

# Policy Switch and the Great Moderation: The Role of Equilibrium Selection\*

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## Abstract

'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 trade-off.

*JEL classification:* E30, E52.

*Keywords:* Great Moderation, indeterminacy, good policy, good luck, equilibrium selection.

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# 1 Introduction

The volatility of U.S. output growth and inflation has dramatically dropped since the mid-1980s.<sup>1</sup> 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 mid-1980s) and 'good policy' (i.e. a shift from 'passive' to 'active' monetary policy leading to a better management of inflation and output volatilities). 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.<sup>2</sup> By contrast, if a switch to a more aggressive monetary policy is the main responsible of the higher U.S. macroeconomic stability, then the high volatility scenario is unlikely to return as long as monetary policy makers keep fighting inflation aggressively enough.<sup>3</sup>

Researchers have employed counterfactual simulations to assess the relative merits of 'luck' and 'policy' and possibly identify the 'smoking gun'. While some authors have chosen to condition their simulations on scenarios admitting a unique solution under rational expectations (e.g. Stock and Watson (2002 and 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 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 up a single equilibrium out of the set of the admissible ones.

Several authors have employed such approach to perform counterfactual experi-

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<sup>1</sup>The quarterly growth rate of real GDP - as measured by its standard deviation - has declined by about half since the mid-1980s, while 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 and 2003), and Kim, Nelson, and Piger (2004) offer stark statistical evidence pointing towards this stylized fact. For similar evidence regarding other industrialized countries, see Blanchard and Simon (2001), Ciccarelli and Mojon (2008), and Mumtaz and Surico (2008).

<sup>2</sup>Supporters of the 'good luck' view include Stock and Watson (2002 and 2003), Primiceri (2005), Canova, Gambetti, and Pappa (2008), Sims and Zha (2006), Smets and Wouters (2007), Canova and Gambetti (2009a), and Justiniano and Primiceri (2008).

<sup>3</sup>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, Galí, and Gertler (2000), Lubik and Schorfheide (2004), Cogley and Sargent (2005), Boivin and Giannoni (2006), Belaygorod and Dueker (2009), and Mavroeidis (2009).

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

To date, not much is known on 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 as 'economically meaningful', we require that the impulse responses associated to such transmission 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.<sup>7</sup>

Our main findings read as follows. First, counterfactual simulations conducted under continuity tend to associate the Fed's systematic conduct to a drop in the inflation volatility, and milder macroeconomic shocks to a drop in the volatility of output growth. However, such association is not warranted when implementing the 'sign restrictions' approach, which reveals that the impact of 'good policy' on the volatilities of interest is very difficult to assess due the uncertainty surrounding it. Second, while under the baseline solution (and our model calibration, which relies upon Lubik and Schorfheide's

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

<sup>5</sup>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.

<sup>6</sup>See also Lubik and Surico (2008), who employ a grid search to select the equilibrium that allows a small scale new-Keynesian model to match as closely as possible the 'Great Moderation' facts.

<sup>7</sup>We are grateful to an anonymous referee for suggesting this exercise to us.

(2004) estimates) the shift towards a more aggressive monetary policy induces the drop of *both* inflation and output growth variability, sign restrictions resurrects the inflation/output volatility trade-off, i.e. a tighter monetary policy is associated to a *higher* output growth volatility for a non-negligible 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 moving 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 the improved inventory management is possibly one of the drivers of the Great Moderation. The improved inventory management may find its rationale in advances in information technology (Kahn et al (2002)).<sup>8</sup> Another likely relevant source of macroeconomic moderation is the variation in financial frictions experienced by the U.S. economy. Dynan et al (2006) and Campbell and Hercowitz (2006) document an 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), Dynan et al (2006), and Justiniano and Primiceri (2005). 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 strategy 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 in 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 versions of it) has been shown to be able

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<sup>8</sup>The 'inventories' driver has been recently 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 questioning 'inventories' as a driver of the 'Great Moderation'.

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 and 2009)). The version of the model proposed by Lubik and Schorfheide (2004) reads as follows:<sup>9</sup>

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

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

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

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

where  $x$  stands for real output,  $\pi$  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  $\varepsilon^{MP}$  is a monetary policy shock.<sup>10</sup> The random variables  $z$  and  $g$  follow AR(1) processes whose roots are - respectively -  $\rho_z$  and  $\rho_g$ . The shocks  $\varepsilon^z$ ,  $\varepsilon^g$ , and  $\varepsilon^{MP}$  are white noise stochastic elements whose variance is, respectively,  $\sigma_{\varepsilon^z}^2$ ,  $\sigma_{\varepsilon^g}^2$ , and  $\sigma_{\varepsilon^{MP}}^2$ .

Eq. (1) is the Euler equation maximizing the profit of the representative, monopolistically competitive firm whose discount factor is identified by the parameter  $\beta$ . 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  $\kappa$  relates output and marginal costs to the inflation rate. Eq. (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 on 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  $\tau$ . Finally, eq. (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  $\varepsilon_t^{MP}$  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

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

<sup>10</sup>Since 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.

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 in the 1960s and 1970s, while the much more aggressive monetary policy stance of the 1980s and 1990s has probably implied the existence of a unique equilibrium.<sup>11</sup>

Lubik and Schorfheide (2003) propose a methodology to simulate the model under indeterminacy. First, they re-write 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  $\xi_t = [x_t, \pi_t, R_t, E_t x_{t+1}, E_t \pi_{t+1}, g_t, z_t]'$ ,  $\varepsilon_t = [\varepsilon_t^{MP}, \varepsilon_t^\pi, \varepsilon_t^x]'$ , and  $\theta$  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 -  $(2 \times 3)$  and  $(2 \times 1)$  matrices constructed by implementing the generalized Schur decomposition while searching for the non-explosive solution(s) of the system,  $\zeta_t \sim i.i.d.(0, \sigma_\zeta^2)$  is a 'sunspot', non fundamental shock possibly hitting the economy, and  $M = [M_R, M_g, M_z]$  is the  $(1 \times 3)$  vector picking up one out of the many possible equilibria under indeterminacy.<sup>12</sup> 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 non-fundamental shock hitting the economy and leading to inefficient fluctuations. Eq. (5) shows how the shock  $\zeta_t$  influences the endogenous forecast errors of the system.<sup>13</sup> 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*

<sup>11</sup>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 (2008a). Castelnovo, Greco, and Raggi (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.

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

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

of *stable* paths for the endogenous variables of the system may arise.<sup>14</sup> Technically, it is possible to 'index' these paths via the  $(1 \times 3)$  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 up some values for the vector  $M$  according to a given criterion.

Lubik and Schorfheide (2004) adopt as baseline solution the continuity one. In a nutshell, for every vector of parameters  $\theta$  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  $\xi_t$  to  $\varepsilon_t$  conditional on a given  $\theta$  mimics the ones conditional on  $g(\theta)$ , i.e.  $M^*$  is the  $M$  vector that minimizes the discrepancy between  $\frac{\partial \xi}{\partial \varepsilon'}(\theta, M)$  and  $\frac{\partial \xi}{\partial \varepsilon'}(g(\theta))$ .<sup>15</sup> Once picked up the vector  $M^*$ , 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.<sup>16</sup>

## 2.2 An alternative selection strategy: Sign restrictions

Of course, while the continuity solution is surely appealing, other equilibria may be sensibly chosen according to some economic criterion.<sup>17</sup> Suppose to be able to sample realizations of the vector of free parameters  $Mfree$  from some density. Then, employ the  $j$ -th  $Mfree^j$  to perturb the continuity solution  $M^*$  as follows:

$$M^j = M^* + Mfree^j \tag{6}$$

Obviously enough, different vectors  $Mfree^j = [M_{MP}^j, M_g^j, M_z^j]'$  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 of the conclusions drawn under continuity to the choice of alternative equilibria 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

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<sup>14</sup>As remarked by e.g. Lubik and Surico (2008), according to Lubik and Schorfheide (2003 and 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).

<sup>15</sup>Lubik and Schorfheide (2004, page 200) show how to compute  $M^*$  via a least-squares criterion.

<sup>16</sup>To reiterate, see Surico (2008), Benati and Surico (2008 and 2009), Castelnuovo and Surico (2009), Castelnuovo (2006), Canova and Gambetti (2009a), and Benati (2008).

<sup>17</sup>It is worth recalling the following statement by Lubik and Schorfheide (2004, page 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 (2008a) empirically prove that deviations from 'continuity' are supported by the data.

to select equilibria under indeterminacy. Given a randomly drawn vector  $Mfree^j$ , we check if the on impact impulse response functions  $\frac{\partial \xi_{t=0}}{\partial \varepsilon^j}(\theta, M_j)$  behave as suggested by conventional wisdom.<sup>18</sup> 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;<sup>19</sup> ii) a (mathematically) *positive* non-policy 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  $Mfree^j$  vector for such a vector not to be rejected.<sup>20</sup> 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  $Mfree^j$  works as follows. Given  $\theta$  and  $M^*(\theta)$ , we

1. draw  $Mfree^j \sim N(0_{1 \times 3}, diag(1_{1 \times 3}))$ , the distribution employed by Lubik and Schorfheide (2004) as prior density for the estimation of the selection matrix;<sup>21</sup>
2. compute  $M^j$  according to eq. (6);
3. compute the on impact impulse response functions  $\frac{\partial \xi_{t=0}}{\partial \varepsilon^j}(\theta, M^j)$ ;
4. if  $\frac{\partial \xi_{t=0}}{\partial \varepsilon^j}(\theta, M^j)$  meet the sign restrictions collected in Table 1, simulate the moments of interest under indeterminacy conditional to  $M^j$  and store them; otherwise, reject the proposed  $Mfree^j$  and go back to step 1.

### 3 Good policy vs. 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 the light of the previously discussed selection criteria. To do so, we allow for shifts in the values for the policy parameters  $\Delta_{policy}^j = \{\rho_\pi^j, \rho_x^j, \rho^j\}$  as well as the standard deviations of the shocks  $\Delta_{luck}^j = \{\sigma_{\varepsilon^z}^j, \sigma_{\varepsilon^g}^j, \sigma_{\varepsilon^{MP}}^j\}$ ,  $j \in \{pre - '79, post - '82\}$ , and we

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<sup>18</sup>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'.

<sup>19</sup>Castelnuovo and Surico (2009) 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.

<sup>20</sup>Under the calibrations adopted in this paper, the 'continuity' solution meets these requirements.

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

fix the remaining parameters  $\Delta_{structure} = \{\beta, \kappa, \tau, \rho_z, \rho_g\}$ .<sup>22</sup> We calibrate the model by borrowing the posterior estimates (mean values) of the parameter of interest by Lubik and Schorfheide (2004),<sup>23</sup> with two exceptions. We set the intertemporal elasticity of substitution (IES)  $\tau$  to 0.05, a value in line with recent estimates by Fuhrer and Rudebusch (2004) and Benati and Surico (2008b). Moreover, we set the  $\rho_{\pi}^{post-'82} = 1.5$ , so 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.<sup>24</sup>

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  $\{\Delta_{policy}^{post-'82}, \Delta_{luck}^{post-'82}\}$  with those stemming from the theoretical scenario  $\{\Delta_{policy}^{pre-'79}, \Delta_{luck}^{pre-'79}\}$ . 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  $\{\Delta_{policy}^{post-'82}, \Delta_{luck}^{pre-'79}\}$  with those coming from the theoretical  $\{\Delta_{policy}^{pre-'79}, \Delta_{luck}^{pre-'79}\}$ . 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 years. In particular, ratios lower (higher) than unity would suggest effectiveness (non-effectiveness) 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  $\{\Delta_{policy}^{pre-'79}, \Delta_{luck}^{post-'82}\}$  with those coming from the theoretical  $\{\Delta_{policy}^{pre-'79}, \Delta_{luck}^{pre-'79}\}$ . With this simulation we counterfactually 'plant the more benign shocks of the 1980s and 1990s in the 1960s and 1970s', so to gauge the effect that milder innovations would have played in those

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<sup>22</sup>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.

<sup>23</sup>We consider the "Pre-Volcker (Prior 2)" and "Post-1982" scenarios as reported by Lubik and Schorfheide (2004), Table 3, page 206.

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

years. Ratios lower than unity would suggest effectiveness (non-effectiveness) 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 a 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. For each simulation, in each period we draw realizations of the structural shocks from zero-mean Normal densities, i.e.  $\varepsilon_t^{MP} \sim N(0, \sigma_{\varepsilon^{MP}}^2)$ ,  $\varepsilon_t^z \sim N(0, \sigma_{\varepsilon^z}^2)$ ,  $\varepsilon_t^g \sim N(0, \sigma_{\varepsilon^g}^2)$ . 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:  $\Delta y_t = \Delta x_t + \Delta y_t^{tr}$ .<sup>25</sup> Justiniano and Primiceri (2008b) 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.<sup>26</sup>

### 3.1 Baseline results: Continuity

As already pointed out, 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.

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 volatility and 55% of inflation's. Moreover, when

<sup>25</sup>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.

<sup>26</sup>An alternative, not entertained here, would be that of 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, while 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.

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 5th 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.

While from a qualitative standpoint the model is able to replicate the 'Great Moderation', our calibrated framework slightly under-predicts 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 (2008a) 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%.<sup>27</sup> Smets and Wouters (2007) estimate barely similar figures - the fall in output growth's variability reads 35%, inflation's 58%.<sup>28</sup> 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 and Primiceri (2008a), above all during the 1960s and 1970s. The relevance of such 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 to account for.<sup>29</sup> Then, 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. While the impact on inflation volatility is pretty visible (the theoretical reduction amounts to 38%), that on output growth is much more moderate

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

<sup>28</sup>See their Table 6, page 604, figures under "1984:1-2004:4, Model" over figures under "1966:1-1979:2, Model".

<sup>29</sup>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 (2009).

(10%). Interestingly, and contrarily 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.<sup>30</sup> Moving to the second counterfactual, we notice that more benign shocks in the 1960s and 1970s would have induced more moderate economic fluctuations, as expected. Figure 1 depicts the densities of the just commented scenarios.

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', while the latter might have been more effective in stabilizing output growth.<sup>31</sup> Then, 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 (2008). 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), Canova and Gambetti (2008b), Canova, Gambetti, and Pappa (2007), Primiceri (2005), Sims and Zha (2006), Smets and Wouters (2007), and Justiniano and Primiceri (2008a).<sup>32</sup>

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 sub-Section.

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<sup>30</sup>This is a possible outcome, but not necessarily the only possible outcome. See discussion in the next sub-Section.

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

<sup>32</sup>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 up the values of the parameters  $\rho_{\pi}^1$  and  $\rho_{\pi}^2$  by 30 percent - a choice made to have both policies to 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%). While 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 footnote 3) and, above all, to shed light on the role of equilibrium selection in the 'good policy' vs. 'good luck' discussion.

### 3.2 Resurrecting the inflation-output volatility trade-off: Sign restrictions

We now turn to the alternative 'sign-restrictions' selection strategy. Table 3 - Bottom panel reports the corresponding results.<sup>33</sup> 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.<sup>34</sup> In this case, the sign restrictions strategy suggests a much larger 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 importantly 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 - that originates from the uncertainty over the  $Mfree$  vector in the simulation - possibly leads to an *increase* of the output growth volatility as a consequence of the shift towards a more aggressive monetary policy. This is due to the interaction between large shocks - this scenario is simulated under the 'bad luck' shocks  $\Delta_{luck}^2$  - 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, while continuity is identified by such 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, so 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 towards 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.

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<sup>33</sup>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  $Mfree$  (up to 10) returned very similar results.

<sup>34</sup>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.

## 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  $\rho_\pi$  deserves a specific attention. Then, we re-do our theoretical and counterfactual simulations by shifting uniquely this parameter while leaving the other policy parameters in the Taylor rule fixed at  $\Delta_{policy}^{post-'82}$ .
- *Parameter uncertainty ('Param. uncertainty')*. We investigate the role of parameter uncertainty surrounding the structure of the economy. We concentrate on three of the parameter belonging to the vector  $\Delta_{structure}$ , i.e. the slope of the new-Keynesian Phillips curve  $\kappa$ , the persistence of the technological shock  $\rho_z$ , and the persistence of the non-policy demand shock  $\rho_g$ . 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.<sup>35</sup>
- *Sunspot shocks ('Sunspot shocks')*. We also check if and how our results change when admitting a sunspot shock 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 (' $\Delta_{luck}^2$ ')*. 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 the systematic U.S. monetary policy conditional on the set of shocks  $\Delta_{luck}^1 = \{\sigma_{\varepsilon^z}^1, \sigma_{\varepsilon^g}^1, \sigma_{\varepsilon^{MP}}^1\}$ . We then repeat our 'good policy' counterfactual by conditioning on the different set of shocks  $\Delta_{luck}^2 = \{\sigma_{\varepsilon^z}^2, \sigma_{\varepsilon^g}^2, \sigma_{\varepsilon^{MP}}^2\}$ . Notice that the 'Theoretical' scenario requires, by construction, two different sets of shocks

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<sup>35</sup>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.

(so to account for the 'good luck' part of the story), which would lead us to our benchmark results, while the 'good luck' results reported among our benchmark case already condition on the milder shocks  $\Delta_{luck}^2$ . Then, for this scenario we just focus on the 'good policy' counterfactual.

- *Higher intertemporal elasticity of substitution*  $\tau$ . Our exercises were conducted by conditioning on a calibrated value for the intertemporal elasticity of substitution  $\tau$  equal to 0.05. While being in line with the likelihood-based estimates provided by Fuhrer and Rudebusch (2004) and Benati and Surico (2008 and 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, i.e.  $\tau = 0.7$ .

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 ' $\Delta_{luck}^2$ ' one. This last finding is interesting, because it supports the interpretation proposed in the previous Section, i.e. it is the combination of 'passive monetary policy' *and* 'bad luck' that leads to robustly reject the 'good policy only' scenario. Moreover, we also verify that a higher intertemporal elasticity of substitution, while basically leaving the message coming from the 'Theoretical' simulations unchanged, induces the trade-off even under the baseline selection criterion.<sup>36</sup>

Table 5 compares the statistics of the most striking divergence between continuity and sign restrictions: the one regarding the inflation/output volatility trade-off. 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 let sign restrictions be surrounded by higher uncertainty. Indeed, this finding reinforces our main messages, i.e. different selection strategies may lead to different model-consistent representations of the macroeconomic volatilities, and results obtained under continuity are somewhat fragile.

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<sup>36</sup>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 be 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).

## 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 reveal that such restrictions may be violated. In particular, as they discuss, under indeterminacy monetary policy unexpected tightenings (Figure 3, Prior 1, page 208) and supply shocks (Figure 5, Prior 1, page 211) may be inflationary, while demand shocks could be slightly deflationary (Figure 4, Prior 1, page 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 feasible draws of our  $M$  vector with the 90% credible sets by Lubik and Schorfheide (2004, page 206). Our picks for the transmission of the monetary policy impulse  $M_R$  form a wider range with respect to 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 non-policy demand and supply shocks in this model conditional to 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 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.<sup>37</sup> In fact, the shrinkage of the uncertainty emerging by 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 slightly relaxing our sign restriction requirements, i.e. when allowing values for  $M$  that are consistent with the violations described above, we do not find large differences in terms of simulated ratios in general, but we find a remarkable drop of the policy trade-off realizations.

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

### 4.3 IRFs: Continuity vs. sign restrictions

A related aspect regards the impulse responses of our model. A comparison of the responses conditional to continuity vs. sign restriction may be informative on the different evidence in favor of the policy trade-off. Figure 3 contrasts the responses to (normalized across scenarios and impulses) shocks 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 under the two cases. The sign restriction confidence bands contain the reactions under continuity triggered by the monetary policy and marginal shocks, while for the non-policy demand shock there is a borderline situation, at least as far as inflation and policy rates are concerned.

Where does the different indication 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 appear to be much larger than that surrounding the reactions to the non-policy demand shock. Moreover, innovations to marginal costs induce also a switch in sign as for the reactions of inflation and the policy rate. Then, if a researcher is willing to accept that we do not know much on the dynamics under indeterminacy and just requires on-impact reactions to line up with conventional wisdom, 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 Lubik and Schorfheide's (2004) and Justiniano and Primiceri's (2008a) 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 for 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 have possibly risen under a tighter monetary policy conduct. While being far from

rebutting the relevance of a firm systematic monetary policy conduct, 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 (2008a) 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.

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	$\pi$	$x$	$R$
$\varepsilon_t^{MP}$	$\leq 0$	$\leq 0$	$\geq 0$
$\varepsilon_t^g$	$\geq 0$	$\geq 0$	$\geq 0$
$\varepsilon_t^z$	$\leq 0$	$\geq 0$	$\leq 0$

Table 1: SIGN RESTRICTIONS FOR THE SELECTION OF THE Mfree VECTOR. Restrictions applied to the on-impact reaction of the endogenous variables to positive realizations of the structural shocks.

	$\Delta_{policy}^{pre-'79}$	$\Delta_{policy}^{post-'82}$
$\rho_\pi$	0.89	1.5
$\rho_x$	0.15	0.30
$\rho$	0.53	0.84
	$\Delta_{luck}^{pre-'79}$	$\Delta_{luck}^{post-'82}$
$\sigma_{\varepsilon^z}$	1.16	0.64
$\sigma_{\varepsilon^g}$	0.21	0.18
$\sigma_{\varepsilon^{MP}}$	0.24	0.18
$\sigma_\zeta$	0	—
	$\Delta_{structure}$	
$\beta$	0.99	
$\tau$	0.05	
$\kappa$	0.75	
$\rho_g$	0.80	
$\rho_z$	0.69	

Table 2: CALIBRATION OF THE DGP NEW-KEYNESIAN MODEL. Calibration: Lubik and Schorfheide's (2004) posterior means where not otherwise indicated in the text.

<i>Panel A - Continuity</i>			
	Theoretical	Counterf.: Good Policy	Counterf.: Good Luck
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]
<i>Panel B - Sign Restrictions</i>			
	Theoretical	Counterf.: Good Policy	Counterf.: Good Luck
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]

Table 3: COUNTERFACTUAL STANDARD DEVIATIONS OF OUTPUT GROWTH AND INFLATION - BENCHMARK SCENARIO. 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.

		<i>Panel A - Continuity</i>		
		Theoretical	Counterf.: Good Policy	Counterf.: Good Luck
<i>Just infl. TR param.</i>	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]
<i>Param. uncertainty</i>	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]
<i>Sunspot shocks</i>	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]
$\Delta_{luck}^2$	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]
		<i>Panel B - Sign Restrictions</i>		
		Theoretical	Counterf.: Good Policy	Counterf.: Good Luck
<i>Just infl. param.</i>	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]
<i>Param. uncertainty</i>	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]
<i>Sunspot shocks</i>	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]
$\Delta_{luck}^2$	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]

Table 4: COUNTERFACTUAL STANDARD DEVIATIONS OF OUTPUT GROWTH AND INFLATION - ROBUSTNESS CHECKS. Median and [5th,95th] percentiles reported in the Table. 'Theoretical', 'Good policy', 'Good luck', 'Continuity', Sign restrictions': See Table 3's 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. 'Diff(luck2)': Scenario simulated under 2nd-subsample's shocks volatilities. 'tau=0.7': IES as in Lubik and Schorfheide (2004).

	<i>Trade-off</i>	
	<i>Continuity</i>	<i>Sign Restrictions</i>
<i>Benchmark</i>	0.00%	15.96%
<i>Just inflation param.</i>	0.00%	15.15%
<i>Param. uncertainty</i>	0.02%	22.80%
<i>Sunspot shocks</i>	0.00%	15.15%
$\Delta_{luck}^2$	0.00%	0.91%
$\tau = 0.7$	99.63%	71.07%

Table 5: OUTPUT GROWTH STDS RATIO, 'GOOD POLICY SCENARIO': PERCENTAGE OF REALIZATIONS OVER UNITY. '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. 'Diff(luck2)': 'Good policy' scenario simulated under second-subsample shocks volatilities.

	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]

Table 6: COUNTERFACTUAL STANDARD DEVIATIONS OF OUTPUT GROWTH AND INFLATION - M VECTOR ESTIMATED BY LUBIK AND SCHORFHEIDE (2004). 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.

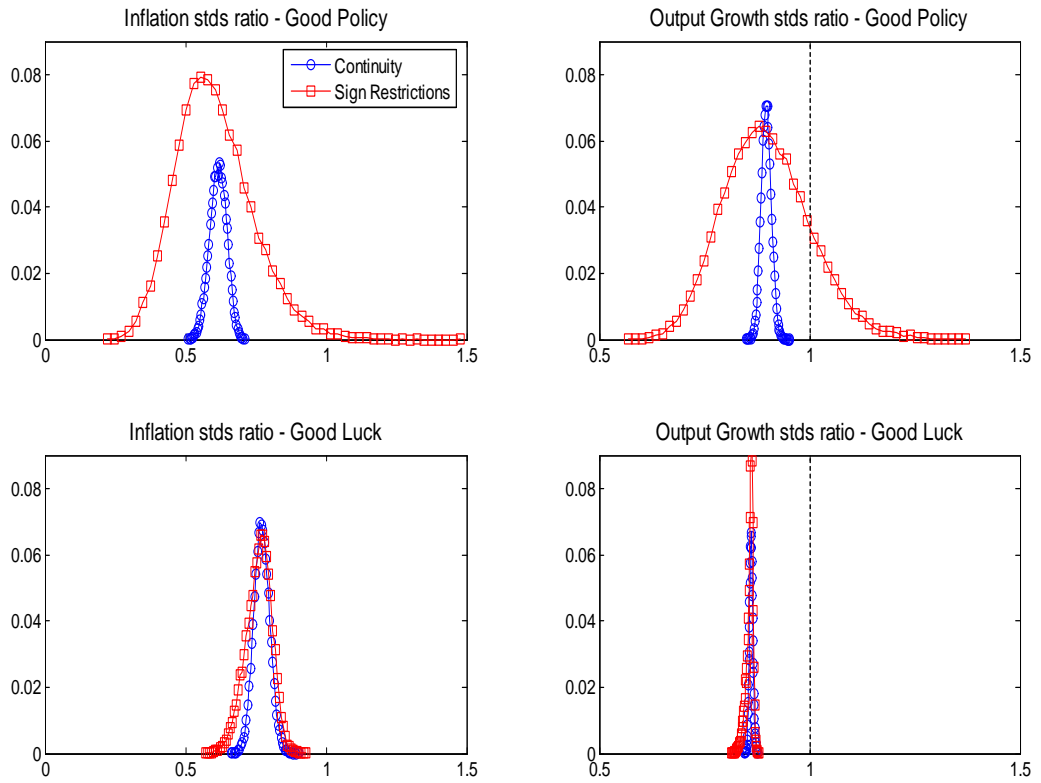


Figure 1: BASELINE SCENARIO: CONTINUITY vs. SIGN RESTRICTIONS. Circled blue line: Continuity. Red line with squares: Sign Restrictions. Explanations on the selection criteria in the text.

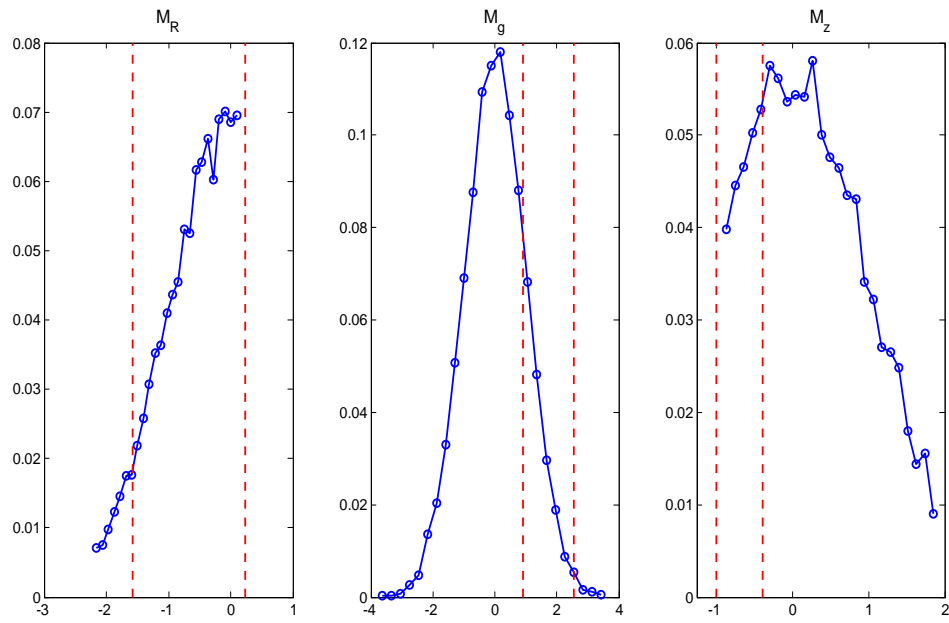


Figure 2: FEASIBLE RANGE OF M VALUES vs. LUBIK AND SCHORFHEIDE'S (2004) 90% CREDIBLE SETS. Circled blue lines: Feasible ranges computed with our 'sign restriction' approach. Red vertical dashed lines: Lubik and Schorfheide's (2004) estimated 90% credible sets.

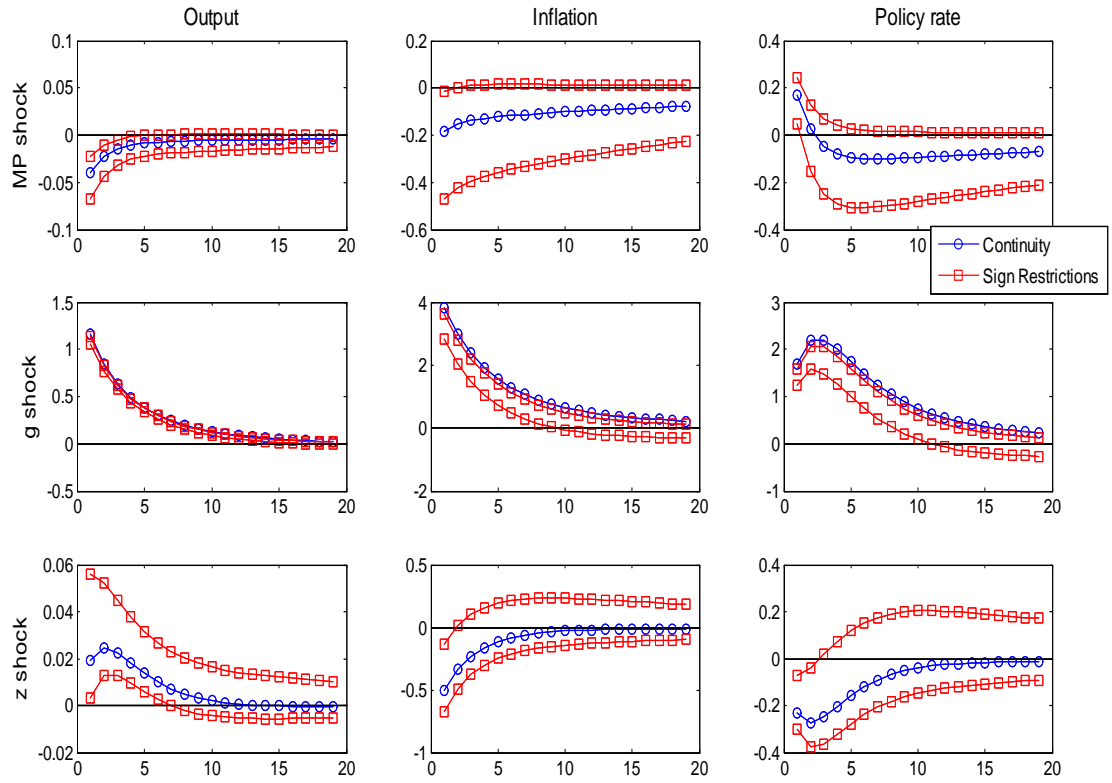


Figure 3: IMPULSE RESPONSE FUNCTIONS: CONTINUITY vs. SIGN RESTRICTIONS. Circled blue line: Continuity. Red line with squares: Sign Restrictions, 5th and 95th percentiles. Draws related to Sign Restrictions are conditional on the existence of the inflation-output policy trade-off. Explanations on the selection criteria in the text.