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The Value of Interest Rate Stabilization Polices When Agents are Learning

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Abstract

We examine the expectational stability (E–stability) of rational expectations equilibrium under optimal interest rate rules in the context of the standard, "New Keynesian" model of the monetary transmission mechanism. We focus on the case where the monetary authority adds interest rate stabilization to its other objectives of inflation and output stabilization. We consider both the case where the monetary authority lacks a commitment technology and as well as the case of full commitment. We show that for both cases, optimal interest rate rules yield rational expectations equilibria that are E-stable for a wide range of empirically plausible parameter values. This finding stands in contrast to the findings of Evans and Honkapohja (2002, 2003ab) for optimal monetary policy rules in environments where interest rate stabilization is not part of the central bank's objective function.

1 Introduction

Evans and Honkapohja (2002, 2003ab) examine the stability, under adaptive learning dynamics, of rational expectations equilibrium (REE) in the standard New Keynesian model of the monetary transmission mechanism[1] when the policy rule of the central bank is optimally derived. They consider the case where the central bank minimizes a quadratic loss function that penalizes deviations of inflation and output from certain exogenous target values. The result of this minimization problem is an optimal interest rate rule which interacts with the equations characterizing the behavior of the private sector.

Evans and Honkapohja report that, regardless of whether the central bank operates under commitment or discretion, the REE of the system is always expectationally *un*stable when the policy rule is derived under the incorrect assumption that the private sector has rational expectations – Evans and Honkapohja call this policy rule the "fundamentals–based" policy rule. While the private sector is assumed to use the correct reduced form model to form expectations, and it upates the parameters of this model in real time using all relevant data, the central bank's fundamentals–based interest rate policy causes this adaptive learning process to diverge away from the REE, and for this reason, the fundamentals–based policy rule is considered undesireable.[2] This instability result suggests that the central bank might do well to assume that the private sector does not (initially) posses rational expectations. Indeed, Evans and Honkapohja show that if the central bank does not assume rational expctations on the part of the private sector, the resulting, optimally derived, "expectations–based" interest rate rule, which conditions on the private sector's expectations of inflation and output, results in a REE that is always expectationally stable.

Conditioning policy on private sector expectations presents some difficulties that may not be so easily overcome. First, the private sector's expectations may not be observable, or might be quite heterogeneous, so that figuring out which expectations to use becomes a complicated task. Second, as Honkapohja and Mitra (2003) point out, if it the central bank was known to be conditioning policy on private sector expectations, the private sector might begin to form its expectations strategically in an effort to steer policy in a direction it found more favorable. Third, conditioning on private sector expectations can increase the likelihood that the REE becomes indetermiante, as shown by Bernanke and Woodford (1997). Indeterminacy implies multiple solution paths preventing the use of standard, comparative static exercises and it also allows for the possibility that non-fundamental

[1] See Clarida et al. (1999) for a presentation of this model.

[2] See Evans and Honkapohja (2001) for a complete treatment of the notion of expectational (in)stability.

sunspot shocks provide and additional source of volatiliy.[3]

In this paper, we consider an alternative approach in which the central bank does not need to condition on private sector expectations. Instead, the central bank continues to presume rational expectations on the part of the private sector, but the central bank expands its loss function to include interest rate stabilization as a third objective, in addition to the traditional twin objectives of inflation and output stabilization. As Woodford (2003) notes, the optimal monetary policy rules derived under this alternative, three-element objective function share many similarities with Taylor-type instrument rules. Specifically, these optimally derived policy rules posit that the nominal interest rate is a function of the inflation and output gaps, and these rules obey Taylor's principle. This same finding is not true of optimal interest rate rules derived under the more typical (but less general) two–element objective function that ignores interest rate stabilization. As Taylor-type instrument rules appear to have considerable empirical validity over time and across countries, (see, e.g. Taylor (1999)), this external validation carries over to the optimal interest rate rules that we consider in this paper.

We show that when the central bank adopts interest rate stabilization as part of its objective, the resulting optimal interest rate rules yield rational expectations equilibria that are stable under adaptive learning dynamics for a wide range of weighting parameters under all calibrations of the New Keynesian model that have appeared in the literature. This result holds, for certain parameter values, regardless of whether the central bank operates under commitment or is limited to discretionary policy decisions.

2 The model

The model of the private sector is the standard, "cashless" New Keynesian model used in analyses of the monetary policy transmission mechanism (as set forth, e.g. in Clarida et al. (1999) or Woodford (2003)) and consists of the following equations:

$$x_t = -\varphi(i_t - E_t\pi_{t+1}) + E_t x_{t+1} + g_t \qquad (1)$$

$$\pi_t = \lambda x_t + \beta E_t \pi_{t+1} + u_t \qquad (2)$$

$$v_t = (g_t, u_t)' = F v_{t-1} + e_t \qquad (3)$$

[3] Evans and Honkapohja (2003ab) are careful to show that indeterminacy of REE is *not* a problem when the central bank uses the optimally dervied, expectations-based interest rate rules that condition on private sector expectations. Berardi (2004) reconciles Evans and Honkapohja's finding with that of Bernanke and Woodford (1997) and shows that the main differences lie in different timing assumptions and in Evans and Honakpohja's assumption that central bank policy is optimally derived.

The parameters φ and λ are assumed to be positive, as is the discount factor, $0 < \beta < 1$. The intertemporal IS equation (1) relates the output gap x_t, to its expected future value $E_t x_{t+1}$, and to the the real interest rate; i_t is the short-term (one-period) nominal interest rate and $E_t \pi_{t+1}$ is the expected inflation rate between t and $t+1$. The aggregate supply equation (2) relates the current inflation rate π_t to expected future inflation and the current output gap. Both equations can be derived from explicit microfounded models. The last equation (3) characterizes how the demand and supply shock processes, g_t and u_t, evolve over time:

$$F = \begin{bmatrix} \mu & 0 \\ 0 & \rho \end{bmatrix}$$

where $|\mu|$, $|\rho| \in (0,1)$, $e_t = (e_{gt}, e_{ut})$ and $e_{it} \sim$ i.i.d.$(0, \sigma_i^2)$, $i = g, u$.

This model is closed by specifying how the central bank determines the short-term nominal interest rate, i_t.

Suppose the central bank's objective is to minimize:

$$E_0 \sum_{t=0}^{\infty} \beta^t L_t, \tag{4}$$

where $\beta \in (0,1)$ is the discount factor and the period loss function is:

$$L_t = (\pi_t - \pi)^2 + \alpha_x (x_t - x)^2 + \alpha_i (i_t - i)^2$$

where π_t denotes the inflation rate between period $t-1$ and t, x_t denotes the time t output gap, and i_t is the short-term nominal interest rate in period t. Variables without subscripts represent central bank target values which are assumed to be constant. In particular, we will assume that $\pi = x = 0$. The relative weights given to the output and interest rate stabilization objectives are $\alpha_x > 0$ and $\alpha_i > 0$. This period loss function differs from the one considered by Evans and Honkapohja (2003ab, 2002) by the inclusion of the third, interest rate stabilization element; Evans and Honkapohja have $\alpha_i = 0$.

3 Discretionary Policy

We first consider the case where the central bank cannot commit to future policies. Optimal monetary policy in this case amounts to minimization of (4) subject to versions of equations (1–2) modified to take account of the central bank's lack of commitment:

$$x_t = -\varphi i_t, \tag{5}$$

$$\pi_t = \lambda x_t. \tag{6}$$

The three first order conditions from this optimization problem can be manipulated to yield the optimal interest rate rule:

$$i_t = i + \frac{\varphi\lambda}{\alpha_i}\pi_t + \frac{\varphi\alpha_x}{\alpha_i}x_t. \tag{7}$$

The rule (7) is of the same form as Taylor's instrument rule, though in this case it has been optimally derived. In particular, (7) requires knowledge of the contemporaneous inflation and output gaps but does not require knowledge of the contemporaneous shocks, u_t, g_t, in contrast to the optimal interest rate rule studied by Evans and Honkapohja (2003) under discretionary policy.

The system under discretionary policy thus consists of equations (1), (2) and (7). Letting $y_t = (x_t,\ \pi_t)'$, this system can be further reduced and written as:

$$y_t = \delta_0 + \delta_y E_t y_{t+1} + \delta_v v_t, \tag{8}$$

where δ_0, δ_y and δ_v representing comformable vectors or matrices with elements that are combinations of structural model parameters.

To study the stability of the rational expectations equilibrium under adaptive learning, we follow Evans and Honkapohja (2001) and suppose that agents have a *perceived* law of motion that corresponds to the minimal state variable (MSV) representation of the rational expectation solution to the system (8). This perceived law of motion may be written as:

$$y_t = d_0 + d_v v_t.$$

Using this perceived law of motion, agents form expectations of y_{t+1}:

$$E_t y_{t+1} = d_0 + d_v F v_t$$

Substituting these expectations into (8) (in lieu of rational expectations) yields a mapping from the perceived law of motion to the *actual* law of motion:

$$y_t = T_{d_0}(d_0) + T_{d_v} v_t,$$

where

$$\begin{aligned} T_{d_0}(d_0) &= \delta_0 + \delta_y d_0 \\ T_{d_v}(d_v) &= \delta_y d_v F + \delta_v \end{aligned}$$

The rational expectations solution consists of values $\overline{d}_0 = T_{d_0}(\overline{d}_0)$ and $\overline{d}_v = T_{d_v}(\overline{d}_v)$. Expectational (E)–stability of $(\overline{d}_0, \overline{d}_v)$ is governed by local asymptotic stability of the matrix differential equation:

$$\frac{d}{d\tau}(d_0, d_v) = T(d_0, d_v) - (d_0, d_v).$$

Evans and Honkapohja (2001) show that E–stability requires that the eigenvalues of

$$\begin{aligned} DT_{d_0} &= \delta_y, \\ DT_{d_v} &= \delta_y F, \end{aligned}$$

have real parts less than unity. As Evans and Honkapohja (2003) point out, these conditions correspond closely to whether or not the rational expectations equilibrium of the system (8) is determinate; the condition for determinacy is that the eigenvalues of δ_y are all less than unity. Indeed, given the restrictions imposed on the matrix F it is clear that in this case of discretionary policy, the determinacy and the E–stability conditions exactly coincide. As Duffy (2003) shows:

$$\delta_y = \frac{1}{\xi}\begin{bmatrix} \alpha_i & \varphi(\alpha_i - \lambda\varphi\beta) \\ \lambda\alpha_i & \varphi(\lambda\alpha_i + \beta\varphi\alpha_x) + \beta\alpha_i \end{bmatrix},$$

where $\xi = \alpha_i + \varphi^2(\alpha_x + \lambda^2)$. Since the eigenvalues of this matrix do not yield clear analytic results, we must investigate them numerically. Duffy (2003) considered one calibration, due to Woodford (1999), but in this paper, we provide a more general analysis, considering several different calibrations that have appeared in the literature and allowing the values of the two weights, α_x and α_i in the central bank's objective function to vary over a grid of plausible values. In addition, Duffy (2003) did not consider the case where the central bank operates under commitment. We now turn to an analysis of that case.

4 Policy Under Commitment

If the central bank can commit to future policies, the problem it faces changes to reflect this possibility. In particular, we follow Woodford (2003) in adopting the timeless perspective to optimal policy under commitment. This perspective requires that the central bank minimizes (4) subject to the original private sector equations, (1)–(2). The first order conditions from this optimization problem can be manipulated to obtain the optimal interest rate rule under commitment:

$$i_t = -\frac{\varphi\lambda i}{\beta} + \frac{\varphi\lambda}{\alpha_i}\pi_t + \frac{\alpha_x\varphi}{\alpha_i}(x_t - x_{t-1}) + \frac{\varphi\lambda + \beta + 1}{\beta}i_{t-1} - \frac{1}{\beta}i_{t-2} \tag{9}$$

As noted by Giannoni and Woodford (2003), the optimal rule (9) bears a close resemblance to the policy-smoothing version of the Taylor instrument rule, though (9) involves greater history dependence (via the variables x_{t-1}, i_{t-2}) than is typically assumed in policy smoothing versions of Taylor instrument rules.

Using the optimal rule (9) to substitute out for i_t in (1), we have

$$\begin{aligned}(1+\frac{\alpha_x\varphi^2}{\alpha_i})x_t &= \frac{\varphi^2\lambda}{\beta}i+\varphi E_t\pi_{t+1}+E_tx_{t+1}-\frac{\varphi^2\lambda}{\alpha_i}\pi_t+\frac{\alpha_x\varphi^2}{\alpha_i}x_{t-1}\\ &-\frac{\varphi(\varphi\lambda+\beta+1)}{\beta}i_{t-1}+\frac{\varphi}{\beta}i_{t-2}+g_t\end{aligned}$$

Defining $y_t=(x_t,\pi_t)'$ and $w_t=(i_t,i_{t-1})'$,the system under commitment can be written as:

$$y_t=\delta_0+\delta_{y1}E_ty_{t+1}+\delta_{y2}y_{t-1}+\delta_w w_{t-1}+\delta_v v_t \tag{10}$$

The interest rule (9) can also be written in matrix notation as

$$\begin{aligned}\begin{bmatrix} i_t \\ i_{t-1}\end{bmatrix} &= \begin{bmatrix} -\frac{\varphi\lambda i}{\beta} \\ 0\end{bmatrix}+\begin{bmatrix}\frac{\alpha_x\varphi}{\alpha_i} & \frac{\varphi\lambda}{\alpha_i}\\ 0 & 0\end{bmatrix}\begin{bmatrix} x_t\\ \pi_t\end{bmatrix}+\begin{bmatrix}-\frac{\alpha_x\varphi}{\alpha_i} & 0\\ 0 & 0\end{bmatrix}\begin{bmatrix}x_{t-1}\\ \pi_{t-1}\end{bmatrix}\\ &+\begin{bmatrix}\frac{\varphi\lambda+\beta+1}{\beta} & 1/\beta\\ 1 & 0\end{bmatrix}\begin{bmatrix} i_{t-1}\\ i_{t-2}\end{bmatrix}\end{aligned}$$

or simply

$$w_t=a_0+a_1y_t+a_2y_{t-1}+a_3w_{t-1} \tag{11}$$

The perceived law of motion (PLM) in this case is:

$$y_t=d_0+d_yy_{t-1}+d_ww_{t-1}+d_vv_t \tag{12}$$

Given (12), (3) and (11), we obtain the expected value of y_{t+1} as

$$E_ty_{t+1}=d_0+d_yy_t+d_w(a_0+a_1y_t+a_2y_{t-1}+a_3w_{t-1})+d_vFv_t$$

Since there are two y_t terms in this equation, we need to apply (12) one more time to eliminate them. Doing this yields

$$E_ty_{t+1}=\psi_0+\psi_yy_{t-1}+\psi_ww_{t-1}+\psi_vv_t, \tag{13}$$

where

$$\begin{aligned}\psi_0 &= d_wa_0+(I+d_y+d_wa_1)d_0\\ \psi_y &= (d_y+d_wa_1)d_y+d_wa_2\\ \psi_w &= (d_y+d_wa_1)d_w+d_wa_3\\ \psi_v &= (d_y+d_wa_1)d_v+d_vF\end{aligned}$$

Substituting (13) into (10), we can get the T-map from the PLM to the actual law of motion (ALM):

$$
\begin{aligned}
T(d_0) &= \delta_0 + \delta_{y1}[d_w a_0 + (I + d_y + d_w a_1)d_0] &(14)\\
T(d_y) &= \delta_{y1}[(d_y + d_w a_1)d_y + d_w a_2] + \delta_{y2} &(15)\\
T(d_w) &= \delta_{y1}[(d_y + d_w a_1)d_w + d_w a_3] + \delta_w &(16)\\
T(d_v) &= \delta_{y1}[(d_y + d_w a_1)d_v + d_v F] + \delta_v &(17)
\end{aligned}
$$

A closer look at this mapping reveals that (15) and (16) are quadratic in d_y and d_w, respectively, so there are multiple MSV rational expectation solutions. Once d_y and d_w are obtained, there are unique values of d_0 and d_v that correspond to them, which is obvious from (14) and (17). Rather than calculate all possible solutions, we focus on the unique, saddle point stable solution. This solution can be found using the Blanchard-Kahn technique described, e.g., in Evans and Honkapohja (2001, Section 10.8). Thus, for the commitment case, we are restricting attention to determinate REE.

The conditions for expectational stability of the REE solutions to the system (10) are again addressed in Evans and Honkapohja (2001, section 10.3) The conditions are that the eigenvalues of the matrices DT_{d_j}, $j = 0,y,w,v$ all have real parts less than unity. The relevant matrices are:

$$
\begin{aligned}
DT_{d_0} &= \delta_{y1}(I + \overline{d_y} + \overline{d_w}a_1)\\
DT_{d_y} &= \overline{d_y'} \otimes \delta_{y1} + I \otimes (\delta_{y1}\overline{d_y} + \delta_{y1}\overline{d_w}a_1)\\
DT_{d_w} &= \overline{d_w'} \otimes \delta_{y1}a_1 + I' \otimes \delta_{y1}(\overline{d_y} + a_1\overline{d_w} + a_3)\\
DT_{d_v} &= \delta_{y1}\overline{d_y} + \delta_{y1}\overline{d_w}a_1 + \delta_{y1}F
\end{aligned}
$$

In the case of optimal policy under commitment, it is no longer the case that determinacy and stability of equilibrium under adaptive learning are inextricably linked; while we focus on determinate REE, these equilibria may or may not satisfy the E-stability conditions given above. Again, it is not possible to obtain analytic results, so we must resort to numerical methods to assess whether the REE in the commitment case are stable under adaptive learning. We now turn to this numerical exercise.

5 Numerical Analysis

The calibrated values of the structural model parameters that we consider in our numerical exercise are due to Woodford (W) (1999), Clarida, Gali and Gertler (CGG) (1999), and McCallum and

Author	φ	λ
W	1/0.157	0.024
CGG	1	0.3
MN	0.164	0.3

Table 1: Three values of the structural parameters of the model

Nelson (MN) (2000) and are given in Table 1. In addition, we assume that $\rho = \mu = .35$ in (3) for all three model calibrations.

The strategy we pursue in our numerical analysis is to consider the stability of the rational expectations equilibrium for each of the three structural model calibrations and for both the case of discretionary policy and policy under commitment – a total of 6 numerical exercises. For each exercise, we vary the weights α_i and α_x in the policymaker's loss function. The case where $\alpha_i = 0$ corresponds to the case that Evans and Honkapohja (2002, 2003ab) considered previously; numerical results when $\alpha_i > 0$ therefore provide us with information on the *value* of interest rate stabilization policies in promoting learnability of the rational expectations equilibrium.

5.1 Numerical Findings Under Discretionary Policy

Figures 1-3 show our numerical findings under discretionary policy for the three calibrations given in Table 1 for various combinations of α_x and α_i. The numerical routine checks the eigenvalues of the matrix δ_y to determine whether the eigenvalues have real parts less than unity. If this is the case, the rational expectations solution is both E–stable and determinate, and a *star* is plotted for that (α_x, α_i) combination. Otherwise, an open circle is plotted indicating that the rational expectations solution is both E–unstable and indeterminate for that (α_x, α_i) combination. (Recall that in the discretionary policy case E-stability and determinacy conditions exactly coincide).

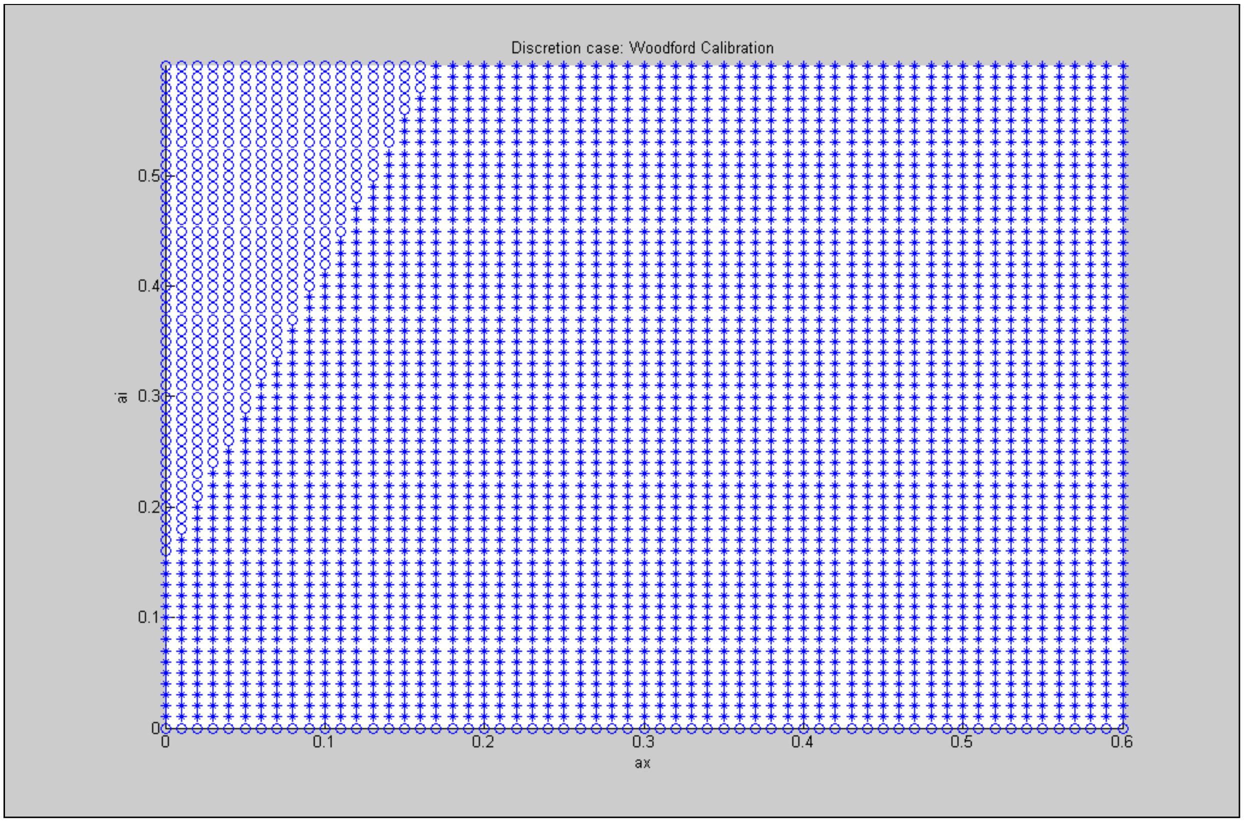

Figure 1: Discretionary Policy, Woodford Calibration

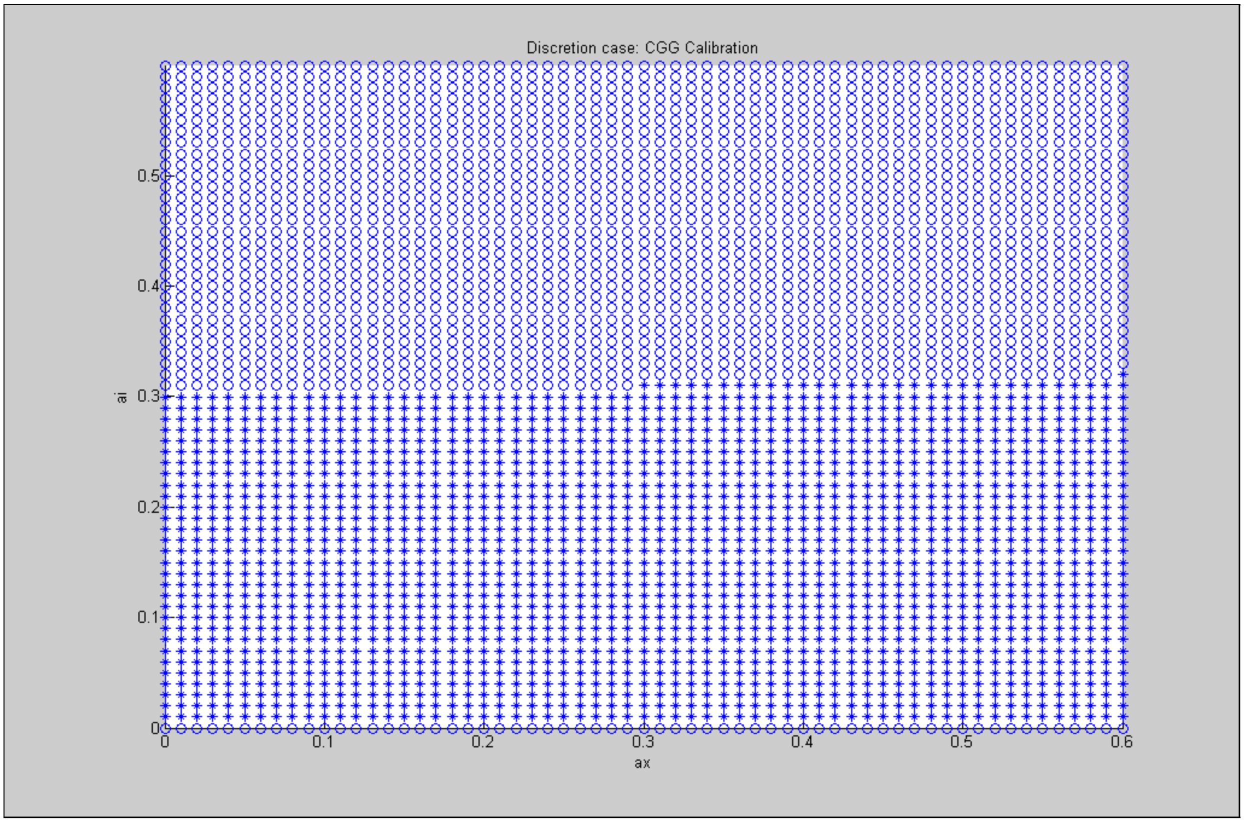

Figure 2: Discretionary Policy, Clarida et al. Calibration

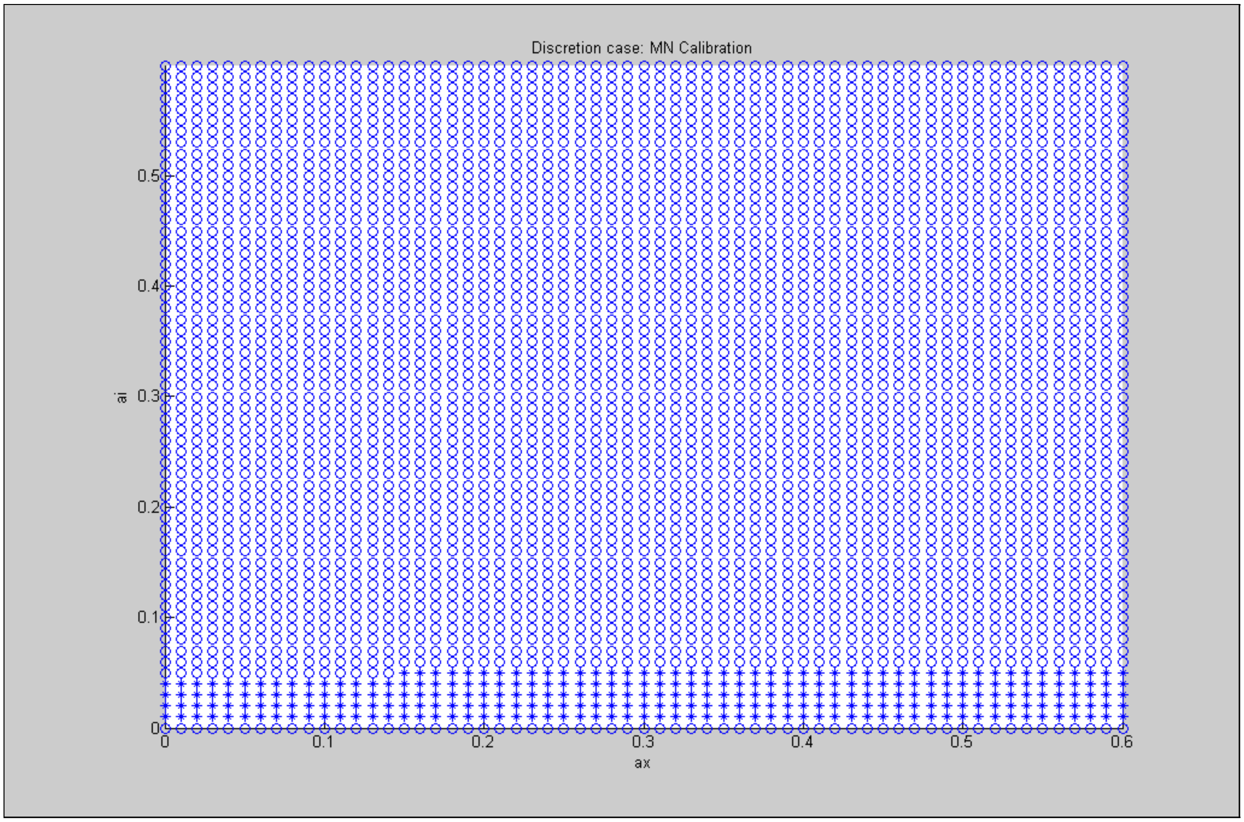

Figure 3: Discretionary Policy, McCallum-Nelson Calibration

Figures 1-3 reveal that for all three calibrations there exist (α_x, α_i) combinations for which the rational expectations equilibrium solution is E-stable and determinate.

Woodford (1999) is the only author to provide calibrations for α_x and α_i; he proposes that $\alpha_x = .047$ and $\alpha_i = .233$. With these choices, and the Woodford (W) calibration of the structural parameters, Figure 1 reveals that the rational expectations equilibrium is both E–stable and determinate. Using the same structural parameter choices as in Woodford (1999), Woodford (2003, Table 6.1) proposes somewhat different weights of $\alpha_x = .048$ and $\alpha_i = .077$. For the latter choices, the rational expectations equilibrium is again found to be both E–stable and determinate. As Figure 1 reveals, determinacy and E-stability are obtained for all values of α_x so long as $\alpha_i \neq 0$ (interest rate stabilization is not an objective) and provided that α_i is not too great.

A similar conclusion holds for the other two calibrations (CGG, MN) as seen in Figures 2–3. The range of $(\alpha_x,\ \alpha_i)$ pairs for which E-stability obtains is greatest in the W calibration, and smallest in the MN calibration. However, there is always some $(\alpha_x,\ \alpha_i)$ pair for which the REE is E–stable and determinate. If the weight given to interest rate stabilization is zero as in Evans and

Honkapohja (2002, 2003ab), the rational expectations equilibrium is never stable under adaptive learning dynamics, hence the value of interest rate stabilization policies when agents are learning.

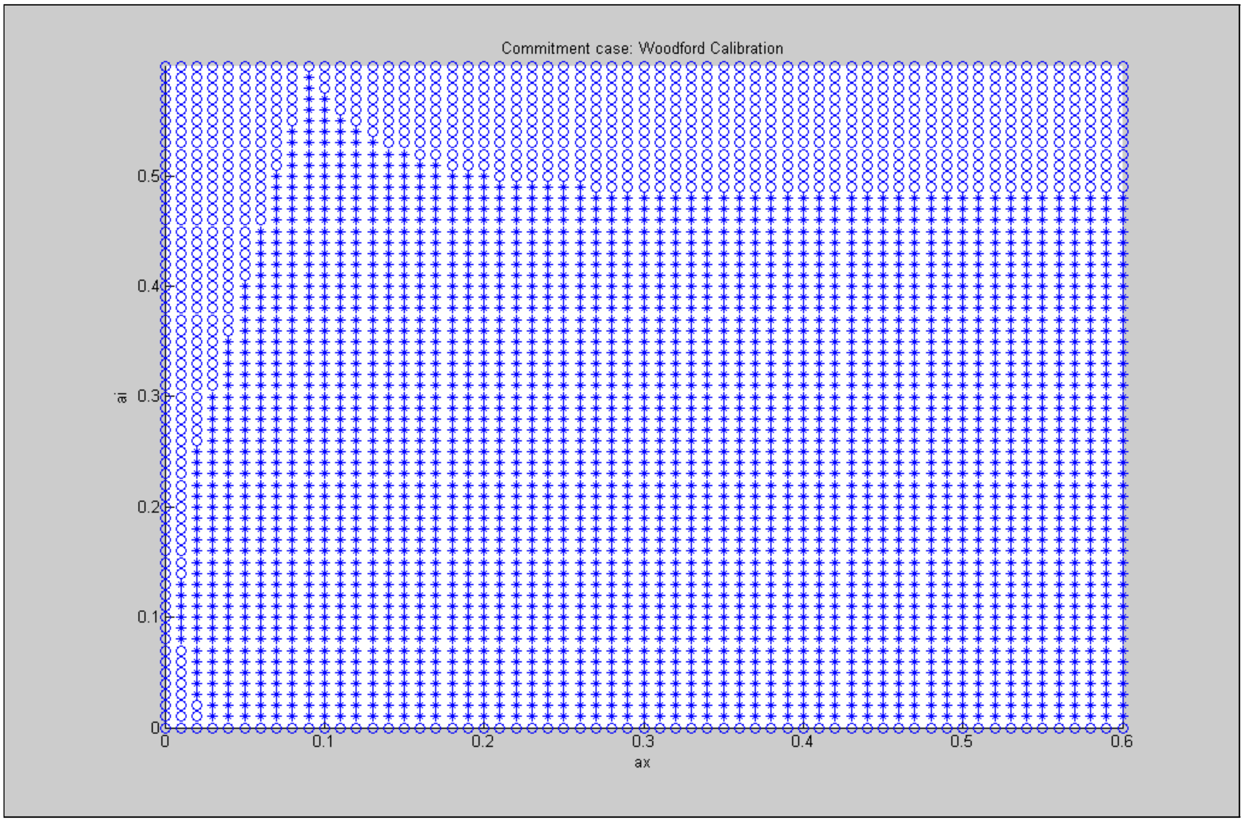

Figure 4: Commitment Policy, Woodford Calibration

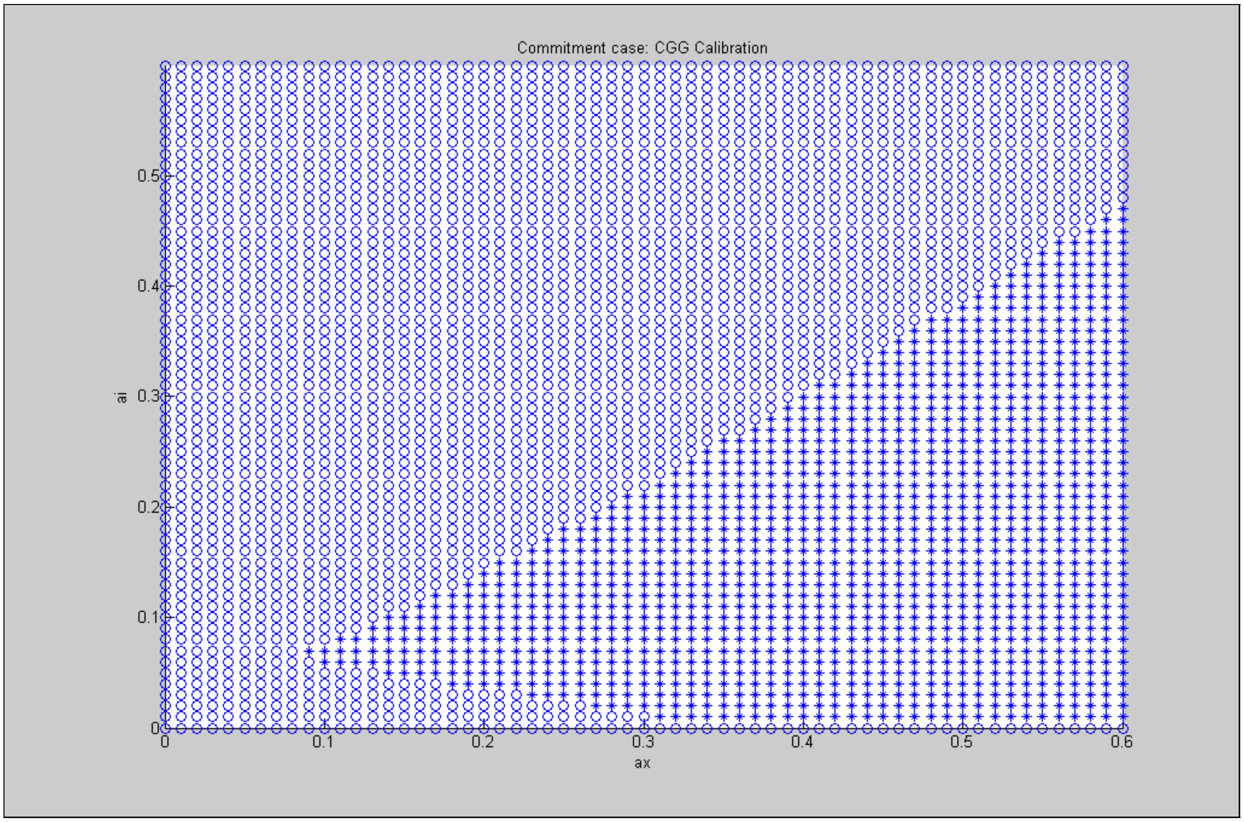

Figure 5: Commitment Policy, Clarida et al. Calibration

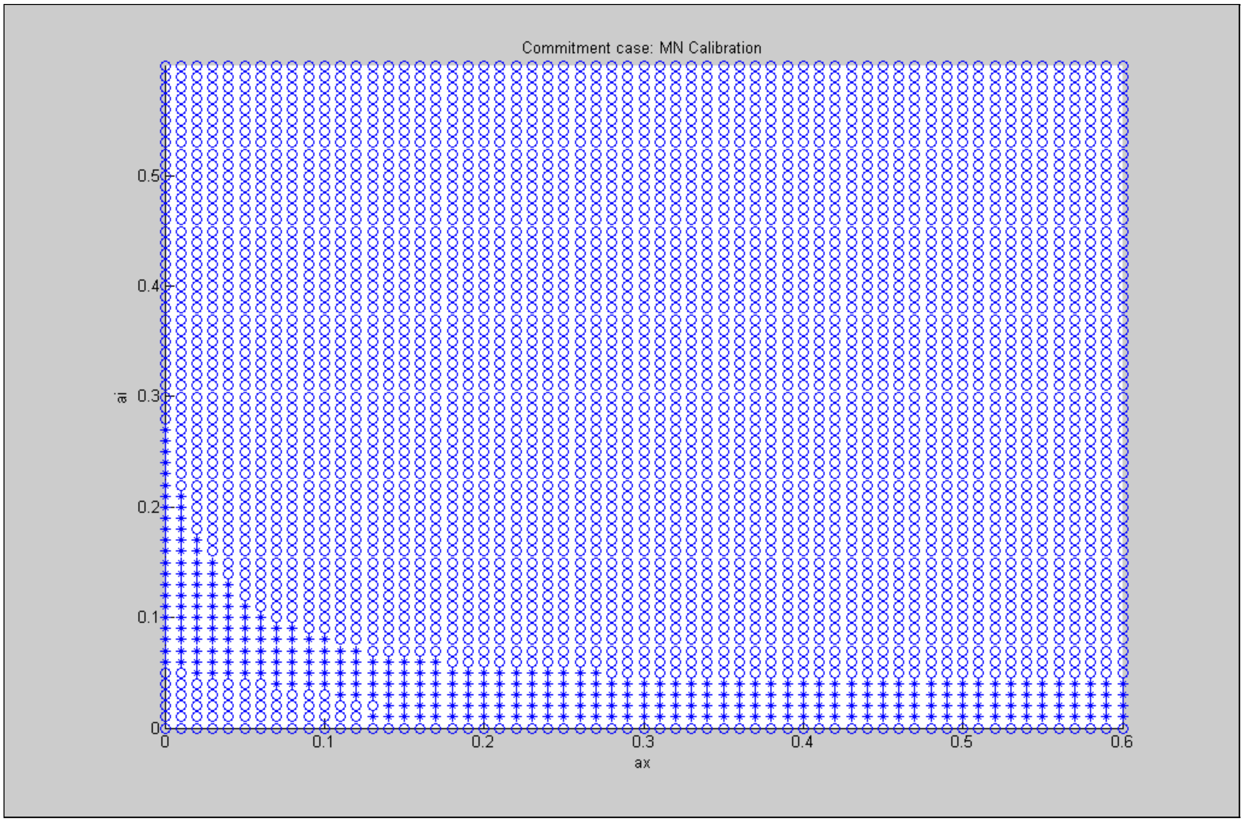

Figure 6: Commitment Policy, McCallum-Nelson Calibration

Figures 4-6 show comparable results for the case of optimal policy under commitment. Recall that for this case, we restricted attention to the unique, determinate, saddle path stable REE. Recall that in the commitment case, the conditions for E–stability and determinacy of equilibrium need not coincide. To assess E–stability, we check whether all of the eigenvalues of the matrices DT_{d_j}, $j = 0,y,w,v$ have real parts less than unity. If this is the case, the REE is E–stable and a star is plotted as before. If this is not the case, the REE is E–unstable, and an open circle is plotted.

Figures 4–6 confirm that in the commitment case, there always exist (α_x, α_i) combinations such that the REE is E–stable. However, the set of policy weight pairs for which E–stability holds for each structural model calibration is more restricted than in the comparable discretionary policy case. For the Woodford (W) calibration, Figure 4 reveals that the weights proposed by Woodford (1999) $\alpha_x = .047$ and $\alpha_i = .233$, are consistent with an E–stable REE. This same finding holds for the alternative pair of weights proposed in Woodford (2003), $\alpha_x = .048$ and $\alpha_i = .077$.

Conclusions

Evans and Honkapohja (2002, 2003ab) consider optimal monetary policy under discretion or commitment, where the central bank's objective is to minimize (4) with α_i set to 0. They show that using the optimal interest rate rule, the fundamentals-based MSV rational expectations equilibrium is always expectationally (E)-unstable in this case. They go on to show that if private sector expectations are included in the central bank's optimal policy rule, that the E-instability finding can be reversed, and the resulting expectations-based policy rule leads to a MSV REE that is E–stable.

We show that if central bankers are concerned with interest rate stabilization, and alter their loss function objective (4) by setting $\alpha_i > 0$, the resulting optimal interest rate policy yields a fundamentals-based MSV rational expectations equilibrium that *is* E-stable for a wide variety of calibrations found in the literature under both discretionary and commitment policy regimes. This result obtains *without* the requirement that the central bank condition its policy decision on private sector expectations, in contrast to the findings of Evans and Honkapohja (2002, 2003ab). Furthermore, the optimal interest rate rules derived under the assumption that $\alpha_i > 0$ closely resemble Taylor–type instrument rules, which are ad hoc, but empirically relevant. Optimal interest rate rules derived under the assumption that $\alpha_i = 0$ do not resemble Taylor rules.

We conclude that the value of interest rate stabilization as a central bank objective is that it may aid private sector learning of the rational expectations equilibrium relative to the case where this objective is absent.

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