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Using Conventional Monetary Policy Unconventionally: Overturning Inflation and Output Gap Dynamics Using a Super-Inertial Interest Rate Rule

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Abstract

Using simulations on different macroeconomic models, we show that monetary policy can mitigate the drop in output after a negative demand shock and lead to a positive inflation gap and convergence to its target from above. Thus, the risk hitting the ELB is lower due to the overshooting inflation. Such dynamics are feasible under a super-inertial rule, i.e., when the degree of interest rate smoothing is above a threshold greater than one. The more backward-looking the economy is, the higher the threshold is. Hence, a super-inertial policy should be in the toolbox of central banks to support demand-shock dominated crisis.

JEL classification: E58, E61

Keywords: Interest rate smoothing, overshooting inflation, super-inertial policy, monetary policy design, conventional and unconventional monetary policy

שימוש במדיניות מוניטרית קונבנציונלית באופן לא קונבנציונלי: היפוך הדינמיקה של האינפלציה ושל פער התוצר באמצעות כלל ריבית סופר אינרטית

גיא סגל

תקציר

באמצעות סימולציות על מודלים מקרו-כלכליים שונים, אנו מראים שהמדיניות המוניטרית יכולה לצמצם את הירידה בתוצר לאחר זעזוע ביקוש שלילי, ולהוביל לפער אינפלציה חיובי ולהתכנסות של האינפלציה ליעדה מלמעלה. תגובת היתר של האינפלציה מורידה את הסיכון של הריבית להגיע למחסום האפקטיבי הנמוך שלה. הדינמיקה המתוארת לעיל מתקבלת תחת כלל ריבית סופר-אינרטית, קרי כאשר מקדם החלקת הריבית עולה על סף הגבוה מ-1; ככל שהמשק יותר צופה פני עבר, הסף הנדרש גבוה יותר. כל אלה תומכים בכך שכלל ריבית סופר-אינרטית צריך להיות חלק מארגז הכלים של בנקים מרכזיים בעת משבר שנובע מירידה בביקושים.

1. Introduction

Since the Global Financial Crisis (GFC, hereinafter) monetary policy in many countries operated in an environment of low inflation and of weak demand pushing downward the natural rates (e.g., Holston et al. (2017)). These two factors led to low levels of central bank (CBs, hereinafter) interest rates that were close to their effective lower bound (ELB, hereinafter). As a result, CBs have used unconventional monetary policy tools to stabilize the economy. In such an environment, there is a growing importance of the expectations channel of the monetary policy transmission, in particular, due to limited ability to use the interest rate and to the low slope of the Phillips curve (e.g. Blanchard (2016), Jordà et al. (2019)). The expectations` channel is crucial in unconventional policies such as forward guidance, long yield term QEs and recently the change in the monetary policy regime of the Fed to average-inflation-targeting.

This paper suggests to use, alongside the unconventional tools, the conventional monetary interest rate, although unconventionally, conditional on the endogenous ELB, when the economy faces negative demand shocks (or when the natural rate of interest,[1] NRI hereinafter, declines). In particular, the paper tests the implications of using different monetary interest rate smoothing degrees on the economy after demand-side shocks.[2] It shows that in the canonical New-Keyensian model, a Taylor-type interest rate rule, where the *sum* of the coefficients of (up to two) lagged interest rates is above a threshold greater than one, overturns future output gap and current and future inflation through expectations – dynamics that are opposite to that under the standard (inertial) Taylor rules.

1 e.g. under the interpretation of Giannoni and Woodford (2003).

2 Simulations of supply-side shocks show that the signs of the impulse response functions are the same under different policy rules (simulations are available from the author upon request). Hence we focus on the demand-side shocks.

Giannoni and Woodford (2003)[3] and Giannoni (2014) define such a rule as *super-inertial*.[4] These papers, Rotemberg and Woodford (1999) and Amato and Laubach (2003) show that super-inertial rules are optimal; that is, they maximize the objective function of the economy and welfare.[5] However, the current paper departs from the normative approach and focuses on the economy's dynamics after a negative demand shock. This focus is usually absent in the normative approach taken in the literature of quadratic loss function and (log-)linear macro-models, as deviations from above the target are penalized the same as deviations below the target. Nevertheless, Woodford (1999, 2003c) and Giannoni and Woodford (2003) note that when (theoretically) using an optimal super-inertial rule, the initial undershooting of the average inflation rate must be offset by a subsequent overshooting in order for the implied dynamics of the interest rate not to be explosive under super-inertial rules.[6]

As optimal rules are model-dependent,[7] we test the implications of different interest rate inertia degrees of Tylor-type rules on the economy, by conducting simulations in many complex macroeconomic models.[8] As a rule of thumb, we find that in most of the tested models, a sufficiently super-inertial rule overturns future output gap from the second year onward, which mitigates output loss immediately, and turns inflation to positive in the first or from the second year, after a demand-side shock. Moreover, under a super-inertial rule, interest rate changes are smaller than under standard inertial rule due

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3 See Giannoni and Woodford (2003, p. 1449).

4 Giannoni (2014) is a substantially revised version of Giannoni (2001).

5 Woodford (2003a, 2003b) shows that in the presence of a zero interest rate lower bound, or in the presence of nonnegligible transaction frictions, the micro-founded objective function of the central bank should be augmented with a squared interest rate term, beyond a squared inflation gap and a squared output gap.

6 Woodford (1999) and Giannoni and Woodford (2003) derive sufficient conditions for determinacy in their models.

7 To name a few examples, consider the micro-founded objective function and structural macroeconomic models with and without inertia, e.g., in the various analyzed models in Woodford (2003).

8 This robustness check is done using the Macroeconomic Model Data Base (Wieland et al., 2012).

to the overturned inflation and output expectations, and thus, it is less likely to hit the ELB.

The contribution of this paper is twofold:

(1) To illustrate that if monetary policy is sufficiently super-inertial, then a positive inflation gap and future output gap, that converge to their targets from above, and mitigated output drop after a negative demand-side shock are both feasible and robust.

(2) To illustrate that the degree of a super-inertial rule needed to overturn inflation and future output gap responses depends on the economy's backward- and forward-looking properties; The more backward-looking the agents and firms in the economy are, the more super-inertial the policy has to be.

Thus, a super-inertial rule can be useful in an environment of a dominated demand shock-driven deflation or a decreasing natural rate of interest. Such an environment characterizes the economy following the COVID-19 and the lockdown imposed in response to it (Guerrieri et al. (2020)), and the change in agents' behavior due to social distancing, after the lockdown is removed, which also has a downward effect on the natural rate. Hence, super-inertial policy should be considered a complementary tool to the unconventional policies when stepping out of the crisis and supporting demand.

The rest of the paper is organized as follows. Section 2 presents the optimal super-inertial policy rule à la Giannoni (2014). Section 3 illustrates the effects of different degrees of interest rate inertia on the economy. Section 4 analyzes the inflation response to different degrees of interest rate smoothing and different backward-looking parameters of the economy. Section 5 tests the interest rate smoothing degree in various macroeconomic models, and Section 6 concludes.

2. The Structural Super-Inertial Rule in the Canonical New Keynesian Model

This section presents the optimal super-inertial policy rule à la Giannoni (2014). Consider the central bank's objective function à la Woodford (2003a, 2003b):

$$(1) \qquad E_0\{L_t\} = 0.5E_0 \sum_{t=0}^{\infty} \beta^t \, [\pi_t^2 + \lambda_x x_t^2 + \lambda_i i_t^2],$$

where π_t is the inflation rate gap, x_t is the output gap, and i_t is the nominal interest rate. The weight of the output gap relative to inflation is $\lambda_x = \kappa/\varepsilon$, where κ is the slope of the Phillips curve and ε is the elasticity of substitution among goods. The weight of the interest rate relative to inflation[9] is λ_i. All variables are expressed as deviations from targets/steady state, and E_t denotes the mathematical expectation at time *t*.

Giannoni and Woodford (2003) show that under the central bank's objective function (Equation (1)) and the canonical New Keynesian (NK) model, the optimal rule from a timeless perspective can be represented as the optimal instrument rule:

$$(2) \qquad i_t = (\sigma\kappa/\lambda_i)\pi_t + (\sigma\lambda_x/\lambda_i)\Delta x_t + (1 + \sigma\kappa/\beta)i_{t-1} + \beta^{-1}\Delta i_{t-1} \,,$$

where σ is the intertemporal elasticity of substitution in consumption, and $\Delta z_t \equiv z_t - z_{t-1}$.

Giannoni (2014) notes[10] that this optimal rule implies a *super-inertial* response of the interest rate, as reflected in the fact that the sum of the coefficients of the lagged interest rates is above one, i.e., $1 + \sigma\kappa/\beta$. Woodford (1999), Giannoni (2007, 2014), and Giannoni and Woodford (2003) show that in canonical NK models, super-inertial rules

[9] Woodford (2003, Ch. 6) shows that in the presence of transaction frictions, or in the presence of a zero interest-rate lower bound, it is the case that λ_i is a function of λ_x, of the interest rate semi-elasticity of money demand, and of the velocity of money, among other variables.

[10] σ in Giannoni and Woodford (2003) and in equation (2) corresponds to $1/\sigma$ in Giannoni (2014).

lead to a positive average inflation gap and a positive future output gap after a *negative* shock to the natural rate of interest[11] or after a *negative* demand shock.[12]

Segal (2017) shows that in a canonical NK model with no inflation indexation and no habit formation, the responses of the interest rate, the inflation gap and the output gap under Giannoni's super-inertial rule are robust to a wide range of structural parameters (Figure 1). As $\rho_l \equiv \lambda_i/\lambda_x$ and σ decline, the nominal interest rate responds more strongly to the demand shock (Figure 1, left). The reason is twofold. (1) A lower ρ_l implies a smaller relative "fine" on deviations of the interest rate term to the output gap's deviations, that is, a smaller tradeoff between the interest rate, on the one hand, and the inflation and output gap, on the other.[13] Hence the interest rate is less constrained. (2) A lower σ implies a higher slope of the New Keynesian Phillips curve, which results in a higher influence of the output gap on inflation.[14] The higher slope also yields, all else equal, a higher relative weight of the output gap/lower relative "fine" on the interest rate in the objective function.[15] Note that although the output gap response is not monotonic (Figure 1, center), it remains positive, leading to positive inflation.

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[11] Woodford (1999), Giannoni (2007, 2014), and Giannoni and Woodford (2003) show the IRFs of a *positive* shock to the natural rate of interest. They get similar results to those in Figure 1, but in opposite signs, with minor *positive* inflation in the first period and *negative* inflation thereafter.

[12] Clarida et al. (1999) use the notation of a reduced-form demand-side shock, which is parallel to the natural rate of interest in Woodford (1999), Giannoni (2007, 2014), and Giannoni and Woodford (2003).

[13] See Woodford (2003, Figure 6.1, p. 432) for more details on this tradeoff.

[14] Woodford's (2003a) specification for the Phillips curve slope, κ, is $\kappa = (1-\theta)(1-\beta\theta)(\omega+\sigma^{-1})/[\theta(1+\omega\varepsilon)]$. Hence, $\partial\kappa/\partial\sigma = -\frac{(1-\theta)(1-\beta\theta)}{\theta\sigma^2(1+\epsilon\omega)} < 0$.

[15] As $\lambda_x = \kappa/\varepsilon$.

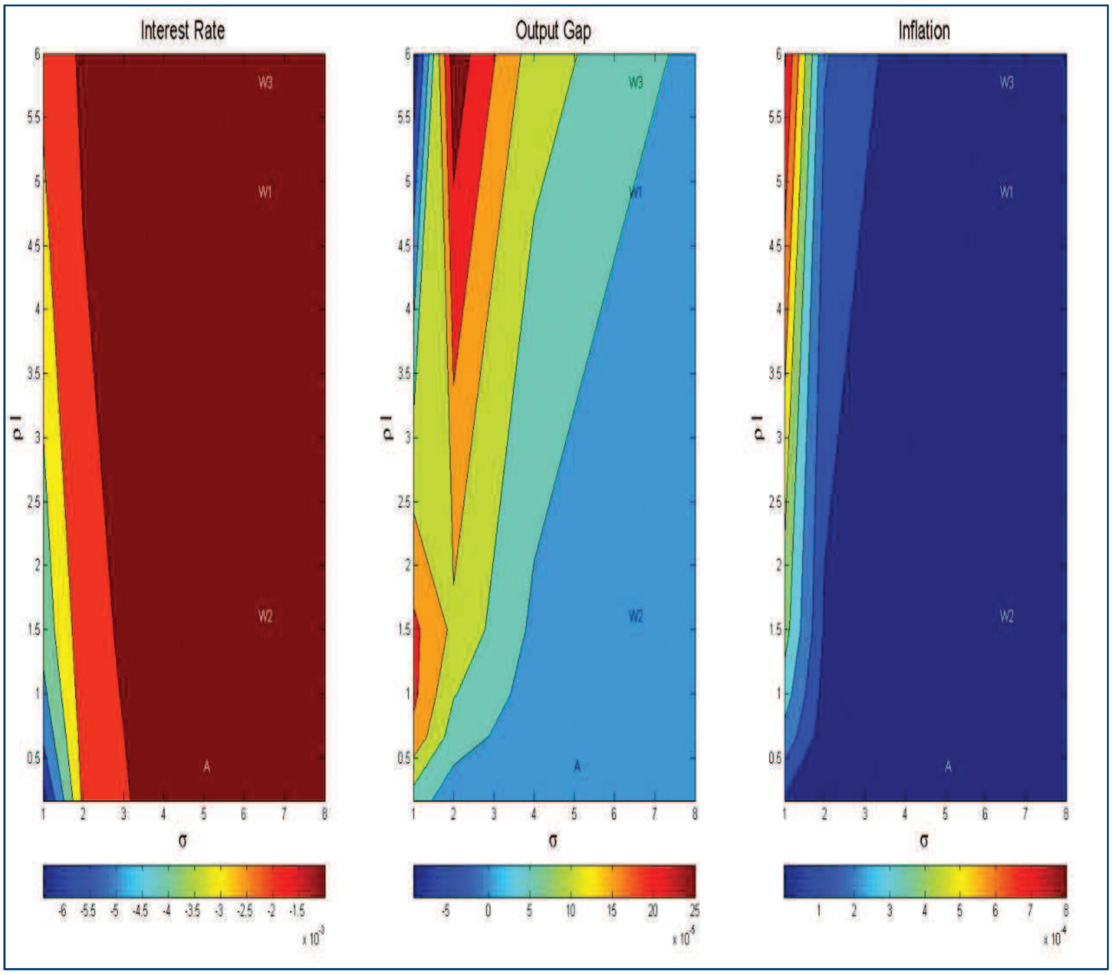

Fig. 1. First-five-period-average response of interest rate gap (left), output gap (center), and inflation gap (right) to a one-standard-deviation negative demand shock (white noise) under the super-inertial rule (Equation 2) for different values of $\rho_l = \lambda_i/\lambda_x$ and σ (the intertemporal elasticity of substitution in consumption). "Wi" denotes Woodford's calibrations, "A" denotes Adolfson et al.'s estimation (Table A.1), and θ=2/3. Source: Segal (2017).

Finally, Amato and Laubach (2003) and Giannoni and Woodford (2003) show that in an extended NK model with habit formation and inflation indexation, super-inertial rules remain optimal.

3. The Effect of Different Interest Rate Smoothing on the Economy: A Simple Illustration

In this section we test the hypothesis that the inflation gap and output gap convergence to their targets from above or below depends on interest rate inertia. We depart from optimal monetary policy analysis and focus, instead, on the implications on the economy when monetary policy is set according to a Taylor-type rule with different smoothing parameters. This analysis is simulated within an NK model with habit formation and inflation indexation.

Specifically, the model we use is given by

$$\pi_t - \gamma_p \pi_{t-1} = \beta\left[E_t\{\pi_{t+1}\} - \gamma_p \pi_t\right] + \kappa x_t + u_t, \tag{3}$$

$$x_t = \gamma_h E_t\{x_{t+1}\} + (1-\gamma_h)x_{t-1} - \hat{\sigma}[i_t - E_t\{\pi_{t+1}\}] + g_t, \tag{4}$$

for $\gamma_h \equiv 1/(1+h)$ and $\hat{\sigma} \equiv (1-h)/[(1+h)\sigma]$, where h is the habit formation parameter, and $\gamma_p \in [0,1]$ is the inflation indexation parameter.[16]

Monetary policy follows the augmented Taylor-type rule (ATR)[17]:

$$i_t = \tilde{\rho}_1 i_{t-1} + \tau_\pi \pi_t^4 + \tau_x x_t, \tag{5}$$

where π_t^4 is the rate of inflation over the past four quarters, i.e., $\pi_t^4 \equiv \pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3}$, which is commonly used in a central bank's models[18] (for the basic calibration of the model, see table B.1).

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[16] The Phillips curve specification (Equation (3)) follows Woodford (2003) and Giannoni and Woodford (2003), and resembles the specification in Amato and Laubach (2003). The dynamic IS (Equation (4)) follows Amato and Laubach (2003).

[17] For simplicity, we use in this section a Taylor rule with one lagged interest rate.

[18] For a brief review of models with a policy rule that responds to the rate of inflation over the past four quarters, see https://www.federalreserve.gov/monetarypolicy/policy-rules-and-how-policymakers-use-them.htm.

Figure 2 presents the impulse response functions (IRFs) of a one-standard-deviation negative demand shock under four different rules[19]: namely, a standard inertial rule ($\tilde{\rho}_1 = 0.8$) and three super-inertial rules ($\tilde{\rho}_1 = 1.2$; $\tilde{\rho}_1 = 1.6$; $\tilde{\rho}_1 = 2$).

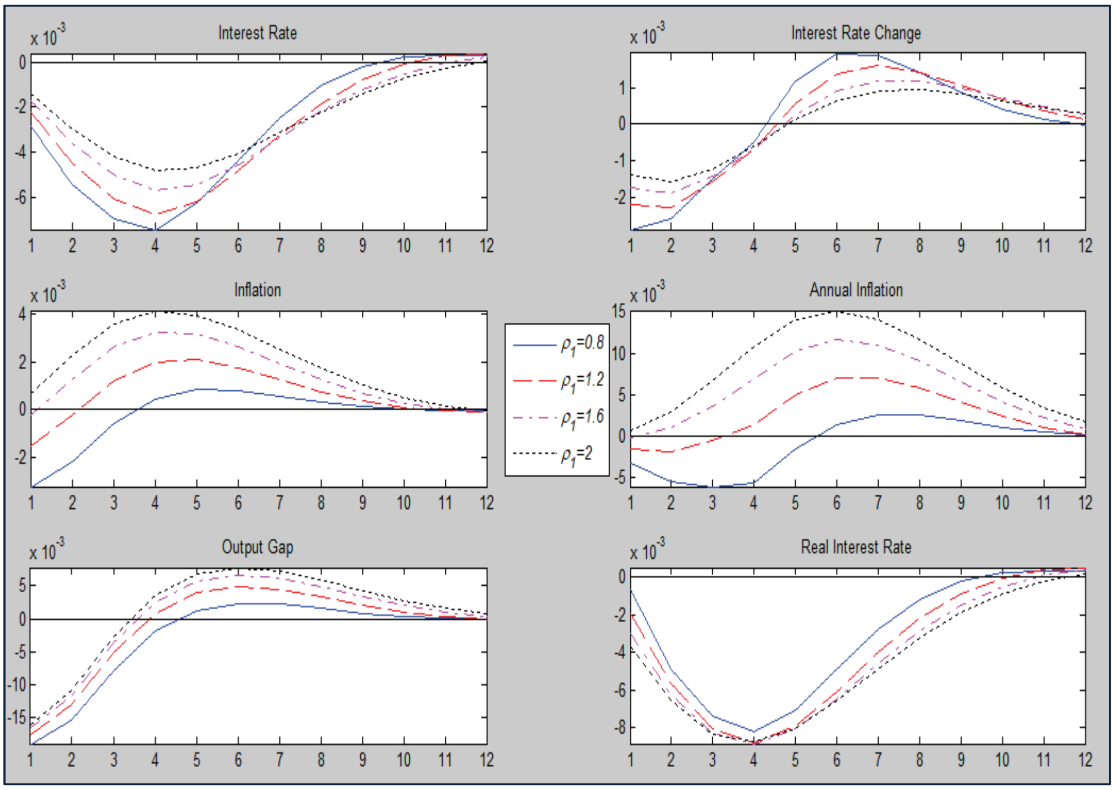

Fig. 2. Impulse response function of a one-standard-deviation negative demand shock under interest rate rules ($i_t = \tilde{\rho}_1 i_{t-1} + \tau_\pi \pi_t + \tau_x x_t + \varepsilon_t$) with four different smoothing parameters: a standard inertial rule (blue solid line, $\tilde{\rho}_1 = 0.8$) and three super-inertial rules (red dashed line, $\tilde{\rho}_1 = 1.2$; purple dotted-dashed line, $\tilde{\rho}_1 = 1.6$; and black dotted line, $\tilde{\rho}_1 = 2$).

Figure 2 shows that under all the rules, the output gap decreases in the first few periods after a negative demand shock. By contrast, the inflation response to the demand shock is highly affected by the interest rate's smoothness: under the standard inertial rule ($\tilde{\rho}_1 = 0.8$), inflation also decreases in the first 3 periods and annual inflation is negative in the first 5 periods (this is the standard no-tradeoff response of inflation and output gap to demand-side shock). This standard response remains the same, albeit to a lesser degree and for a shorter period, even under a super-inertial rule with $\tilde{\rho}_1 = 1.2$.

[19] All simulations were calculated using Dynare software.

However, higher smoothing parameters lead to a positive inflation gap (for both quarterly and annual inflation) and convergence to steady state from above the target. Under a super-inertial rule with $\tilde{\rho}_1 = 1.6$ or $\tilde{\rho}_1 = 2$, the explanation for the inflation dynamics is that if a determinate equilibrium exists,[20] then for the implied dynamics of the interest rate not to be explosive, the initial undershooting of the output gap must be offset by a subsequent overshooting of the inflation (Woodford, 1999, 2003c; Giannoni and Woodford, 2003).

The next section expands the analysis using an interest rate rule with two lags. Specifically, we test the economy's dynamics after a demand shock with different smoothing and habit formation parameters.

4. Designing Monetary Policy through Interest Rate Smoothing

In this section we test the hypothesis that the inflation gap and the output gap depend on interest rate inertia and, in particular, on the *sum* of the coefficients of the lagged interest rate under the monetary rule. In light of a frequent criticism about model-based evaluation of policy, namely, that it is by its nature model-dependent, we depart from the normative approach of analyzing optimal rules. Specifically, we use an augmented Taylor-type rule presented by Equation (6), with $\tau_\pi = 0.2 \cdot 1.5 = 0.3$, and[21] $\tau_x = 0.2 \cdot 0.5 = 0.1$:

[20] The use of a super-inertial rule has been examined by many researchers in light of the question of whether such a rule leads to a determinate equilibrium. Giannoni and Woodford (2003), Bullard and Mitra (2007) and Ascari and Ropele (2009) show that a super-inertial rule may lead to determinacy. Bullard and Mitra (2007) also show that a super-inertial rule leads to a smooth path of the interest rate. By contrast, Levin and Williams (2003) and Lubik and Marzo (2007) show that in a backward-looking model, a super-inertial rule may lead to negative outcomes and even to explosive dynamics. We find that in various macroeconomic models, a super-inertial rule does not lead to explosive dynamics and satisfies determinacy. Woodford (1999) and Giannoni and Woodford (2003) derive sufficient conditions for determinacy in their models.

[21] This calibration follows Taylor's (1993) calibration multiplied by a smoothing parameter of 0.8, that is consistent with the literature. See, e.g., Adolfson et al. (2011), Christiano et al. (2005), and Smets and Wouters (2007).

$$(6) \qquad i_t = \tilde{\rho}_1 i_{t-1} + \tilde{\rho}_2 i_{t-2} + 0.3\pi_t^4 + 0.1x_t.$$

The augmentation of the Taylor-type rule (Equation (6)) consists of including the second lag of the interest rate. We choose this augmentation of the rule so that Giannoni's rule (Equation (2)) can be included in it as a special case. Note, however, that in contrast to Giannoni's rule, the ATR in Equation (6) responds to the level of the output gap rather than to its first difference.

Following Giannoni (2014) and Giannoni and Woodford (2003), the interest rule in Equation (6) is super-inertial if the sum of the coefficients of the lagged interest rates, $\tilde{\rho}_1 + \tilde{\rho}_2$, is above one.[22]

Next, we test the endogenous variables, and specifically the first-year inflation response following a negative AR(1) demand shock.[23] Specifically, we let $\tilde{\rho}_1$ vary in the range of $\tilde{\rho}_1 = \{0.41, 0.61, \ldots, 2.41\}$ and we let the ratio $\frac{\tilde{\rho}_2}{\tilde{\rho}_1}$ vary in $\frac{\tilde{\rho}_2}{\tilde{\rho}_1} = \{-0.6, -0.4, -0.2, \ldots, 0.6\}$. The $\frac{\tilde{\rho}_2}{\tilde{\rho}_1}$ bounds are set in order for $\tilde{\rho}_1$ to be dominant. Note that these bounds imply that $\tilde{\rho}_2$ can be either positive or negative.[24]

Figure 3 confirms our hypothesis (for $\gamma_p = h = 0.2$): there is a frontier that separates a positive and negative average inflation response. The zero-inflation frontier is around the *super-inertial path* $\tilde{\rho}_1 + \tilde{\rho}_2 = 1$ (the black starred line) but it is not identical to it; for $\tilde{\rho}_1 < 1.67$, the frontier is above one, while for $\tilde{\rho}_1 > 1.67$, it is below one. Above the frontier (in the north-east region of it), the average inflation response is positive. For example, setting $\tilde{\rho}_1 = 2.15$ and $\tilde{\rho}_2 = -1.01$ as in Giannoni and Woodford (2003) leads

22 Setting $\tilde{\rho}_1 = 1 + \sigma\kappa/\beta + \beta^{-1}$ and $\tilde{\rho}_2 = -\beta^{-1}$ and $\tau_\pi = -\beta/\lambda_i$ yields the smoothing parameters of Giannoni's (2014) rule.

23 Following Giannoni (2014) and Gannoni and Woodford (2003), we assume an AR(1) demand shock with an autoregressive parameter of 0.35.

24 See, e.g., Giannoni (2014), Coibion and Gorodnichenko (2012), and Judd and Rudebusch (1998).

to the unconventional positive inflation response. Another example is setting $\tilde{\rho}_1 > 1.2$ with any positive $\tilde{\rho}_2$, which also leads to the positive inflation response.

Note also that for a large enough $\tilde{\rho}_1 > 1.67$, the zero-inflation frontier is below one; that is, there are $\tilde{\rho}_2 < -0.67$ that will lead to the positive average inflation response after a year. However, such a rule leads to very volatile responses of the endogenous variables, as expected. Hence, the use of such parameterization seems not plausible.

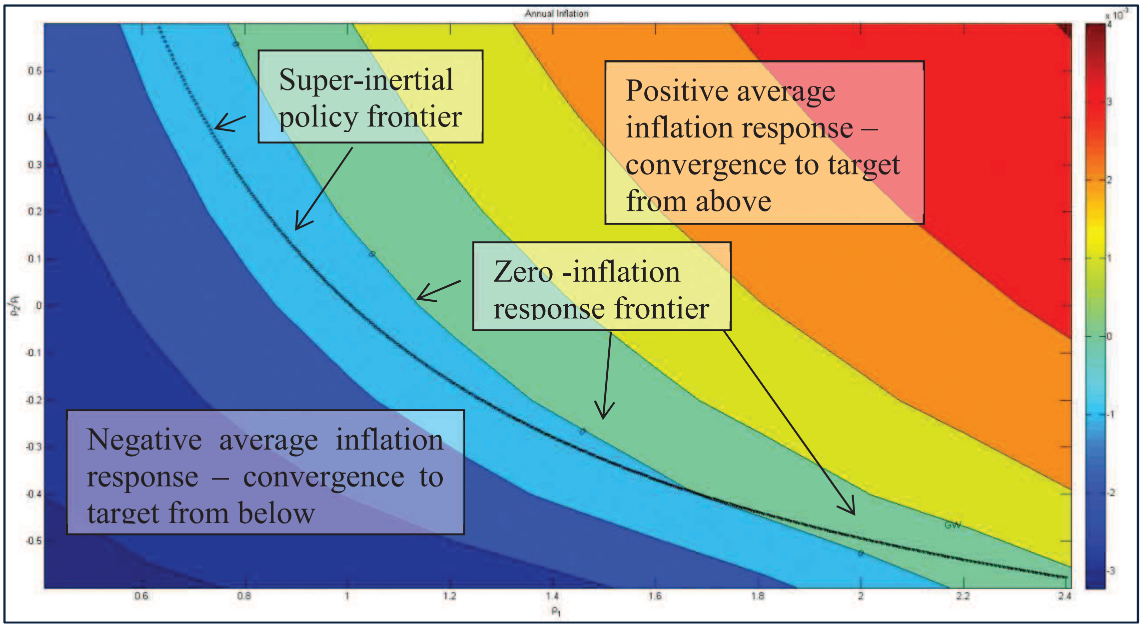

Fig. 3. First-four-period-average response of inflation to one-standard-deviation negative demand shock under $i_t = \tilde{\rho}_1 i_{t-1} + \tilde{\rho}_2 i_{t-2} + 0.3\pi_t^4 + 0.1x_t$, for different values of $\tilde{\rho}_1$ and $\tilde{\rho}_2$. The (black) starred line represents the $\tilde{\rho}_1 + \tilde{\rho}_2 = 1$ line. GW stands for the values of $\tilde{\rho}_1$ and $\tilde{\rho}_2$ in Giannoni and Woodford (2003).

The standard inertial Taylor-type rules that are mostly used in the literature, where $0.6 > \tilde{\rho}_1 > 0.9$ and $\tilde{\rho}_1 = 0$, are in the negative-inflation response region (the standard response). Similarly, Branch (2014), Coibion and Gorodnichenko (2012), and Judd and Rudebusch (1998) find that $\tilde{\rho}_1 > 1$, $\tilde{\rho}_2 < 0$, and $\tilde{\rho}_1 + \tilde{\rho}_2 < 1$, which are "located" in the negative response region.

Hence, after a negative demand shock, policy can lead to either positive or negative inflation gap and future output gap responses, depending on the *sum* of the coefficients of the lagged interest rates, that is, on interest rate smoothing.

Figure 4 repeats the simulations and presents the zero-inflation frontiers for different inflation indexation and habit formation parameters. The simulations show that the higher the inflation indexation and/or habit formation parameters are, the higher zero-inflation frontier is.

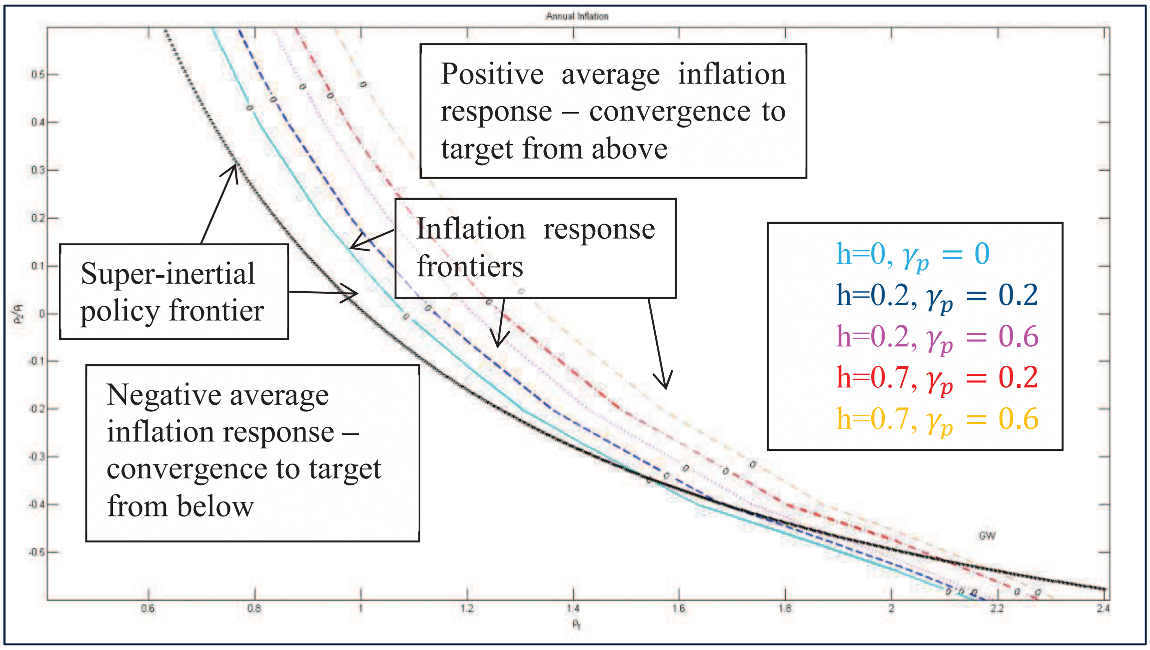

Fig. 4. Zero-inflation frontiers depending on different parameters of inflation indexation and habit formation, for different values of $\tilde{\rho}_1$ and $\tilde{\rho}_2$. The (black) starred line represents the $\tilde{\rho}_1 + \tilde{\rho}_2 = 1$ line. GW stands for the values of $\tilde{\rho}_1$ and $\tilde{\rho}_2$ in Giannoni and Woodford (2003).

Thus, in order to overturn the inflation dynamics after a demand shock, the rule has to be more super-inertial.[25] The transmission mechanism for overturning the inflation response (through the future output gap) works through the expectations. The more backward-looking the agents in the economy are, the higher interest rate smoothing has to be in

[25] Giannoni and Woodford (2003, p. 1438) find that for small parameters of inflation inertia, the higher the inflation indexation parameter is, the lower the optimal super-inertial smoothing parameter is. However, in addition to the augmented Taylor-type rule used in this paper, their rule includes forecasts of inflation and output gap.

order to offset the backward-looking property and overturn the inflation and future output gap dynamics.

5. Testing Inertial and Super-inertial Rules in Different Models

We showed that in the canonical NK model there is a frontier that separates between the positive and the negative response of average inflation and future output gap to a (negative) demand shock: (1) a standard negative response when the *sum* of the coefficients of the lagged interest rates is below the frontier, and (2) a positive response when the *sum* is above it.

In this section we test whether these results hold in different models. We use the Macroeconomic Model Data Base (henceforth, MMB) framework of Wieland et al. (2012) to test inflation gap, output gap, output, and interest rate responses to a *negative*[26] unit fiscal policy shock, i.e., a demand-side shock, under different policy rules with different smoothing parameters. Specifically, we test the impulse response functions (IRFs) in 9 models with habit formation, out of 23 MMB macroeconomic models that contain a fiscal policy shock.

5.1. The benchmark rule: Inertial Taylor-type (1993) rule

Our benchmark rule is the standard smoothed Taylor rule (recall Equation (5)). We denote this benchmark inertial augmented Taylor-type rule with a smoothing parameter below one by **ITR**. Note that the standard inertia implied in the standard Taylor-type rules is in

[26] We use Macroeconomic Model Data Base version 2.0, which allows us to compare the impulse response functions (IRFs) of endogenous variables to a positive fiscal policy shock in different macroeconomic models. To present the IRFs that correspond to a negative unit fiscal policy shock (Figures 5–9), we plot negative IRFs. For further details about the Macroeconomic Model Data Base and the various models, see Wieland et al. (2012).

many tested models the result of using the beta distribution as the prior for the smoothing parameter.

Under the benchmark standard inertial Taylor rule,[27] the IRFs in all 9 tested models are the standard IRFs of a no-tradeoff demand-side shock in the first year, with decreasing output, output gap, inflation, and interest rate, and convergence to targets/steady state from below (Figure 5).[28]

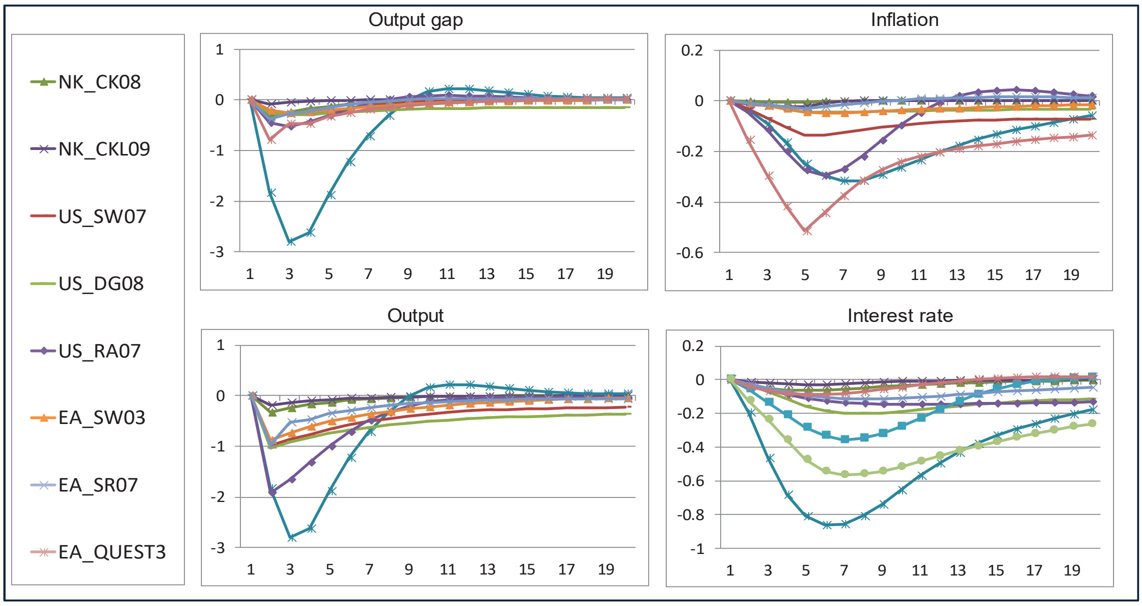

Fig. 5. 5-years Impulse Response Functions (IRFs) of endogenous variables to a negative unit fiscal shock in 9 different macroeconomic models (Left Box) under the standard Taylor rule: $\boldsymbol{i_t = 0.8 \cdot i_{t-1} + (1 - 0.8) \cdot (1.5\pi_t + 0.5x_t)}$.

5.2.1 The tested alternative rules

Next, we use four different rules as per Equation 6:

1. $\boldsymbol{\tilde{\rho}_1 = 1.5}$ and $\boldsymbol{\tilde{\rho}_2 = -0.7}$, that is, where the sum of the coefficients of the lagged interest rates is below one. We denote this inertial augmented Taylor rule by **IATR**. Note that although $\boldsymbol{\tilde{\rho}_1}$ is above one, this rule is not super-inertial because the *sum* of the coefficients of the lagged interest rates is below one.

[27] The assumption in this exercise is that the parameters in each model are orthogonal to the interest rate rule.

[28] Similar results (in signs) are obtained in 9 other models, with no habit formation, in the MMB framework.

2. $\tilde{\boldsymbol{\rho}}_{\mathbf{1}} = \mathbf{1.5}$ and $\tilde{\boldsymbol{\rho}}_{\mathbf{2}} = -\mathbf{0.3}$, that is, where the *sum* of the coefficients of the lagged interest rates is above one. We denote this super-inertial augmented Taylor rule by **SIATR**.
3. $\tilde{\boldsymbol{\rho}}_{\mathbf{1}} = \mathbf{0.8}$ and $\tilde{\boldsymbol{\rho}}_{\mathbf{2}} = \mathbf{0.4}$, that is, where each of the lagged interest rate coefficients is below one, but their *sum* is above one. We denote this super-inertial augmented Taylor rule by **SIATR2**.
4. $\tilde{\boldsymbol{\rho}}_{\mathbf{1}} = \mathbf{1}$ and $\tilde{\boldsymbol{\rho}}_{\mathbf{2}} = \mathbf{0}$, that is, where the *sum* of the coefficients of the lagged interest rates is one. In this rule we set $\boldsymbol{\tau}_{\boldsymbol{\pi}} = \boldsymbol{\tau}_{\mathbf{x}} = \mathbf{0.5}$, following Orphanides and Wieland (2013). We denote this first-difference Taylor rule by **FDTR**.

The first-difference Taylor rule is an interesting case because the analysis in Section 4 raises the possibility that such a rule can sterilize demand-side shocks. Such a rule is robust to model uncertainty (Levin et al., 1999; Orphanides and Williams, 2008), is used for analysis in the FED (Fischer, 2017, and the Federal Reserve's Monetary policy reports[29]), and nicely characterizes the ECB policy rate (Orphanides and Williams, 2013).

Next, the different IRFs relating to the different tested rules are presented. Figure 6 shows the IRFs under IATR, where the coefficient of the first-lagged interest rate is above one, the coefficient of the second-lagged interest rate is negative, and the *sum* of the two is less than one. The IRFs under IATR remarkably resemble the IRFs under the benchmark inertial rule; i.e., they show classic demand-side IRFs. Moreover, the IRFs of inflation, output, and output gap are almost identical under the two inertial rules. The major difference is in the IRFs of the interest rate, whose responses are stronger under IATR than under ITR.

[29] E.g. see, https://www.federalreserve.gov/monetarypolicy/mpr_default.htm

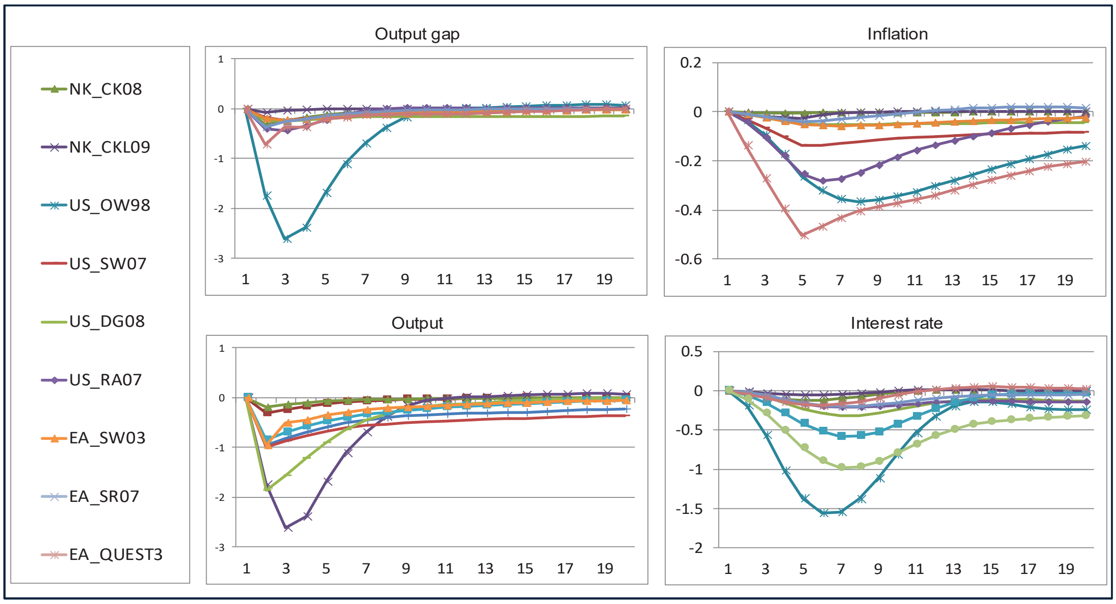

Fig. 6. 5-years IRFs of endogenous variables to a negative unit fiscal shock, in 9 different macroeconomic models, under an inertial augmented Taylor rule:
$\boldsymbol{i_t = 1.5 \cdot i_{t-1} - 0.7 \cdot i_{t-1} + (1 - 0.8) \cdot (1.5\pi_t + 0.5x_t)}$; the IRFs present a classic no-tradeoff demand-side IRFs.

Next, we test the IRFs of the tested super-inertial augmented Taylor rules. Figure 7 repeats Figures 5 and 6 under SIATR, where the coefficient of the first-lagged interest rate is above one, the coefficient of the second-lagged interest rate is negative, but the *sum* of the two is above one.

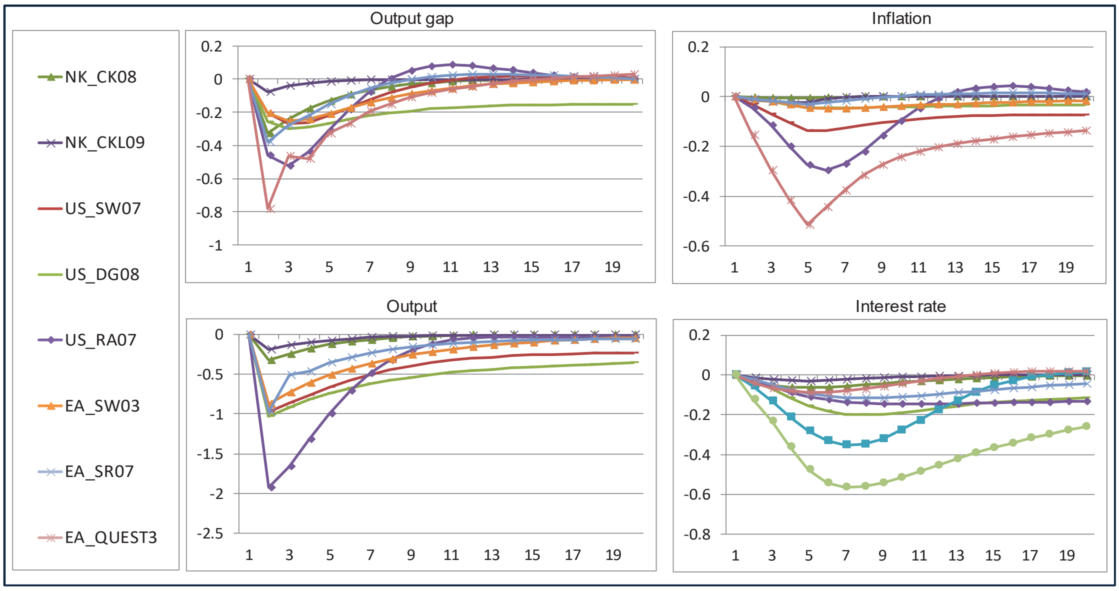

Fig. 7. 5-years IRFs of endogenous variables to a negative unit fiscal shock in 9 different macroeconomic models under the super-inertial augmented Taylor rule:
$\boldsymbol{i_t = 1.5 \cdot i_{t-1} - 0.3 \cdot i_{t-1} + (1 - 0.8) \cdot (1.5\pi_t + 0.5x_t)}$. The IRFs show positive inflation and future output gap (from the second year onward in most models) responses to a negative demand-side shock.

Similarly to the results of the analysis in Sections 3 and 4, the use of SIATR after a negative demand-side shock yields a positive inflation response in 7 out of the 9 tested models. The other 2 tested models[30] also yield that response but with a delay: they show a minor average negative inflation response around the first year, followed by a stronger positive inflation response (in absolute values) in subsequent periods. The positive inflation rates stem from the future positive output gaps (from the sixth period onward, in 7 out of the 9 models).[31] However, in 6 out of the 9 models, SIATR leads to a decrease in output.

Figure 8 repeats the above exercises under SIATR2, where each of the lagged interest rate coefficients is below one but the sum of them is above one. This exercise also yields a similar picture to that obtained under SIATR, with positive average inflation rates (gaps) and future output gaps. In 5 out of the 9 tested models the inflation gap is positive right from the start. In the other 4 tested models there is a minor negative inflation response up to the fifth period, followed by a stronger positive inflation response (in absolute values) in subsequent periods.

30 The two models are NK_CKL09 and US_RA07; see Wieland et al. (2012) for details.

31 Iterating forward the New Keynesian Phillips curve in the canonical NK model while using the law of iterated expectations yields $E_t\{\pi_{t+1}\} = \kappa E_t \sum_{j=0}^{\infty} \beta^j \, [x_{t+1+j}]$.

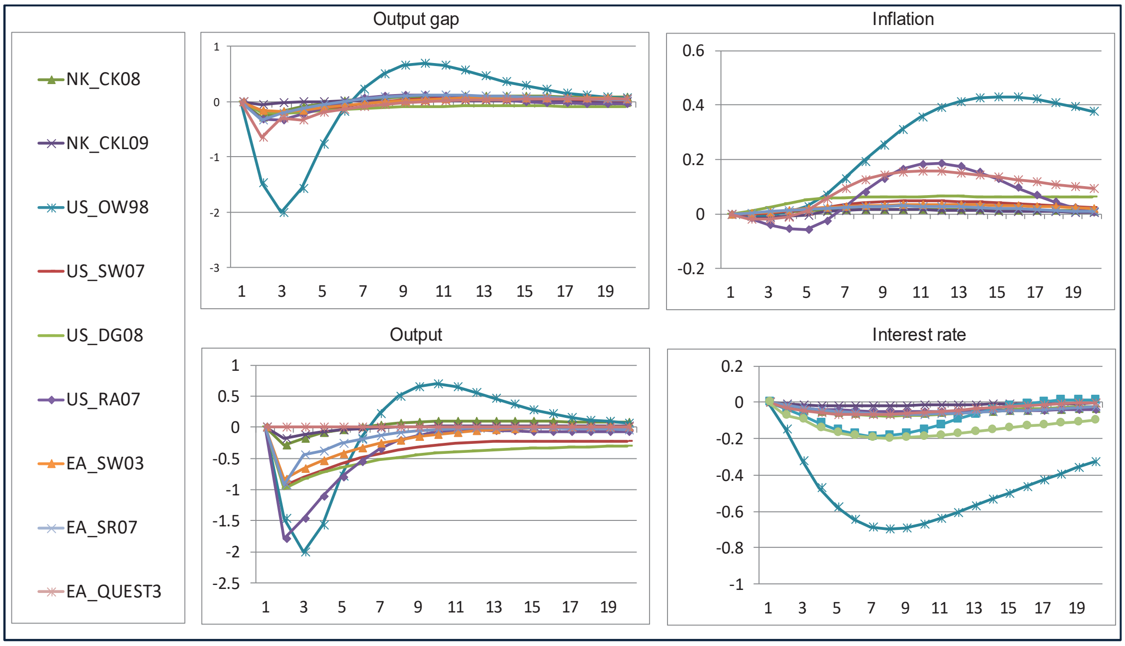

Fig. 8. 5-years IRFs of endogenous variables to a negative unit fiscal shock in 9 different macroeconomic models under the super-inertial augmented Taylor rule: $\boldsymbol{i_t = 0.8 \cdot i_{t-1} + 0.4 \cdot i_{t-1} + (1 - 0.8) \cdot (1.5\pi_t + 0.5x_t)}$. The IRFs show positive inflation and future output gap (from the second year onward in most models) responses to a negative demand-side shock.

Finally, Figure 9 repeats the above exercises under FDTR, the first-difference Taylor rule. In this case, the positive inflation responses also characterize the dynamics but with a more complex picture in the first year: in 4 out of the 9 models, the inflation response in the first year is negative, while it is positive in the other models. In the second year, in 7 out of the 9 models, the inflation response is positive and it converges to the target from above. Note that the inflation responses are more minor under FDTR, but with a stronger response of the interest rate, than those obtained under the other tested rules.

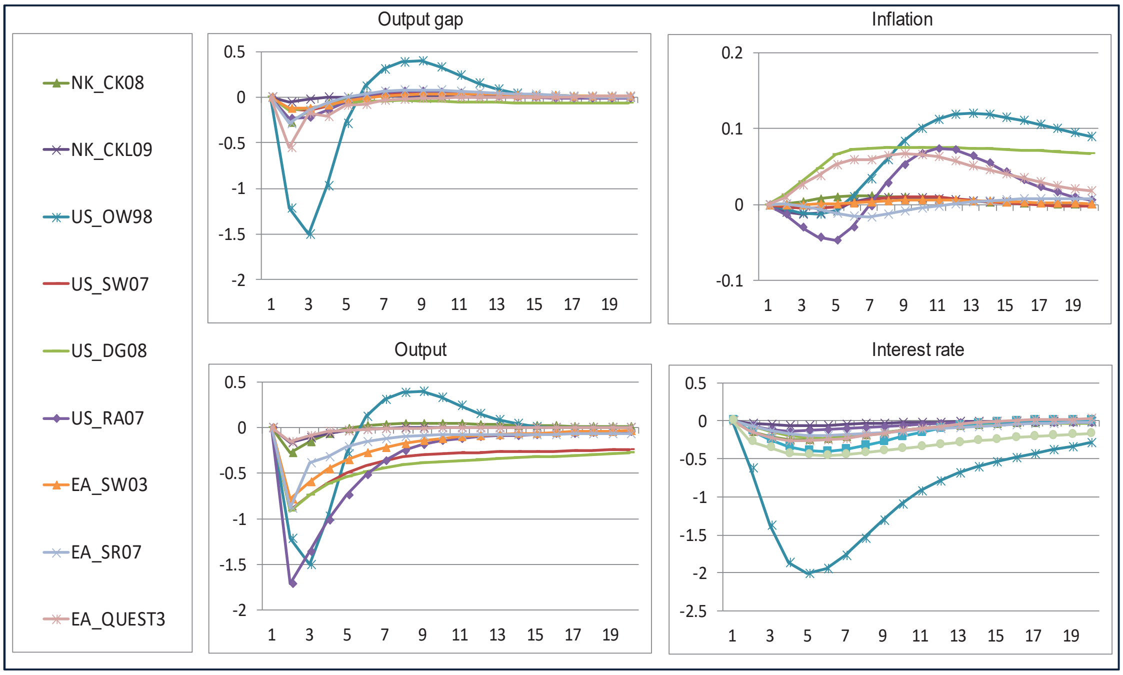

Fig. 9. 5-years IRFs of endogenous variables to a negative unit fiscal shock in 9 different macroeconomic models under a first-difference Taylor rule:
$\boldsymbol{i_t = i_{t-1} + 0.5\pi_t + 0.5x_t}$. The inflation responses in the first year are mixed.

To summarize so far, the super-inertial rules yield robust positive inflation gap and future output gap responses in almost all models and periods,[32] while the standard inertial policy rules yield the well-known result: negative inflation and output gap responses. The first-difference rule yields similar results to the super-inertial rules but with a mixed inflation response in the first year.

5.2.2 *Another look at the results*

We showed that the IRFs of the tested inertial rules differ substantially from those of the super-inertial rules. Hence, Figure 10 compares the responses of the endogenous variables under a super-inertial rule (SIATR2) to that under the standard inertial rule (TR), among the tested 9 macromodels and for 19 periods, in a different manner, using a "traffic-light"

[32] Similar results are obtained under super-inertial rules that respond to the first-difference output gap rather than to the level of the output gap. However, the overturned inflation's response come with a delay of around a year; it turns positive in the second year after having been either zero or slightly negative in the first year. Results are available upon request.

mapping;[33] Figure 10 shows that in the case of a demand driven recession, super-inertial policy is preferable than standard inertial policy, as it mitigates activity drop (output), and leads to a more moderate inflation gap (either positive or negative), which also mitigate the risk of hitting the ELB. The Figure also shows that almost in all tested models and periods the interest rate response is milder under the super-inertial policy (SIATR2) than under the inertial policy (TR), due to the overshooting inflation.

In particular, a greenish "light" in Figure 10 relates to a higher level of the endogenous variable under SIATR2 than the level under TR, and a reddish "light" corresponds to the opposite case. Specifically, dark green relates to a positive level under SIATR2 and a negative level under TR. For example, in the US_SW07 model (4th row), output gap is positive from the 8th quarter for 3 quarters (8th to 10th columns, upper figure) under SIATR2, and negative under TR; inflation (second upper figure) is positive in all quarters under SIATR2, and negative under TR, as was shown earlier. Mild green relates to positive levels under both compared policy rules, with a higher level under SIATR2, and light green relates to negative levels under both compared policy rules, but with a higher level (less negative) under SIATR2. In a similar logic, a reddish light corresponds to a lower level of the tested endogenous variable under SIATR2 than its level under TR (see the legend). Note that SIATR2 leads to higher levels of output (or less negative levels) than those under TR (excluding after 3 years in one out of the 9 tested models).

[33] A similar comparison of SIATR to the Taylor rule yields a very similar picture. It is available from the author upon request.

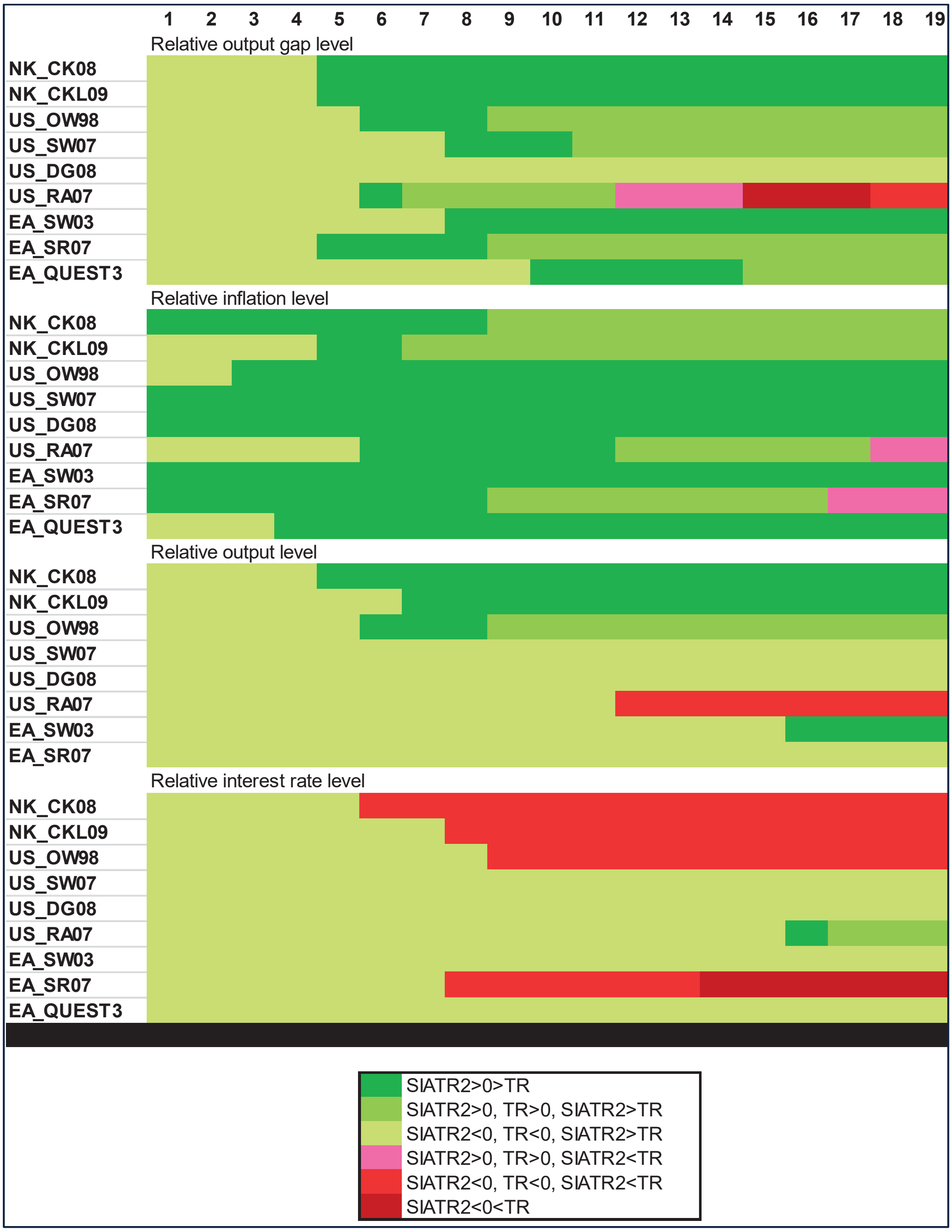

Fig. 10. Relative levels of endogenous variables under SIATR2 and under TR. Greenish "light" relates to higher level under SIATR2 than under TR, and reddish "light" shows the opposite. For example. Light green box relates to a negative response under both tested rules, but less negative under SIATR2.

Similarly, Figure 11 compares between the FDTR and TR. Comparing Figures 10 and 11, it is evident that the responses under FDTR are more complex than those under SIATR2, that is it is less robust, as was described earlier. Furthermore, the output gap and output levels are higher in more models and periods under SIATR2 than under FDTR. A major difference between SIATR2 and FDTR is in the lower level of the interest rate under FDTR.

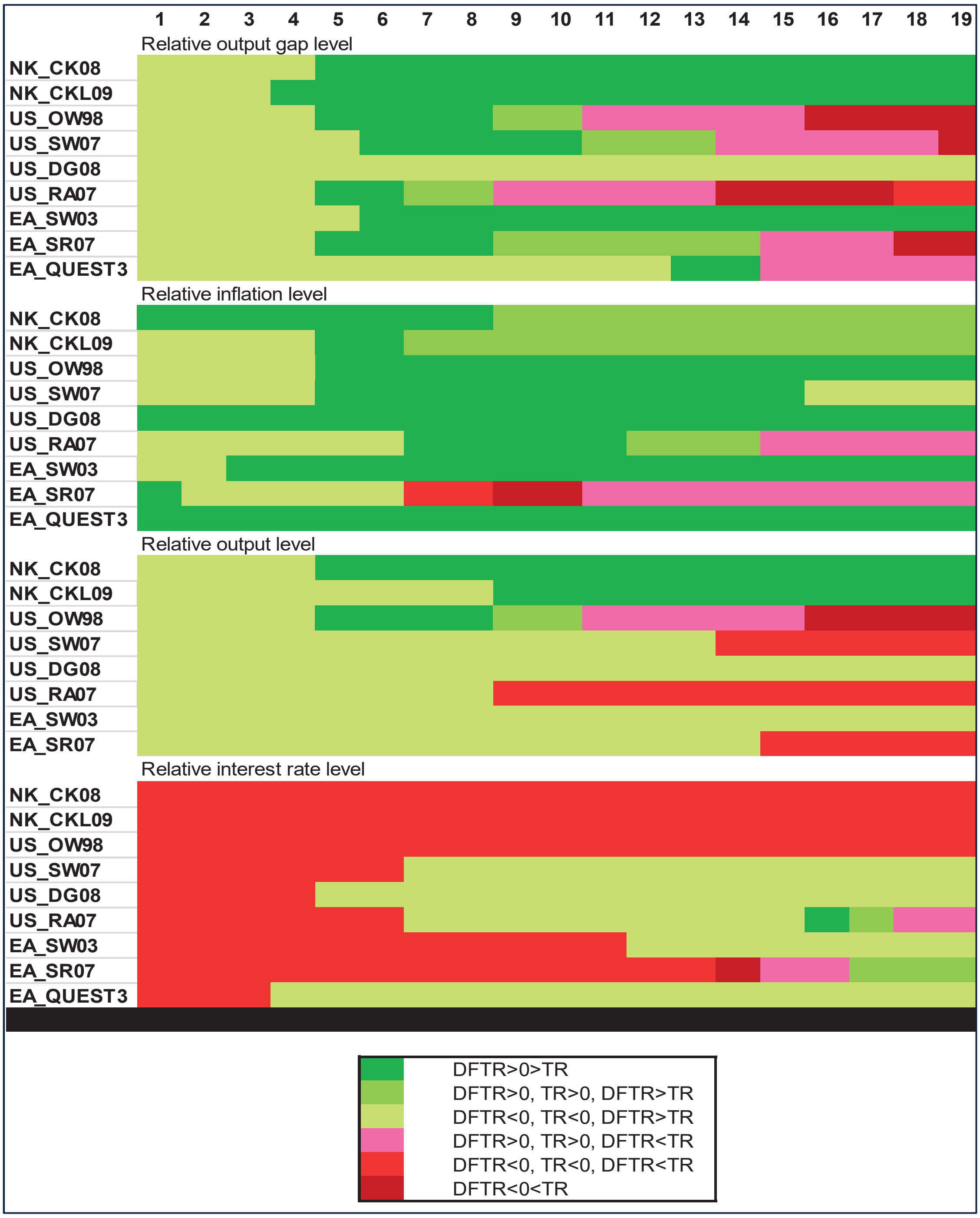

Fig. 11. Relative levels of endogenous variables under FDTR and under TR. Greenish "light" relates to higher level under FDTR than under TR, and reddish "light" shows the opposite.

Next we analyze the unconditional variance of the inflation gap, output gap, output, and interest rate under each of the tested rules.

5.3 Unconditional variance of endogenous variables

We showed that a super-inertial interest rate rule overturns expectations and with them the economy's dynamics.[34] In order to assess which rule is preferable, one alternative would be to calculate the welfare loss for each rule. However, because the welfare loss function is model-dependent, we choose another alternative and compare the unconditional variance of the inflation gap, output gap, output, and interest rate under each of the tested rules. We should point out, however, that this exercise sheds only some light on welfare analysis, because we test only demand-side shocks, and not all shocks.

Figure 12 shows (the natural log of) the ratio of the endogenous variables' unconditional variance under IATR, SIATR, SIATR2, and FDTR to that under the benchmark standard inertial Taylor rule, in each of the 9 tested models. Hence, a ratio below zero reflects a higher unconditional variance under the benchmark rule than under the alternative rule, and conversely.

Several conclusions emerge:

(1) Both inertial rules (ITR and IATR) yield similar unconditional variances of inflation gap, output gap, and output: the natural log of the ratio between the two rules is close to zero in almost all of the tested models. However, ITR yields lower interest rate volatilities in all models.

(2) Both super-inertial rules (SIATR and SIATR2) yield lower interest rate volatilities than the other tested rules in 6 out of the 9 models, with SIATR2 yielding the lowest

[34] While this outcome is, without a doubt, desirable in the case of deflation, it may also be desirable in the case of ongoing inflation with a positive output gap deviation from steady state.

interest rate volatilities. Both super-inertial rules also yield lower inflation rate volatilities, demonstrating a major improvement over ITR in 4 out of the 9 models.

(3) However, there may be a tradeoff: the lower volatility of the interest rate and inflation under the super-inertial rules comes at the cost of the considerably higher volatility of the output gap and the output in 3 out of the 9 models, respectively.

(4) SIATR2 is preferable to SIATR, as it yields a lower interest rate, output gap, and output volatilities in 8, 6, and 6 out of the 9 tested models, respectively. As for inflation, SIATR2 represents a major improvement in 2 models, similar volatility in 4 models, and slightly higher volatility in the remaining model.

(5) Out of all the rules tested, the first-difference Taylor rule yields the lowest output gap volatilities (in all models) and output volatilities (in all but one model). As for inflation, there is no dominance relation between the SIATRs and FDTR in terms of lower inflation volatility.

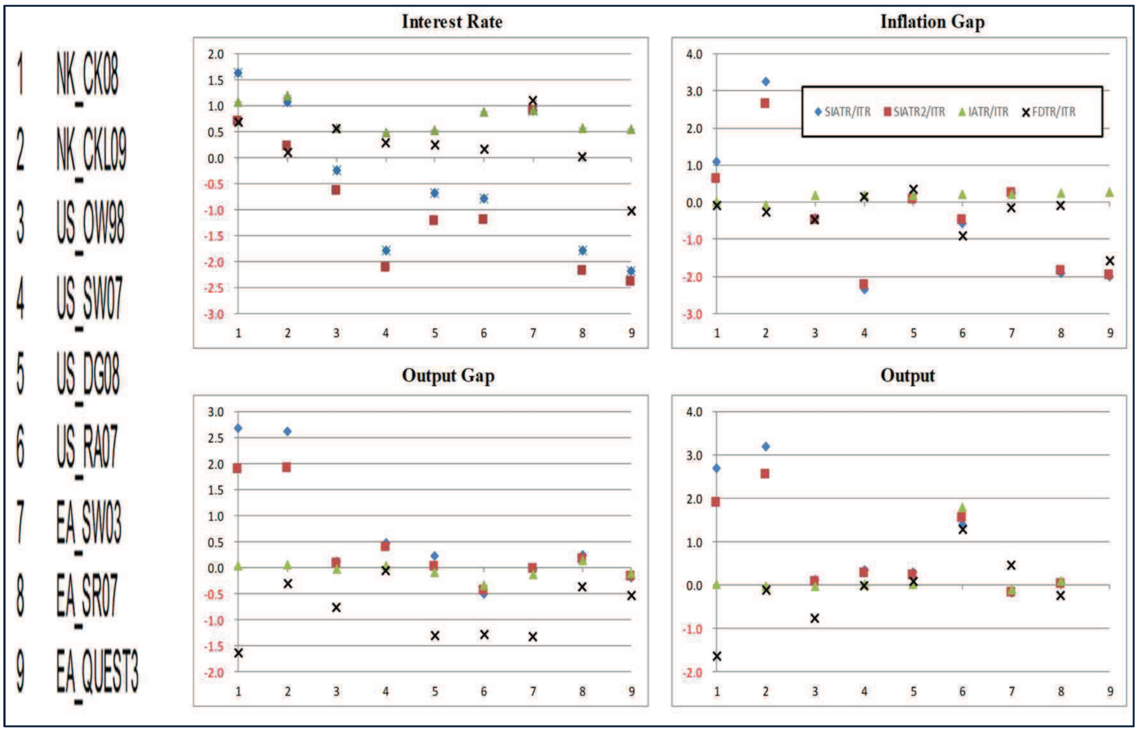

Fig. 12. The (natural log of the) ratio of unconditional variance to that under the benchmark Taylor rule, in different macroeconomic models. A below-zero ratio (y axis) reflects higher unconditional variance under the inertial benchmark rule than under the alternative rule, and conversely. Axis x relates to the 9 tested macromodels.

6. Summary and Conclusions

We show that super-inertial interest rate rules, where the *sum* of the coefficients of lagged interest rates is above a threshold greater than one, yield robust positive inflation gap and positive future output gap responses after a negative demand-side shock, in a wide range of macroeconomic models. super-inertial rules also robustly mitigate the output decline after a negative demand shock, and the risk of hitting the ELB.

As the transmission mechanism for overturning the inflation and the future output gap responses works through the expectations channel, we show that the more backward-looking the economy is, the higher the threshold is.

We also show that a super-inertial rule yields a less volatile interest rate and inflation compared to standard inertial rules. In particular, a super-inertial rule where each of the lagged interest rate coefficients is below one leads, in most tested models, to more efficient outcome of lower interest rate and inflation volatilities together with similar output gap and output volatilities, compared to other tested super-inertial and inertial rules.

Hence, our simulations imply that a super-inertial Taylor-type rule may be more effective than a standard inertial rule, because it overturns inflation dynamics, rather than gradually making it converge to steady state. Thus, super-inertial policy can be useful in an environment of deflation (respectively, ongoing inflation) due to negative (respectively, positive) demand shocks, or when stepping out of a recession or a demand-driven crisis. As such, it is a conventional tool that may be used to attain unconventional results.

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Table A.1 Published estimated weights in the objective function and (inverse) risk aversion parameter

	λ_x	λ_i	$\lambda_{\Delta i}$	σ
Woodford (2003a)	0.048	0.236/0.077/0.277		1/0.1571
Givens (2012)	0.0401		0.6309	1.3667
Adolfson et al. (2011)	1.091		0.476	5

Table B.1

Parameter	Value	Description
β	0.99	Discount factor
κ	0.1	Slope of the Phillips Curve
γ_p	0.2	Inflation indexation
h	0.2	Parameter of habit formation
$\hat{\sigma}$	1.5	Consumption intertemporal elasticity of substitution
$\tilde{\rho}_1$	0.8	Interest rate smoothing in the policy rule
τ_π	$0.2 \cdot 1.5$	Coefficient of the inflation term in the policy rule
τ_x	$0.2 \cdot 0.5$	Coefficient of the output gap in the policy rule
ρ_g	0.35	AR(1) coefficient of the demand shock

The baseline calibration (Table B.1) is mostly based on Woodford (2003a, p. 431), Giannoni (2014) and Smets and Wouters (2007).