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Trend inflation and macroeconomic volatilities in the post-WWII U.S. economy☆

Efrem Castelnuovo*

University of Padua, Via del Santo 33, I-35123 Padova (PD), Italy

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ABSTRACT

This paper estimates a new-Keynesian model of the business cycle for the post-WWII U.S. economy and performs theoretical and counterfactual simulations to isolate the role played by *systematic* monetary policy and macroeconomic *shocks* in shaping the volatilities of inflation and output. *Shocks* to *trend inflation* are found to be a key-driver of raw inflation and the inflation gap. In contrast, shocks to output are likely to have played a major role as regards the volatility of the business cycle. Overall, my results work against the 'good policy only' interpretation of the U.S. Great Moderation.

1. Introduction

This paper asks the following question: *To what extent do changes in the inflation target pursued by the Federal Reserve Bank have affected the post-WWII U.S. macroeconomic volatilities?* To answer this

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* Tel.: +39 049 827 4257; fax: +39 049 827 4211.
E-mail address: efrem.castelnuovo@unipd.it.

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question, I estimate a new-Keynesian model of the business cycle focusing on two different periods, the 'Great Inflation', a sample ending in 1979: II in correspondence with the appointment of Paul Volcker as chairman of the Federal Reserve Bank (Fed), and the 'Great Moderation', characterized by dramatically milder macroeconomic volatilities.[1] I then perform theoretical and counterfactual simulations to isolate the role played by systematic monetary policy and different shocks – to output, inflation, the policy rate, and the inflation target – in shaping the volatility of 'raw' inflation, the inflation *gap*– i.e. the difference between raw inflation and the time-varying inflation target set by the Fed – and cyclical output.

This paper's motivation is straightforward. Macroeconomists have often employed models featured by the presence of a *constant* inflation target. Studies aiming at identifying the drivers of the Great Moderation have reached contrasting conclusions, with Clarida, Gali, and Gertler (2000), Lubik and Schorfheide (2004) and Boivin and Giannoni (2006) supporting the 'good policy' interpretation – a shift towards a more hawkish monetary policy able to hamper macroeconomic fluctuations – vs. Smets and Wouters (2007) and Justiniano and Primiceri (2008b) offering evidence in favor of the 'good luck' interpretation – less volatile macroeconomic shocks in the 1980s and 1990s.[2] A somewhat related string of papers has *rejected* the assumption of a constant inflation target in favor of a process able to pick up low frequency movements of the inflation rate. Such process has been interpreted as the *time-varying inflation target*– otherwise labeled 'trend inflation' – pursued by the Fed in the post-WWII sample Cogley and Sargent(2005a), Bjørnland, Leitemo, and Maih (2007), Cogley and Sbordone (2008), Castelnuovo, Greco, and Raggi (2008) and Cogley, Primiceri, and Sargent (2010).[3] Consequently, trend inflation candidates itself as another possibly relevant driver of the Great Moderation. Therefore, I take this driver into account and I assess the relative role played by shocks to trend inflation in influencing the 1960: I-2008: II U.S. macroeconomic dynamics.

My findings read as follows. First, the estimated macroeconomic model is able to replicate – at least qualitatively – the observed drop in U.S. inflation and output volatility. Interestingly, this model turns out to have a superior descriptive power with respect to its somewhat 'natural' competitor, i.e. a small-scale version of the new-Keynesian model displaying a constant inflation target and price indexation to past inflation popularized by Christiano, Eichenbaum, and Evans (2005).[4] Second, in terms of inflation *gap* volatility, the model suggests a *larger* drop than that estimated for raw inflation. This is due to the smaller fluctuations of the trend inflation process in the Great Moderation sample, and qualifies trend inflation as a possibly important driver of the Great Moderation. Third, counterfactual exercises suggest that a better systematic policy could have dampened most of the fluctuations in raw inflation and the inflation gap observed under the Burns-Miller monetary policy management. However, a policy trade-off arises, i.e. the 'good policy only' explanation of the Great Moderation in inflation turns out to be inconsistent with the observation of the Great Moderation in detrended output. Fourth, if the Fed had maintained a constant inflation target over the 1960s and 1970s, the (counterfactual) inflation volatilities would have been significantly smaller. By contrast, the estimated reduction of detrended output volatility would have been much less appreciable. This latter finding squares up with the indications coming from the variance-decomposition analysis, which stresses the role of non-policy 'demand' shocks as far as the volatility of output is concerned.

[1] The term 'Great Moderation' is usually employed to indicate the generalized reduction in output and inflation volatility observed since the mid-1980s in the U.S. and other industrialized countries Kim and Nelson (1999); McConnell and Perez-Quiros (2000); Blanchard and Simon (2001) and Stock and Watson (2002).

[2] The Great Moderation has also been associated to the increase in the *absolute* ability by forecasters to predict inflation (as measured by a variety of statistics, e.g. root-mean-squared error), but to a fall of their *relative* ability to beat a random-walk Stock and Watson (2007). D'Agostino, Giannone, and Surico (2006) show that this finding is robust across a variety of macroeconomic indicators. Interestingly, Benati and Surico (2008) replicate this fall in relative predictability with an estimated new-Keynesian framework in which monetary policy switches towards a more aggressive systematic conduct.

[3] Ascari (2004) coined the term 'trend inflation' to indicate a strictly positive level of steady state inflation around which to approximate firms' first order condition in the derivation of the new-Keynesian Phillips curve. The literature has recently considered the case of a time-varying inflation target. I will use the terms 'time-varying inflation target' and 'trend-inflation' interchangeably.

[4] In this paper I refrain from considering elements such as capital accumulation, variable capital utilization, and staggered wage contracts, which are by contrast present in Christiano et al.'s (2005) set up. I leave the analysis of the role of trend inflation in the full-scale Christiano et al.'s (2005) framework to future research.

This contribution supports the time-varying inflation target as one of the relevant ingredients to interpret the U.S. inflation dynamics in the post-WWII sample. Imperfect knowledge of the economic structure and the evolution of the perceived inflation-output volatility trade-off by the Fed is one of the possible ways to make the trend inflation process endogenous (in this paper, it is assumed to be an exogenous process). Interesting efforts in this direction have already been undertaken by Cogley and Sargent (2005b), Primiceri (2006), Sargent, Williams, and Zha (2006) and Primiceri (2005).

The paper closest to mine is probably Cogley et al. (2010). They employ a VAR with time-varying parameters and conditional volatilities to scrutinize the predictability of the *inflation gap* at different horizons. They find that the predictability of this object has fallen in a statistically significant manner when entering the Great Moderation period.[5] To interpret this fact, they estimate a new-Keynesian model similar to the one employed in this paper for the Great Inflation-Great Moderation subsamples, and they perform counterfactual simulations to assess the role of policy parameters vs. good luck in shaping the volatility of the inflation gap as well as its predictability. I depart from Cogley et al. (2010) along several dimensions. First, I scrutinize the drivers of a wider range of macroeconomic objects, i.e. inflation, the inflation gap, and the output gap (they focus exclusively on the inflation gap). Second, I propose the analysis of the impulse response functions and the variance decomposition, which they do not offer. This leads to a more complete picture of the dynamics of the U.S. economy and of the relative importance of the shocks hitting it. Third, I allow trend inflation to enter the log-linearized new-Keynesian Phillips curve, an assumption I share with Woodford (2007) and Goodfriend and King (2008). Fourth, I propose a formal comparison between the trend inflation model I focus on and the more standard constant inflation target model that displays price indexation to past inflation. My contribution may be seen as complementary to Cogley et al. (2010).

I organize the paper as follows. Section 2 presents the new-Keynesian model I employ in my empirical analysis. Section 3 describes the Bayesian technique employed to perform my empirical exercises and presents my findings, both in terms of posterior densities and as regards objects such as impulse response functions and variance decomposition. Section 4 presents and discuss the theoretical and counterfactual simulations I implement. Section 5 concludes.

2. The model with time-varying inflation target

The inflation model I work with reads as follows:

$$\pi_t = \pi_t^* + \beta E_t(\pi_{t+1} - \pi_{t+1}^*) + \kappa x_t + v_t^{\pi}, \tag{1}$$

$$\pi_t^* = \rho_* \pi_{t-1}^* + \varepsilon_t^*. \tag{2}$$

Eq. (1) is a 'trend inflation' enriched new-Keynesian Phillips curve, where π_t stands for the inflation rate, π_t^* is the current inflation target, β identifies the discount factor, x_t a measure of detrended output (often interpreted as the 'output gap') whose impact on current inflation is influenced by the slope-parameter κ. The autoregressive process $v_t^{\pi} = \rho_\pi v_{t-1}^{\pi} + \varepsilon_t^{\pi}$ is interpreted as 'inflation' shock, or 'supply' shifter.[6] Such curve may be derived from first-principles by assuming that monopolistically competitive firms have a lower-then-unity probability of re-setting their prices each period. When

[5] Importantly, they find *decisive* evidence in favor of the fall of the inflation gap persistence when entering the post-Volcker experiment period. They interpret the fact that their results are stronger than those in their previous papers (Cogley and Sargent, 2005a; Primiceri, 2005) with their focus on the *pseudo-*R^2 (as opposed to the normalized spectrum at zero frequency) as a measure of predictability.

[6] In this paper I use the term 'detrended output' and 'output gap' interchangeably. Justiniano and Primiceri (2008a) work with a medium-scale DSGE model and show that the degree of adherence of the theoretically relevant 'gap' to statistically detrended output depends on how the 'gap' is defined. In fact, while the gap defined with the counterfactual, *potential* (efficient) output that would prevail under perfect competition closely resembles detrended output, that computed with the counterfactual *natural* level of output – that would prevail under flexible prices and wages but in presence of inefficiencies due to firms' market power – is extremely more volatile than detrended output. Interestingly, Justiniano and Primiceri (2008a) show that mark up shocks are in fact 'empirically equivalent' to measurement errors, because both capture the very high frequencies of price and wage inflation. Under this alternative interpretation, potential and natural output move one-to-one, and the implied theoretical gaps closely resemble statistical measures of the 'output gap' as the one employed in this paper.

not allowed to re-optimize, firms automatically index their prices to the current realization of the stochastic inflation target, which is assumed to be perfectly observable after its realization (in each period). Cogley and Sbordone (2008) show that, when trend inflation is embedded in an otherwise standard NKPC, the estimated degree of price indexation drops to zero.[7] Accordingly, I shape the inflation process with the purely forward looking process formalized by Eq. (1). This NKPC is the same employed in some recent studies by Woodford (2007) and Goodfriend and King (2008).

The evolution of the inflation target – formalized by Eq. (2) – is dictated by the autoregressive parameter ρ_* as well as the volatility σ_* of its innovation ε_t^*. This process is typically assumed to be a random walk or a very-persistent variance-stationary process capturing the low-frequency component of the inflation rate, which is a sensible representation of the time-varying inflation target set by monetary-policy authorities.

To close the model, I postulate the following laws of motion for the cyclical component of output – the 'output gap' – x_t and the policy rate R_t:

$$x_t = (1+h)^{-1}E_t x_{t+1} + h(1+h)^{-1}x_{t-1} - \tau(R_t - E_t\pi_{t+1}) + \varepsilon_t^x, \quad (3)$$

$$R_t = (1-\phi_R)(\phi_\pi(\pi_t - \pi_t^*) + \phi_x x_t) + \phi_R R_{t-1} + \varepsilon_t^R. \quad (4)$$

Eq. (3) is a standard dynamic Euler equation for output, where h identifies the degree of habit formation by the representative agent, while τ is the intertemporal elasticity of substitution regulating the impact of the ex-ante real interest rate on consumption's decisions. Eq. (4) is a Taylor rule that suggests a gradual response to oscillations of the gaps in inflation and output by the Fed.

Finally, I assume the following distributions for the serially and mutually uncorrelated shocks of the model:

$$\varepsilon_t^j \sim i.i.d.N(0, \sigma_j^2), \quad j \in \left\{\pi, *, x, R\right\}. \quad (5)$$

A note on the shocks modeled in this framework is warranted. Here I label as 'structural' the shocks to inflation ε_t^π and output ε_t^x. In fact, such shocks are possibly convolutions of 'deep' innovations. For instance, the 'cost-push' shock ε_t^π allows for departures with respect to the 'deterministic' counterpart of the NKPC (1). However, the identification of the sources of such 'cost-push' shock is not investigated. Indeed, shocks to, e.g. the price mark-up or to the possibly time-varying elasticity of substitution among goods are collected by the 'inflation shifter' catch-all ε_t^π. The same holds as for the 'non-policy demand shifter' ε_t^x, which clearly allows for non-systematic departures of the output gap level with respect to what suggested by the deterministic counterpart of the Euler equation (3), but does not discriminate among, e.g. a technology shock, or a shock to consumers' preferences, or a fiscal shock. Nevertheless, one should keep in mind that, ultimately, this paper's aim is that of pinning down the relative role played by identified shocks such as shocks to trend inflation and monetary policy shocks in shaping the U.S. macroeconomic dynamics. Importantly, the 'reduced form' nature of the inflation and output shocks does not prevent me from performing such an assessment.

3. Empirical analysis

I estimate the model (1)–(5) with Bayesian techniques. Given the vector of the structural parameters $\xi = (\beta, \kappa, h, \tau, \phi_\pi, \phi_x, \phi_R, \rho_\pi, \rho_*, \sigma_\pi, \sigma_*, \sigma_x, \sigma_R)'$, that of the endogenous variables $z_t = [x_t, \pi_t, R_t]'$, the exogenous shock $\varepsilon_t = [\nu_t^\pi]'$, the vector of the innovations $\eta_t = [\varepsilon_t^\pi, \varepsilon_t^*, \varepsilon_t^x, \varepsilon_t^R]'$ and that of the

[7] A distinct, even if somewhat related, point is made by Benati (2008), who undertakes an extensive analysis involving ten OECD countries and the Euro Area aggregate to show that, under stable regimes with clearly defined nominal anchors (U.K., Canada, Sweden, New Zealand, Switzerland under inflation targeting, the Euro Area under the European Monetary Union), inflation can be modeled with a purely forward looking NKPC. His findings work against the notion of price indexation being a 'structural' parameter in the sense of Lucas. The Federal Reserve Bank has never officially adopted an inflation targeting monetary policy strategy. However, several contributions point towards the shift to a more aggressive monetary policy at the end of the 1970s. The association of a lower value for the U.S. price indexation parameter in the Great Moderation subsample to a more hawkish systematic policy by the Fed is conceptually in line with Benati's (2008a) position on the indexation parameter being a reduced-form one. For a recent study providing compelling evidence in favor of time-varying inflation persistence in a large number of countries, see Kouretas and Wohar (2009).

observables I aim at tracking $Y_t = [x_t^{obs}, \pi_t^{obs}, R_t^{obs}]'$, the solution under rational expectations of the new-Keynesian model (1)–(5) may be expressed in state space form as follows:

$$\begin{bmatrix} z_t \\ \varepsilon_t \end{bmatrix} = A(\xi) \begin{bmatrix} z_{t-1} \\ \varepsilon_{t-1} \end{bmatrix} + B(\xi)\eta_t,$$
$$Y_t = C(\xi) \begin{bmatrix} z_t \\ \varepsilon_t \end{bmatrix}, \tag{6}$$

where the system of equations (6) (top) refers to the law of motion of the endogenous and exogenous variables of the system, while the remaining system represent the measurement equations relating latent processes to observable variables (without assuming any measurement errors).

I then employ the Kalman filter to evaluate the likelihood $L(\{Y_t\}_{t=1}^T|\xi)$. The posterior distribution $p(\xi|\{Y_t\}_{t=1}^T)$ is then proportional to the product of the likelihood function $L(\{Y_t\}_{t=1}^T|\xi)$ and the priors $\Pi(\xi)$, which I impose over the parameters I estimate. Unfortunately, there is no closed-form expression for the posterior density. Nevertheless, such density can be numerically evaluated by implementing an algorithm like the random-walk Metropolis-Hastings, which allows to store a selected number of draws from the posterior itself. I then use such draws to estimate the moments of the posterior distribution. Canova and Sala (2009) show that, as for the estimation of DSGE models, this technique is preferable to alternatives (indirect inference, maximum likelihood) along several dimension (consistency, efficiency). Further discussions are proposed by An and Schorfheide (2007) and Fernandez-Villaverde (2009). For a detailed textbook presentation of this technique, see Canova (2007).[8]

3.1. *Prior densities*

I then need to set priors so to augment the likelihood of the model with some a-priori knowledge. Following Cogley et al. (2010), I set the autoregressive parameter ρ_* to 0.995 to capture the low-frequency movements in inflation with the inflation target process (2).[9] The remaining priors are standard and in line with Benati and Surico (2008) and Cogley et al. (2010) as for the parameters in common between their models and mine. In particular, I aim to be relatively uninformative as regards the persistence parameters, and I allow the domain of the volatilities of the model to be wide enough to let the data free to speak as regards the impact of the various shocks on the U.S. macroeconomic environment. At it is customary in the literature, I calibrate the discount factor β to 0.99. The priors employed in my exercise are collected in Table 1.

8 To perform Bayesian estimation I employed Dynare 4.0, a set of algorithms developed by Michel Juillard and collaborators and freely available at http://www.cepremap.cnrs.fr/dynare/. The posterior mode was computed by the 'csminwel' algorithm developed by Chris Sims. A check of the posterior mode, performed by plotting the posterior density for values around the mode for each estimated parameter in turn, confirmed the goodness of the optimization. I employed such mode to inizialize the random walk Metropolis-Hastings algorithm to simulate the posterior distributions. The inverse of the Hessian of the posterior distribution evaluated at the posterior mode was used to define the variance-covariance matrix of the chain. The initial VCV matrix of the forecast errors in the Kalman filter was set to be equal to the unconditional variance of the state variables. I used the steady-state of the model to initialize the state vector in the Kalman filter. I simulated two chains of 200,000 draws each, and discarded the first 50% as burn-in. To scale the variance-covariance matrix of the random walk chain, I used a factor so to achieve an acceptance rate belonging to the [23%,40%] range. To assess the stationarity of the chains, I considered the convergence checks proposed by Brooks and Gelman (1998). The region of acceptable parameter realizations was truncated so to obtain equilibrium uniqueness under rational expectations.

9 Alternatively, one may impose a unit-root in the trend inflation process. I decided against this option for two reasons. First, convergence towards the posterior mode proved to be much more difficult. Second, Cogley et al. (2010) show that a unit root trend inflation may induce a low inflation gap predictability in models like the one at hand, a prediction that goes against the significantly high(er) VAR based inflation gap predictability they find in the Great Moderation subsample.

Table 1
Posterior densities. The table reports posterior medians and the [5th,95th] percentiles. 'TI Model': Model with trend inflation and no indexation to past inflation. 'IND Model': Model with constant inflation target and indexation to past inflation. Details on the estimation are reported in the text.

Param.	Priors	TI Model Post.-GInflation	TI Model Post.-GModer.	IND Model Post.-GInflation	IND Model Post.-GModer.
β	0.99(*calibr.*)	0.99	0.99	0.99	0.99
κ	$\Gamma(0.1, 0.025)$	0.0462 [0.0266,0.0675]	0.0261 [0.0135,0.0422]	0.0347 [0.0197,0.0508]	0.0237 [0.0112,0.0453]
h	$\beta(0.5, 0.1)$	0.8050 [0.7307,0.8785]	0.8728 [0.8196,0.9244]	0.8255 [0.7588,0.8871]	0.8563 [0.8032,0.9054]
τ	$\Gamma(0.15, 0.05)$	0.1284 [0.0677,0.1967]	0.0256 [0.0109,0.0427]	0.1074 [0.0601,0.1573]	0.0382 [0.0219,0.0558]
ϕ_π	$N(1.7, 0.3)$	1.8377 [1.4820,2.2150]	2.0767 [1.6279,2.5762]	1.1550 [1.0000,1.3986]	2.1498 [1.7347,2.5376]
ϕ_x	$\Gamma(0.3, 0.2)$	0.2804 [0.1619,0.4110]	0.2718 [0.0801,0.5024]	0.1894 [0.1076,0.2907]	0.2113 [0.0897,0.3281]
ϕ_R	$\beta(0.5, 0.28)$	0.8091 [0.7362,0.8771]	0.9372 [0.8961,0.9680]	0.7694 [0.6810,0.8575]	0.8932 [0.8635,0.9225]
ρ_π	$\beta(0.6, 0.1)$	0.7655 [0.6486,0.8700]	0.5267 [0.3278,0.8566]	0.4591 [0.3237,0.6074]	0.4781 [0.2530,0.7344]
ρ_*	0.995 (*calibr.*)	0.995	0.995	–	–
σ_π	$I\Gamma(0.25, 2)$	0.1080 [0.0729,0.1466]	0.0995 [0.0608,0.1339]	0.1758 [0.1432,0.2104]	0.1218 [0.0976,0.1441]
σ_*	$I\Gamma(0.25, 2)$	0.0871 [0.0571,0.1225]	0.0652 [0.0474,0.0837]	–	–
σ_x	$I\Gamma(0.25, 2)$	0.6539 [0.5466,0.7620]	0.3693 [0.3135,0.4282]	0.6255 [0.5269,0.7309]	0.3667 [0.3092,0.4271]
σ_R	$I\Gamma(0.25, 2)$	0.1925 [0.1661,0.2221]	0.1367 [0.1189,0.1549]	0.1947 [0.1685,0.2221]	0.1349 [0.1187,0.1518]
$\log(ML)$	–	−159.6977	−92.6441	−173.5153	−110.4929

3.2. Data

I use data on the quarterly growth rate of the GDP deflator, the log-deviation of real GDP with respect to the measure of potential output provided by the Congressional Budget Office, and the Federal Funds Rate (average of monthly data). The source of the data is the Federal Reserve Bank of St. Louis' website, i.e. http://research.stlouisfed.org/fred2/. In line with, e.g. Cogley et al. (2010), I consider the following two subsamples: 1960:I-1979:II, which corresponds to the 'Great Inflation' period ended with the appointment of Paul Volcker as Fed's Chairman, and 1982:IV-2008:II, which corresponds to the post-'Volcker experiment' period, and largely overlap the 'Great Moderation' sample.

3.3. Posterior densities

Table 1 collects the results of my econometric investigation. Several comments are in order. First, all the posterior medians are economically sensible and in line with previous studies (see e.g. Benati and Surico, 2008; Cogley et al., 2010). Second, the Taylor rule parameter ϕ_π displays a larger value in the second subsample (sixth row, fourth column). While finding a more aggressive systematic policy in the second subsample, I do not find a difference between the estimated long-run reaction to inflation fluctuations in the two subsamples as large as those proposed by Clarida et al. (2000); Lubik and Schorfheide (2004); Boivin and Giannoni (2006). This is likely to be due to my choice to ensure equilibrium uniqueness while estimating the model, which leads me to 'truncate' the parameter space and concentrate on the 'determinacy territory'.[10] Also, the object I deal with – i.e. the inflation gap – is not the one Clarida et al. (2000); Lubik and Schorfheide (2004); Boivin and Giannoni (2006) deal with,

[10] The debate on the evidence in favor of an indeterminate equilibrium in the pre-Volcker subsample is very lively, with Lubik and Schorfheide (2004) and Boivin and Giannoni (2006) supporting it, and Sims and Zha (2006), Justiniano and Primiceri (2008b) and Cogley et al. (2010) casting doubs on multiple equilibria as a relevant feature to describe the dynamics of the 1960s and 1970s. Castelnuovo and Surico (in press) show that indeterminacy may offer a rationale for the price puzzle typically found when estimating the effects of a monetary policy shocks with VAR models. Surico (2006) discusses the perils coming from merging two subsamples featuring different equilibria. For a paper disputing the 'one-policy shift only' hypothesis, see Bianchi (2009).

i.e. raw inflation (for further investigations on the relevance of this difference in a Taylor-rule context, see Castelnuovo et al. (2008)). Interestingly, my estimates of the Taylor rule parameters (sixth and seventh rows, third and fourth columns) are barely in line with those by Cogley et al. (2010). I also find evidence in favor of a large degree of interest rate smoothing (eighth row, third and fourth columns), a result in line with some previous estimates (e.g. Castelnuovo, 2003).

The remaining posterior densities are also of interest. There is a marked reduction in the slope of the NKPC, in the intertemporal elasticity of substitution, and in the persistence of the inflation shock (third, fifth, and ninth rows—compare third and fourth columns).[11] Another striking result I obtain is the generalized reduction of the volatilities of the structural shocks in the second subsample, a finding that captures in first approximation the evidence put forward by Justiniano and Primiceri (2008b) with a framework allowing for time-varying conditional volatilities (eleventh up to fourteenth rows, compare third and fourth columns). Notably, the variance of the inflation target shock is remarkably lower in the second subsample (twelfth row, compare third and fourth column), a result I share with Stock and Watson (2007) and Cogley et al. (2010). This finding is consistent with trend inflation as being one of the drivers of the Great Moderation. I concentrate on this hypothesis in the remainder of the paper.

3.4. Model comparison: trend inflation vs. price indexation

Of course, one may wonder if the model scrutinized so far is actually interesting from a positive standpoint. Indeed, this model is substantially different with respect to a more popular alternative, i.e. the new-Keynesian framework with constant inflation target and price-indexation to past inflation. This latter framework is characterized by the following NKPC and policy rule:

$$\pi_t = \frac{\beta}{1+\alpha\beta}E_t\pi_{t+1} + \frac{\alpha}{1+\alpha\beta}\pi_{t-1} + \kappa x_t + v_t^{\pi}, \tag{7}$$

$$R_t = (1-\phi_R)(\phi_\pi \pi_t + \phi_x x_t) + \phi_R R_{t-1} + \varepsilon_t^R. \tag{8}$$

Eq. (7) displays the parameter α, which identifies non-reoptimizing firms' indexation to past inflation. Christiano et al. (2005) set $\alpha = 1$. I follow their choice for two reasons: (i) it is conceptually in line with the assumption of full indexation to trend inflation I rely upon when working with the trend inflation framework ('TI' henceforth); (ii) it would be difficult to identify separately α and the autoregressive parameter ρ_π. I then estimate the 'IND' model – identified by Eqs. (3), (5), (7) and (8) (the latter where applicable) – and assess its relative fitting power via Marginal Likelihood comparison.

The Marginal Likelihood (*ML*) is equal to the integral of the likelihood function across the parameter space using the prior as the weighting function. Given that a closed-form solution is not available, I employ the estimator proposed by Geweke (1998), which relies upon the draws of the Metropolis-Hastings. Importantly, the *ML* takes into account that the size of the parameter space for different models can be different. Consequently, richly parametrized models will not necessarily over-perform less parametrized ones if the extra-parameters are unimportant. This is so because the *ML* visits all the regions of the parameter space, so taking averages over relatively larger and smaller values of the likelihood function. Then, if the trend inflation model turns out to be superior to the alternative price-indexation framework, this is not due to over-parameterization. Interestingly for our case, the Marginal Likelihood allows to compare also non-encompassing frameworks.

To compare the two models, I assume a uniform prior over the two alternatives. This induces the equivalence between the ratio of the Marginal Likelihoods (ML_TI/ML_IND) and the object ultimately of interest for model comparison, i.e. the Bayes factor.

[11] One might question the validity of counterfactual simulations performed by conditioning on a given set of distributions for the structural parameters of the model in the light of the variation of such distributions that apparently occurred with the monetary policy shift. In other words, such parameters may not be 'structural in the sense of Lucas'. I interpret my results as evidence for possibly time-varying structural parameters, but not necessarily in favor of a causal link going from a monetary policy regime change to these parameters' variation.

Table 1 collects the estimates of the model 'IND' (fifth and sixth columns). Interestingly, most of the structural parameters assume values in line with those of the 'TI' framework, but a few significant differences emerge. First, the Taylor parameter ϕ_π (sixth row, fifth and sixth columns) takes values much closer to those proposed by e.g. Clarida et al. (2000), Lubik and Schorfheide (2004) and Boivin and Giannoni (2006). In particular, during the Great Inflation, such value is just slightly above one (recall that, to impose equilibrium uniqueness, I truncated the parameter space to force the 'Taylor principle' constraint $\phi_\pi > 1 - [(1-\beta)/\kappa]\phi_x$ to be satisfied), while during the Great Moderation it is close to two. This is interesting, because it suggests that the estimated long-run reaction to inflation depends upon the *definition* of the *inflation object*. In other words, one does not necessarily tell the same story when focusing on the reaction of the Fed to raw inflation vs. the inflation gap. Another difference one may detect when contrasting 'TI' and 'IND' regards the degree of inflation shock persistence (ninth row), which is much lower for the latter model. This is not surprising. In fact, price indexation creates a link between current and lagged inflation, so directly modeling (at least in part) inflation persistence.

Most importantly, the Bayes factor clearly favors the model with trend inflation in both subsamples. Indeed, the log-difference in terms of ML (whose values in logs are proposed in the last row of Table 1) suggests 'definitive' evidence – according to standard Bayesian scales – in favor of the 'TI' model. I will then keep focusing on it, and discard the alternative price indexation model.

3.5. Impulse response functions (IRFs)

A 'first-glance' at impulse response functions may be informative as for the drivers of the macroeconomic dynamics at stake. Such functions display the dynamic reaction of the endogenous variables of interest to the structural shocks of the economic system. Then, given the normalization of the size of the shocks across subsamples, differences in the impulse response functions must be due to changes in the transmission mechanism. The IRFs densities are computed by sampling 500 vectors of realizations of the estimated parameters (per each subsample), and simulating, per each drawn vector, the IRF of interest. Then, the 5th and 95th percentiles of each distribution in each quarter of the IRF of interest are picked up along with the distribution mean.

Fig. 1 overlaps the dynamics responses estimated for the 'Great Inflation' and the 'Great Moderation' subsamples and the corresponding 90% credible sets. Despite of the – in some cases remarkable – uncertainty surrounding the response functions, one may detect a common pattern across responses, i.e. the short-run reactions in the Great Moderation subsample are dampened with respect to those under the Great Inflation, and tend to be more persistent. This may be seen as an attempt by monetary policy makers to implement a more efficient monetary policy conduct. This interpretation is corroborated by Fig. 1 (panel [3,1]), which highlights the higher degree of interest rate smoothing undertaken under the Great Moderation, possibly to anchor expected inflation (Woodford (2003)). Another possible interpretation points towards a 'structurally' more stable environment, e.g. a lower NKPC slope in the Great Moderation sample renders demand shocks less 'inflationary'.

In terms of signs and evolutions, these dynamic responses line up with those by Ireland (2007). In particular, a shock to the inflation target induces an increase in both realized and expected inflation (the latter not shown). Such increase leads to a short-run negative real interest, which triggers a temporary but prolonged output expansion, and calls for a monetary policy tightening even in the face of a negative inflation gap (not shown).

Fig. 1 (panel [1,1]) suggests that inflation was more prone to react to monetary policy shocks in the Volcker–Greenspan–Bernanke regime (up to 2008:II, last quarter of our analysis), an evidence pointing towards the larger role that this shock may have played in the last 25 years.[12] This leads to the next step, which is the analysis of the forecast error variance decomposition.

[12] In contrast, some VAR-based evidence (e.g. that reported by Boivin and Giannoni (2006)) suggests a reduction in the importance of the monetary policy shock during the Great Moderation. It must be noted, however, that such VAR evidence is conditional on a likely-to-be misspecified VAR, which has been shown to produce wrong conditional dynamics (Castelnuovo and Surico, in press). More research on this issue is warranted.

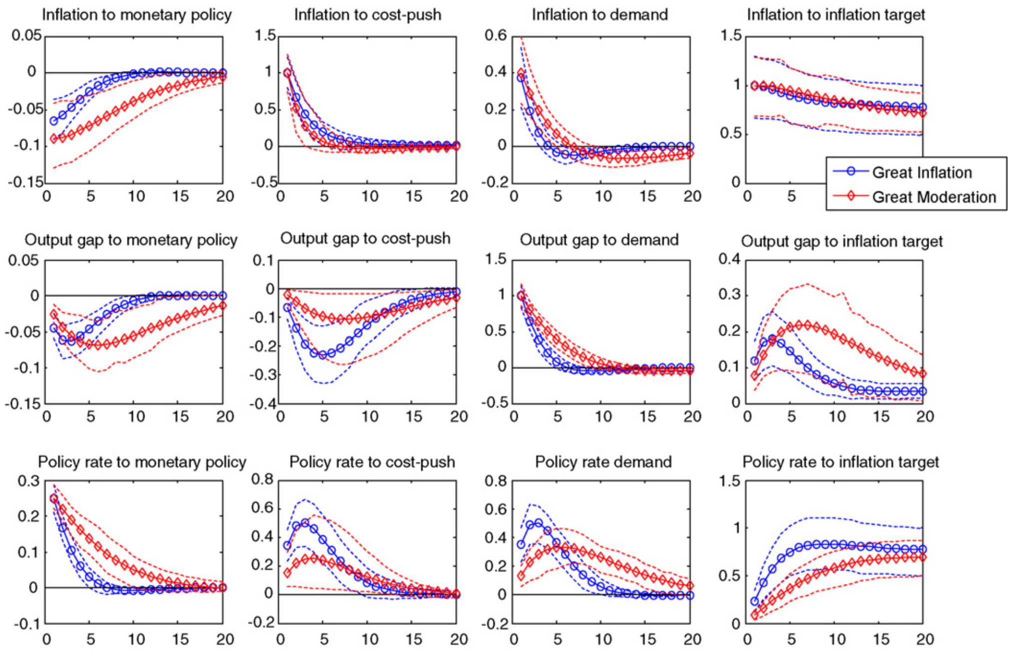

Fig. 1. Impulse response functions: Great Inflation vs. Great Moderation. Blue-circled lines: Great Inflation. Red lines with diamonds: Great Moderation. Mean responses plotted along with 5th and 95th percentile of the posterior distributions constructed with 500 draws from the posterior densities. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

3.6. *Forecast error variance decomposition (FEVDs)*

Fig. 2 plots the n-step ahead variance decomposition – $n \in [1, 40]$ – for each variable-shock-subsample. As often done in the literature, the FEVDs are constructed by computing the contribution of each structural shock to the forecast errors over the modeled variables on the basis of the subsample specific posterior modes.

Notably, the inflation target shock plays a very relevant role as regards inflation and the policy rate, above all at low-frequencies, i.e. in the 'middle-to-long' run (panels [1,1], [1,2], [3,1], and [3,2]). To be clear, this result is not necessarily a direct by-product of the calibration I imposed on the autoregressive trend inflation parameter $\rho_* = 0.995$. Indeed, the volatility of the trend inflation process is clearly driven also by such a parameter, but a key-role is obviously played by the trend inflation shock σ_*, which is *estimated*. Moreover, while being clearly very relevant for the unconditional ($n \to \infty$) FEVDs analysis (given its high persistence), the role of such an imposition on the short-run FEVDs is *a-priori* much less obvious, and its assessment requires the employment of an estimated model.

As regards inflation, the contribution of its own 'cost-push shock' is instead remarkable at higher frequencies, and the same holds true as far as the policy rate and the policy shock are concerned (panels [1,1] and [1,2]). Interestingly, while exerting an indirect influence on aggregate demand via the real ex-ante interest rate, the participation of trend inflation for the dynamics of output is relatively very modest, above all when compared to that of the non-policy 'demand' shock (panels [2,1] and [2,2]).

In is also of interest to compare the variations in the contributions of the shocks across subsamples. To fix ideas, Table 2 collects the forty-step ahead forecast error variance decomposition for output, inflation, and the policy rate. Notably, when moving to the Great Moderation subsample, the role of inflationary shocks for inflation basically halves, and for the output gap and the policy rate simply vanishes (compare rows 5–7 to rows 2–4, third column). This is due to the larger weight assumed by the two policy shocks—the 'traditional' monetary policy shock and the trend inflation shock, which

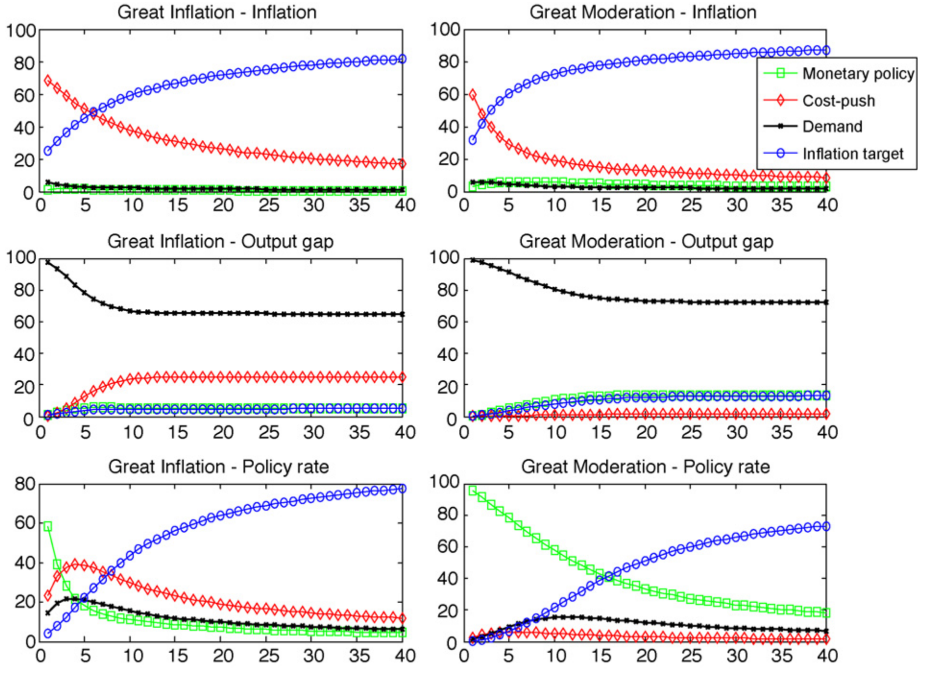

Fig. 2. Forecast error variance decomposition: Great Inflation vs. Great Moderation. Shock-specific forecast errors computed over the horizons [1,40] by calibrating the model with the mode of the posterior densities.

doubles as far as detrended output is concerned and increases as regards inflation. The policy rate volatility is also more firmly guided by the 'traditional' monetary policy shock, with a almost five-fold participation (compare row 7 to row 4, fifth column). By contrast, there is a slight decrease in the participation of the trend inflation shock for the volatility of the policy rate (compare row 7 to row 4, sixth column). The contribution of the non-policy 'demand' shock (fourth column) is very large – and increasing over time – as regards the business cycle volatility (compare row 6 to row 3), negligible when looking at inflation (row 5 to row 2), and moderate in terms of policy rate fluctuations (row 7 to row 4). Again, it is important to understand that here the 'demand' shifter is a convolution of processes such as public expenditures, technology, and possibly time-varying consumers' tastes. Therefore, it may very well be that the driving force shifting the output gap in this model be, ultimately, technology. It appears clear, anyhow, that trend inflation shocks do not play a marked role as for the U.S. business cycle.

Table 2
Forecast error variance decomposition: Great Inflation vs. Great Moderation. Figures reported in the table refer to the forty-step ahead FEVDs. Shock-specific forecast errors computed by calibrating the model with the mode of the posterior densities.

	ε_t^{π}	ε_t^{x}	ε_t^{R}	ε_t^{*}
Great Inflation				
π	16.96	0.97	0.46	81.61
x	24.88	64.82	5.19	5.11
R	11.93	6.15	4.48	77.44
Great Moderation				
π	8.56	1.55	2.76	87.14
x	1.44	72.13	13.34	13.08
R	1.69	6.75	18.27	73.28

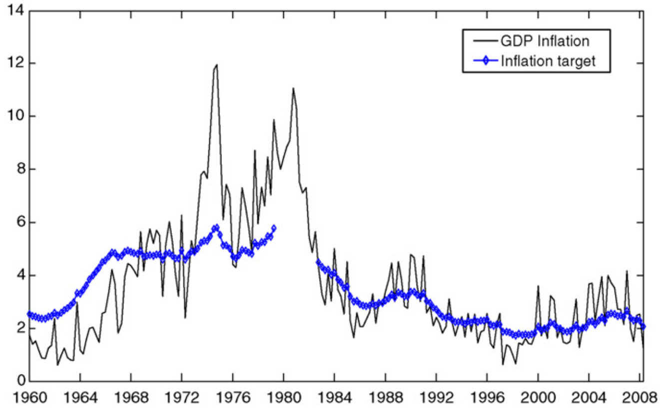

Fig. 3. Realized vs. trend inflation. Thin line: realized GDP deflator inflation. Diamonded line: Trend inflation as implied by the estimated new-Keynesian model (smoothed latent variable).

3.7. Inflation and trend component

Summing up, IRFs and FEVDs give a first feeling on the role that trend inflation might have played in the determination of the macroeconomic variables I focus on, i.e. a possibly significant one as regards inflation and the inflation gap, while very secondary as a driver of the real business cycle. However, to isolate the role of shocks vs. systematic components of the model such as the policy conduct, one has to resort to counterfactual simulations, which is what I do in the remainder of the paper. Before moving to counterfactuals, however, it is key to assess the economic sensibility of the estimated trend inflation path. Fig. 3 superimposes the estimated inflation target process on actual annualized quarterly inflation. Trend inflation was low – even if higher than realized inflation – at the beginning of the 1960s, then it began rising in the mid-1960s and it stabilized (after doubling with respect to the early 1960s) in the late 1960s-early 1970s. In the 1960s, movements in inflation target led movements in inflation, a finding in line, in particular, with Kozicki and Tinsley (2005). Then, entering the 1970s, trend inflation started to assume values more in line with the low frequency of inflation, then it took values clearly lower than raw inflation in the quarters following the two oil shocks in the 1970s. Subsequently, it remarkably dropped during the Volcker disinflation, and it somewhat stabilized around the 2 percent level since then. Eyeball econometrics suggests that the estimated evolution of the inflation target is very similar to those previously proposed by Kozicki and Tinsley (2005), Cogley and Sbordone (2008), Ireland (2007), Bjornland et al. (2007), Castelnuovo et al. (2008) and Cogley et al. (2010).

Comforted by this evidence, I now move to the theoretical and counterfactual simulations to gauge the role played by systematic monetary policy and ‘good luck’ in shaping inflation, the inflation gap, and output volatilities in the post-WWII period.

4. Theoretical and counterfactual simulations

First, I compute the theoretical moments of interest, i.e. the standard deviations of inflation, the inflation gap, and detrended output implied by the estimated model.

4.1. Theoretical simulations

The quarterly growth rate of the U.S. real output – as measured by its standard deviation – has declined by half since the mid-1980s, while quarterly inflation’s variability has fallen by about two thirds. Justiniano and Primiceri (2008b) estimate a medium scale DSGE model with post-WWII U.S. data and show that they can replicate – in terms of median values – a fall of output growth variability

Table 3
Theoretical and counterfactual standard deviations. Figures in the table: Model consistent standard deviations (even columns), percentage deviations with respect to the first scenario (odd columns but the first one). First two rows: theoretical exercise to replicate the Great Inflation (1960:I-1979:II) and Great Moderation (1982:IV-2008:II) facts. 'Policy 2, Private 1' simulates what would have happened in the first subsample – identified by Private 1 sector values calibrated according to the estimated model, median values – if the monetary policy had been as aggressive as the one estimated in the second subsample - median values. The other scenarios 'plant' in the first subsample just selected parts of second subsample's monetary policy (as indicated.) 'Policy 1, Private 2' replaces the Private 2 sector values in the first subsample.

Scenarios	$\sigma_{\hat{\pi}}$	$\Delta\sigma_{\hat{\pi}}$, %	σ_{π}	$\Delta\sigma_{\pi}$, %	σ_{x}	$\Delta\sigma_{x}$, %
Great Inflation	1.01	–	1.83	–	1.61	–
Great Moderation	0.56	−44	1.17	−36	1.29	−20
Policy 2, Private 1	0.72	−29	1.28	−30	1.93	+20
ϕ_{π}	0.84	−17	1.65	−10	1.62	+1
$\phi_{\pi}, \phi_{x}, \phi_{R}, \sigma_{R}$	0.87	−14	1.65	−10	2.01	+25
σ_{*}	0.82	−19	1.40	−23	1.58	−2
$\sigma_{*} = 0$	0.46	−54	0.46	−75	1.55	−4
Policy 1, Private 2	0.87	−14	1.72	−6	1.17	−27

of about 25%, and a drop of inflation variability of about 75%.[13] Smets and Wouters (2007) estimate barely similar figures - the fall in output growth's variability reads 35%, in inflation's 58%.[14] The data I work with suggest a fall of the standard deviation of the cyclical component of output of about 25%, and that of quarterly inflation of about 50%.

Table 3 (second and third rows) collects the simulated theoretical moments.[15] The model clearly works in the direction of a Great Moderation, and it suggests a fall in the inflation gap very close to that recorded by Cogley et al. (2010). However, it somewhat underestimates the drop in the volatilities of detrended output and inflation. This might be due to different factors. First, the model at hand is estimated by imposing equilibrium uniqueness. This assumption is very handy, because it avoids to undertake the highly arbitrary choice of the selection of a single equilibrium under indeterminacy (for further discussions, see Castelnuovo, 2009). However, it may also limit the extent to which the improvement in systematic monetary policy has modified the U.S. macroeconomic dynamics. Another issue is model misspecification. A likely relevant source of macroeconomic moderation is the variation in financial frictions experienced by the U.S. economy. Dynan, Elmendorf, and Sichel (2006) and Campbell and Hercowitz (2006) document an easier access to external financing by households since the beginning of the 1980s, a dating intriguingly squaring with the beginning of the Great Moderation. It may very well be that a model with financial frictions – not modeled here – could perform better in replicating the drop in the U.S. macroeconomic volatilities. Then, bearing these caveats in mind, I proceed to analyze the outcome of my counterfactual analysis.

4.2. Counterfactual simulations

I conduct counterfactual exercises with the goal of identifying the drivers of the Great Moderation. I then split the parameters of the model in two subsets. I consider as 'Policy' coefficients those entering the Taylor rule, i.e. $[\phi_{\pi}, \phi_{x}, \phi_{R}, \sigma_{R}, \rho_{*}, \sigma_{*}]$, and 'Private' sector parameters the remaining ones. I take the theoretical moments of the first subsample as references, and I run counterfactual simulations by 'planting' the estimated 'Policy' parameters of the second subsample – all or just some of them – in an environment characterized by the 'Private' sector parameters estimated with the first subsample. In particular, I conduct the simulation 'Policy 2, Private 1'. This is the 'good policy' scenario that 'plants' our estimates of Volcker–Greenspan–Bernanke's conduct in the 1960s and 1970s. This scenario aims at understanding what would have happened if the monetary policy conduct had been more aggressive against inflation fluctuations. I then scrutinize the 'Policy' vector element-by-element so to gain

[13] See their Table 5, first column, Panel A, page 631, median values.
[14] See their Table 6, page 604, figures under "1984:1-2004:4, Model" over figures under "1966:1-1979:2, Model".
[15] I compute the population standard deviation of the variables of interest by exploiting the state-space representation of the model and numerically solving the associated Lyapunov equation (Ljungqvist and Sargent, 2000, first Chapter).

insights of the relative participation to the overall effect, paying particular attention to the role of trend inflation. Finally, I consider the complementary ‘Policy 1, Private 2’ scenario – i.e. ‘good luck’ scenario, featured by more moderate supply and demand shock – to double-check the relevance of changes in policy vs. private sector parameters while conditioning on the policy of the 1960s and 1970s.

Table 3 collects the outcome of my counterfactual simulations. I report both the model-consistent standard deviations and the percentage variations of each variable-scenario with respect to the theoretical ‘Great Inflation’ scenario. Several comments are in order. First, the improvement in systematic monetary policy is likely to have played a significant role in moderating inflation and the inflation gap fluctuations (fourth row, columns 2–5). By contrast, a better systematic monetary policy *per se* would have induced a counterfactually *larger* business cycle volatility, i.e. the estimated model presents an inflation/output volatility trade-off (fourth row, columns 6 and 7).[16] This implies that for the estimated model to be consistent with the stylized facts, at least qualitatively, one needs to allow for both a better systematic monetary policy and ‘good luck’.

Digging deeper in the context of a better monetary policy, it can be noticed that the deterministic component of the ‘Policy’ vector may have played a partial role in shaping the inflation gap volatility, with a contribution *de facto* comparable to that of the evolution of trend inflation. As regards the volatility of inflation, the contribution of trend inflation turns out to be twice as much that of systematic monetary policy. By contrast, the milder behavior of trend inflation in the second part of the sample leaves virtually unaffected the volatility of output, which is largely explained by ‘good luck’, as suggested by the ‘Policy 1, Private 2’ simulation. However, one should take this result with a grain of salt. Giannone, Reichlin, and Lenza (2008) show that a misspecified VAR may lead to support the ‘good luck’ explanation of the Great Moderation – i.e. to point towards the reduction of the conditional heteroskedasticity of the U.S. economy as the main driver of the milder macroeconomic unconditional volatilities – while, in fact, a better specified VAR offers support to ‘good policy’.

One may then wonder how different the economic environment would have been if a constant inflation target had been imposed by the Fed. I then perform a ‘back-on-the-envelope’ calculation by comparing the theoretical volatilities with those associated to the fixed-target counterfactual scenario, the latter simulated by setting to zero the volatility of the trend inflation process. Table 3 (eight row) reveals that the gains in terms of macroeconomic stabilization would have been large as regards the inflation gap, and even larger as for raw inflation. By contrast, the business cycle volatility would have been just slightly affected.

5. Conclusions

This paper has estimated a new-Keynesian model of the business cycle to assess the role played by shocks to trend inflation for the U.S. Great Moderation. Several findings are worth mentioning. First, the estimated macroeconomic model is able to replicate, at least qualitatively, the observed drop in the U.S. macroeconomic dynamics of interest. In particular, I show that a purely forward looking NKPC with trend inflation is superior to a hybrid NKPC with price indexation (and no trend inflation) in terms of data-fitting. Second, as for the inflation *gap* volatility, the model indicates a drop larger than that estimated for raw inflation. This is due to the smaller fluctuations of the trend inflation process in the Great Moderation sample, and it suggests that milder variations in the level of inflation targeted by the Fed may have represented an important driver of the Great Moderation. Third, counterfactual exercises undertaken with the estimated framework at hand suggest that a better systematic policy could have dampened most of the raw inflation and inflation gap fluctuations observed under the Burns-Miller monetary policy regimes. However, a policy trade-off is present, i.e. according to the estimated new-Keynesian framework at hand, the ‘good policy only’ explanation of the Great Moderation in inflation is not consistent with the observation of the Great Moderation in detrended output.

[16] While this is an implication typically associated to the unique solution of a model with rational expectation, Lubik and Surico (in press) show that a shift from indeterminacy to a unique equilibrium due to a more stabilizing systematic monetary policy may induce the fall of both inflation and output volatility. For further discussions on the role of equilibrium selection under indeterminacy in this context, see Castelnuovo (2009).

This paper establishes a clear empirical link between trend inflation and inflation volatility in the post-WWII U.S. economy. Then, my findings support studies that aim at understanding the reasons underlying the evolution of the low-frequency component of inflation in the last fifty years. Interesting contributions focusing on the role that the learning process of the structure of the economy by the Fed may have played in shaping the low frequencies of the U.S. inflation process have recently been proposed by Cogley and Sargent (2005b), Primiceri (2006), Sargent et al. (2006) and Carboni and Ellison (2009), but more work is warranted.

References

An, S., & Schorfheide, F. (2007). Bayesian analysis of DSGE models. *Econometric Reviews*, *26*, 113–172.

Ascari, G. (2004). Staggered prices and trend inflation: Some nuisances. *Review of Economic Dynamics*, *7*, 642–667.

Benati, L. (2008). Investigating inflation persistence across monetary regimes. *The Quarterly Journal of Economics*, *123*(3), 1005–1060.

Benati, L., & Surico, P. (2008). Evolving U.S. monetary policy and the decline of inflation predictability. *Journal of the European Economic Association*, *6*(2/3), 634–646.

Bianchi, F. (2009). Regime switches, agents' beliefs, and post-world war II U.S. macroeconomic dynamics. Mimeo: Princeton University.

Bjørnland, H., Leitemo, K., & Maih, J. (2007). Estimating the natural rates in a simple new keynesian framework. Norges Bank Working Paper 2007/10.

Blanchard, O., & Simon, J. (2001). The long and large decline in U.S. output volatility. *Brookings Papers on Economic Activity*, *1*, 135–174.

Boivin, J., & Giannoni, M. (2006). Has monetary policy become more effective? *The Review of Economics and Statistics*, *88*(3), 445–462.

Brooks, S., & Gelman, A. (1998). General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statistics*, *7*(4), 434–455.

Campbell, J., Hercowitz, Z. (2006). The role of collateralized households debt in macroeconomic stabilization. Mimeo: Federal Reserve Bank of Chicago and Tel Aviv University

Canova, F. (2007). *Methods for applied macroeconomic research*. Princeton, NJ: Princeton University Press.

Canova, F., & Sala, L. (2009). Back to square one: Identification issues in DSGE models. *Journal of Monetary Economics*, *56*(4), 431–449.

Carboni, G., Ellison, M. (2009). The Great Inflation and the greenbook. *Journal of Monetary Economics, 56*(6), 831–841.

Castelnuovo, E. (2003). Taylor rules, omitted variables, and interest rate smoothing in the US. *Economics Letters*, *81*(1), 55–59.

Castelnuovo, E. (2009). Policy switch and the Great Moderation: The role of equilibrium selection. Mimeo: University of Padua.

Castelnuovo, E., Greco, L., Raggi, D. (2008). Estimating regime switching Taylor rules with trend inflation. Bank of Finland Discussion Paper, 20.

Castelnuovo, E., Surico, P. (in press). Monetary policy shifts, inflation expectations and the price puzzle. *Economic Journal*.

Christiano, L., Eichenbaum, M., & Evans, C. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, *113*(1), 1–45.

Clarida, R., Gali, J., & Gertler, M. (2000). Monetary policy rules and macroeconomic stability: Evidence and some theory. *Quarterly Journal of Economics*, *115*, 147–180.

Cogley, T., Primiceri, G. E., Sargent, T. (2010). Inflation-gap persistence in the U.S. *American Economic Journal: Macroeconomics, 2*(1) 43–69.

Cogley, T., & Sargent, T. (2005a). Drifts and volatilities: Monetary policies and outcomes in the post war u.s. *Review of Economic Dynamics*, *8*, 262–302.

Cogley, T., & Sargent, T. (2005b). The conquest of u.s. inflation: Learning and robustness to model uncertainty. *Review of Economic Dynamics*, *8*, 528–563.

Cogley, T., & Sbordone, A. (2008). Trend inflation, indexation, and inflation persistence in the new keynesian phillips curve. *The American Economic Review*, *98*(5), 2101–2126.

D'Agostino, A., Giannone, D., & Surico, P. (2006). (Un)predictability and macroeconomic stability. European Central Bank Working Paper Series 605.

Dynan, K., Elmendorf, D., & Sichel, D. (2006). Can financial innovation help to explain the reduced volatility of economic activity? *Journal of Monetary Economics*, *53*(1), 123–150.

Fernandez-Villaverde, J. (2009). The econometrics of DSGE models. NBER Working Paper No. 14677.

Geweke, J. (1998). Using simulation methods for Bayesian econometric models: Inference, development and communication. *Federal Reserve Bank of Minnesota Staff Report No. 249*.

Giannone, D., Reichlin, L., & Lenza, M. (2008). Explaining the Great Moderation: It is not the shocks. *Journal of the European Economic Association*, *6*(2/3), 621–633.

Goodfriend, M., & King, R. G. (2008). The Great Inflation drift. In M. D. Bordo, & A. Orphanides (Eds.), *The Great Inflation*. NBER.

Ireland, P. (2007). Changes in federal reserve's inflation target: Causes and consequences. *Journal of Money, Credit and Banking*, *39*(8), 1851–1882.

Justiniano, A.,& Primiceri, G. (2008a). Potential and natural output. Mimeo: Federal Reserve Bank of Chicago and Northwestern University.

Justiniano, A., & Primiceri, G. (2008). The time-varying volatility of macroeconomic fluctuations. *The American Economic Review*, *98*(3), 604–641.

Kim, C., & Nelson, C. (1999). Has the u.s. economy become more stable? A Bayesian approach based on a markov-switching model of the business cycle. *The Review of Economics and Statistics*, *81*, 608–616.

Kouretas, G. P., & Wohar, M. E. (2009). The dynamics of inflation: A study of a large number of countries. Mimeo: Athens University and University of Nebrasca at Omaha.
Kozicki, S., & Tinsley, P. (1985–2015). Permanent and transitory policy shocks in an empirical macro model with asymmetric information. *Journal of Economic Dynamics and Control*, 29.
Ljungqvist, L., & Sargent, T. (2000). *Recursive macroeconomic theory*. Cambridge, Massachusetts: MIT Press.
Lubik, T., & Schorfheide, F. (2004). Testing for indeterminacy: An application to U.S. monetary policy. *The American Economic Review*, *94*(1), 190–217.
Lubik, T., & Surico, P. (in press). The lucas critique and the stability of empirical models. *Journal of Applied Econometrics*.
McConnell, M., & Perez-Quiros, G. (2000). Output fluctuations in the united states: What has changed since the early 1980s? *The American Economic Review*, *90*, 1464–1476.
Primiceri, G. (2005). Time-varying structural vector autoregressions and monetary policy. *Review of Economic Studies*, *72*, 821–852.
Primiceri, G. (2006). Why inflation rose and fell: Policymakers' beliefs and u.s. postwar stabilization policy. *Quarterly Journal of Economics*, *121*, 867–901.
Sargent, T., Williams, N., & Zha, T. (2006). Shocks and government beliefs: The rise and fall of american inflation. *The American Economic Review*, *96*(4), 1193–1224.
Sims, C., & Zha, T. (2006). Were there regime switches in u.s. monetary policy? *The American Economic Review*, *96*(1), 54–81.
Smets, F., & Wouters, R. (2007). Shocks and frictions in US business cycle: A Bayesian DSGE approach. *The American Economic Review*, *97*(3), 586–606.
Stock, J., & Watson, M. (2002). Has the business cycle changed and why? In M. Gertler, & K. Rogoff (Eds.), *NBER macroeconomic annual*. Cambridge, MA: MIT Press.
Stock, J., & Watson, M. (2007). Why has inflation become harder to forecast? *Journal of Money, Credit and Banking*, *39*(1), 3–33.
Surico, P. (2006). Monetary Policy Shifts and Inflation Dynamics. In D. Cobham (Ed.), *The travails of the Eurozone*. London: Palgrave.
Woodford, M. (2003). Optimal interest-rate smoothing. *Review of Economic Studies*, *70*, 861–886.
Woodford, M. (2007). How important is money in the conduct of monetary policy? *Journal of Money, Credit and Banking*, *40*(8), 1561–1598.