

POLICY SWITCH AND THE GREAT MODERATION: THE ROLE OF EQUILIBRIUM SELECTION

EFREM CASTELNUOVO

University of Padua

and

Bank of Finland

“Good policy” and “good luck” have been identified as two of the possible drivers of the “Great Moderation,” but their relative importance is still widely debated. This paper investigates the role played by equilibrium selection under indeterminacy in the assessment of their relative merits. We contrast the outcomes of counterfactual simulations conditional on the “continuity” selection strategy—largely exploited by the literature—with those obtained with a novel “sign restriction” based strategy. Our results suggest that conclusions achieved under “continuity” are not necessarily robust to the selection of different—still economically sensible—equilibria. According to our simulations, the switch to a hawkish systematic monetary policy may very well induce an *increase* in output volatility. Hence, our sign restriction–selection strategy “resurrects” the inflation–output policy tradeoff.

Keywords: Great Moderation, Indeterminacy, Good Policy, Good Luck, Equilibrium Selection

1. INTRODUCTION

The volatility of U.S. output growth and inflation has dropped dramatically since the mid-1980s.¹ Stock and Watson (2002) labeled this phenomenon the “Great Moderation.” A question naturally arising is, “What drove the U.S. output growth and inflation volatilities down?”

Recent contributions have mainly focused on two distinct drivers: “good luck” (i.e., more benign macroeconomic shocks hitting the U.S. economy since the

This paper is a substantially revised version of a paper previously circulated under the title “Assessing Different Drivers of the Great Moderation in the U.S.” We are grateful to the Editor, William A. Barnett, an associate editor, and two anonymous referees for their comments and suggestions, which greatly improved the quality of the paper. We also thank Viola Angelini, Giovanni Di Bartolomeo, Margherita Fort, Francesco Lisi, Giovanni Lombardo, Thomas Lubik, Fabio Milani, Michael Reiter, Paolo Surico, and seminar participants at the Society for Computational Economics (Limassol), the Far Eastern Meeting of the Econometric Society (Beijing), the First Piero Moncasca Money–Macro Workshop (Pavia), and the second ICE³ (Rimini) for helpful suggestions on earlier drafts of the paper. Financial support by the Italian Ministry of University and Research is gratefully acknowledged (PRIN 2005-N. 2005132539). All remaining errors are mine. The opinions expressed in this contributions are not necessarily those of the Bank of Finland. Address correspondence to: Efrem Castelnuovo, Department of Economics, University of Padua, Via del Santo 33, I-35123 Paduva (PD), Italy; e-mail: efrem.castelnuovo@unipd.it.

mid-1980s) and “good policy” (i.e., a shift from “passive” to “active” monetary policy leading to better management of inflation and output volatility). If the Great Moderation is mostly due to the former driver, then nothing in principle can rule out a return to the high-volatility scenario experienced in the 1960s and 1970s.² In contrast, if a switch to a more aggressive monetary policy is the main cause of higher U.S. macroeconomic stability, then the high-volatility scenario is unlikely to return as long as monetary policymakers keep fighting inflation aggressively enough.³

Researchers have employed counterfactual simulations to assess the relative merits of luck and policy and possibly identify the “smoking gun.” Although some authors have chosen to condition their simulations on scenarios admitting a unique solution under rational expectations [e.g., Stock and Watson (2002, 2003), Smets and Wouters (2007)], part of the literature has dealt with the issue of *indeterminacy*.

It is well known that, under passive monetary policy, new-Keynesian dynamic stochastic general equilibrium (DSGE) models are prone to indeterminacy when solved for rational expectations; i.e., different equilibrium paths of the endogenous variables are consistent with the same model parameter values as well as realizations of the structural shocks. In the context of modern new-Keynesian models of the business cycle, Lubik and Schorfheide (2003) have shown how to simulate under indeterminacy, i.e., how to pick a single equilibrium out of the set of admissible ones.

Several authors have employed such approach to perform counterfactual experiments. Typically, the reference criterion adopted to select an equilibrium under indeterminacy has been that of continuity; i.e., impulse responses to structural shocks on impact are required to be “continuous” when moving from indeterminacy to the boundary of the determinacy region.⁴ As plausible as it is, this baseline solution is not the only sensible one researchers may adopt to simulate under indeterminacy.⁵ Indeed, Lubik and Schorfheide (2004) and Justiniano and Primiceri (2008b) estimate a “perturbation” of the baseline solution, and find such perturbation to be empirically important.⁶ In general, one may think of different solutions under indeterminacy meeting some “minimum number of requirements” to be judged as “economically sensible.” Obviously, such different solutions may very well induce different simulated moments of interest, thus affecting the assessment of the relative importance of the good policy vs. good luck drivers.

To date, not much is known about the impact of this “solution uncertainty under indeterminacy” as regards this debate. This paper makes a step in this direction by performing counterfactual simulations with a version of the small-scale new-Keynesian DSGE model popularized by Woodford (2003). In particular, we compare the results obtained with the baseline continuity to those conditional on a somewhat less restrictive, but still economically meaningful, selection criterion. In short, we work with perturbations of the baseline solution to account for alternative transmission mechanisms from the structural shocks to the endogenous variables.

For each given transmission to be judged economically meaningful, we require that the impulse responses associated with it be in line with conventional wisdom. In spirit, this equilibrium selection strategy lines up with the “sign restriction” approach proposed by Canova and Pina (1999) and Uhlig (2005) for the identification of structural shocks in the VAR context.⁷

Our main findings are as follows. First, counterfactual simulations conducted under continuity tend to associate the Fed’s systematic conduct with a drop in the inflation volatility, and milder macroeconomic shocks with a drop in the volatility of output growth. However, such association is not warranted when the sign restrictions approach is implemented, which reveals that the impact of good policy on the volatility of interest is very difficult to assess due to the uncertainty surrounding it. Second, whereas under the baseline solution [and our model calibration, which relies on Lubik and Schorfheide’s (2004) estimates] the shift toward a more aggressive monetary policy induces a drop of *both* inflation and output growth variability, sign restrictions resurrect the inflation/output volatility tradeoff; i.e., tighter monetary policy is associated with *higher* output growth volatility for a nonnegligible share of realizations. This latter result suggests that the uncertainty surrounding the relative role of the two analyzed drivers of the Great Moderation is somewhat larger than that suggested by the pure continuity solution.

Before we move to our analysis, it is important to stress that the literature has considered other potentially important drivers of the Great Moderation. McConnell and Perez-Quiros (2000) identify a change in the behavior of inventories in the 1980s, and claim that improved inventory management is possibly one of the drivers of the Great Moderation. Improved inventory management may find its rationale in advances in information technology [Kahn et al. (2002)].⁸ Another likely relevant source of macroeconomic moderation is the variation in financial frictions experienced by the U.S. economy. Campbell and Hercowitz (2006) and Dynan et al. (2006) document easier access to external financing by households since the beginning of the 1980s, a fact interestingly squaring with the drastic reduction in volatility of the time series of durables and investments, above all residential ones, as documented by—among others—Stock and Watson (2002) and Dynan et al. (2006). Accounting for these drivers would render the framework we employ more realistic and our investigation more complete. We leave the analysis of these possibly important drivers to future research.

The paper is structured as follows. Section 2 describes the model we employ for our counterfactual exercises as well as the two equilibrium selection strategies under indeterminacy we focus on: continuity and sign restriction. Section 3 explains the alternative scenarios we investigate and presents our results. Section 4 scrutinizes the robustness of our findings, compares the ranges of impulse distortions admitted under indeterminacy by our selection strategy vs. that proposed by Lubik and Schorfheide (2004), and contrasts the conditional correlations arising under continuity vs. sign restrictions. Section 5 concludes.

2. MACROECONOMIC FRAMEWORK

We begin our analysis by replicating—at least to a first approximation—the Great Moderation facts with a small-scale new-Keynesian DSGE model of the type popularized by Woodford (2003). This model (or similar models) has been shown to be able to successfully track U.S. inflation and output in the post-WWII period [Lubik and Schorfheide (2004), Boivin and Giannoni (2006), Benati and Surico (2008, 2009)]. The version of the model proposed by Lubik and Schorfheide (2004) reads as follows:⁹

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(x_t - z_t), \tag{1}$$

$$x_t = E_t x_{t+1} - \tau(R_t - E_t \pi_{t+1}) + g_t, \tag{2}$$

$$R_t = (1 - \rho)[\rho_\pi \pi_t + \rho_x(x_t - z_t)] + \rho R_{t-1} + \varepsilon_t^{\text{MP}}, \tag{3}$$

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z, g_t = \rho_g g_{t-1} + \varepsilon_t^g, \tag{4}$$

where x stands for real output, π represents inflation, R is the short-term nominal interest rate, z captures exogenous shifts of the marginal costs of production, g is a demand disturbance, and ε^{MP} is a monetary policy shock.¹⁰ The random variables z and g follow AR(1) processes whose roots are—respectively— ρ_z and ρ_g . The shocks ε^z , ε^g , and ε^{MP} are white noise stochastic elements whose variance is, respectively, $\sigma_{\varepsilon^z}^2$, $\sigma_{\varepsilon^g}^2$, and $\sigma_{\varepsilon^{\text{MP}}}^2$.

Equation (1) is the Euler equation maximizing the profit of the representative monopolistically competitive firm, whose discount factor is identified by the parameter β . Prices are sticky due either to a Calvo-type rigidity that allows only a fraction of firms to reoptimize their prices or to quadratic adjustment costs. The slope coefficient κ relates output and marginal costs to the inflation rate. Equation (2) is a log-linearized IS curve stemming from the household’s intertemporal problem, in which consumption and bond holdings are the control variables. Contemporaneous output is driven both by expectations for future realizations of the business cycle and by the ex ante real interest rate, the impact of the latter being regulated by the intertemporal elasticity of substitution τ . Finally, equation (3) is an interest rate rule according to which the central bank adjusts the policy rate in response to fluctuations in inflation and output, the latter in deviation with respect to marginal costs. We interpret the random variable $\varepsilon_t^{\text{MP}}$ as the monetary policy shock.

2.1. Equilibrium Selection Under Indeterminacy: Continuity

The linear rational expectations model described above can be associated to a unique solution as long as the Taylor principle is satisfied, i.e., the condition

$$\rho_\pi > 1 - \frac{(1 - \beta)}{\kappa} \rho_x$$

is met [Clarida et al. (2000), Woodford (2003), Lubik and Marzo (2007)]. If this condition does not hold—i.e., if monetary policy is passive—multiple equilibria arise. Lubik and Schorfheide (2004) and Belaygorod and Dueker (2009) estimate the new-Keynesian model (1)–(4) and show that the indeterminacy scenario is supported by the data from the 1960s and 1970s, whereas the much more aggressive monetary policy stance of the 1980s and 1990s has probably implied the existence of a unique equilibrium.¹¹

Lubik and Schorfheide (2003) propose a methodology for simulating the model under indeterminacy. First, they rewrite the above-presented DSGE model in its “canonical form” (Sims, 2001),

$$\Gamma_0(\theta)\xi_t = \Gamma_1(\theta)\xi_{t-1} + \Psi(\theta)\varepsilon_t + \Pi(\theta)\eta_t,$$

where $\xi_t = [x_t, \pi_t, R_t, E_t x_{t+1}, E_t \pi_{t+1}, g_t, z_t]'$, $\varepsilon_t = [\varepsilon_t^{\text{MP}}, \varepsilon_t^\pi, \varepsilon_t^x]'$, and θ is the vector collecting the parameters of the model. Importantly, $\eta_t = [(x_t - E_{t-1}x_t), (\pi_t - E_{t-1}\pi_t)]'$ is the vector collecting the endogenous forecast errors of the system. Then, they show that the generic expression for the solution of the endogenous forecast errors reads

$$\eta_t = [A(\theta) + B(\theta)M]\varepsilon_t + B(\theta)\zeta_t, \quad (5)$$

where A and B are, respectively, (2×3) and (2×1) matrices constructed by implementing the generalized Schur decomposition while searching for the nonexplosive solution(s) of the system, $\zeta_t \sim \text{i.i.d. } (0, \sigma_\zeta^2)$ is a “sunspot,” nonfundamental shock possibly hitting the economy, and $M = [M_R, M_g, M_z]$ is the (1×3) vector picking up one out of the many possible equilibria under indeterminacy.¹² If the system features a unique solution under rational expectations, then $B(\theta) = [0, 0]'$, and the mapping going from fundamental shocks to endogenous forecast errors is *uniquely* determined by the vector $A(\theta)$. By contrast, indeterminacy implies *two* key departures with respect to uniqueness [Lubik and Schorfheide (2003)]. First, it allows for the presence of a sunspot shock, i.e., a nonfundamental shock hitting the economy and leading to inefficient fluctuations. Equation (5) shows how the shock ζ_t influences the endogenous forecast errors of the system.¹³ Second, and more importantly, the transmission going from shocks to endogenous variables of the system is influenced by the vector M . This implies that, for a given model calibration and for given realizations of the structural shocks, a *multiplicity of stable paths* for the endogenous variables of the system may arise.¹⁴ Technically, it is possible to index these paths via the (1×3) vector M . In other words, simulations under indeterminacy require the researcher to select one out of the many equilibria, and such selection is performed by picking some values for the vector M according to a given criterion.

Lubik and Schorfheide (2004) adopt as a baseline solution the continuity one. In a nutshell, for every vector of parameters θ belonging to the indeterminacy region, one may construct a vector $g(\theta)$ that lies on the boundary of the determinacy region and choose $M = M^*$ such that the responses of ξ_t to ε_t conditional on

a given θ mimic the ones conditional on $g(\theta)$; i.e., M^* is the M vector that minimizes the discrepancy between $\partial\xi/\partial\varepsilon'(\theta, M)$ and $\partial\xi/\partial\varepsilon'(g(\theta))$.¹⁵ Once the vector M^* , has been picked, simulations under indeterminacy can be performed. As already stressed, the continuity solution has been adopted by a variety of studies on inflation dynamics and on the good policy–good luck debate.¹⁶

2.2. An Alternative Selection Strategy: Sign Restrictions

Of course, although the continuity solution is surely appealing, other equilibria may be chosen sensibly according to some economic criterion.¹⁷ Suppose it is possible to sample realizations of the vector of free parameters M^{free} from some density. Then employ the j th M^{free^j} to perturb the continuity solution M^* as follows:

$$M^j = M^* + M^{\text{free}^j}. \quad (6)$$

Obviously enough, different vectors $M^{\text{free}^j} = [M_{\text{MP}}^j, M_g^j, M_z^j]'$ will lead to the selection of different equilibria, and different realizations of the endogenous variables will occur. Given the importance that equilibrium selection assumes in the computation of the model-consistent (theoretical) moments of interest, an investigation on the robustness to the choice of alternative equilibria of the conclusions drawn under continuity is warranted.

To be interesting, such equilibria must possess some plausibility from an economic standpoint. As an alternative to continuity, we propose a sign restrictions based strategy to select equilibria under indeterminacy. Given a randomly drawn vector M^{free^j} , we check if the on-impact impulse response functions $\partial\xi_{t=0}/\partial\varepsilon'(\theta, M_j)$ behave as suggested by conventional wisdom.¹⁸ In particular, we require (i) a (mathematically) *positive* monetary policy shock *not to decrease* the nominal interest rate and *not to increase* output and inflation;¹⁹ (ii) a (mathematically) *positive* nonpolicy demand shock *not to decrease* output, inflation, and the policy rate; and (iii) a (mathematically) *positive* technological shock *not to increase* inflation and the policy rate and *not to decrease* output. Table 1 collects the sign restrictions that must be induced by a randomly drawn M^{free^j} vector for such a vector not to be rejected.²⁰ In spirit, this approach is close to the “agnostic” identification of structural shocks in SVARs put forth by Canova and Pina (1999) and Uhlig (2005).

Our algorithm to draw and assess the j th proposal M^{free^j} works as follows. Given θ and $M^*(\theta)$, we

- (1) draw $M^{\text{free}^j} \sim N(0_{1 \times 3}, \text{diag}(1_{1 \times 3}))$, the distribution employed by Lubik and Schorfheide (2004) as prior density for the estimation of the selection matrix;²¹
- (2) compute M^j according to (6);
- (3) compute the on-impact impulse response functions $\partial\xi_{t=0}/\partial\varepsilon'(\theta, M^j)$;
- (4) if $\partial\xi_{t=0}/\partial\varepsilon'(\theta, M^j)$ meet the sign restrictions collected in Table 1, simulate the moments of interest under indeterminacy conditional on M^j and store them; otherwise, reject the proposed M^{free^j} and go back to step (1).

TABLE 1. Sign restrictions for the selection of the M free vector

	π	x	R
$\varepsilon_t^{\text{MP}}$	≤ 0	≤ 0	≥ 0
ε_t^g	≥ 0	≥ 0	≥ 0
ε_t^z	≤ 0	≥ 0	≤ 0

Note: Restrictions applied to the on-impact reaction of the endogenous variables to positive realizations of the structural shocks.

3. GOOD POLICY VERSUS GOOD LUCK: COUNTERFACTUALS AND THE ROLE OF EQUILIBRIUM SELECTION

We now turn to the assessment of the relative merits of good policy and good luck in light of the previously discussed selection criteria. To do so, we allow for shifts in the values for the policy parameters $\Delta_{\text{policy}}^j = \{\rho_\pi^j, \rho_x^j, \rho^j\}$ as well as the standard deviations of the shocks $\Delta_{\text{luck}}^j = \{\sigma_{\varepsilon^z}^j, \sigma_{\varepsilon^g}^j, \sigma_{\varepsilon^{\text{MP}}}^j\}$, $j \in \{\text{pre-}'79, \text{post-}'82\}$, and we fix the remaining parameters $\Delta_{\text{structure}} = \{\beta, \kappa, \tau, \rho_z, \rho_g\}$.²² We calibrate the model (see Table 2) by borrowing the posterior estimates (mean values) of the parameter of interest by Lubik and Schorfheide (2004),²³ with two exceptions. We set the intertemporal elasticity of substitution τ to 0.05, a value in line with recent estimates by Fuhrer and Rudebusch (2004) and Benati and Surico (2008, 2009). Moreover, we set the $\rho_\pi^{\text{post-}'82} = 1.5$, thus adopting the calibration proposed by Taylor (1993) and Christiano et al. (2005), which also belongs to the 90% credible set estimated by Lubik and Schorfheide (2004). To highlight the relative importance of the systematic monetary policy switch vs. the switch in the structural shocks, we set $\sigma_\zeta = 0$; i.e., we offset the role played by the sunspot shock under indeterminacy.²⁴

We consider the following three scenarios:

- “*Theoretical.*” We compute inflation and output growth variability ratios constructed by comparing realizations of volatilities (standard deviations) of inflation and output growth stemming from the theoretical scenario $\{\Delta_{\text{policy}}^{\text{post-}'82}, \Delta_{\text{luck}}^{\text{post-}'82}\}$ with those stemming from the theoretical scenario $\{\Delta_{\text{policy}}^{\text{pre-}'79}, \Delta_{\text{luck}}^{\text{pre-}'79}\}$. This simulation is performed to assess the ability of the model to replicate the Great Moderation facts.
- “*Good policy.*” We compute the above mentioned ratios by comparing realizations from the counterfactual good policy scenario $\{\Delta_{\text{policy}}^{\text{post-}'82}, \Delta_{\text{luck}}^{\text{pre-}'79}\}$ with those coming from the theoretical $\{\Delta_{\text{policy}}^{\text{pre-}'79}, \Delta_{\text{luck}}^{\text{pre-}'79}\}$. With this simulation we counterfactually “plant Volcker–Greenspan” in the 1960s and 1970s to gauge the effect that better monetary policy would have played in those

TABLE 2. Calibration of the DGP new-Keynesian model

	$\Delta_{\text{policy}}^{\text{pre-'79}}$	$\Delta_{\text{policy}}^{\text{post-'82}}$
ρ_{π}	0.89	1.5
ρ_x	0.15	0.30
ρ	0.53	0.84
	$\Delta_{\text{luck}}^{\text{pre-'79}}$	$\Delta_{\text{luck}}^{\text{post-'82}}$
σ_{ε^z}	1.16	0.64
σ_{ε^g}	0.21	0.18
$\sigma_{\varepsilon^{\text{MP}}}$	0.24	0.18
σ_{ζ}	0	—
	$\Delta_{\text{structure}}$	
β	0.99	
τ	0.05	
κ	0.75	
ρ_g	0.80	
ρ_z	0.69	

Note: Calibration: Lubik and Schorfheide’s (2004) posterior means where not otherwise indicated in the text.

years. In particular, ratios lower (higher) than unity would suggest effectiveness (noneffectiveness) of an aggressive monetary policy in dampening inflation/output growth fluctuations.

- “*Good luck.*” We compute the above-mentioned ratios by comparing realizations from the counterfactual good luck scenario $\{\Delta_{\text{policy}}^{\text{pre-'79}}, \Delta_{\text{luck}}^{\text{post-'82}}\}$ with those coming from the theoretical $\{\Delta_{\text{policy}}^{\text{pre-'79}}, \Delta_{\text{luck}}^{\text{pre-'79}}\}$. With this simulation we counterfactually plant the more benign shocks of the 1980s and 1990s in the 1960s and 1970s, to gauge the effect that milder innovations would have played in those years. Ratios lower than unity would suggest effectiveness (noneffectiveness) of milder structural shocks in dampening inflation/output growth fluctuations.

These experiments are conducted as follows. For each scenario, we simulate 30,000 pseudo-subsamples of length comparable to that of the two subsamples 1960Q1–1979Q2/1982Q4–1997Q4, i.e., 78 observations (periods) for the first subsample, and 61 for the second one. We focus on these subsamples to follow Lubik and Schorfheide (2004), whose estimates we borrow to calibrate our model (see Table 2). For each simulation, in each period we draw realizations of the structural shocks from zero-mean Normal densities, i.e., $\varepsilon_t^{\text{MP}} \sim N(0, \sigma_{\varepsilon^{\text{MP}}}^2)$, $\varepsilon_t^z \sim N(0, \sigma_{\varepsilon^z}^2)$, $\varepsilon_t^g \sim N(0, \sigma_{\varepsilon^g}^2)$. The model simulations are stochastically initialized

with 100 pseudo-observations, which are then discarded. Once these simulations have been performed, we compute volatility ratios as described above.

A note on the computation of the theoretical measure of output growth is warranted. The measure of output x_t simulated by the model is log-output y_t in deviations with respect to its long-run trend y_t^{tr} . In estimating their model, Lubik and Schorfheide (2004) approximate such long run trend with the Hodrick–Prescott filter. To compute the output growth rate, we computed y_t^{tr} as the HP filter of the real GDP (source: Federal Reserve Bank of St. Louis) in the sample 1954Q3–2007Q2, and applied the following formula: $\Delta y_t = \Delta x_t + \Delta y_t^{\text{tr}}$.²⁵ Justiniano and Primiceri (2008a) show that the HP-detrended output is empirically close to the theoretical concept of output gap in their model, i.e., log deviation of real output with respect to its *frictionless* counterfactual level.²⁶

3.1. Baseline Results: Continuity

As already pointed out, the quarterly growth rate of U.S. real output—as measured by its standard deviation—has declined by half since the mid-1980s, whereas quarterly inflation’s variability has fallen by about two-thirds.

Table 3 collects the outcome of our simulations based on the continuity solution as regards simulations under indeterminacy. First of all, the theoretical scenario suggests a fall of about 25% of output growth’s volatility and 55% of inflation’s. Moreover, when considering the overall distribution of the ratios of interest, the model predicts a drop of about 40% of output growth and almost 70% of inflation (figures suggested by the fifth percentile of the distribution). In our tables, we do not report simulated statistics for the policy rate, which is typically not investigated in this type of analysis. For the sake of completeness, the model predicts a drop of about 25% (95th percentile of the distribution), larger than the actual drop of the federal funds rate, i.e., 12% when conditioning on the two subsamples indicated earlier. Very similar figures for the interest rate are obtained with the sign restriction–selection strategy, whose results are discussed in Section 3.2. Following most of the literature on the Great Moderation, we focus on the drop in the volatilities of inflation and output growth.

Although from a qualitative standpoint the model is able to replicate the Great Moderation, our calibrated framework slightly underpredicts the actual fall in inflation volatility, and predicts just half of the volatility drop of the growth rate of output. Other authors are more successful in replicating the facts. 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 of about 25%, and a drop of inflation variability of about 75%.²⁷ Smets and Wouters (2007) estimate barely similar figures—the fall in output growth’s variability reads 35%, inflation’s 58%.²⁸ These authors employ large-scale models of the business cycle and deal with a larger set of shocks and frictions. In particular, a shock that we do not model, i.e., the investment-specific shock, turns out to be the main driver of output growth according to Justiniano

TABLE 3. Counterfactual standard deviations of output growth and inflation: Benchmark scenario

	Theoretical	Counterf.: good policy	Counterf.: good luck
Panel A—Continuity			
Inflation	0.46 [0.33,0.63]	0.62 [0.57,0.66]	0.77 [0.72,0.82]
Output	0.75 [0.61,0.91]	0.90 [0.88,0.92]	0.86 [0.85,0.87]
Panel B—Sign restrictions			
Inflation	0.44 [0.29,0.64]	0.59 [0.40,0.84]	0.76 [0.68,0.83]
Output	0.74 [0.60,0.91]	0.89 [0.74,1.08]	0.86 [0.84,0.87]

Note: Median and [5th, 95th] percentiles reported in the table. “Output” refers to output growth. Theoretical scenarios: ratio of standard deviations (stds) implied by the calibrated models in the second (numerator) to the first (denominator) subsamples. Good policy scenarios: ratio of counterfactual stds when in the first subsample we replace the Taylor rule calibration of the second subsample. Good luck scenarios: ratio of counterfactual stds when in the first subsample we replace the distributions of the shocks of the second subsample. Continuity: Selection of the equilibrium under indeterminacy according to Lubik and Schorfheide’s (2004) baseline strategy. Sign restrictions: Perturbation of the continuity solution as explained in the text.

and Primiceri (2008b), above all during the 1960s and 1970s. The relevance of this shock is supported also by Smets and Wouters (2007). As anticipated in the Introduction, another likely relevant source of moderation of the business cycle is the variation in financial frictions experienced by the U.S. economy, also an ingredient we miss accounting for.²⁹ Thus, our quantitative conclusions on the relevance of our shocks on the real side of the economy, i.e., output growth, should be taken with a grain of salt. However, this does not affect our main point, i.e., the fragility of conclusions drawn on the basis of a given strategy of equilibrium selection under indeterminacy.

When turning to counterfactuals, under good policy the model suggests a fall in *both* output growth and inflation volatility. In fact, the impact over the two objects of interest is very different. Although the impact on inflation volatility is pretty visible (the theoretical reduction amounts to 38%), that on output growth is much more moderate (10%). Interestingly, and contrary to what one could expect, in correspondence to the shift from passive to active systematic monetary, the inflation–output volatility trade-off does *not* emerge. This is due to the inefficient fluctuations that indeterminacy is associated to, which are due to higher persistence of the variables of interest (above all inflation) in equilibrium [see Lubik and Schorfheide (2004)]. Then, when an aggressive policy enters the picture, such inefficient fluctuations are discarded, and the *whole* economic system is less volatile.³⁰ Moving to the second counterfactual, we notice that more benign shocks

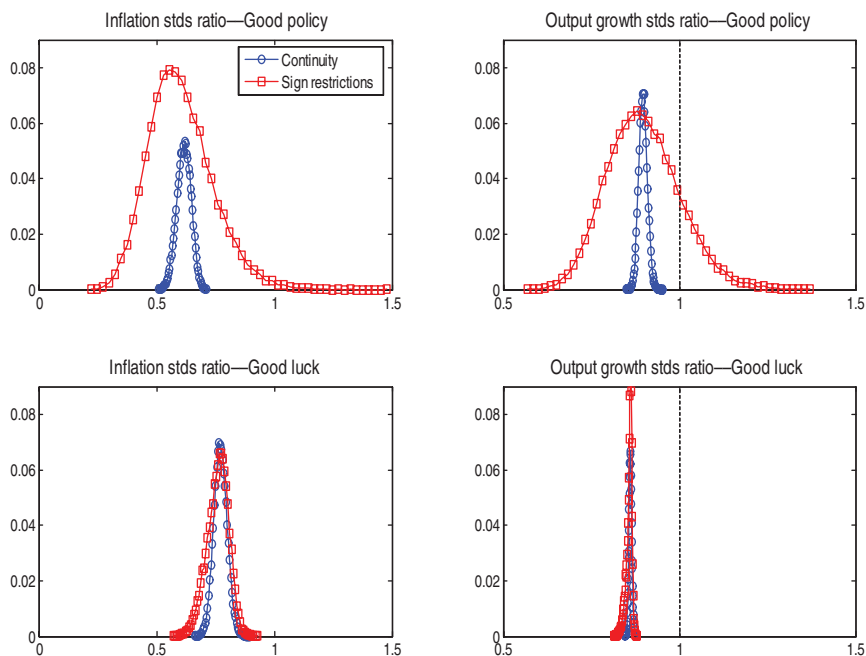


FIGURE 1. Baseline scenario: continuity vs. sign restrictions. Explanations of the selection criteria in the text.

in the 1960s and 1970s would have induced more moderate economic fluctuations, as expected. Figure 1 depicts the densities of the scenarios just commented on.

The absence of a metric and of a formal statistical analysis renders the attribution of the relative merits of good luck and good policy somewhat arbitrary. However, it is noticeable that, conditional on this model and the calibration we adopted, good policy might have exerted a stronger effect on inflation stabilization than good luck, whereas the latter might have been more effective in stabilizing output growth.³¹ Thus, our baseline exercise supports the role possibly played by the Fed in the 1980s and 1990s in stabilizing the volatility of the inflation rate, as also suggested by Cogley and Sargent (2005), Mumtaz and Surico (2008), and Lubik and Surico (in press). By contrast, business cycle fluctuations seem to have been mainly driven by the macroeconomic shocks hitting the economy, a conclusion drawn also by Stock and Watson (2002 and 2003), Primiceri (2005), Sims and Zha (2006), Canova et al. (2008), Smets and Wouters (2007), Canova and Gambetti (in press), and Justiniano and Primiceri (2008b).³²

To reiterate, our benchmark exercise suggests that, for a given model calibration and under continuity, *both* output growth and inflation volatility fall as a reaction to a systematically tighter monetary policy. Is this result robust to the selection of alternative, economically sensible equilibria under indeterminacy? We tackle this issue in the next section.

3.2. Resurrecting the Inflation–Output Volatility Tradeoff: Sign Restrictions

We now turn to the alternative sign-restrictions selection strategy. Table 3, bottom panel, reports the corresponding results.³³ This exercise reveals that the results achieved under continuity are robust to the employment of alternative selection vectors as far as the theoretical and good luck scenarios are concerned. Interestingly, a different story may be told as regards the good policy counterfactual.³⁴ In this case, the sign restrictions strategy suggests a much greater uncertainty for both inflation and output growth volatility ratios. The effect on the former is indeed large, and leads to a much wider domain of the density of the stds ratio than the one obtained under continuity. This suggests that such uncertainty propagates strongly in the system, and one may find realizations on the inflation ratio under good luck more favorable than some of those under good policy even if, for most of the realizations, good policy is confirmed as the more powerful of the two drivers in this respect.

Importantly enough, equilibrium uncertainty—which originates from the uncertainty over the M free vector in the simulation—possibly leads to an *increase* of the output growth volatility as a consequence of the shift toward a more aggressive monetary policy. This is due to the interaction between large shocks—this scenario is simulated under the bad luck shocks Δ_{luck}^2 —and the contrast between good and bad monetary policy. In particular, bad monetary policy induces indeterminacy and allows for a vector of different solutions that is investigated much more widely under sign restrictions. This is so because sign restrictions is not forced to match the impulse responses of the model under indeterminacy with those at the boundary of the determinacy/indeterminacy territory, whereas continuity is identified by such a criterion. This allows the solutions picked up via sign restrictions to be possibly less connected to those under uniqueness. Hence, sign restrictions is likely to scrutinize more fully the span of solutions under passive monetary policy, thus offering a more complete picture of the outcomes of counterfactual simulations under indeterminacy.

According to our simulations, about 15% of the realizations of the output growth standard deviation ratios are larger than one; i.e., the output growth rate increases after a shift toward a more hawkish monetary policy. This result resurrects the inflation/output volatility trade-off, and suggests that conclusions drawn under continuity are surrounded by a possibly large uncertainty.

4. ROBUSTNESS CHECKS AND FURTHER INVESTIGATIONS

4.1. Robustness Checks

Given that our conclusions hinge upon exercises conducted with a calibrated—as opposed to estimated—model, we engage in different perturbations of the benchmark calibration—performed one at the time—to gauge the robustness of their results. We investigate along the following dimensions:

- *Just inflation parameter* (“*Just inflation param.*”). We assess further the role *individually* played by the policy parameters in these simulations. In particular, the parameter ρ_π deserves specific attention. Then we redo our theoretical and counterfactual simulations by shifting this parameter uniquely while leaving the other policy parameters in the Taylor rule fixed at $\Delta_{\text{post}}^{\text{policy}-82}$.
- *Parameter uncertainty* (“*Param. uncertainty*”). We investigate the role of parameter uncertainty surrounding the structure of the economy. We concentrate on three of the parameters belonging to the vector $\Delta_{\text{structure}}$: the slope of the new-Keynesian Phillips curve κ , the persistence of the technological shock ρ_z , and the persistence of the nonpolicy demand shock ρ_g . In particular, for each simulation in each scenario—*theoretical*, *good policy*, and *good luck*—we draw from the following distributions: $\kappa \sim N(0.75, 0.2104^2)$, $\rho_z \sim N(0.8, 0.0305^2)$, $\rho_g \sim N(0.69, 0.0427^2)$. The moments of the distributions are calibrated to replicate the posterior densities proposed by Lubik and Schorfheide (2004, Table 3, “Pre-Volcker” scenario), which we assumed to be normally distributed.³⁵
- *Sunspot shocks* (“*Sunspot shocks*”). We also check whether and how our results change when a sunspot shock is admitted to hit the economy under indeterminacy. In particular, we draw from $\zeta \sim N(0, 0.23^2)$, a calibration coming from Lubik and Schorfheide (2004).
- *Milder structural shocks* (“ Δ_{luck}^2 ”). Following Boivin and Giannoni (2006), we consider a different set of shock distributions when running our good policy counterfactuals. To reiterate, our good policy simulations have admitted a change in systematic U.S. monetary policy conditional on the set of shocks $\Delta_{\text{luck}}^1 = \{\sigma_{\varepsilon^z}^1, \sigma_{\varepsilon^g}^1, \sigma_{\varepsilon^{\text{MP}}}^1\}$. We then repeat our good policy counterfactual by conditioning on the different set of shocks $\Delta_{\text{luck}}^2 = \{\sigma_{\varepsilon^z}^2, \sigma_{\varepsilon^g}^2, \sigma_{\varepsilon^{\text{MP}}}^2\}$. Notice that the theoretical scenario requires, by construction, two different sets of shocks (to account for the good luck part of the story), which would lead us to our benchmark results, whereas the good luck results reported among our benchmark case already condition on the milder shocks Δ_{luck}^2 . Thus, for this scenario, we just focus on the good policy counterfactual.
- *Higher intertemporal elasticity of substitution* τ . Our exercises were conducted by conditioning on a calibrated value for the intertemporal elasticity of substitution τ equal to 0.05. Although in line with the likelihood-based estimates provided by Fuhrer and Rudebusch (2004) and Benati and Surico (2008, 2009), this calibration is much lower than the one obtained by Lubik and Schorfheide (2004). We then employ a value in line with their estimates, $\tau = 0.7$.

Table 4 collects the outcomes of our robustness checks, which corroborate our main conclusion. Indeed, sign restrictions reveal that the inflation/output volatility trade-off is possibly present across different scenarios, with the exception of the Δ_{luck}^2 one. This last finding is interesting, because it supports the interpretation proposed in the preceding section; i.e., it is the combination of passive monetary

TABLE 4. Counterfactual standard deviations of output growth and inflation: Robustness checks

		Theoretical	Counterf.: good policy	Counterf.: good luck
Panel A—Continuity				
Just infl. TR param.	Inflation	0.63 [0.46,0.84]	0.84 [0.83,0.86]	0.76 [0.72,0.80]
	Output	0.75 [0.61,0.91]	0.90 [0.88,0.91]	0.86 [0.85,0.87]
Param. uncertainty	Inflation	0.43 [0.31,0.59]	0.63 [0.60,0.67]	0.70 [0.65,0.75]
	Output	0.77 [0.63,0.94]	0.94 [0.91,0.96]	0.86 [0.85,0.87]
Sunspot shocks	Inflation	0.45 [0.32,0.62]	0.61 [0.55,0.67]	0.76 [0.71,0.83]
	Output	0.75 [0.61,0.91]	0.90 [0.88,0.92]	0.86 [0.85,0.87]
Δ^2_{luck}	Inflation	—	0.46 [0.42,0.50]	—
	Output	—	0.76 [0.75,0.77]	—
$\tau = 0.7$	Inflation	0.49 [0.38,0.63]	0.68 [0.59,0.78]	0.73 [0.70,0.77]
	Output	0.73 [0.60,0.88]	1.07 [1.03,1.11]	0.72 [0.69,0.75]
Panel B—Sign restrictions				
Just infl. param.	Inflation	0.60 [0.41,0.86]	0.81 [0.57,1.13]	0.76 [0.67,0.83]
	Output	0.75 [0.60,0.91]	0.89 [0.74,1.08]	0.86 [0.84,0.87]
Param. uncertainty	Inflation	0.41 [0.27,0.61]	0.60 [0.39,0.88]	0.70 [0.61,0.77]
	Output	0.77 [0.62,0.94]	0.93 [0.77,1.12]	0.86 [0.83,0.87]
Sunspot shocks	Inflation	0.43 [0.29,0.63]	0.59 [0.40,0.83]	0.86 [0.67,0.94]
	Output	0.74 [0.60,0.91]	0.89 [0.73,1.08]	0.86 [0.84,0.87]
Δ^2_{luck}	Inflation	—	0.44 [0.30,0.63]	—
	Output	—	0.76 [0.63,0.92]	—
$\tau = 0.7$	Inflation	0.36 [0.17,0.62]	0.51 [0.24,0.86]	0.68 [0.57,0.80]
	Output	0.76 [0.55,1.06]	1.13 [0.82,1.55]	0.74 [0.66,0.81]

Note: Median and [5th, 95th] percentiles reported in the Table. Theoretical, good policy, good luck, continuity, sign restrictions: See Table 3 caption. Just infl. TR param.: shift in the Taylor rule inflation parameter only. Param. uncertainty: stochastic structural parameters, densities indicated in the text. Sunspot shocks: sunspot shock allowed under indeterminacy. Δ^2_{luck} : Scenario simulated under second subsample's shock volatilities. $\tau = 0.7$: IES as in Lubik and Schorfheide (2004).

policy and bad luck that leads to robust rejection of the good policy only scenario. Moreover, we also verify that a higher intertemporal elasticity of substitution, although basically leaving the message coming from the theoretical simulations unchanged, induces the tradeoff even under the baseline selection criterion.³⁶

TABLE 5. Output growth stds ratio, good policy scenario: Percentage of realizations over unity

	Trade-off (%)	
	Continuity	Sign restrictions
Benchmark	0.00	15.96
Just inflation param.	0.00	15.15
Param. uncertainty	0.02	22.80
Sunspot shocks	0.00	15.15
Δ_{luck}^2	0.00	0.91
$\tau = 0.7$	99.63	71.07

Note: Benchmark: see description in the text. Just infl. TR param.: shift in the Taylor rule inflation parameter only. Param. uncertainty: realizations of the parameters of the structure of the economy drawn from densities as defined in the text. Sunspot shocks: indeterminacy scenarios simulated by allowing for a sunspot shock to hit the economy. Δ_{luck}^2 : good policy scenario simulated under second-subsample shocks volatilities.

Table 5 compares the statistics of the most striking divergence between continuity and sign restrictions: the one regarding the inflation/output volatility tradeoff. The point made by this table is clear: if one simulates under continuity, the risk of missing a counterfactual increase of output growth volatility under good policy is present. The exception is represented by the $\tau = 0.7$ case, which clearly indicates the existence of the Taylor curve under both scenarios, but lets sign restrictions be surrounded by higher uncertainty. Indeed, this finding reinforces our main messages: different selection strategies may lead to different model-consistent representations of the macroeconomic volatilities, and results obtained under continuity are somewhat fragile.

4.2. Comparison between Our M and Lubik and Schorfheide's (2004)

The analysis conducted so far has put the role of the selection vector M in evidence. Our approach focuses on the sign of the on-impact reaction of inflation, output, and interest rate to the identified structural shocks we model. Our sign requirements reflect conventional wisdom on the impulse that demand and supply shocks exert via a textbook AD/AS framework. In fact, a closer inspection of Lubik and Schorfheide's (2004) impulse responses reveals that such restrictions may be violated. In particular, as they discuss, under indeterminacy, monetary policy unexpected tightenings (Figure 3, Prior 1, p. 208) and supply shocks (Figure 5, Prior 1, p. 211) may be inflationary, whereas demand shocks could be slightly deflationary (Figure 4, Prior 1, p. 210). This is possibly due to a difference between the feasible range of our M values and their estimated selection vector.

To shed further light on how altering the transmission of fundamental shocks may affect volatility declines, Figure 2 contrasts the empirical densities of the

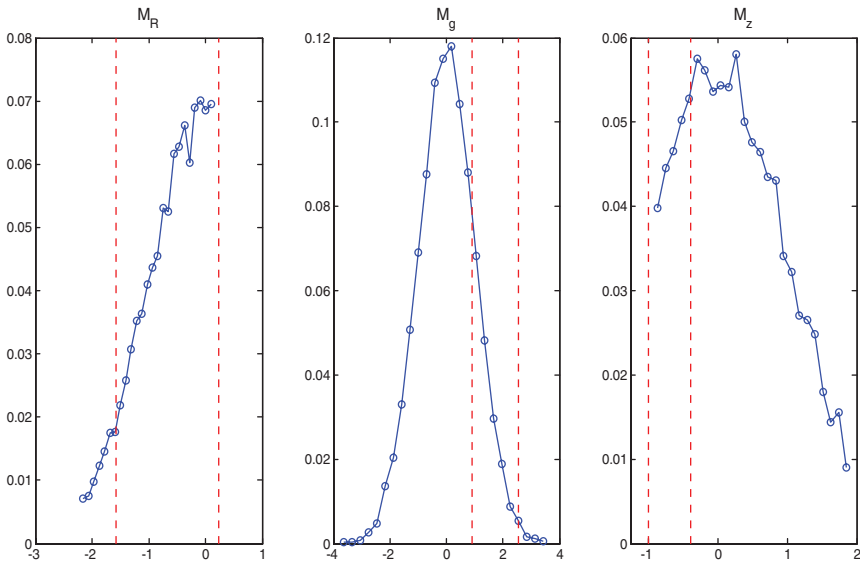


FIGURE 2. Feasible range of M values vs. Lubik and Schorfheide’s (2004) 90% credible sets. Circled lines: Feasible ranges computed with our sign restriction approach. Vertical dashed lines: Lubik and Schorfheide’s (2004) estimated 90% credible sets.

feasible draws of our M vector with the 90% credible sets by Lubik and Schorfheide (2004, p. 206). Our picks for the transmission of the monetary policy impulse M_R form a wider range than Lubik and Schorfheide’s estimates, in particular as regards negative realizations. To a large extent, however, the two overlap (the estimated 90% bounds contain about 92% of our realizations). Quite differently, our admissible ranges for M_g and M_z cover a very different set of realizations (just (respectively) 18% and 21% of our realizations are located within the estimated bounds), and switches in the estimated signs of the M -elements are present. This suggests that a much wider “uncertainty,” with respect to that estimated by Lubik and Schorfheide, could surround the transmission of the nonpolicy demand and supply shocks in this model conditional on our sign restriction criterion. Consequently, one could expect the theoretical and counterfactual standard-deviation ratios computed with Lubik and Schorfheide’s estimated M to admit less uncertainty as well. But how much less? Table 6 collects the ratios computed by assuming a normally distributed vector M free whose means and standard deviations are calibrated with Lubik and Schorfheide’s estimates.³⁷ In fact, the shrinkage of the uncertainty emerging from contrasting Table 6 with Table 3, Panel B, turns out to be very mild. Interestingly, however, the percentage of realizations suggesting the existence of a policy trade-off is halved; i.e., 7.87%. To summarize, when our sign restriction requirements are slightly relaxed, i.e., when values are allowed for M that are consistent with the violations described above, we do not find large

TABLE 6. Counterfactual standard deviations of output growth and inflation: M vector estimated by Lubik and Schorfheide (2004)

	Theoretical	Counterf.: good policy	Counterf.: good luck
Inflation	0.41 [0.29,0.58]	0.55 [0.40,0.75]	0.78 [0.74,0.83]
Output	0.73 [0.59,0.88]	0.87 [0.72,1.04]	0.86 [0.85,0.87]

Note: Median and [5th, 95th] percentiles reported in the table. Output refers to output growth. Theoretical scenarios: ratio of standard deviations (stds) implied by the calibrated models in the second (numerator) to the first (denominator) subsamples. Good policy scenarios: ratio of counterfactual stds when in the first subsample we replace the Taylor rule calibration of the second subsample. Good luck scenarios: ratio of counterfactual stds when in the first subsample we replace the distributions of the shocks of the second subsample. Perturbation of the continuity solution as explained in the text.

differences in terms of simulated ratios in general, but we find a remarkable drop of the policy trade-off realizations.

4.3. IRFs: Continuity versus Sign Restrictions

A related aspect concerns the impulse responses of our model. A comparison of the responses conditional on continuity vs. sign restriction may be informative on the different evidence in favor of the policy trade-off. Figure 3 contrasts the responses to shocks (normalized across scenarios and impulses) computed under continuity with the 90% confidence bands computed under sign restriction *conditional* on the presence of the policy trade-off (about 16% of the overall realizations). The on-impact sign and the shape of the reactions are basically the same in the two cases. The sign restriction confidence bands contain the reactions under continuity triggered by the monetary policy and marginal shocks, whereas for the nonpolicy demand shock there is a borderline situation, at least as far as inflation and policy rates are concerned.

Where do the different indications on the existence of the policy trade-off come from? The main discrepancies arise for the monetary policy and marginal cost shocks. The uncertainty suggested by the reaction to these two shocks appears to be much larger than that surrounding the reactions to the nonpolicy demand shock. Moreover, innovations in marginal costs also induce a switch in sign, as for the reactions of inflation and the policy rate. Thus, if a researcher is willing to accept that we do not know much about the dynamics under indeterminacy and just requires on-impact reactions to line up with conventional wisdom, he or she may find out that the larger ranges admitted by sign restriction (mostly due to shocks to policy and marginal costs) may pretty much reveal the existence of a policy trade-off otherwise discarded by the particular continuity choice. It is important to recall that the pure-continuity solution is de facto rejected by

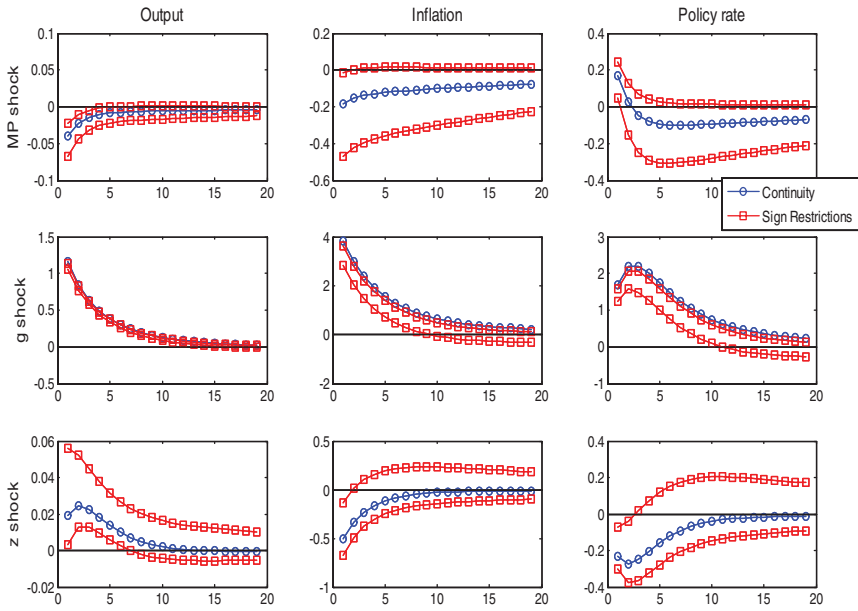


FIGURE 3. Impulse response functions: Continuity vs. sign restrictions. Circled lines: continuity. Red lines with squares: sign restrictions, 5th and 95th percentiles. Draws related to sign restrictions are conditional on the existence of the inflation–output policy trade-off. Explanations of the selection criteria in the text.

Lubik and Schorfheide’s (2004) and Justiniano and Primiceri’s (2008b) empirical investigations. Therefore, the warning launched by our exercise on the fragility of the predictions conditional on continuity appears to be well grounded.

5. CONCLUSIONS

This paper has investigated the role of equilibrium selection under indeterminacy in the assessment of the relative merits of good policy vs. good luck as drivers of the Great Moderation. Our results show that the continuity solution, often employed when simulating under indeterminacy, leads to results whose robustness may be questioned. We use sign restrictions as an alternative selection device to pick up equilibria under indeterminacy, and we show that a wide uncertainty surrounds the impact of good policy when assessed via counterfactual exercises. When simulating the good policy counterfactual (i.e., when counterfactually planting Volcker–Greenspan in the 1960s and 1970s) under sign restriction, we find that the volatility of output growth would possibly have risen under tighter monetary policy. Despite being far from rebutting the relevance of a firm systematic monetary policy, our analysis calls for other causes to explain the more moderate macroeconomic fluctuations of the 1980s and 1990s, first and foremost more benign structural shocks.

We would like to put a word of caution on what we labeled as good luck in this paper. In fact, what we called “exogenous shocks” might in fact be (at least in part) the product of economic policies. Citing Krueger (2003, p. 64), “The [shock] that leaps to mind immediately is the oil price increase in 1973–74, which I think of as having come at the end of a commodity price boom—itself a result of the dollar inflation and, for that matter, labor union strikes and things like this, which I think were partly because of uncertainty about relative prices. If so, treating those as macroeconomic shocks that are quite exogenous may understate quite significantly the role of improved monetary policy.”

To take Krueger’s consideration up, one should work with more sophisticated models able to consider the role played by exchange rate fluctuations, imperfections in the labor market, price dispersion, financial frictions, and so on, in influencing the equilibrium values of the macroeconomic variables of interest. These features are just absent in the simplified view of the world offered by the small-scale DSGE new-Keynesian monetary policy model employed in this study. A contribution highlighting the risks of focusing on a (too) limited information set when performing factual and counterfactual analysis of the business cycle has recently been proposed by Giannone et al. (2008). Using a medium-scale model with a variety of additional frictions with respect to the framework employed in this paper, Justiniano and Primiceri (2008b) offer some support to the evolution of financial frictions—not modeled here—as a possibly relevant driver of the Great Moderation, at least as far as output growth volatility is concerned. We plan to pursue further research along this avenue in the future.

NOTES

1. The quarterly growth rate of real GDP—as measured by its standard deviation—has declined by about half since the mid-1980s, whereas quarterly inflation’s variability—measured via GDP deflator—has fallen by about two-thirds. Kim and Nelson (1999), McConnell and Perez-Quiros (2000), Blanchard and Simon (2001), Stock and Watson (2002, 2003), and Kim et al. (2004) offer statistical evidence pointing toward this stylized fact. For similar evidence regarding other industrialized countries, see Blanchard and Simon (2001), Ciccarelli and Mojon (in press), and Mumtaz and Surico (2008).

2. Supporters of the “good luck” view include Stock and Watson (2002, 2003), Primiceri (2005), Sims and Zha (2006), Smets and Wouters (2007), Canova et al. (2008), Canova and Gambetti (2009), and Justiniano and Primiceri (2008a).

3. Evidence of a switch of the systematic U.S. monetary policy at the end of the 1970s is provided—among others—by Judd and Rudebusch (1998), Clarida et al. (2000), Lubik and Schorfheide (2004), Cogley and Sargent (2005), Boivin and Giannoni (2006), Belaygorod and Dueker (2007), and Mavroeidis (2009).

4. See, e.g., Castelnuovo (2006), Surico (2008), Benati and Surico (2008, 2009), Canova and Gambetti (in press) and Castelnuovo and Surico (in press), Benati (2008) estimates a small-scale new-Keynesian DSGE model with time-varying trend inflation under indeterminacy by relying on continuity.

5. Boivin and Giannoni (2006) adopt the minimal-state variable (MSV) “bubble-free” criterion proposed by McCallum (1983) to estimate the model under indeterminacy and perform counterfactual simulations.

6. See also Lubik and Surico (in press), who employ a grid search to select the equilibrium that allows a small-scale new-Keynesian model to match the Great Moderation facts as closely as possible.

7. We are grateful to an anonymous referee for suggesting this exercise to us.

8. The “inventories” driver has recently been discussed by several authors. See Maccini and Pagan (2003) for theoretical issues, and Stock and Watson (2002) and Herrera and Pesavento (2005) for empirical investigations exploring inventories as a driver of the Great Moderation.

9. The variables of the model are expressed as percentage deviation with respect to their steady state values, or in the case of output from a trend path.

10. Because the underlying model has no investment, output is proportional to consumption up to an exogenous process that can be interpreted as time-varying government spending or, more broadly, as preference change.

11. Judd and Rudebusch (1998), Clarida et al. (2000), Cogley and Sargent (2005), Boivin and Giannoni (2006), and Mavroeidis (2009) also support the monetary policy switch at the end of the Volcker experiment. For contrasting results, see Sims and Zha (2006) and Justiniano and Primiceri (2008b). Castelnovo et al. (2008) and Bianchi (2009) find that the behavior of the Federal Reserve has repeatedly fluctuated between more and less aggressive regimes over the post-WWII sample.

12. See Lubik and Schorfheide (2003) for a detailed explanation on the computation of the matrices $A(\theta)$ and $B(\theta)$.

13. To be precise, Lubik and Schorfheide (2003, 2004) show that $\eta_t = [A(\theta) + B(\theta)M]e_t + B(\theta)M_2\zeta_t^*$, where M_2 is a vector influencing the impact of the structural sunspot shock ζ_t^* on the endogenous forecast errors. Following Lubik and Schorfheide (2004), we set $\zeta_t \equiv M_2\zeta_t^*$.

14. As remarked by, e.g., Lubik and Surico (in press), according to Lubik and Schorfheide (2003, 2004) indeterminacy arises because of the presence of *too much* stability (of the continuum of solutions of the first-difference economic system) in the economy (as opposed to explosiveness/lack of stability).

15. Lubik and Schorfheide (2004, p. 200) show how to compute M^* via a least-squares criterion.

16. To reiterate, see Castelnovo (2006), Benati (2008), Benati and Surico (2008 and 2009), Surico (2008), Canova and Gambetti (2009), and Castelnovo and Surico (in press).

17. It is worth recalling the following statement by Lubik and Schorfheide (2004, p. 200): “While our baseline indeterminacy solution provides a plausible benchmark, our estimation under indeterminacy is not restricted to this specific solution.” Lubik and Schorfheide (2004) and Justiniano and Primiceri (2008b) empirically prove that deviations from continuity are supported by the data.

18. The continuity strategy considers the on-impact dynamic responses to structural shocks. Consistently, we limit our attention to the on-impact impulse responses also as regards sign restrictions.

19. Castelnovo and Surico (in press), work with pseudo-data produced via Lubik and Schorfheide’s (2004) framework under a plausible calibration and show that a negative model-consistent inflation reaction to a monetary policy shock is consistent with the “price puzzle” typically produced by possibly misspecified SVARs.

20. Under the calibrations adopted in this paper, the continuity solution meets these requirements.

21. $\text{diag}(1_{1 \times 3})$ stands for a squared matrix of dimension 3 with unitary values on the main diagonal and zeros off the main diagonal.

22. Boivin and Giannoni (2006) work with a similar small-scale model and conclude that changes in the structure of the economy have hardly driven significant changes in the volatilities of inflation and output.

23. We consider the “Pre-Volcker (Prior 2)” and “Post-1982” scenarios as reported by Lubik and Schorfheide (2004, Table 3, p. 206.)

24. For a similar strategy, see Lubik and Surico (in press) and Benati and Surico (2008, 2009). A robustness check allowing for the sunspot shock in our simulations is provided in the next section.

25. Lubik and Schorfheide (2004) employ the sample 1955Q1–1998Q4 to compute the HP-filtered log real GDP. We employed a longer sample to exploit more observations for the computation of the output trend. In fact, the representation of the trend obtained with Lubik and Schorfheide’s sample is virtually equivalent to ours.

26. An alternative, not entertained here, would be modeling a stochastic trending process for technology. As correctly pointed out by a referee, in the current model the z shock affects only marginal costs, whereas in models with a stochastic trend this shock would have an additional direct effect on output growth; i.e., it would be a shock to the changes in the growth rate of the trend. In this case, the change in trend would need not be smooth at all, as the HP trend is. The exploration on the impact of this additional channel on the transmission of fundamental shocks and its effects of variance declines is left to future research.

27. See their Table 5, first column, Panel A, p. 631, median values. When conditioning of equilibrium uniqueness, these figures read 43% (output growth) and 31% (inflation).

28. See their Table 6, p. 604, figures under “1984:1–2004:4, Model” over figures under “1966:1–1979:2, Model.”

29. Some empirical support in favor of financial frictions as a driver of the U.S. business cycle is offered, with a small-scale model similar to ours, by Castelnuovo and Nisticò (2010).

30. This is a possible outcome, but not necessarily the only possible outcome. See discussion in the next subsection.

31. Castelnuovo (2006) shows that these results, obtained under continuity, are robust to a variety of different model calibrations.

32. These results have been obtained by allowing for indeterminacy in our simulations. Of course, one may allow for a policy shift *within* the determinacy territory. We performed a set of exercises by first boosting the values of the parameters ρ_π^1 and ρ_π^2 by 30%—a choice made to have both policies induce equilibria well inside the uniqueness territory—and then performing the counterfactuals as described in the text. In the theoretical scenario, the median drop for inflation (output) turned out to be 56% (22%); in the good policy scenario, 39% (6%); in the good luck scenario, 24% (15%). Although a simulation of the policy switch conditional on uniqueness may deliver statistics in line with the Great Moderation facts, we keep investigating indeterminacy in the light of the evidence in favor of a weak response of the Fed—i.e., passive policy—to inflation fluctuations (see contributions cited in note 3) and, above all, to shed light on the role of equilibrium selection in the good policy vs. good luck discussion.

33. The rejection ratio, computed as a fraction of rejected proposals for calibrating the vector M over the total number of (feasible and unfeasible) draws, is 57%. Simulations performed by admitting larger variances of the normally distributed M free (up to 10) returned very similar results.

34. One should keep in mind that the density $h(X/Y) \neq f(X)/g(Y)$. Given that a closed-form solution for the model-consistent standard deviations cannot be derived, we keep resorting to simulations to compute the distribution of the ratios of interest in different scenarios.

35. We thank an anonymous referee for proposing these two investigations to us. Notice that, when dealing with parameter uncertainty, we simulate from the *marginal* posterior of the three parameters as estimated by Lubik and Schorfheide (2004), not from the *joint* posterior, as we should ideally do to produce an accurate Bayesian measure of parameter uncertainty.

36. Notably, under the Just inflation param. scenario, a tighter monetary policy induces to a certain percentage of realizations (15.28%), suggesting a worse outcome for inflation under aggressive monetary policy. At the first glance, this finding may appear puzzling. However, under indeterminacy, nothing in principle prevents distortions of the transmission from the inflationary shocks to inflation from being efficient. Further simulations—whose figures are not shown here, but are available upon request—highlight the role of interest rate smoothing for the stabilization of inflation in this exercise; i.e., when the higher degree of interest rate smoothing of the second subsample is admitted to operate in the counterfactual good policy exercise, inflation stabilization is clearly dampened (as already shown in Figure 1).

37. We impose a diagonal variance–covariance matrix over the volatilities of the M vector, allowing for independent draws for the elements of such vector. In so doing, we ignore the restrictions resulting from full inference.

REFERENCES

- Belaygorod, A. and M. Dueker (2007) Indeterminacy, change points and the price puzzle, *Journal of Economic Dynamics and Control* 33(3), 624–648.
- Benati, L. (2008) Are “Intrinsic Inflation Persistence” Models Structural in the Sense of Lucas (1976)? Mimeo, European Central Bank.
- Benati, L. and P. Surico (2008) Evolving U.S. monetary policy and the decline of inflation predictability. *Journal of the European Economic Association* 6(2–3), 634–646.
- Benati, L. and P. Surico (2009) VAR analysis and the Great Moderation. *American Economic Review* 99(4), 1636–1652.
- Bianchi, F. (2009) Regime Switches, Agents’ Beliefs, and Post-World War II U.S. Macroeconomic Dynamics. Mimeo, Princeton University.
- Blanchard, O. and J. Simon (2001) The long and large decline in U.S. output volatility. *Brookings Papers on Economic Activity* 1, 135–174.
- Boivin, J. and M.P. Giannoni (2006) Has monetary policy become more effective? *Review of Economics and Statistics* 88(3), 445–462.
- Campbell, J.R. and Z. Hercowitz (2006) The Role of Collateralized Households Debt in Macroeconomic Stabilization. Mimeo, Federal Reserve Bank of Chicago and Tel Aviv University.
- Canova, F. and L. Gambetti (in press) Do inflation expectations matter? The Great Moderation revisited. *American Economic Journal: Macroeconomics*. Forthcoming.
- Canova, F. and L. Gambetti (2009) Structural changes in the US economy: Is there a role for monetary policy? *Journal of Economic Dynamics and Control* 33(2), 477–490.
- Canova, F., L. Gambetti, and E. Pappa (2008) The structural dynamics of the U.S. output and inflation: What explains the changes? *Journal of Money, Credit, and Banking* 40(2–3), 369–388.
- Canova, F. and J. Pina (1999) Monetary Policy Misspecification in VAR Models. CEPR Discussion Paper 2332.
- Castelnuovo, E. (2006) Assessing Different Drivers of the Great Moderation in the U.S. Working paper 25, University of Padua.
- Castelnuovo, E., L. Greco, and D. Raggi (2008) Estimating Regime-Switching Taylor Rules with Trend Inflation. Bank of Finland research discussion paper 20.
- Castelnuovo, E. and S. Nisticò (2010) Stock market conditions and monetary policy in a DSGE model for the U.S. *Journal of Economic Dynamics and Control* 34(9), 1700–1731.
- Castelnuovo, E. and P. Surico (in press) Monetary policy, inflation expectations, and the price puzzle. *The Economic Journal*.
- Christiano, L.J. M. Eichenbaum, and C.L. Evans (2005) Nominal rigidities and the dynamic effect of a shock to monetary policy. *Journal of Political Economy* 113(1), 1–45.
- Ciccarelli, M. and B. Mojon (in press) Global inflation. *Review of Economics and Statistics*.
- Clarida, R., J. Gali, and M. Gertler (2000) Monetary policy rules and macroeconomic stability: Evidence and some theory. *Quarterly Journal of Economics* 115(1), 147–180.
- Cogley, T. and T. J. Sargent (2005) Drift and volatilities: Monetary policies and outcomes in the post WWII US. *Review of Economic Dynamics* 8(2), 262–302.
- Dynan, K.E., D.W. Elmendorf, and D.E. Sichel (2006) Can financial innovation help to explain the reduced volatility of economic activity? *Journal of Monetary Economics* 53(1), 123–150.
- Fuhrer, J.C. and G.D. Rudebusch (2004) Estimating the Euler equation for output. *Journal of Monetary Economics* 51(6), 1133–1153.
- Giannone, D., M. Lenza, and L. Reichlin (2008) Explaining the great Moderation: It is not the shocks. *Journal of the European Economic Association* 6(2–3), 621–633.
- Herrera, A.M. and E. Pesavento (2005) The decline of U.S. output volatility: Structural changes in inventory investment. *Journal of Business and Economic Statistics* 23(4), 462–472.
- Judd, John and Glenn D. Rudebusch (1998) Taylor’s rule and the Fed: 1970–1997. *Federal Reserve Bank of San Francisco Economic Review* 3, 1–16.
- Justiniano, A. and G. Primiceri (2008a) Potential and Natural Output. Mimeo, Federal Reserve Bank of Chicago and Northwestern University.

- Justiniano, A. and G. Primiceri (2008b) The time varying volatility of macroeconomic fluctuations. *American Economic Review* 98(3), 604–641.
- Kahn, J.A., M. McConnell, and G. Perez-Quiros (2002) On the causes of the increased stability of the U.S. economy. *Federal Reserve Bank of New York Economic Policy Review* 8(1).
- Kim, C. and C. Nelson (1999) Has the U.S. economy become more stable? A Bayesian approach based on a Markov-switching model of the business cycle. *Review of Economics and Statistics* 81(4), 608–616.
- Kim, C., C. Nelson, and J. Piger (2004) The less volatile U.S. economy: A Bayesian investigation of timing, breadth, and potential explanations. *Journal of Business and Economic Statistics* 22(1), 80–93.
- Krueger, A. (2003) General Discussion: Has the Business Cycle Changed? Evidence and Explanations. In Federal Reserve Bank of Kansas City, *Proceedings of the Symposium on "Monetary Policy and Uncertainty," Jackson Hole, Wyoming, August 28–30*.
- Lubik, T.A. and M. Marzo (2007) An inventory of simple monetary policy rules in a new Keynesian macroeconomic model. *International Review of Economics and Finance* 16(1), 15–36.
- Lubik, T.A. and F. Schorfheide (2003) Computing sunspot equilibria in linear rational expectations models. *Journal of Economic Dynamics and Control* 28(2), 273–285.
- Lubik, T.A. and F. Schorfheide (2004) Testing for indeterminacy: An application to US monetary policy. *American Economic Review* 94(1), 190–217.
- Lubik, T.A. and P. Surico (in press) The Lucas critique and the stability of empirical models. *Journal of Applied Econometrics*.
- Maccini, L.J. and A. Pagan (2003) Exploring the Role of Inventories in the Business Cycle. Mimeo, Johns Hopkins University and Australian National University.
- Mavroeidis, S. (in press) Monetary policy rules and macroeconomic stability: Some new evidence. *American Economic Review*.
- McCallum, B. (1983) On non-uniqueness in rational expectations models: An attempt at perspective. *Journal of Monetary Economics* 11, 139–168.
- McConnell, M. and G. Perez-Quiros (2000) Output fluctuations in the United States: What has changed since the early 1980's? *American Economic Review* 90(5), 1464–1476.
- Mumtaz, H. and P. Surico (2008) Evolving International Inflation Dynamics: Evidence from a Time-Varying Dynamic Factor Model. CEPR discussion paper 6767.
- Primiceri, G. (2005) Time varying structural vector autoregressions and monetary policy. *Review of Economic Studies* 72, 821–852.
- Sims, C.A. (2001) Solving linear rational expectations models. *Journal of Computational Economics* 20, 1–20.
- Sims, C.A. and T. Zha (2006) Were there regime switches in US monetary policy? *American Economic Review* 96(1), 54–80.
- Smets, F. and R. Wouters (2007) Shocks and frictions in US business cycle: A Bayesian DSGE approach. *American Economic Review* 97(3), 586–606.
- Stock, J.H. and M.W. Watson (2002) Has the business cycle changed and why? In M. Gertler and K. Rogoff (eds.), *NBER Macroeconomic Annual*. Cambridge, MA: MIT Press.
- Stock, J.H. and M.W. Watson (2003) Has the business cycle changed? Evidence and explanations. In Federal Reserve Bank of Kansas City, *Proceedings of the Symposium on "Monetary Policy and Uncertainty," Jackson Hole, Wyoming, August 28–30*.
- Surico, P. (2008) Monetary Policy Shifts and Inflation Dynamics. Working paper 338, Bank of England.
- Taylor, J.B. (1993) Discretion vs. policy rules in practice. *Carnegie–Rochester Conference Series on Public Policy* 39, 195–214.
- Uhlig, H. (2005) What are the different effects of monetary policy on output? Results from an agnostic identification procedure. *Journal of Monetary Economics* 52(2), 381–419.
- Woodford, M. (2003) *Interest and Prices: Foundation of a Theory of Monetary Policy*. Princeton, NJ: Princeton University Press.