Z_t around such trend. One of the focuses of the paper is to study the effects that the trend growth rate has on rankings of monetary policies, that is, trend growth allows us to compare monetary policy rules in both high and low growth economies.

The economy is composed of three sectors: a continuum of infinitely-lived households who derive utilities from consumption and leisure, monopolistically-competitive firms that hire labor as the only input to produce differentiated products and face an adjustment cost for changing prices, and the monetary authority. The paper assumes an efficient labor market.

2.2. Households

The representative household seeks to maximize the objective function:

$$
E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \tag{2}
$$

where $\beta \in (0, 1)$ is the subjective discount factor, E_0 is the mathematical expectation operator conditional on information available

[1] Seen in the work of Perron (1989) and Perron (1997), a large body of literature has shown that the linear deterministic trend model can reproduce the serial correlation properties of the data just as well as the random-walk model, provided that the possibility of infrequent structural breaks in the trend is allowed for.

in period 0. c_t is the composite consumption index, and l_t is labor. The period utility function $U(c_t, l_t)$ is assumed to be continuous and twice differentiable, satisfying the usual properties: $\frac{\partial U(\cdot)}{\partial c^2} \leqslant 0$, $\frac{\partial U(\cdot)}{\partial l} < 0$, and $\frac{\partial U(\cdot)}{\partial l^2} \leqslant 0$.

As standard in NK models, consumption c_t is a Dixit-Stiglitz aggregator of differentiated products $c_{j,t}$, supplied by monopolistically-competitive firms:

$$c_t = \left(\int_0^1 c_{j,t}^{\frac{\varepsilon_t - 1}{\varepsilon_t}} d_{j,t} \right)^{\frac{\varepsilon_t}{\varepsilon_{t-1}}} \tag{3}$$

where ε_t measures the elasticity of substitution between two varieties of final goods. The elasticity of substitution is set to be time-varying to allow for exogenous cost-push shocks. All else equal, an increase in ε_t leads to a fall in the desired markup, and hence to less inflationary pressure in equilibrium. The paper allows for markup shocks (i.e. variations in ε_t) to avoid the 'Divine Coincidence' result. In what follows, the study also considers a constant elasticity of substitution, which is the case with TFP shocks only.

The solution to the household's problem of maximizing the consumption bundle c_t for any given level of expenditures yields the set of demand equations:

$$c_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{-\varepsilon_t} c_t, \tag{4}$$

where $P_t = \left(\int_0^1 P_{j,t}^{1-\varepsilon_t} dj \right)^{\frac{\varepsilon_t}{\varepsilon_{t-1}}}$ is the Dixit-Stiglitz price index that results from cost minimization.

Each household has preferences over leisure and consumption, defined by the period-utility function

$$U(c_t, l_t) = \frac{c_t^{1-\sigma}}{1-\sigma} (1-l)^{(1-\theta)} \tag{5}$$

In order to have a system of preferences consistent with balanced growth, the paper restrict the parameters value in the utility function to satisfy $\sigma > 1$, $\theta > 1$. For future reference, note that σ denotes the inverse of the intertemporal elasticity of substitution in consumption and $\theta \frac{l}{1-l}$ denotes the inverse of the steady state elasticity of labor supply (IES).

The consumer seeks to maximize the expected discounted stream of lifetime utility flows subject to the sequence of the budget constraints of the form:

$$c_t + \frac{B_t}{P_t} = \frac{R_{t-1} B_{t-1}}{P_t} + \frac{W_t l_t}{P_t} + \frac{Tr_t}{P_t} + \frac{\Pi_t}{P_t} \tag{6}$$

where B_t represents the quantity of one-period nominally riskless bond that is purchased in period t and matures in period $t+1$. Each bond pays one unit of money at maturity. R_t is the nominal gross policy (or market) interest rate. W_t denotes nominal wage, and w_t denotes the real wage expressed as $\frac{W_t}{P_t}$. Tr_t is the net nominal transfers, and Π_t stands for nominal profits from the ownership of firms. Household's choices of c_t, l_t and B_t yield the following optimality conditions:

$$\left(\frac{1-\theta}{1-\sigma} \right) \frac{c_t}{1-l_t} = w_t \tag{7}$$

and

$$(c_t)^{-\sigma} (1-l_t)^{1-\theta} = \beta E_t \left\{ R_t \frac{(c_{t+1})^{-\sigma} (1-l_{t+1})^{1-\theta}}{\pi_{t+1}} \right\} \tag{8}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate. Eq. (7) describes the labor supply decisions, and Eq. (8) describes the optimal consumption decisions, which is the Euler equation in consumption.

2.3. Firms

There is a continuum of identical monopolistically-competitive firms indexed by $j \in [0, 1]$. Each firm j hires labor as the only input and produces a differentiated product $y_{j,t}$ using the identical technology:

$$y_{j,t} = Z_t l_{j,t} = z_t A^t l_{jt} \tag{9}$$

where z_t is assumed to be common to all firms, and to evolve exogenously over time,which follows the trend-stationary model specified in Eq. (1). $l_{j,t}$ is the labor hired by firm j at time t. First consider the cost minimization problem of firm j, min $W_t l_{j,t}$ s.t. $y_{j,t} = Z_t l_{j,t}$, where by symmetry, it implies

$$mc_t = \frac{w_t}{z_t A^t} \tag{10}$$

where mc_t is the Lagrange multiplier on the output constraint (9) and also the real marginal cost of production. Eq. (10) specifies the labor demand function.

Moreover, following Rotemberg (1982), the monopolistic firm faces a quadratic cost of adjusting nominal prices, that can be measured in terms of the final-good and given by

$$\frac{\phi}{2} \left(\frac{P_{j,t}}{P_{j,t-1}} - \bar{\pi}^{\eta} \right)^2 y_t \tag{11}$$

where $\phi > 0$ determines the degree of nominal price rigidity and $\bar{\pi}$ is the gross steady-state inflation rate. As stressed in Rotemberg (1982), the adjustment cost seeks to account for the negative effects of price changes on the customer-firm relationship. These negative effects increase in magnitude with the size of the price change and with the overall scale of economic activity, y_t. The adjustment cost depends on the ratio between the new reset price and the one set during the previous period, adjusted by the steady state inflation with partial indexation $\eta \in [0, 1]$. When $\eta = 0$, Eq. (11) would be the more common pricing function. The goal of introducing this parameter is to examine if conclusions are robust to partial indexation and to avoid the discussions of which extreme (i.e. $\eta = 0$ versus $\eta = 1$) has better microfoundations.

The problem for firm j is then to choose its price to maximize the expected present discounted stream of profits:

$$E_0 \sum_{t=0}^{\infty} \frac{\beta^t U_{c,t}}{U_{c,0}} \left\{ \left(\frac{P_{j,t}}{P_t} - mc_{j,t} \right) y_{j,t} - \frac{\phi}{2} \left(\frac{P_{j,t}}{P_{j,t-1}} - \bar{\pi}^{\eta} \right)^2 y_t \right\} \tag{12}$$

subject to the downward-sloping demand curve that firm j faces:

$$y_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{-\varepsilon} y_t \tag{13}$$

where $\frac{\beta^t U_{c,t}}{U_{c,0}}$ is the stochastic discount factor.

Subject to the adjustment cost, firms can change their prices in each period. Therefore, all the firms face the same problem, and thus will choose the same price and produce the same quantity. In other words, $P_{j,t} = P_t$ and $y_{j,t} = y_t$ for any j. Hence, the first-order condition for a symmetric equilibrium

$$1 - \phi(\pi_t - \bar{\pi}^{\eta})\pi_t + \beta\phi E_t \left[\frac{U_{c,t+1}}{U_{c,t}} (\pi_{t+1} - \bar{\pi}^{\eta}) \pi_{t+1} \frac{y_{t+1}}{y_t} \right] = \varepsilon_t (1 - mc_t) \tag{14}$$

is the Rotemberg version of the non-linear Phillips curve showing that current inflation is a function of future expected inflation, the real marginal cost, and the level of output.

Since all firms will employ the same amount of labor, the aggregate production function is simply given by:

$$y_t = z_t A^t l_t \tag{15}$$

2.4. Market clearing

In equilibrium, the aggregate resource constraint is given by:

$$y_t = c_t + \frac{\phi}{2}(\pi_t - \bar{\pi}^{\eta})^2 y_t \tag{16}$$

3. Policy regimes

Given the model described above, I examine the performance of three policy rules in the benchmark analysis. One rule targets the growth rate of nominal output, one resorts to the nominal interest rate as the instrument to respond to changes of the economy (a Taylor type of rule) and one targets the inflation rate. Next, I discuss these three regimes and analyze their performances following a negative TFP shock and a negative markup shock with the exogenous processes of z_t and ε_t.

3.1. Nominal GDP growth targeting rule

McCallum (1998), Orphanides (1999), and Trehan (1999) suggest that monetary policy should focus on nominal output growth because such a strategy does not rely on uncertain estimates of the level of the output gap. Rudebusch (2002) admits that it automatically takes into account movements in both prices and real output and can serve as a long-run nominal anchor for monetary policy. Such a target linked to a weighted average of inflation and employment will better address the Fed's dual mandate, according to Sumner (2014). In the debate on nominal income level targeting versus growth rate targeting, Billi (2015) provides evidence that in the presence of persistent supply and demand shocks, nominal GDP level targeting (NGDP-LT) is not preferable. During ZLB episodes, NGDP-LT leads to larger fluctuations in economic activity. Therefore, the paper mainly focuses on the growth-rate targeting. In the NGDP-GT regime, policymakers observe and respond only to the variations of nominal GDP growth rate.

Nominal GDP growth targeting assumes that the monetary authority commits to a certain growth rate of nominal GDP. Letting Y_t being nominal output, this rule reads:

$$\frac{Y_t}{Y_{t-1}} = \bar{k} \tag{17}$$

where $\bar{k}$ is the growth rate of NGDP. Equation (17) can be rewritten as:

$$\frac{y_t}{y_{t-1}}\pi_t = \bar{k} \tag{18}$$

The regime of NGDP-GT implies a positive steady state inflation (or zero inflation when $\bar{k}$ is set to 1).

3.2. A Taylor type of rule

Following Faia (2008), a standard nonlinear version of the Taylor rule without labor market inefficiency is an interest rate reaction function of the following form:

$$\log\left(\frac{R_t}{\bar{R}}\right) = \rho_r \log\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho_r)\left[\rho_\pi \log\left(\frac{\pi_t}{\bar{\pi}}\right) + \rho_y \log\left(\frac{y_t}{\bar{y}}\right)\right] \tag{19}$$

where $\bar{R}$ and $\bar{y}$ represent the steady-state values of nominal gross interest rate and real output, ρ_r denotes the smoothing coefficient of the interest rate, and ρ_π and ρ_y are respectively the coefficients of inflation and output. In line with the literature, the interest rate responds to the deviations of inflation and output from their targets (or steady-state values).

3.3. Inflation targeting rule

Besides Taylor type rules and NGDP-GT rules, the strict inflation targeting (IT) rule receives much attention. There are about 28 countries, including the United Kingdom, Canada, Australia, New Zealand, Sweden, Brazil, Norway, and other countries, that are using inflation targeting through fixing the consumer price index (CPI) as their monetary policy goal, as in Jahan (2012). In this subsection, I add this inflation-type-rules into the pool to examine the relative performance of NGDP-GT rule among a wider range of regimes.

As in Svensson (1999), the monetary authority is assumed to have perfect control over the inflation rate. It sets the inflation rate in each period. For simplicity purpose, I assume the inflation rate is set at its steady-state value $\bar{\pi}$ at any period t. Inflation targeting can be written

$$\pi_t = \bar{\pi} \tag{20}$$

4. The equilibrium

4.1. The stationary equilibrium

Given trend growth, variables like consumption and output inherit a deterministic trend from the productivity index, which prevents the system from converging to a steady state. For a steady-state equilibrium to be definable, therefore, the system needs to be transformed to ensure stationarity. The obvious transformation in this case is to divide the generic trending variable X_t by the time trend, and I denote the transformed variable with a "hat": $\hat{X}_t \equiv X_t/A^t$.

In terms of the transformed variables, the system is described by:

$$\left(\frac{1-\theta}{1-\sigma}\right)\frac{\hat{c}_t}{1-l_t} = (mc_t)(z_t) \tag{21}$$

$$(\hat{c}_t)^{-\sigma}(1-l_t)^{1-\theta} = \beta A^{-\sigma} R_t E_t\left[\frac{(\hat{c}_{t+1})^{-\sigma}(1-l_{t+1})^{1-\theta}}{\pi_{t+1}}\right] \tag{22}$$

$$1 - \phi(\pi_t - \bar{\pi}^{\eta})\pi_t + \beta\phi A^{1-\sigma} E_t \left[\left(\frac{\hat{c}_{t+1}}{\hat{c}_t}\right)^{-\sigma}\left(\frac{1-l_{t+1}}{1-l_t}\right)^{1-\theta}(\pi_{t+1} - \bar{\pi}^{\eta})\pi_{t+1}\frac{\hat{y}_{t+1}}{\hat{y}_t}\right] = \varepsilon_t(1-mc_t) \tag{23}$$

$$\hat{y}_t = z_t l_t \tag{24}$$

$$\hat{y}_t = \hat{c}_t + \frac{\phi}{2}(\pi_t - \bar{\pi}^{\eta})^2 \hat{y}_t \tag{25}$$

Eq. (21) is at the equilibrium where labor demand is equal to labor supply, Eq. (22) represents the consumption Euler equation, Eq. (23) describes the Philips curve, Eq. (24) denotes the production function and Eq. (25) represents the resource constraint. While the model economy grows indefinitely over time, therefore, the stationary system above converges to a non-zero inflation steady state, in which the average rate of growth A enters the Euler equation for consumption and the pricing equation of consumption goods. Given the exogenous processes of z_t and ε_t the private sector equilibrium is a state-contingent sequence of allocations of $\{\hat{c}_t, l_t, \hat{y}, R_t, mc_t, \pi_t\}$ that satisfies the equilibrium conditions of (21)- (25).

Table 1
Values of the parameters.

Parameter	Description	Value
β	Households' discount factor	0.990
σ	Risk aversion	1.500
A	trend growth rate of technology	1.000
θ	determines the IES of labor supply	2.567
ϕ	Price adjustment cost parameter	18.473
η	partial indexation to steady state inflation	1.000
μ_z	Mean of productivity index	1.000
μ_ε	Mean of elasticity of substitution between goods	6.000
$\bar{k}$	Nominal GDP growth rate(gross)	1.016
$\bar{R}$	Steady-state gross interest rate	1.026
$\bar{\pi}$	Steady-state gross inflation	1.016
$\bar{\hat{y}}$	Steady-state output	0.210
ρ_r	Smoothing coefficient of the interest rate	0.900
ρ_π	Coefficients of inflation in Taylor Rule	1.500
ρ_y	Coefficients of output in Taylor Rule	0.125
ρ_z	AR(1) coefficient of TFP	0.950
ρ_ε	AR(1) coefficient of MKP	0.900
$\rho_{\bar{y}}$	Coefficients of real GDP growth in new Taylor Rule	2.000
σ_z	Standard deviation of the innovation term in TFP	0.096
σ_ε	Standard deviation of the innovation term in MKP	0.761

4.2. The transformed monetary policy rules

The nominal GDP growth targeting rule Eq. (18) can be rewritten as

$$\frac{\hat{y}_t}{\hat{y}_{t-1}} A\pi_t = \bar{k} \tag{26}$$

The Taylor type of rule can ben written as

$$\log\left(\frac{R_t}{\bar{R}}\right) = \rho_r \log\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho_r)\left[\rho_\pi \log\left(\frac{\pi_t}{\bar{\pi}}\right) + \rho_y \log\left(\frac{\hat{y}_t}{\bar{\hat{y}}}\right)\right] \tag{27}$$

Different from most of the literature about the Taylor Rule, the paper does not presume a zero (net) inflation steady state. For the purpose of consistency, the value of $\bar{\pi}$ in the Taylor rule anchors at the value of $\bar{\pi}$ in the NGDP-GT rule, which equals to $\frac{\bar{k}}{A}$. These identical steady-state inflation settings under the two policy frameworks ensure that the steady-state values under both rules are the same. Any differences between the rules will not result from the different steady states, allowing for direct comparisons and contrasts between the policies to be made. For the benchmark analyses, $\bar{\pi}$ in the benchmark analysis is set to 1.016 ($A = 1$).

The inflation targeting Eq. (20) doesn't change its form.

4.3. Exogenous processes

There are two exogenous variables in the model, the total factor productivity shock and the markup shock. The total factor productivity and the elasticity of substitution are assumed to follow the stationary AR(1) processes:

$$\log(z_t) = (1-\rho_z)\log(\mu_z) + \rho_z \log(z_{t-1}) + v_t \tag{28}$$

$$\log(\varepsilon_t) = (1-\rho_\varepsilon)\log(\mu_\varepsilon) + \rho_\varepsilon \log(\varepsilon_{t-1}) + u_t \tag{29}$$

5. Parameterization:

Table 1 lists the baseline parameter values. These parameters are set to widely accepted values based on U.S. data. Assuming a time unit of one quarter, the discount factor β is set to 0.99, implying a 4% annual interest rate. The risk aversion parameter σ is set to 1.5, so that the deterministic steady-state value of l is 0.21, implying an average workweek of 35 hours, which is in line with the empirical average of weekly hours over the period of 1964:Q1-2014:Q1, as in Abo-Zaid (2015). The underling theory introduced in Faia and Monacelli (2007) and Abo-Zaid (2015) implies the adjustment cost parameter $\phi = \frac{\lambda(\lambda-1)(\varepsilon-1)}{\lambda-\beta(\lambda-1)}$, with λ being the quarterly price duration. Following Christiano, Eichenbaum, and Evans (2005) and Abo-Zaid (2015), the price duration is set to 2.5 quarters. The deterministic steady-state value of ε_t is set to 6, so that the net steady-state markup is 20%, consistent with the literature. In the benchmark calibration, I assume the monetary authority targets the nominal GDP growth rate $\bar{k}$ at 1.016 based on the historical quarterly GDP growth rate over the period of 1947:Q1-2019:Q1. The value of $\bar{R}$ can be easily derived from the consumption Euler equation: $\bar{R} = \bar{\pi}A^\sigma/\beta$. The benchmark model sets $A = 1, \eta = 1$, indicating firms adjust prices in terms of positive trend inflation, which is in compliance with the concept of the Federal Reserve and European Central Bank's optimal inflation rate. The steady-state output level $\bar{y}$ is determined by the aggregate production function. Values of ρ_r, ρ_π and ρ_y are set following Faia (2008). ρ_z and ρ_ε are the AR(1) coefficients of these processes, with μ_z and μ_ε being the deterministic steady state value of z_t and ε_t respectively, normalized to 1 and 6. the innovation terms are $v_t \sim N(0, \sigma_z^2)$ and $u_t \sim N(0, \sigma_\varepsilon^2)$. In the benchmark model, σ_z is set to 0.0782 and σ_ε is set to 0.5357 to generate a 0.015 standard deviation in output under the Taylor rule.

6. Quantitative results

This section presents the numerical results regarding the two policy rules when the economy is hit by a negative TFP shock and a negative markup shock. A general approach to policy evaluation is to check the ability of the policy to smooth output, consumption, inflation, labor and other important aggregates' paths around the potential levels. This smoothing can be achieved by producing the least fluctuations in these important economic indicators. Tables 2 and 3 and Figures 1 and 2 provide the dynamic results of these three policy regimes with respect to a negative TFP shock and markup shock.

6.1. Moment conditions

6.1.1. When $A = 1, \eta = 1$.

Tables 2 and 3 report the results of the first and second moments of the economic indicators following shocks of the same magnitude. Compared to the Taylor rule, the prevention of swings of NGDP growth vastly helps prevent deviations of economic aggregates from their trend path. Most of the variables under the NGDP-GT render to be substantially less volatile than under the Taylor rule. The standard deviations of labor, real marginal cost and nominal interest rate under the NGDP-GT are about 61%, 76%, 76% and 10%, respectively, of the ones under the Taylor rule when the economy is hit by a negative TFP shock. Moreover, NGDP-GT performs almost as well as the Taylor rule in stabilizing output and consumption, generating only 4.9% more volatility than the Taylor rule. Remarkably, the inflation's volatility is 39% lower under the NGDP-GT regime. Following an exogenous markup shock, the difference between the NGDP-GT and the Taylor rule is even smaller: the NGDP-GT regime produces only 3.8% more fluctuations in output and consumption. However, volatility of inflation under the NGDP-GT is only 76% as in the Taylor rule. The performance of the interest rate also resembles its performance in the TFP shock scenario. In summary, compared to the Taylor rule, NGDP-GT performs almost as well in output and consumption, but it has surprising effect in stabilizing inflation. The summary of the performance of NGDP-GT rule relative to TR is shown in Table 4.

Relative to the strict inflation targeting rule, NGDP-GT generates 27% less volatilities in output and consumption and 77% less fluctu-

Table 2
Moment Conditions under the three regimes following a TFP shock (HP filter, lambda = 1600).

Policies	Moments	π	R	l	mc	$\hat{c}$	$\hat{y}$
TR	$\bar{x}$	1.0163	1.0266	0.2100	0.8335	0.2097	0.2097
	$std(x)$	0.0573	0.0180	0.0138	0.0694	0.0150	0.0150
	$autocorr(x)$	0.4468	0.8832	0.4074	0.4074	0.9130	0.913 0
	$corr(x, \hat{y})$	−0.2867	−0.9650	−0.1129	−0.1129	1.0000	1.0000
NGDP-GT	$\bar{x}$	1.0160	1.0263	0.2100	0.8334	0.2097	0.2097
	$std(x)$	0.0351	0.0018	0.0105	0.0525	0.0157	0.0157
	$autocorr(x)$	0.4386	0.9165	0.4429	0.4429	0.8936	0.8936
	$corr(x, \hat{y})$	−0.2306	−0.953	−0.3213	−0.3213	1.0000	1.0000
IT	$\bar{x}$	1.0160	1.0264	0.2100	0.8333	0.2097	0.2097
	$std(x)$	0.0000	0.0079	0.0000	0.0000	0.0215	0.0215
	$autocorr(x)$	1.0251	0.7145	1.0128	0.9979	0.7145	0.7145
	$corr(x, \hat{y})$	0.0038	−1.0000	0.0052	0.0060	1.0000	1.0000

Note: $\bar{x}$ represents the variable mean, $std(x)$ is the standard deviation of a variable, $autocorr(x)$ stands for autocorrelation, and $corr(x, y)$ is the correlations between a variable and y.

Table 3
Moment Conditions under the two regimes following a markup shock (HP filter, lambda = 1600).

Policies	Moments	π	R	l	mc	$\hat{c}$	$\hat{y}$
TR	$\bar{x}$	1.0161	1.0264	0.2099	0.8326	0.2099	0.2099
	$std(x)$	0.0475	0.0140	0.0150	0.0753	0.0150	0.0150
	$autocorr(x)$	0.4345	0.8735	0.8934	0.8934	0.8934	0.8934
	$corr(x, \hat{y})$	−0.461	−0.9955	1.0000	1.0000	1.0000	1.0000
NGDP-GT	$\bar{x}$	1.0160	1.0263	0.2099	0.8326	0.2099	0.2099
	$std(x)$	0.0362	0.0015	0.0156	0.0782	0.0156	0.0156
	$autocorr(x)$	0.4229	0.4380	0.8847	0.8847	0.8847	0.8847
	$corr(x, \hat{y})$	−0.2402	0.0663	1.0000	1.0000	1.0000	1.0000
IT	$\bar{x}$	1.0160	1.0264	0.2098	0.8325	0.2098	0.2098
	$std(x)$	0.0000	0.0121	0.0229	0.1152	0.0229	0.0229
	$autocorr(x)$	1.0251	0.6939	0.6939	0.6939	0.6939	0.6939
	$corr(x, \hat{y})$	0.0057	−1.0000	1.0000	1.0000	1.0000	1.0000

Note: $\bar{x}$ represents the variable mean, $std(x)$ is the standard deviation of a variable, $autocorr(x)$ stands for autocorrelation, and $corr(x, y)$ is the correlations between a variable and y.

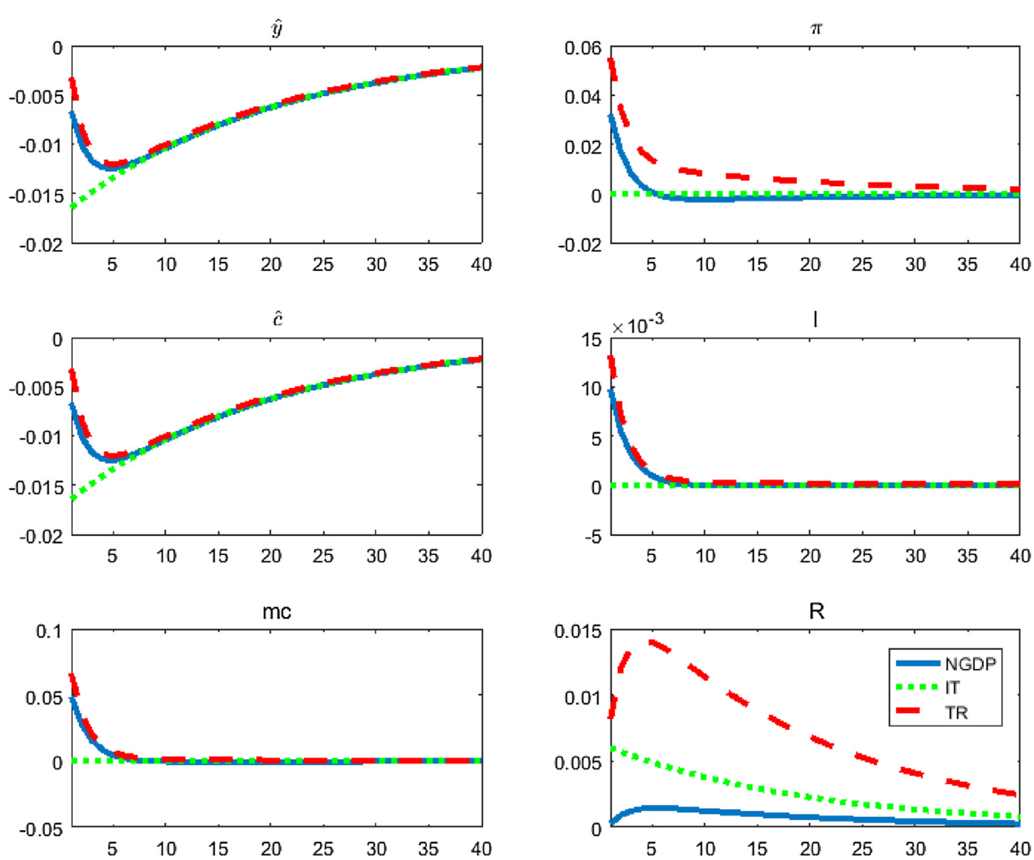

Fig. 1. Impulse Responses to a negative TFP shock.

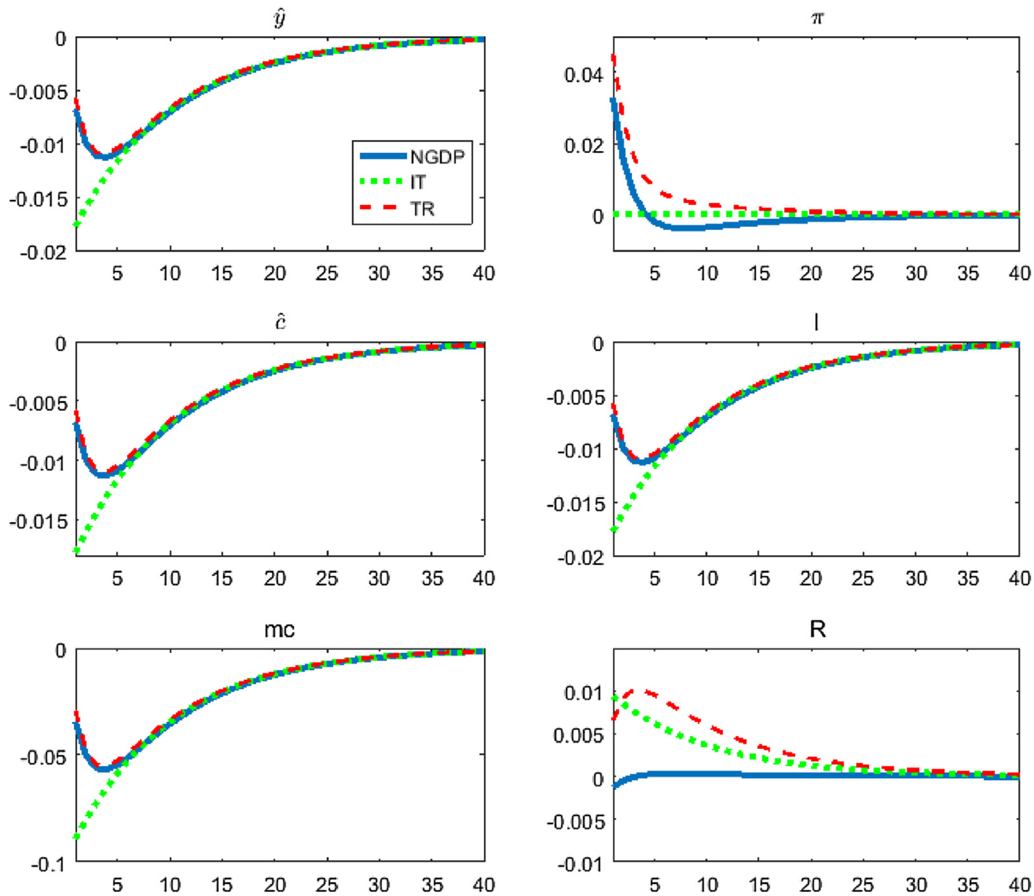

Fig. 2. Impulse Responses to a markup shock.

Table 4
Policy regimes comparing.

Policies	$\hat{y}$	$\hat{c}$	π
NGDP-GT	≡	≡	√
TR	≡	≡	⊗

Note: "≡" denotes that the policy regime is equivalent to the other one in stabilizing a particular variable, "√" represents that a particular policy has substancial advantage in generating the less volitility of a variable, and ⊗ means that a policy rule is dominated by the other regime in stabilizing a particular variable.

Table 5
Policy regimes comparing.

Policies	$\hat{y}$	$\hat{c}$	π
NGDP-GT	√	√	≡
IT	⊗	⊗	≡

ations in nominal interest rate when the economy is subject to a TFP shock. By the definition of inflation targeting, NGDP-GT has slight disadvantage in stabilizing inflation, labor and real marginal cost, producing respectively 3.5%, 1% and 5% more fluctuations, being almost as well as the IT rule. When a markup shock hits the economy, NGDP-GT reduces volatilities of output, consumption, labor, and real marginal cost by 32%, and reduce nominal interest rate's fluctuations by 88%. In inflation, NGDP-GT produces 3.6% more fluctuations, weakly dominated by the IT rule. Therefore, NGDP-GT is almost as well as IT in stabilizing inflation, labor and real marginal cost. But NGDP-GT can substantially stabilize output and consumption. The summary the performance of NGDP-GT relative to the IT rule is presented in Table 5.

The effect of NGDP-GT on inflation and real economic activity's stability is novel to what economic intuition would suggest when the economy is subject to supply shocks. The above numbers and the nature of the three policy rules reflect the mechanism that makes the NGDP-GT rule a 'systematic improvement'. In contrast, NGDP-GT does not cause inflation instability, but produces considerably low standard deviations. The reason is that the NGDP-GT allows output and inflation to share the shock burden, which results in output and inflation's mild variations compared to the Taylor rule and inflation targeting rule, albeit either regime weakly dominates NGDP-GT in either output or inflation. The Taylor rule stabilizes output and consumption, causing inflation volatility; it places a larger weight on the deviation of inflation from its target. Through the policy instrument of interest rates, the Taylor rule allows for variations in output as well as other economic aggregates to absorb any shocks in order to keep inflation under control. However, this builds an undesirable environment for inflation and leads to inflation's "surprising"instability relative to the NGDP-GT rule: generating 63% more fluctuations. While stricit inflation targeting places all the weight in stabilizing inflation, creating a less desirable framework.

An interesting point is labor's performance following a productivity shock. The negative correlation of labor with output shown in Table 2 and labor's impulse responses following TFP shocks under the NGDP-GT rule is consistent with the theoretical indication of Gali (1999) in his class of models with imperfect competition, sticky prices, and variable effort. The combination of price stickiness and demand constraints leads firms, in the short run, to contract labor in the presence of a positive TFP shock and to expand labor in the face of a negative TFP shock.

6.2. When $A > 1$

Tables 6 and 7 present the moment conditions of three policy rules following a productivity shock and a markup shock in a high growth environment. The result is consistent with conclusions from the benchmark model in which $A = 1$. When a productivity shock hits the economy, the NGDP-GT substantially outperforms Taylor rule in stabilizing inflation, that is reducing inflation volatilities by 38% also. The NGDP-GT is weakly dominated by the Taylor rule in output and consumption stabilization, producing only 5%-7% more fluctuations. The NGDP-GT is substantially more desirable than the IT rule, generating about 25% less volatilities in output and consumption, without creating high inflation instability. When the economy is subject to a markup shock, the NGDP-GT produces 22% less fluctuations in inflation, and generates only 4% to 7% more volatilities in output and consumption compared to the Taylor rule. The NGDP-GT does almost as well as inflation targeting in stabilizing inflation, but producing 30% to 40% less fluctuations in output and consumption.

6.3. When $A < 1$

Tables 8 and 9 show the moment conditions of three policy rules in a low growth environment. The results are similar to the conclusions from the high growth environment.

6.4. Impulse responses

The impulse responses enable us to observe the short-run behavior of some key variables following a negative TFP shock and a negative markup shock in order to gain some insights about the model. Fig. 1 presents the response of the economy to a shock to productivity. Fig. 2 displays the behavior of the key variables following a negative markup shock.

In general, a negative TFP or markup shock decreases the aggregate supply and output, leading to higher inflation that, in turn, drives up the nominal interest rate. A negative TFP shock also reduces the demand for labor, causing a decline in the labor and wages.

Fig. 1 shows that under an inflation targeting rule, a negative TFP shock greatly undermines output and consumption, associated with a soaring nominal interest rate, which as a consequence, further discourages consumption and output. When shocked with the same magnitudes under the NGDP-GT framework, the above variables become inertial around the steady-state values with the assistance of the systematic stability of NGDP-GT. Impulse responses of output, consumption and labor almost overlap under NGDP-GT and the Taylor rule.

The responses to an exogenous markup shock essentially resemble the results of a TFP shock with some differences in the behavior of labor. A markup shock directly affects the marginal cost and inflation. The markup shock in Fig. 2 causes a rise in inflation, in line with the standard result in the NK model with ad-hoc cost push shocks. This shock also leads to drops in output, consumption, labor and real marginal cost as in the case of the TFP shock (except labor). Fig. 2 provides the solid evidence that even after introducing an exogenous process to generate a trade-off between stabilizing output and stabilizing inflation, NGDP-GT rule does better in stabilizing key economic indicators than the inflation targeting rule.

One side effect of policy rules, according to Hall and Mankiw (1994), is that it may bring high volatility to other variables when keeping one variable under tight control. The NGDP-GT rule, however, does not rely solely on the interest rate as an instrument. With the economy anchored at a constant NGDP growth rate, the monetary authority will respond accordingly once the actual growth rate deviates from the target. Targeting the growth rate assists to find the point where the relative levels of output and inflation lead to lower volatility of the economy. One of the advantages of NGDP-GT is that maintaining output stability also serves as maintaining inflation stability[2], which does not compromise to the introduction of a trade-off between inflation and output stability. These indicate NGDP-GT's stability property, and could effectively prevent the economy from stumbling into severe recessions when the economy is subject to negative supply shocks.

6.5. The optimal monetary policy problem

This paper employs a Ramsey-type approach to study the optimal monetary policy; the monetary authority chooses allocations to maximize the life time utility of households subject to the resource constraint and the private sector equilibrium conditions. This formulation also assumes commitment in the solution to the optimal policy problem.

Definition: Given the exogenous process of z_t and ε_t, the monetary authority chooses a sequence of allocations of $\{\hat{y}_t, \pi_t, \hat{c}_t, l_t, mc_t, R_t\}$ to maximize (2) subject to the equilibrium conditions of (21)- (25) and the monetary composite.

7. Welfare analysis

This section presents welfare results to assess the optimal monetary policy relative to ad-hoc monetary policy rules by employing the consumption equivalence (CE) as a standard. Using "CE" as a measure of welfare, the results for key economic variables are shown in Tables 10 and 11 . The numbers are the percentage difference of a variable's value under the particular policy rule from its value under the optimal policy. For example, the first entry in column I suggests that consumption under the NGDP-GT rule is lower by 0.1349 percent than its value under the optimal policy. The consumption equivalence represents by which consumption should be increased so that the welfare under the particular policy is equivalent to welfare under the optimal policy.

When the economy is subject to a productivity shock, Table 10 presents consumption equibalance for the three different rules for different combinations of trend growth rate and the level of partial index to steady state inflation. Focus first on the case where trend growth rate and partial indexation level are both 1. The Taylor type of rule dominates the other two rules, generating a compensating variation of only 0.1273 percent of consumption. Nominal GDP targeting does almost as well, which produces a welfare loss of only 0.1349, 0.06% more than the Taylor rule. Inflation targeting performs very poorly, with a welfare loss of 0.1445 percent, the least desirable policy compared to the other two rules.

Mattesini and Nisticò (2010) shows that the estimated average trend growth rate of the United States is about 1.01. The policy rankings in this paper are tested under both low and high growth environment, with different levels of partial indexation to steady state inflation. The Taylor rule, again, weakly dominates the other two policy regimes for all combinations of trend growth rate and the level of partial indexation. Inflation targeting is the least desirable policy regime. However, the difference among policy rules tend to decreases as trend growth rate rises.

Table 11 repeats the exercises in Table 10 conditional on a markup shock. Policy performances are roughly the same as they do in the case of the productivity shock. NGDP-GT produces about 1.4 percent to 6.8 percent more welfare loss than the desirable

[2] This could also be observed through log-linearization of the policy equation (1.16) in period t and $t+1$: $logy_{t+1} - logy_t + \log\pi_{t+1} = \bar{k}$, $logy_t - logy_{t-1} + \log\pi_t = \bar{k}$. By reorganizing these two equations, we can derive $\log[\frac{g_{y_{t+1}}}{g_{y_t}}] + \log[\frac{\pi_{t+1}}{\pi_t}] = 0$, where $g_{y_{t+1}} = \log(y_{t+1}/y_t)$.

Table 6
Moment Conditions of three regimes following a TFP shock $A = 1.01$(HP filter, lambda = 1600).

Policies	Moments	π	R	l	mc	$\hat{c}$	$\hat{y}$
TR	$\bar{x}$	1.0062	1.0317	0.2100	0.83335	0.2097	0.2097
	$std(x)$	0.0569	0.0181	0.0138	0.0690	0.0150	0.0150
	$autocorr(x)$	0.4449	0.8827	0.4059	0.4059	0.9128	0.9128
	$corr(x, \hat{y})$	−0.2879	−0.9653	−0.1167	−0.1167	1.0000	1.0000
NGDP-GT	$\bar{x}$	1.0059	1.0314	0.21002	0.8334	0.2097	0.2097
	$std(x)$	0.0349	0.0018	0.0104	0.0522	0.0158	0.0158
	$autocorr(x)$	0.4367	0.9160	0.4409	0.4409	0.8932	0.8932
	$corr(x, \hat{y})$	−0.2311	−0.9520	−0.3207	−0.3207	1.0000	1.0000
IT	$\bar{x}$	1.0059	1.0315	0.2100	0.8333	0.2097	0.2097
	$std(x)$	0.0000	0.0079	0.0000	0.0000	0.0215	0.0215
	$autocorr(x)$	1.0017	0.7145	1.0128	0.9979	0.7145	0.7145
	$corr(x, \hat{y})$	0.0063	−1.000	0.0052	0.0060	1.0000	1.0000

Note: For $A > 1$, this paper tested $A = 1.1$, $A = 1.01$, and $A = 1.008$ and find consistent results

Table 7
Moment Conditions under the two regimes following a markup shock when $A = 1.01$ (HP filter, lambda = 1600).

Policies	Moments	π	R	l	mc	$\hat{c}$	$\hat{y}$
TR	$\bar{x}$	1.0061	1.0315	0.2099	0.8326	0.2099	0.2099
	$std(x)$	0.0472	0.0141	0.0150	0.0755	0.0150	0.0150
	$autocorr(x)$	0.4327	0.8730	0.8929	0.8929	0.8929	0.8929
	$corr(x, \hat{y})$	−0.4616	−0.9956	1.0000	1.0000	1.0000	1.0000
NGDP-GT	$\bar{x}$	1.0059	1.0314	0.2099	0.8326	0.2099	0.2099
	$std(x)$	0.0361	0.0015	0.0156	0.0786	0.0156	0.0156
	$autocorr(x)$	0.4211	0.4364	0.8842	0.8842	0.8842	0.8842
	$corr(x, \hat{y})$	−0.2407	0.0657	1.0000	1.0000	1.0000	1.0000
IT	$\bar{x}$	1.0059	1.0315	0.2098	0.8325	0.2098	0.2098
	$std(x)$	0.0000	0.0122	0.0229	0.1152	0.0229	.00229
	$autocorr(x)$	1.0017	0.6939	0.6939	0.6939	0.6939	0.6939
	$corr(x, \hat{y})$	0.0072	−1.0000	1.0000	1.0000	1.0000	1.0000

Note: $\bar{x}$ represents the variable mean, $std(x)$ is the standard deviation of a variable, $autocorr(x)$ stands for autocorrelation, and $corr(x, y)$ is the correlations between a variable and y.

Table 8
Moment Conditions of three regimes following a TFP shock $A = 0.98$ (HP filter, lambda = 1600).

Policies	Moments	π	R	l	mc	$\hat{c}$	$\hat{y}$
TR	$\bar{x}$	1.0371	1.0163	0.2100	0.8335	0.2097	0.2097
	$std(x)$	0.0582	0.0178	0.0139	0.0699	0.0150	0.0150
	$autocorr(x)$	0.4505	0.8842	0.4105	0.4105	0.9135	0.9135
	$corr(x, \hat{y})$	−0.2842	−0.9642	−0.1052	−0.1052	1.0000	1.0000
NGDP-GT	$\bar{x}$	1.0367	0.0160	0.2100	0.8334	0.2097	0.2097
	$std(x)$	0.0354	0.0018	0.0106	0.0530	0.0156	0.0156
	$autocorr(x)$	0.4432	0.3174	0.4467	0.4467	0.8946	0.8946
	$corr(x, \hat{y})$	−0.2296	−0.9550	−0.3226	−0.3226	1.0000	1.0000
IT	$\bar{x}$	1.0367	1.0161	0.2100	0.8333	0.2097	0.2097
	$std(x)$	0.0000	0.0078	0.0000	0.0000	0.0215	0.0215
	$autocorr(x)$	1.0040	0.7145	1.0128	0.9979	0.7145	0.7145
	$corr(x, \hat{y})$	0.0011	−1.0000	0.0052	0.0060	1.0000	1.0000

Note: For $A > 1$, this paper tested $A = 1.1$, $A = 1.01$, and $A = 1.008$ and find consistent results.

Table 9
Moment Conditions under the two regimes following a markup shock when $A = 0.98$ (HP filter, lambda = 1600).

Policies	Moments	π	R	l	mc	$\hat{c}$	$\hat{y}$
TR	$\bar{x}$	1.0369	1.0161	0.2099	0.8326	0.2099	0.2099
	$std(x)$	0.0481	0.0138	0.0149	0.0750	0.0149	0.0149
	$autocorr(x)$	0.4382	0.8745	0.8944	0.8944	0.8944	0.8944
	$corr(x, \hat{y})$	−0.4602	−0.9954	1.0000	1.0000	1.0000	1.0000
NGDP-GT	$\bar{x}$	1.0367	1.0160	0.2099	0.8326	0.2099	0.2099
	$std(x)$	0.0364	0.0015	0.0154	0.0776	0.0154	0.0154
	$autocorr(x)$	0.4266	0.4411	0.8856	0.8856	0.8856	0.8856
	$corr(x, \hat{y})$	−0.2391	0.0676	1.0000	1.0000	1.0000	1.0000
IT	$\bar{x}$	1.0376	1.0160	0.2098	0.8325	0.2098	0.2098
	$std(x)$	0.0000	0.0120	0.0229	0.1152	0.0229	0.0229
	$autocorr(x)$	1.0040	0.6939	0.6939	0.6939	0.6939	0.6939
	$corr(x, \hat{y})$	0.0032	−1.0000	1.0000	1.0000	1.0000	1.0000

Note: $\bar{x}$ represents the variable mean, $std(x)$ is the standard deviation of a variable, $autocorr(x)$ stands for autocorrelation, and $corr(x, y)$ is the correlations between a variable and y.

Table 10
Consumption equivalent welfare losses from different policy rules, only productivity shocks.

Policy Rule	$A = 1.00$ $\eta = 1.00$	$A = 1.01$ $\eta = 1.00$	$A = 0.98$ $\eta = 1.00$	$A = 1.00$ $\eta = 0.50$	$A = 1.01$ $\eta = 0.60$	$A = 0.98$ $\eta = 0.50$
NGDP-GT	0.1349	0.1349	0.1345	0.1235	0.1240	0.2023
IT	0.1445	0.1445	0.1445	0.1330	0.1335	0.2114
TR	0.1273	0.1273	0.1278	0.1168	0.1168	0.1923

Table 11
Consumption equivalent welfare losses from different policy rules, only markup.

Policy Rule	$A = 1.00$ $\eta = 1.00$	$A = 1.01$ $\eta = 1.00$	$A = 0.98$ $\eta = 1.00$	$A = 1.00$ $\eta = 0.50$	$A = 1.01$ $\eta = 0.60$	$A = 0.98$ $\eta = 0.50$
NGDP-GT	0.0710	0.0715	0.0710	0.0600	0.0619	0.2341
IT	0.0810	0.0810	0.0810	0.0696	0.0720	0.2437
TR	0.0672	0.0672	0.0672	00562	0.0581	0.2260

Table 12
Consumption equivalent welfare losses from different policy rules, only productivity shocks.

Policy Rule	$A = 1.00$ $\eta = 1.00$	$A = 1.01$ $\eta = 1.00$	$A = 0.98$ $\eta = 1.00$	$A = 1.00$ $\eta = 0.50$	$A = 1.01$ $\eta = 0.60$	$A = 0.98$ $\eta = 0.50$
NGDP-GT	0.1349	0.1349	0.1345	0.1235	0.1240	0.2023
IT	0.1445	0.1445	0.1445	0.1330	0.1335	0.2114
TR-II	0.1311	0.4722	1.7107	0.1192	0.4218	2.5396

Table 13
Consumption equivalent welfare losses from different policy rules, only markup.

Policy Rule	$A = 1.00$ $\eta = 1.00$	$A = 1.01$ $\eta = 1.00$	$A = 0.98$ $\eta = 1.00$	$A = 1.00$ $\eta = 0.50$	$A = 1.01$ $\eta = 0.60$	$A = 0.98$ $\eta = 0.50$
NGDP-GT	0.0710	0.0715	0.0007	0.0600	0.0006	0.0023
IT	0.0810	0.0810	0.0008	0.0696	0.0007	0.0024
TR-II	0.0100	0.0700	0.0165	0.0581	0.0050	0.02576

Taylor rule, while NGDP-GT substantially outperforms the inflation targeting rule.

8. Robustness analysis

8.1. Another Taylor type of rule (TR-II)

In the benchmark model's specification, the Taylor rule takes the simple form, that nominal interest rate responds to the deviations of inflation and output from their respective steady state levels. However, Schmitt-Grohé and Uribe (2007) suggested that from a welfare perspective the simple form is undesirable. Therefore, in this subsection, the central bank uses real output growth rate instead of current output level to measure real economic activity. Hense, Taylor rule-II (TR-II) responds to deviations of inflation and output growth from their steady state levels.

$$\log\left(\frac{R_t}{\bar{R}}\right) = \rho_r \log\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho_r)\left[\rho_\pi \log\left(\frac{\pi_t}{\bar{\pi}}\right) + \rho_{\tilde{y}} \log\left(\frac{\hat{y}_t}{\hat{y}_{t-1}}\right)\right]$$

As shown in Table 12 when a TFP shock hits the economy, typically when $A = 1$, TR-II generates the least welfare loss and NGDP-GT takes the second place, weakly dominated by the TR-II (producing only 3% more welfare loss). But when $A \neq 1$, NGDP-GT is the most desirable policy rule and TR-II generates the most welfare loss. When the economy is subject to a markup shock as shown in Table 13, when $A \geq 1$ and (or) $\eta = 1$, TR-II dominates the other two regimes and NGDP-GT again, ranks number two. For other cases, NGDP-GT outperforms inflation targeting and the TR-II.

Generally, rankings of policy rules from the welfare perspective depend on the trend growth rate, the level of partial indexation to steady state inflation and different specifications of the Taylor rule. However, the surprising result here is that NGDP-GT performs very stable relative to other rules. It is either weakly dominated by either the Taylor rule or TR-II for some cases with particular parameter values, or NGDP-GT dominates other regimes, suggesting that NGDP-GT has some desirable properties.

9. Conclusion

In this paper, I examine the performance of a nominal GDP growth targeting (NGDP-GT) rule, two Taylor types of rules (TR and TR-II) and inflation targeting (IT) in a New Keynesian model with a positive trend inflation, trend TFP growth and incomplete inflation indexation. From the stability perspective, results show that the primary benefits of the NGDP-GT are lower volatilities in inflation compared to the Taylor rule. The NGDP-GT framework reduces inflation volatility by a quarter or more. Furthermore, NGDP-GT performs almost as well in output and consumption relative to the Taylor rule.

Compared to the strict inflation targeting regime, NGDP-GT framework produces at least a quarter less fluctuations in output and consumption, while NGDP-GT is almost as well as inflation targeting in stabilizing inflation: generating only about 3.5% more volatilities. The above conclusions are not conditioning on the trend growth rate and the level of inflation indexation.

The paper examines the welfare effects using consumption equivalence as the welfare measure. When the Taylor rule takes the simple form, that is, the interest rate responds to deviations of inflation and current output level, inflation targeting is the least desirable policy and NGDP-GT is weakly dominated by the Taylor rule. The conclusions are not conditioning on the trend growth rate or the level of inflation indexation. However, when the Taylor rule takes the form that interest rate responds to deviations of inflation and output growth, the trend growth rate, the level of partial inflation indexation and the shock affect the rankings of policy rules. Specifically, when a TFP shock hits the economy, and $A = 1$, TR-II generates of the least welfare loss and NGDP-GT performs almost as well, producing only 3% more welfare loss. When $A \neq 1$, NGDP-GT is the most desirable policy regime and TR-II is the least desirable framework. When the economy is subject to a markup shock, $A \geq 1$ and (or) $\eta = 1$, TR-II dominates the other two regimes. For other cases, however, NGDP-GT outperforms the TR-II and inflation targeting.

NGDP-GT performs very stably relative to other policy frameworks. It is weakly dominated by the Taylor rule. Although the welfare losses associated with the TR-II is smaller for some cases with particular parameter values, NGDP-GT outperforms alternative policy regimes for most cases, suggesting that NGDP-GT has some desirable properties.

Declaration of interest statement

I have no relevant interest(s) to disclose. This summary statement will be ultimately published if the article is accepted.

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