# Japan's bubble: Monetary stability and structural economic reform

Huw Pill
Harvard University*

March 12, 2003

**Abstract**

In the context of a small monetary DSGE model of the business cycle, this paper investigates the interrelationship between structural economic reform (modeled as the introduction of greater competition in the goods market) and monetary stability (captured by the dynamic stability of the resulting macroeconomic system). After making minor but plausible adjustments to the standard New Keynesian macroeconomic framework, the paper demonstrates that a conventional monetary policy framework, defined by adherence to the so-called Taylor principle, may – contrary to the received wisdom – fail to maintain macroeconomic and monetary stability. The likelihood of such failure increases as structural economic reform is introduced for two reasons: first, greater goods market competition narrows equilibrium mark-ups and thus the leverage monetary policy exerts over cyclical inflation developments; and, second, private sector expectations are subject to non-fundamental shocks that arise from the uncertainty surrounding the effectiveness of structural reform.

JEL classification: E42, E52, E58
Key words: Monetary stability, structural reform, Taylor principle.

* Morgan 279, Harvard Business School, Boston, MA 02163, USA.
Tel. + 1 617 / 495-6788. Fax + 1 617 / 496-5944. E-mail hpill@hbs.edu.

This paper was originally prepared for Keio University and the National Institute for Research Advancement Design Japan conference, which was held in Tokyo on 27-28 February 2003. The HBS Division of Research provided financial support and the HBS Japan Research Office (and in particular Masako Egawa) offered invaluable assistance. Thanks are due to participants in the conference, especially the discussant Professor Naoyuki Yoshino. Dieter Gerdesmmeier, Massimo Rostagno, Klaus Masuch and Roberto Motto also gave valuable advice and comments on the material underlying this paper. The responsibility for all remaining errors is entirely that of the author.

# 1 Introduction

In prescribing solutions to Japan's ongoing economic malaise, foreign commentators fall into two camps. On the one hand, a number of prominent Western macroeconomists (e.g., Krugman, 1999; Svensson, 2001) have emphasized the need for macroeconomic stimulus, advocating a more active use of monetary policy (if necessary by the adoption of unconventional operational techniques). On the other hand, business academics and microeconomists (e.g., Porter, et al., 2000) emphasize the importance of structural economic reform, including extensive restructuring of the corporate sector and modernization of its institutional environment. Seeking a middle way, others propose "not one or the other [of these strategies], but both" (The Economist, 2001).

This paper does not evaluate the merits of the arguments presented by these two rival camps. Rather it outlines an analytical framework that reveals some of the important interrelationships among macroeconomic policies, structural microeconomic reforms and technological change, thereby suggesting that the dichotomy characteristic of the existing literature is somewhat misplaced. In developing these relationships, the paper adopts an essentially backward-looking perspective. It offers scope for developing a better understanding of how Japan reached its current state, but does not prescribe solutions to her ongoing problems. Nonetheless, understanding the past is a prerequisite for facing the future.

A large literature has evaluated the performance of monetary policy rules in dynamic stochastic general equilibrium (DSGE) models of the macroeconomy (e.g., many of the papers contained in Taylor, 1999a). This paper contributes to that literature in two ways. First, it develops a small monetary DSGE model, which – in contrast to the benchmark New Keynesian model characteristic of the existing literature (e.g., Clarida, et al., 1999) – allows monetary dynamics to influence the evolution of key macroeconomic variables such as inflation and output. While only a first and very modest step in this direction, such an approach seems desirable given the prominence attached to monetary and financial issues in many (if not most) discussion of Japan's current malaise. Second, the paper investigates whether a monetary policy following the existing conventional wisdom (itself derived from the New Keynesian framework) is sufficient to maintain macroeconomic stability within the monetary DSGE model in the face of structural change and technological innovation of uncertain magnitude. In particular, the paper considers the vulnerability of the economy to the emergence of expectational bubbles.

The remainder of the paper is organized as follows. Section 2 provides some background by briefly summarizing relevant literature on the Japanese economy. Section 3 derives the monetary model of the economy from its microeconomic foundations. Section 4 evaluates the stability of this model under the conventional monetary policies associated with the Taylor principle. Section 5 reintroduces the microfoundations of the model and considers how changes to "deep" structural parameters induced by economic reform and technological change affect the stability of the macroeconomic system. Section 6 discusses the results against the background of the existing literature. Section 7 briefly concludes.

## 2 Background

McCallum (1999, 2000) has argued that an analysis of Japan's monetary policy which neglects the role of money can be misleading, since it fails to recognize that policy was "too tight" during the early 1990s. Arguably this is the period which acted as the catalyst for the subsequent prolonged stagnation of the real economy. McCallum's analysis is based on the observation that Japanese short-term nominal interest rates during this period closely followed the prescriptions of a Taylor rule. As shown in Figure 1, during the crucial 1989-93 period Japanese short-term nominal interest rates moved broadly in line with the guidance offered by the Taylor rule. Some simple empirical evidence to this effect is offered in Tables 1 and 2. It was only later in the 1990s, as nominal interest rates encountered their zero lower bound and Japan was caught in a liquidity trap, that monetary policy was demonstrably too tight on the metric provided by the Taylor rule.

Another way of looking at this question is to evaluate how closely Japanese monetary policy followed the *Taylor principle*, viz. that nominal interest rates should increase more than proportionately in the face of rising inflation expectations. Mankiw (2001) and Taylor (1999b) have used this principle to evaluate whether monetary policy was well-designed and implemented in the United States. By regressing short-term nominal interest rates on inflation, one can assess whether a more than proportional relationship characterizes the data on the basis of the estimated coefficient. Table 3 reports a number of such regressions, showing both that the Taylor principle is respected by a "comfortable margin" over the entire sample period 1985-2001 and, in particular, during the crucial years 1989-93.

If a monetary policy was well-designed on conventional criteria, but nonetheless the Japanese economy fell into a stagnant state, it would seem that either the causes of stagnation lie elsewhere – plausibly on the supply-side of the economy – or the conventional criteria to evaluate monetary policy design are flawed. This paper argues that these alternatives – far from being mutually exclusive – are, in fact, complementary. Conventional monetary policy can fail to maintain price stability precisely because it is not robust to technological change and structural economic reform that may have been introduced to address concerns about supply-side weakness.

To anticipate the results of the subsequent analysis somewhat, we derive two main conclusions.

First, the paper demonstrates that within a monetary DSGE model, the Taylor principle fails in the following sense: Adherence to the Taylor principle is not sufficient to maintain macroeconomic stability. Where monetary factors play an important role in macroeconomic dynamics – as casual empiricism might suggest to have been the case in Japan during the 1980s and 1990s – a Taylor-like monetary policy may permit substantial macroeconomic instability and, in particular, bubble-like dynamics in prices.

Second, the paper shows that the more "active" a Taylor-like monetary policy (i.e., the more aggressively nominal interest rates increase in response to rising inflation expectations), the less robust that policy is to structural economic change and technological innovation. While this result holds in the context of the benchmark New Keynesian macroeconomic model familiar from the existing literature, it applies *a fortiori* in the context of the monetary DSGE model employed here (and is more likely to prove empirically relevant).

# 3 The model

Consistent with the existing literature, this paper employs a small DSGE model to investigate the properties of monetary policy rules. The paper develops an extension to the benchmark New Keynesian model by introducing a role for monetary developments in macroeconomic dynamics. This role arises from both a relaxation of the restrictions imposed on consumer preferences over consumption and real balances and the introduction of more plausible timing assumptions about the key transactions role of money. The paper then employs the model to evaluate how structural reform impacts the stability of the resulting macroeconomic system.

## 3.1 The consumer problem

A representative consumer has preferences defined by the following intertemporal utility function:

$$\mathbb{W}_t = \sum_{s=0}^{\infty} \beta^s \;\left[ U\left(C_{s+t}, A_{s+t}/P_{s+t}\right) - \eta h_{s+t} \right] \tag{1}$$

where $C_t$ is consumption of the composite final good in period $t$, $A_t$ is the consumer's holding of monetary assets during period $t$, $P_t$ is the price of the final composite good (the consumer price level) in period $t$ and $h_t$ is labour supplied by the representative consumer in period $t$. The parameter $\eta > 0$ measures the disutility of work effort while $\beta \in (0, 1)$ is the intertemporal discount rate.

As is conventional, intertemporal utility ($\mathbb{W}$) is time additive separable. Labour supply is separable in the period utility function, whereas, crucially, money holdings are not separable from consumption. As is widely recognized in the literature (Ireland, 2000; McCallum, 2001), it is this latter feature of the period utility function that gives rise to a role for money in price dynamics. The resulting structural relationship between money and inflation underlies some of the results offered later in this paper.

The representative consumer's budget constraint is given by:

$$M_{t+1} = M_t + R_{t-1}B_{t-1} + W_t h_t + D_t - B_t - P_t C_t + X_t \tag{2}$$

where $M_t$ is the representative consumer's money holdings at the start of period $t$; $W_t$ is the nominal market wage rate; $D_t$ is the nominal dividend payment received by the representative consumer resulting from his ownership of monopolistically competitive intermediate goods firms (discussed below); $X_t$ is a lump-sum payment received from the government to distribute seigniorage revenues; and $B_t$ is his holding of nominal risk-free one-period bonds at the end of period $t$. These bonds mature in period $t+1$, bearing a (gross) nominal return of $R_t$.

The preceding discussion distinguishes between money held at the *start* of the period ($M_t$) and money held *during* the period ($A_t$). It is the latter that is relevant for transactions purposes and thus, within this money-in-the-utility-function framework, should enter the period utility function (*contra* Ireland (2000), *inter alia*).

As demonstrated by Carlstrom and Fuerst (1999), drawing a distinction between "cash-when-you're-done" ($M_{t+1}$) and "cash-in-advance" ($A_t$) has important empirical and theoretical implications that are explored in companion papers. Here it is sufficient to describe the relationship between the two concepts as follows:

$$A_t = M_t + R_{t-1}B_{t-1} - B_t + X_t \tag{3}$$

Note that this relationship assumes that financial markets – offering scope to trade money for bonds – open before or in parallel with goods markets. Intuitively, this assumption appears preferable to that implicitly employed elsewhere in the literature (e.g., Ireland, 2000), whereby financial markets open only after the goods market has closed.

Solving the consumer problem involves maximizing intertemporal utility subject to the budget constraint and the definition of relevant money holdings, taking the price level, nominal wage, interest rate, dividends and lump-sum transfer as given. The following first-order conditions emerge:

$$
\begin{aligned}
u_c(t) + u_m(t) &= \frac{\beta R_t}{\pi_{t+1}} \; [u_c(t+1) + u_m(t+1)] && (4)\\
u_m(t) &= (R_t - 1)\; u_c(t) && (5)\\
\frac{W_t}{P_t} &= \frac{\eta}{u_c(t)} && (6)\\
C_t &= \frac{W_t}{P_t}\; h_t + \frac{D_t}{P_t} && (7)
\end{aligned}
$$

where $u_c(t)$ is the marginal period utility of consumption at time $t$, $u_m(t)$ is the marginal period utility of real money balances during time $t$ and $\pi_t$ is the (gross) inflation rate at time $t$ (equal to $P_t/P_{t-1}$).

These first-order conditions are amenable to straightforward economic interpretation. Condition (4) represents a conventional Euler equation describing the intertemporal trade off between marginal utility in one period and the next.[1] Condition (5) states that the marginal utility of holding real balances in any period must equal the marginal utility of the consumption opportunities foregone by holding cash rather than an interest-bearing asset. Condition (6) equates the market real wage (measured in terms of the composite final good) with the marginal disutility of work effort evaluated in terms of foregone final consumption. Condition (7) is the budget constraint embodying both credit market clearing $B_t = 0\ \forall t$ (no net issuance of bonds) and the government budget constraint $M_{t+1} - M_t = X_t\ \forall t$.

Note that (when substituted into expression (3)) credit market clearing and the government budget constraint also imply $A_t = M_{t+1}$ in equilibrium. Hence the distinction between money held during the period to facilitate transactions ($A_t$) and money available at the start of the next period ($M_{t+1}$) disappears in equilibrium, although it remains relevant to individual consumers' choices.

## 3.2 The final good producing firm

The final composite good ($Y$) is produced competitively by aggregation of intermediate goods ($y(i)$) indexed over $i \in [0,1]$. Following the existing literature, this aggregation is achieved using the Dixit-Spence-Stiglitz functional form, i.e.

$$
Y_t = \left[ \int_0^1 y_t(i)^{\frac{\theta-1}{\theta}} \; di \right]^{\frac{\theta}{\theta-1}} \tag{8}
$$

Profit maximization yields the following demand function for intermediate goods:

$$
y_t(i) = Y_t \; \left[ \frac{p_t(i)}{P_t} \right]^{-\theta} \tag{9}
$$

[1] Here the condition is extended to allow for the utility yielded by real money balances.

while the zero profit condition for the competitive final goods producer implies that the price of the composite final good is given by:

$$P_t = \left[ \int_0^1 p_t(i)^{1-\theta} \, di \right]^{\frac{1}{1-\theta}} \tag{10}$$

Against this background, it is straightforward to see that the own price elasticity of the demand for each intermediate good is $-\theta$. Later in the paper, structural economic reform will be modeled as variation in the parameter $\theta > 1$. The introduction of greater competitive pressure in the intermediate goods market though structural reform will increase the elasticity of demand and thus raise $\theta$. In the limit, a perfectly competitive market will have an infinite elasticity and the equilibrium mark-up over marginal cost will be zero.

## 3.3 The intermediate goods producing firms

Intermediate goods producing firms are indexed $i \in [0, 1]$, each producing the corresponding good. These firms operate in a monopolistically competitive environment, where demand for each good is given by expression (9). Goods are produced according to a linear production function where labour is the only input, i.e.

$$y_t(i) = \kappa \; h_t(i) \tag{11}$$

In the manner of Rotemberg (1982), intermediate goods firms are subject to quadratic costs of price adjustment. This assumption provides the microeconomic foundations for nominal rigidity in this model. Such rigidity implies that monetary policy is not neutral in the short run. Monetary business cycles arise and the potential exists for certain monetary policies to yield real indeterminacy. Price changes in excess of the steady state rate of inflation impose costs on the firm given by:

$$\text{cost of price adjustment} \;=\; \frac{\phi}{2} \left[ \frac{p_t(i)}{\bar{\pi} \; p_{t-1}(i)} - 1 \right]^2 \tag{12}$$

where $\phi > 0$ is a parameter increasing in the costs of adjustment and $\bar{\pi}$ is the steady state rate of inflation, to be defined later.

The intermediate goods producing firm will maximize the real value of its discounted stream of current and future dividends, valued in terms of the marginal utility of consumption to the representative consumer (on the basis that the representative consumer is also the owner of the firm). This gives rise to the following problem:

$$\max \sum_{s=0}^{\infty} \beta^s \; u_c(c_{s+t}, A_{s+t}/P_{s+t}) \; \frac{D_{s+t}}{P_{s+t}}$$

$$\text{where} \;\; \frac{D_t}{P_t} = \frac{p_t(i) \; y_t(i)}{P_t} - \frac{W_t}{P_t} \; h_t(i) - \frac{\phi}{2} \left[ \frac{p_t(i)}{\bar{\pi} \; p_{t-1}(i)} - 1 \right]^2$$

which, after substitution of expression (11), yields the following first-order optimizing condition:

$$
\begin{aligned}
(1-\theta)\left[\frac{p_t(i)}{P_t}\right]^{-\theta}\frac{Y_t}{P_t} \;+\; & \frac{W_t}{P_t}\frac{\theta}{\kappa}\frac{Y_t}{P_t}\left[\frac{p_t(i)}{P_t}\right]^{-(\theta+1)} \\
-\,\phi\left[\frac{p_t(i)}{\bar{\pi}\;p_{t-1}(i)}-1\right] & \frac{1}{\bar{\pi}\;p_{t-1}(i)}Y_t \\
+\,\beta\phi\frac{u_c(t)}{u_c(t+1)}\left[\frac{p_{t+1}(i)}{\bar{\pi}\;p_t(i)}-1\right] & \left[\frac{p_{t+1}(i)}{\bar{\pi}\;p_t(i)^2}\right]Y_{t+1} \;=\; 0
\end{aligned}
\tag{13}
$$

### 3.4 Linearizing the model around the desired steady state

As shown in the Appendix, this model can be linearized around a desired steady state using conventional methods. This steady state is defined by an inflation rate $\bar{\pi}$ chosen by the monetary authorities.

Other steady states may exist, as analyzed by Carlstrom and Fuerst (1999) in a similar framework. However, in this paper analysis is restricted to an investigation of the properties of conventional monetary policy in a linearized approximation to the underlying model. This approximation holds only in the vicinity of the desired steady state. Inducing stability around this desired steady state should be seen as a necessary – but not necessarily as a sufficient – feature of a well designed monetary policy rule.

For reasons of tractability, analysis is restricted to the symmetric equilibrium, where all intermediate goods producing firms act identically and, as a result, $p_t(i) = P_t\ \forall i$.

By choosing a desired steady state inflation rate $\bar{\pi}$, the monetary authorities pin down the steady state nominal interest rate, since expression (4) demands that the steady state real interest rate is the inverse of the discount rate. With inflation at its steady state rate, equation (12) implies that costs of price adjustment are zero and thus final goods market clearing ensures $\bar{C}$ (the steady state level of final good consumption) is equal to $\bar{Y}$ (the steady state level of final good production). The steady state level of consumption and real money holdings ($\bar{m}$) are then defined by the remaining two first order conditions:

$$
u_m(\bar{C},\bar{m}) \;=\; (\bar{R}-1)\;u_c(\bar{C},\bar{m}) \tag{14}
$$

$$
\theta\;\eta \;=\; (\theta-1)\;u_c(\bar{C},\bar{m})\;\kappa \tag{15}
$$

where (6) is substituted into (15) and symmetry imposed in order to obtain (17).

The linearized approximation of the model can then be written as:

$$\hat{\pi}_t = \beta\, E_t\hat{\pi}_{t+1} + \psi_y \hat{Y}_t + \psi_m \hat{m}_{t+1} + \varepsilon_t^{\pi} \tag{16}$$

$$\hat{Y}_t = E_t\hat{Y}_{t+1} + \mu_r(\hat{R}_t - E_t\hat{\pi}_{t+1}) + \mu_m(E_t\hat{m}_{t+2} - \hat{m}_{t+1}) + \varepsilon_t^d \tag{17}$$

$$\hat{m}_{t+1} = \gamma_y \hat{Y}_t + \gamma_r \hat{R}_t + \varepsilon_t^m \tag{18}$$

where $\varepsilon_t^{\pi}$, $\varepsilon_t^d$ and $\varepsilon_t^m$ represent (stationary) cost-push, demand and money demand shocks respectively, and $\hat{x}$ is the percentage deviation of variable $x$ from its steady state level $\bar{x}$, i.e. $\hat{x} = (x - \bar{x})/\bar{x}$. One important feature of this linearized approximation of the model is that $\hat{m}_{t+1}$ is predetermined, i.e. the stock of money holdings outstanding at the start of the period depends solely on decisions made in the past and not on expectations of future variables.

The microfoundations of this model (analyzed more extensively in the Appendix) give rise to a number of cross-equation restrictions, viz.

$$\begin{aligned}
\gamma_y &= \frac{\gamma_r}{\mu_r}\,(1 - \mu_r \frac{\psi_y}{\Psi}) \\
\frac{\bar{R}}{\mu_r} &= \frac{1}{\Psi}\left[\psi_y + \psi_m \frac{\bar{Y}}{\bar{m}}\right] \\
\gamma_y &= \frac{\gamma_r}{\Psi\ \bar{R}}\left[(1-\bar{R})\psi_y + \psi_m \frac{\bar{Y}}{\bar{m}}\right]
\end{aligned}$$

where $\Psi = (\theta - 1)/\phi$. These restrictions have important theoretical and empirical implications, which are developed in companion papers.[2]

For the purposes of this paper, the more important issue is the relationship between the parameters defining the macroeconomic system (16) through (18) and the underlying "deep" microeconomic parameters from the consumer and firm optimization problems. Specifically, it is demonstrated in the Appendix that:

$$\begin{aligned}
\psi_m &= \frac{-(\theta-1)}{\phi}\left[\frac{\bar{m}\ u_{cm}(\bar{C},\bar{m})}{u_c(\bar{C},\bar{m})}\right] \\
\gamma_r &= \left[\frac{u_c(\bar{C},\bar{m})}{u_{mm}(\bar{C},\bar{m}) + (1-\bar{R})\ u_{cm}(\bar{C},\bar{m})}\right]\frac{\bar{R}}{\bar{m}}
\end{aligned}$$

where $u_{ij}(\bar{C},\bar{m}) = \partial^2 U/\partial i\,\partial j$ evaluated at the steady state. The relationship between these two parameters turns out to be a key determinant of the stability of the macroeconomic system.

[2] Notably, the cross-equation restrictions derived in this context do not require that money should only enter the Phillips curve equation (18) if it enters the dynamic IS equation (19), as in Ireland (2000).

We anticipate that $\psi_m > 0$, i.e. a monetary overhang raises inflationary pressure. To ensure this (given other parameter values and the usual restrictions on the period utility function), we require that $u_{cm}(\bar{C}, \bar{m}) < 0$. This seems plausible since one might expect to be able to economize on money holdings for transactions purposes as the level of consumption rises.[3]

We would also anticipate that $\gamma_r < 0$, i.e. the interest rate elasticity of the demand for money is negative. This requires $u_{mm}(\bar{C}, \bar{m}) + (1 - \bar{R})\ u_{cm}(\bar{C}, \bar{m}) < 0$, which can be compatible with both the preceding restriction and the restrictions imposed by the quasiconcavity of the period utility function.

### 3.5 Characterizing monetary policy

To close the model, monetary policy has to be characterized. Following the existing literature, monetary policy is analyzed as a contingent rule for the nominal interest rate, $R_{t.}$ Rather than investigate the properties of complex rules or construct so-called optimal rules (as has been pursued elsewhere), the stabilizing properties of a simple conventional monetary policy rule are assessed. Specifically, we consider the properties of a rule of the form:

$$R_t = \bar{R} + \alpha\beta\ (E_t\pi_{t+1} - \bar{\pi}) \tag{19}$$

Conventional wisdom (reflected in the work of Clarida, et al. (1999), *inter alia* and developed in the Appendix) argues that $\alpha > 1$ constitutes a well-designed policy framework in this context.[4]

The intuition behind this claim is as follows. Raising nominal interest rates more than proportionately in response to deviations of (expected) inflation from the steady state rate desired by the monetary authorities implies that real interest rates rise in the face of emerging inflationary pressures. Through intertemporal substitution, higher real rates serve to dampen current aggregate demand, reduce incipient inflationary pressure and thus stabilize inflation around the desired steady state.

Following his seminal contribution to analysis of monetary policy rules (Taylor, 1993), such conventional wisdom has been labeled the *Taylor principle*, and has been analyzed extensively in historical and cross-country contexts (e.g., Taylor, 1999b).

In this paper, we investigate whether the Taylor principle is sufficient to ensure macroeconomic and monetary stability in the vicinity of the desired steady state in our linearized approximation of the underlying macroeconomic

[3] Note that this is one implication of inventory-theoretic models of money demand proposed by Baumol (1952) and Tobin (1956))

[4] Strictly speaking, $\alpha$ should be greater than unity but bounded from above, as shown in the Appendix. $\beta$ is included here since we consider deviations from steady state in levels rather than percentages, as below.

model. Moreover, using the microeconomic foundations developed above, we are able to analyze those conditions under which adherence to the Taylor principle may prove inadequate.

# 4 Stability under the Taylor principle

After some tedious algebra, the macroeconomic system described by equations (16) through (19) can be expressed in state-space form as:

$$E_t \begin{bmatrix} \hat{\pi}_{t+1} \\ \hat{Y}_{t+1} \\ \hat{m}_{t+1} \\ \hat{R}_t \end{bmatrix} = \tilde{\mathbf{A}} \begin{bmatrix} \hat{\pi}_t \\ \hat{Y}_t \\ \hat{m}_t \\ \hat{R}_{t-1} \end{bmatrix} + \tilde{\mathbf{B}} \begin{bmatrix} \varepsilon_t^{\pi} \\ \varepsilon_t^{d} \\ \varepsilon_t^{m} \\ 0 \end{bmatrix} \tag{20}$$

where $\tilde{\mathbf{A}}$ and $\tilde{\mathbf{B}}$ are matrices with elements related to the parameters of the model (as shown in the Appendix).

One important feature of this model is that $\tilde{\mathbf{A}}$ has a block recursive structure. Notwithstanding the structural role played by money in inflation and income dynamics, it is possible to write down the system in reduced form where money holdings are determined by inflation and output dynamics, but not vice versa. This follows from the previous observation that money holdings at the start of period $t$ are pinned down by inflation, output and interest rates in that period. $\hat{m}_{t+1}$ is therefore a predetermined variable, not a forward-looking variable, and one can substitute for it using $\hat{\pi}_t$, $\hat{Y}_t$ and $\hat{R}_t$.

Since this paper is concerned with the relationship between macroeconomic stability and structural reform rather than understanding the importance of monetary factors in the inflation process, it is useful to simplify the framework as follows, by dropping money from the system.[5]

$$E_t \begin{bmatrix} \hat{\pi}_{t+1} \\ \hat{Y}_{t+1} \\ \hat{R}_t \end{bmatrix} = \mathbf{A} \begin{bmatrix} \hat{\pi}_t \\ \hat{Y}_t \\ \hat{R}_{t-1} \end{bmatrix} + \mathbf{B} \begin{bmatrix} \varepsilon_t^{\pi} \\ \varepsilon_t^{d} \\ \varepsilon_t^{m} \\ 0 \end{bmatrix} \tag{21}$$

Blanchard and Kahn (1980) show that the nature of the solutions to (21) hinges crucially on the eigenvalues of matrix $\mathbf{A}$ and the presence of only one predetermined variable in the system, $R_t$. Only when the number of eigenvalues lying outside the unit circle equals the number of non-predetermined variables will a unique, non-explosive saddle-path equilibrium exist, with inflation, output and the nominal interest rate converging to their steady state levels.

[5] Note however that money demand shocks remain relevant and therefore there is a structural role for money in the inflation process.

Should the number of eigenvalues outside the unit circle exceed the number of non-predetermined variables, the system will be explosive. Explosive behaviour clearly violates any meaningful definition of macroeconomic stability.

Should the number of eigenvalues outside the unit circle fall short of the number of non-predetermined variables, the system is prone to *multiplicity*. Many possible solutions exist, associated with the evolution of sunspot variables. Inflation, output and nominal interest rates may fluctuate randomly around their steady state values, even in the absence of shocks to fundamentals, as a result of self-fulfilling revisions to expectations. While these fluctuations will be stationary, they are potentially very persistent (with the degree of persistence measured by the highest stable eigenvalue of $\mathbf{A}$). Such fluctuations may prove difficult to reconcile with an operational definition of macroeconomic and monetary stability.

In order to investigate the properties of the model under the Taylor principle, we therefore need to consider how the eigenvalues of matrix $\mathbf{A}$ vary with the monetary policy parameter $\alpha$. To anticipate the results somewhat, we show that (when the monetary policy rule is restricted to the form described by (19)) adherence to the Taylor principle is a necessary, but *not* sufficient, condition for a unique saddle-path equilibrium to obtain in the monetary DSGE model. This contrasts with results based on conventional New Keynesian models which allow no role for money in the Phillips curve or dynamic IS equations.

In undertaking this analysis, three distinct cases can be distinguished. These relate to the discontinuity produced in one of the eigenvalues of matrix $\mathbf{A}$ when $\alpha = -\beta(\psi_m \gamma_r)^{-1} = \chi$.

## 4.1 *Case 1:* $\beta + \psi_m \gamma_r < -1$

Note that this condition is feasible since $\gamma_r < 0$. The more interest elastic the demand for money balances, the more likely that this case will be relevant. In this context, the relationship between (the absolute value of) the eigenvalues of matrix $\mathbf{A}$ and the monetary policy parameter $\alpha$ is described by Figure 2. The discontinuity in the eigenvalue labeled $\lambda_3$ occurs at a value $\chi < 1$.

Under the condition defining case 1, there is no value of $\alpha$ that can give two eigenvalues greater than unity in absolute value. Hence there is no monetary policy of the form described by (19) that can guarantee a unique saddle path equilibrium. The Taylor principle therefore fails. When monetary disequilibrium affects inflation and the interest elasticity of money demand is large, any policy linking nominal interest rate dynamics solely to inflation expectations will be vulnerable to prolonged deviations from steady state.

The intuition behind this result is as follows. The Taylor principle associated with conventional New Keynesian models relies on *real* interest rates acting on aggregate demand to control inflation. Within the model entertained in this paper, there is an additional channel through which interest rates can control inflation, namely by influencing monetary dynamics. But this influence is exerted through *nominal* interest rates affecting the demand for (non-interest bearing) money. Provided that this latter channel of monetary policy transmission is strong enough (i.e., $\psi_m$ and / or $\gamma_r$ are "large" in absolute value, as required by the condition above), then the scope exists for inflation expectations to evolve in a manner that permits real interest rate and nominal interest rate developments to offset one another, such that monetary policy does not fully anchor those expectations.

## 4.2 *Case 2:* $\beta + \psi_m \gamma_r \in (-1, 0)$

If transmission of monetary policy through monetary dynamics is more muted (as in case 2), then the Taylor principle does hold. The relationship between the absolute value of the eigenvalues and the monetary policy parameter is described by Figure 3. For $\alpha \in (1, \alpha^*)$, the number of eigenvalues of matrix $\mathbf{A}$ with absolute value greater than one is two, the same as the number of non-predetermined variables. Thus a unique saddle-path equilibrium exists.

In this context, it can be shown that:

$$\alpha^* = \frac{\mu_r(\psi_y + \psi_m \gamma_y) - 2(1+\beta)(1+\mu_m \gamma_y)}{\mu_r(\psi_y + \psi_m \gamma_y) + 2\psi_m \gamma_r(1+\mu_m \gamma_y)} \tag{22}$$

with $\alpha^* > 1$ (as required for a non-empty set) where $\beta + \psi_m \gamma_r > -1$.

For the purposes of this paper, the key result is that:

$$\frac{\partial \alpha^*}{\partial \psi_m \gamma_r} > 0$$

which implies that, as the strength of monetary transmission through monetary dynamics increases (proxied by an increasingly negative value for $\psi_m \gamma_r$), the range of monetary policy parameters that preserve a unique stable equilibrium shrinks from above.

## 4.3 *Case 3:* $\beta + \psi_m \gamma_r > 0$

Finally, for completeness, the case of weak transmission through monetary dynamics is considered. The results are essentially the same as in case 2, with a range $\alpha \in (1, \alpha^*)$ of values for the monetary policy parameter ensuring a unique saddle-path equilibrium as required for well-designed monetary policy. The relationship between the eigenvalues of matrix $\mathbf{A}$ and $\alpha$ is shown in Figure 4.

$\alpha^*$ is defined as in case 2 and therefore the same relationship between the strength of monetary dynamics in monetary transmission and the size of the feasible set of parameters $\alpha$ remains. However, the range of values of $\alpha$ consistent with the Taylor principle include $\chi$, where the eigenvalue is degenerate and the dynamics of the system not well defined. Setting the monetary policy equal to $\chi$ would therefore have to be ruled out.

In case 3, it is also possible that complex roots to the characteristic equation emerge. While this outcome does not affect the main results relevant for this paper, it does imply that convergence of macroeconomic variables to their steady-state level along the unique saddle-path equilibrium may involve some cyclical oscillations around that steady state.

# 5 The impact of structural economic reform

In Section 4, it was shown that the Taylor principle is not sufficient to ensure macroeconomic and monetary stability within the model considered in this paper. Specifically, under certain configurations of the parameter values, the Taylor principle permits a multiplicity of solutions to the model which may involve persistent deviations from the steady state that are unrelated to underlying economic fundamentals. Furthermore, in Section 3, the development of microeconomic foundations for the model allowed parameters of the macroeconomic system to be related to the underlying "deep" parameters embedded in the optimizing problems of consumers and firms.

In this section, these two sets of analysis are integrated by substituting the "deep" microeconomic parameters from Section 3 into the conditions for macroeconomic stability derived in Section 4.

## 5.1 *Case 1:* $\beta + \psi_m \gamma_r < -1$

First, consider case 1 where no value of $\alpha$ can support a unique saddle-path equilibrium. Using the expressions for the macroeconomic parameters derived from the structural microeconomic analysis,[6] by substitution we obtain the following expression defining this situation:

$$\beta - \frac{(\theta - 1)\ \bar{R}}{\phi} \left[ \frac{u_{cm}(\bar{C}, \bar{m})}{u_{mm}(\bar{C}, \bar{m}) + (1 - \bar{R})\ u_{cm}(\bar{C}, \bar{m})} \right] < -1 \tag{23}$$

Recall from Section 3 that (and in order to maintain the plausibility of macroeconomic parameters on economic grounds) the sign restrictions $u_{cm}(\bar{C}, \bar{m}) < 0$ and $u_{mm}(\bar{C}, \bar{m}) + (1 - \bar{R})\ u_{cm}(\bar{C}, \bar{m}) < 0$ have been imposed. With these restrictions in mind, it is straightforward to see that for a sufficiently high value of $\theta$, the own price elasticity of demand in the intermediate goods sector, the condition defining case 1 will hold. In other words, as the intermediate goods sector becomes more competitive and the elasticity of demand for intermediate goods

[6] These are described in Section 8.1 in the Appendix.

rises, eventually the structure of the economy will be such that no monetary policy rule of the form (19) will be able to ensure macroeconomic stability.[7]

In relation to the existing literature, two points should be emphasized. These arise from the active role played by monetary dynamics in the evolution of macroeconomic variables in the model under consideration, which distinguishes it from the benchmark New Keynesian formulation.

First, note that, while the result requires $u_{cm}(\bar{C}, \bar{m}) \neq 0$, it is compatible with very modest values of the cross-partial. Therefore empirical estimates suggesting that the cross-partial between final goods consumption and money holdings in the period utility function is of modest magnitude are *not* sufficient to support conclusions obtained using conventional New Keynesian models, such as favouring the Taylor principle in the design of monetary policy. Even modest but non-zero values of $u_{cm}$ are sufficient to create problems of macroeconomic instability.

Second, condition (23) does not directly include the steady state level of the money stock, $\bar{m}$. Even where money holdings are small in equilibrium, it is still the case that adherence to the Taylor rule will result in potential macroeconomic instability when competition in the intermediate goods sector is sufficiently intense and/or the costs of price adjustment is small. Observing small real money balances in steady state is therefore insufficient to deny the importance of monetary dynamics to the stability of the underlying macroeconomy.

### 5.2 *Cases 2 and 3:* $\beta + \psi_m \gamma_r > -1$

Case 1 can be seen as a "catastrophic" situation, where the introduction of structural reform renders any monetary policy of the form (19) unable to maintain macroeconomic stability robustly. If the transmission of monetary policy through monetary dynamics is weaker (as in cases 2 and 3), a more subtle risk to macroeconomic stability emerges as structural reform is introduced.

Recall from Section 4 that a unique saddle-path equilibrium exists when the monetary policy parameter falls within a range bounded from below by unity and from above by $\alpha^*$. Macroeconomic stability can be maintained by choosing a value of $\alpha$ within this range. However, the upper bound of the range is defined by a complicated function of the macroeconomic parameters (expression (22)). Moreover, as shown in Section 2, these macroeconomic parameters are themselves functions of the underlying microeconomic "deep" parameters, including the elasticity of demand for intermediate goods.

As shown in the Appendix, substitution of the deep parameters into expression yields the following expression for $\alpha^*$:

[7] A similar result obtains as $\phi$, the cost of price adjustment for intermediate goods firms, diminishes towards zero.

$$\alpha^* = \Omega\left(1 + \frac{\phi}{(\theta-1)}\,(1+\beta)\,\Theta\right) \tag{24}$$

where $\Theta$ and $\Omega$ are functions of the first and second derivatives of the period utility function and the steady-state levels of income, money holdings and nominal interest rates.

The key observation from expression (24) is:

$$\frac{\partial \alpha^*}{\partial \theta} < 0$$

In other words, as the elasticity of demand for intermediate goods rises, the set of monetary policy parameters that maintains macroeconomic stability shrinks from above. (A similar result holds as the cost of price adjustment $\phi$ declines towards zero.)

This has two important implications.

First, a monetary policy that maintained macroeconomic stability prior to the implementation of structural economic reform may prove inadequate to maintain stability after the reform has increased competition in the intermediate goods sector. In other words, although $\alpha \in (1, \alpha_0^*)$ and macroeconomic stability is maintained, once structural reform raises $\theta$ – and thereby reduces the upper bound of the acceptable set of values for the monetary policy parameter – we may have $\alpha > \alpha_1^*$, i.e. macroeconomic instability may arise. Therefore, if monetary policy is to be implemented according to a rule like (19), policy makers need to remain aware of the implications for the dynamics of the system as the structural parameters change. Adherence to the Taylor principle alone is insufficient.

Second, in the face of structural change modeled as variation in the parameter $\theta$, the most *robust* monetary policy regime among the set of possible regimes consistent with (19) – understood to mean the regime that ensures a unique saddle-path equilibrium under the broadest possible set of values for $\theta$ (and $\phi$) – is one that sets the monetary policy parameter $\alpha$ arbitrarily close to unity (from above). This is a consequence of the observation that as $\theta$ increases, the set of acceptable values of the monetary policy parameter, i.e. $\alpha \in (1, \alpha^*)$, collapses towards unity from above as $\alpha^*$ declines.

# 6 Discussion

On grounds of both economic theory and statutory responsibility, monetary policy makers are charged with maintaining macroeconomic stability in general, and price stability in particular. This paper operationalizes macroeconomic stability in the following way. A unique saddle-path rational expectations equilibrium must exist for the macroeconomic system defined by the underlying optimizing behaviour of consumers and firms and the monetary policy regime chosen by the central bank. In this context, inflation, output and interest rates will all converge to their steady-state levels consistent with the central bank's chosen definition of price stability.

It is straightforward to see that explosiveness of the system is incompatible with macroeconomic stability, since inflation, output and interest rates will not converge to their desired steady-state levels. In fact, such explosiveness does not arise in the model considered in this paper and so we need not concern ourselves further with the issue in this discussion.

Less intuitive is the incompatibility of multiplicity with macroeconomic stability. When multiple equilibria exist, inflation, output and interest rates can fluctuate around their steady-state levels due to self-fulfilling expectational shocks that are unrelated to economic fundamentals. These fluctuations must be stationary, but they can be highly persistent. In particular, one can envisage stochastic expectational bubbles being incorporated into the evolution of macroeconomic variables. These are martingale difference series (i.e. the expected one-step-ahead change is zero), but can be characterized by explosive-like behaviour over some period punctuated by sharp corrections back towards steady-state. Such bubble-like behaviour is typical of some macroeconomic data and can account for persistent deviations from macroeconomic stability.

Within the context of a monetary DSGE model, we have shown the limitations of monetary policies that follow the Taylor principle – one characterization of what is popularly called "inflation targeting". In particular, we have shown that the efficacy of the Taylor principle in maintaining macroeconomic stability depends crucially on the intensity of competition in the intermediate goods sector, and thus on the extent of structural economic reform.

Two important implications for monetary policy making emerge.

First, contrary to the conclusions of the standard New Keynesian literature (e.g., Clarida, et al., 1999), the Taylor principle cannot be relied on to maintain macroeconomic stability. There are plausible configurations of parameter values – associated with intense competition in the intermediate goods sector, low costs of price adjustment and high interest rate elasticities of money demand – that render any inflation targeting monetary policy rule of the form:

$$\hat{R}_t = \alpha \, E_t \hat{\pi}_{t+1} \tag{25}$$

unable to attain a unique saddle-path equilibrium in the macroeconomic system.

At a minimum, this result should caution monetary policy makers against relying on naive versions of inflation targeting (or pursuit of so-called Taylor rules for monetary policy) as a bulwark against macroeconomic instability. This caution should multiply when structural economic change (resulting from policy-driven economic liberalization and/or technological change) may be increasing competition in the goods market, reducing the menu costs of price setting or increasing the interest elasticity of money demand. As shown in the preceding sections, such structural change increases the likelihood that the Taylor principle will fail.

Moreover, structural change also increases the likelihood of expectational errors by forward-looking private agents and thus renders the economy more vulnerable to the self-fulfilling expectational shocks. Increased prevalence of such expectational shocks will be destabilizing in an economy that suffers from multiplicity, where a unique saddle-path equilibrium is not guaranteed. As discussed in McKinnon and Pill (1997), the implementation of apparently well-designed structural economic reform and/or the introduction of new technology can be very destabilizing to private expectations, since the success of reform and the impact of technological innovation can be hard to evaluate at the outset.

It is left to companion papers to consider the design of monetary policy regimes that are superior to those governed by naive inflation targeting rules such as (25). In particular, one can envisage rules that allow interest rates to respond to monetary dynamics as having superior stabilizing properties in the context of the monetary DSGE model of the business cycle developed here. Suffice to say that, as suggested by McCallum (1999) in the specific context of Japan during 1985-2000, analyzing nominal interest rate developments in relation to a Taylor-like rule – and thereby neglecting the evolution of the money stock in relation to some benchmark level – can offer a very misleading impression of the monetary policy stance, especially when structural reform and technological innovation (and the attendant uncertainties) are taking place.

Second, if we do limit consideration to naive inflation targeting rules like (25), this paper demonstrates that the most robust policy in the face of uncertainty about the parameters $\theta$ and $\phi$ is one that maintains real interest rates at their steady-state level, $\bar{r} = \bar{R} / \bar{\pi}$.

Monetary policy makers inevitably face considerable uncertainty regarding the structure of the economy and, in particular, about the parameters underlying economic behaviour. In the face of such uncertainty, it has been argued (e.g. by Hansen and Sargent, 1999) that robust policies should be pursued. Gerdesmeier, et al. (2002) operationalize the concept of robustness by suggesting central banks should employ policies that maintain macroeconomic stability for the broadest possible set of models (defined over a parameter space).

With policy choices limited to naive inflation targeting along the lines of (25), setting the monetary policy parameter arbitrarily close to unity (from above) gives macroeconomic stability (defined as a unique saddle path equilibrium) for the largest set of $\theta$ and $\phi$.[8] Contrary to some results obtained in the literature (e.g., Onatski and Stock, 2000), robust monetary policy within this framework therefore requires a muted response of real interest rates to deviations of inflation expectations from their desired steady-state level.

If monetary policy is to be conducted as a form of naive inflation targeting, this paper can therefore be interpreted as giving support for such a policy being implemented "with a steady hand". Of course, nominal interest rates will change frequently within this framework (because inflation expectations will fluctuate in response to fundamental shocks to the economy). But the objective of such nominal interest rate adjustments is to maintain a stable real interest rate at its steady-state level. Monetary policy "activism" – defined as an attempt to manipulate real interest rates in a pro-cyclical manner in an attempt to stabilize the economy (as implicit in the Taylor principle) – can be counterproductive in this context, since it renders the system vulnerable to multiplicity under certain possible configurations of the underlying parameters.

# 7 Conclusion

In order to consider the current economic malaise in Japan, it is crucial to understand the sources of the underlying problems. This paper has developed a monetary DSGE model of the business cycle which, following McCallum (1999), illustrates how Japanese monetary policy in the 1980s – despite following the conventional guidance offered by the Taylor principle – in fact left the Japanese economy vulnerable to considerable macroeconomic instability in the face of structural economic reform.

Failure to anchor price expectations appropriately at the outset of economic liberalization permitted an expectational bubble to be incorporated into macroeconomic dynamics, with associated costs in terms of greater macroeconomic volatility unrelated to economic fundamentals. Japan continues to suffer from these costs, since the inevitable collapse of the bubble has destabilized other aspects of the Japanese economic system (especially the financial sector and fiscal accounts, which are not modeled here). This experience stands as a cautionary tale for monetary policy makers elsewhere.

In debating how to address Japan's current problems, opinion often divides into two camps. On the one hand, some emphasize the need for thoroughgoing structural economic reform, introducing greater competition and thereby

[8] As shown in the Appendix, this result applies to benchmark New Keynesian models (e.g., Clarida, *et al.*, 1999), as well as to the monetary DSGE model considered in this paper. However, with conventional New Keynesian models, setting $\alpha = (1 + \epsilon)$ is sufficient to guarantee a unique saddle-path equilibrium. With the model used in this paper, such a policy choice is merely necessary: it does not guarantee uniqueness for all values of $\theta$ and $\phi$, as discussed above.

intensified restructuring into the corporate sector. On the other hand, others emphasize the need for macroeconomic stimuli and, in particular, monetary expansion. Many observers have suggested that these policies be implemented in parallel, each seen as reinforcing the other.

This paper does not shed light on this issue directly. However, within a framework that helps to understand the possible causes of Japan's malaise, the paper does demonstrate the important interaction *between* macroeconomic (and especially monetary) policies and structural change to the economy. A monetary policy that is effective in one structural environment may be destabilizing as structural change takes place. Finding macroeconomic policies that are robust to these changes is crucial.

The paper suggests that naive inflation targeting frameworks for monetary policy (the operational form of the Taylor principle) are likely to be inadequate as competition intensifies in the goods market, as menu costs decline, as the interest elasticity of money demand rises and as overall uncertainty (and thus the likely incidence of non-fundamental expectational shocks) increases. Therefore, proposals to introduce this form of monetary policy regime as economic liberalization is intensified seem misplaced.

# 8 Appendix

## 8.1 Deriving the linearized model

The main text discusses a linear approximation of the monetary DSGE model in the vicinity of the steady state associated with the central bank's desired steady state rate of inflation $\bar{\pi}$. To derive this linear approximation, we simply apply first-order Taylor expansions to the first order conditions summarized in Section 3 of the main text (expressions (4) through (7) and (13)) around the desired steady state.

Rewriting the resulting linearized model gives rise to the following definitions of the macroeconomic parameters in the system described by expression (16) through (18) in terms of the "deep" microeconomic parameters.

$$\psi_y = \frac{-(\theta-1)}{\phi}\frac{\bar{Y}u_{cc}^*}{u_c^*} > 0 \tag{26}$$

$$\psi_m = \frac{-(\theta-1)}{\phi}\frac{\bar{m}u_{cc}^*}{u_c^*} > 0 \tag{27}$$

$$\mu_r = \frac{(u_c^* + u_m^*)}{(u_{cc}^* + u_{cm}^*)\bar{Y}} < 0 \tag{28}$$

$$\mu_m = \frac{(u_{cm}^* + u_{mm}^*)\bar{m}}{(u_{cc}^* + u_{cm}^*)\bar{Y}} > 0 \tag{29}$$

$$\gamma_y = \frac{-(u_{cm}^* + (1-\bar{R})u_{cc}^*)\bar{Y}}{(u_{mm}^* + (1-\bar{R})u_{cm}^*)\bar{m}} > 0 \tag{30}$$

$$\gamma_r = \frac{u_c^*\bar{R}}{(u_{mm}^* + (1-\bar{R})u_{cm}^*)\bar{m}} < 0 \tag{31}$$

It is these expressions that give rise to the cross-equation restrictions that are mentioned in the main text and which are employed in empirical estimation in a companion paper. Note that in addition to the sign restrictions imposed in Section 3 (which are necessary to produce plausible signs for the expressions above), we have also imposed $u_{cm}^* + (1-\bar{R})u_{cc}^* > 0$.

## 8.2 Motivating the Taylor principle

To understand the motivation for the Taylor principle, one needs to consider a standard New Keynesian model, which denies a role to money in the cyclical dynamics of inflation and output (as in Clarida, et al., 1999). In other words, consider a model of the form described by (16) through (18) but with $\psi_m = 0$ and $\mu_m = 0$. As in the main text, we choose to drop the money demand equation in the interests of parsimony.[9]

$$\begin{aligned}\hat{\pi}_t &= \beta\ E_t\hat{\pi}_{t+1} + \psi_y \hat{Y}_t + \varepsilon_t^{\pi} &(32)\\ \hat{Y}_t &= E_t\hat{Y}_{t+1} + \mu_r(\hat{R}_t - E_t\hat{\pi}_{t+1}) + \varepsilon_t^{d} &(33)\end{aligned}$$

After adding the monetary policy rule (19) and some rearranging one can write the system in the form:

$$E_t \begin{bmatrix} \hat{\pi}_{t+1} \\ \hat{Y}_{t+1} \\ \hat{R}_t \end{bmatrix} = \mathbf{A} \begin{bmatrix} \hat{\pi}_t \\ \hat{Y}_t \\ \hat{R}_{t-1} \end{bmatrix} + \mathbf{B} \begin{bmatrix} \varepsilon_t^{\pi} \\ \varepsilon_t^{d} \\ 0 \end{bmatrix} \tag{34}$$

where the matrix $\mathbf{A}$ is defined as:

$$\mathbf{A} = \begin{bmatrix} \frac{1}{\beta} & -\frac{1}{\beta}\psi_y & 0 \\ -\frac{1}{\beta}\mu_r(\alpha-1) & 1+\frac{1}{\beta}\mu_r\psi_y(\alpha-1) & 0 \\ \alpha\frac{1}{\beta} & -\alpha\frac{1}{\beta}\psi_y & 0 \end{bmatrix}$$

The three eigenvalues of matrix $\mathbf{A}$ are:

$$\begin{aligned}\lambda_1 &= 0 \\ \lambda_{2,3} &= \frac{(1+\beta)+(\alpha-1)\mu_r\psi_y \pm \sqrt{-4\beta+[(1+\beta)+(\alpha-1)\mu_r\psi_y]^2}}{2\beta} &(35)\end{aligned}$$

In this context, the (absolute value of the) eigenvalues of $\mathbf{A}$ are described by Figure 5, where $\alpha^*$ is defined by:

$$\alpha^* = 1 - \frac{2(1+\beta)}{\psi_y\mu_r} > 1 \tag{36}$$

which (after substitution of the "deep" microeconomic parameters, as in Section 5 of the main text) can be rewritten as:

$$\alpha^* = 1 + \frac{2(1+\beta)\phi}{(\theta-1)} \tag{37}$$

Under the parameter restrictions imposed throughout this paper ($\beta \in (0,1)$; $\phi > 0$; $\theta > 1$), for all values of $\alpha \in (1, \alpha^*)$ there are exactly two eigenvalues greater than unity in absolute value. Given that there are two non-predetermined variables in the system, this implies that a unique saddle-path

[9] Ireland (2000) shows that these parameter restrictions arise in the case where money holdings are separable from consumption in the period utility function, i.e., $u_{cm} = 0$, albeit in a model which has "money-when-you're-done" timing

equilibrium exists. For values of $\alpha < 1$ or $\alpha > \alpha^*$, the number of eigenvalues greater than unity in absolute value is less than two, implying multiplicity. (Explosiveness does not arise within the system since the number of unstable eigenvalues never exceeds two if the monetary policy rule is defined by equation (19), since $\lambda_1 = 0 \ \forall \alpha$.)

As discussed in some detail by Clarida, et al. (1999), Figure 5 demonstrates that, in the context of a benchmark New Keynesian macroeconomic model with known parameter values, adherence to the Taylor principle $\alpha \in (1, \alpha^*)$ is a *sufficient* condition for well-designed monetary policy, in the sense that it gives rise to a unique saddle-path equilibrium. Mankiw (2001), *inter alia* have used this result to argue that the quality of monetary policy can be assessed by estimating $\alpha$. Moreover, this result motivates the adoption of the Taylor principle and monetary policy rules described by (19) as an organizing principle for the analysis presented in the main text.

Two additional points that have not been emphasized elsewhere are worth mentioning.

First, expression (37) for $\alpha^*$ is independent of the form of the period utility function. Thus the key Taylor principle result is robust to wide variation in the functional form of the utility function.

Second, a robust monetary policy (defined as a policy that maintains macroeconomic stability through ensuring a unique saddle-path equilibrium in the face of a range of parameter values) will set $\alpha$ arbitrarily close to unity from above. Within the benchmark New Keynesian model, $\alpha = (1 + \epsilon)$ is a *sufficient* condition for macroeconomic stability for all values of $\theta > 1$ and $\phi > 0$. In the context of such a model (which requires $u^*_{cm} = 0$), a central bank that stabilizes the real interest rate at its steady state or "neutral" level will maintain macroeconomic stability, regardless of the values of structural parameters, the desired steady-state inflation rate or the functional form of the period utility function.

## 8.3 Constructing Figures 2 through 4

We can conduct a similar exercise for the monetary DSGE model outlined in the main text. After some tedious algebra and the exclusion of the money demand equation, we can rewrite the macroeconomic system (16) through (18) in state-space form as:

$$E_t \begin{bmatrix} \hat{\pi}_{t+1} \\ \hat{Y}_{t+1} \\ \hat{R}_t \end{bmatrix} = \mathbf{A} \begin{bmatrix} \hat{\pi}_t \\ \hat{Y}_t \\ \hat{R}_{t-1} \end{bmatrix} + \mathbf{B} \begin{bmatrix} \varepsilon_t^{\pi} \\ \varepsilon_t^{d} \\ \varepsilon_t^{m} \\ 0 \end{bmatrix} \tag{38}$$

where the crucial matrix $\mathbf{A}$ is given by:

$$\mathbf{A} = \begin{bmatrix} \Gamma\frac{1}{\beta} & -\Gamma\frac{1}{\beta}(\psi_y + \psi_m\gamma_y) & 0 \\ -\Gamma\frac{1}{\beta}\frac{\mu_r(\alpha-1)}{(1+\mu_m\gamma_y)} & 1+\Gamma\frac{1}{\beta}\frac{\mu_r(\alpha-1)}{(1+\mu_m\gamma_y)}(\psi_y + \psi_m\gamma_y) & 0 \\ \alpha\Gamma\frac{1}{\beta} & -\alpha\Gamma\frac{1}{\beta}(\psi_y + \psi_m\gamma_y) & 0 \end{bmatrix}$$

and the parameter $\Gamma$ is given by:

$$\Gamma = \left(1 + \frac{\alpha}{\beta}\psi_m\gamma_r\right)^{-1}$$

The eigenvalues of matrix $\mathbf{A}$ in such a model are given by:

$$\begin{aligned} \lambda_1 &= 0 \\ \lambda_{2,3} &= \frac{\delta \pm \sqrt{\vartheta}}{\omega} \end{aligned} \tag{39}$$

where

$$\begin{aligned} \delta &= (1+\beta+\alpha\,\psi_m\gamma_r)(1+\gamma_y\mu_m) + (\alpha-1)\mu_r(\psi_y+\psi_m\gamma_y) \\ \vartheta &= (-\delta)^2 - 4(1+\gamma_y\mu_m)^2(\beta+\alpha\,\psi_m\gamma_r) \\ \omega &= 2(1+\gamma_y\mu_m)(\beta+\alpha\,\psi_m\gamma_r) \end{aligned}$$

Explosiveness will not arise in this model, since $\lambda_1 = 0\ \forall\alpha$. The crucial question is therefore for what values of $\alpha$ both $\lambda_2$ and $\lambda_3$ exceed unity in absolute value. This will guarantee a unique saddle-path equilibrium and thus macroeconomic stability.

Figures 2 through 4 trace out the relationship between $\alpha$ and $\lambda_{2,3}$ on the basis of the above expressions. Three points can be discussed.

First,

$$\alpha = 1 \Longrightarrow \lambda_2 = 1,\ |\lambda_3| = \left|\frac{1}{(\beta+\psi_m\gamma_r)}\right| \gtreqless 1 \tag{40}$$

This result is key, since it is one of the elements that distinguishes among the three cases discussed in Section 4 of the main text. It demonstrates that $\alpha = (1+\epsilon)$ in a monetary policy rule like (19) is *not* a sufficient condition for macroeconomic stability in the monetary DSGE model. Although the underlying assumptions differ in only minor respects, fundamentally different results are obtained regarding the effectiveness of the Taylor principle.

Second,

$$\lim_{\alpha\to\infty} \lambda_2 \quad\to\quad 1 + \frac{\mu_r(\psi_y+\psi_m\gamma_y)}{\psi_m\gamma_r(1+\gamma_y\mu_m)} = 1+\rho > 1,\ \lambda_3 \to 0 \tag{41}$$

$$\lim_{\alpha\to-\infty} \lambda_2 \quad\to\quad 0,\ \lambda_3 \to 1 + \frac{\mu_r(\psi_y+\psi_m\gamma_y)}{\psi_m\gamma_r(1+\gamma_y\mu_m)} = 1+\rho > 1 \tag{42}$$

which pins down the properties of the eigenvalues at extremes values of $\alpha$.

Finally, for a specific value of the monetary policy parameter

$$\alpha = -\frac{\beta}{\psi_m \gamma_r} = \chi > 0 \tag{43}$$

the eigenvalues are not well defined. In the analysis outlined in the main text, this point is (implicitly) ignored.[10]

It is straightforward to see from Figures 3 and 4 that $\alpha^*$ is defined by $\lambda_3(\alpha^*) = -1$. This gives the following expression for $\alpha^*$ in terms of the parameters of the macroeconomic system:

$$\alpha^* = \frac{\mu_r(\psi_y + \psi_m \gamma_y) - 2(1+\beta)(1+\gamma_y \mu_m)}{\mu_r(\psi_y + \psi_m \gamma_y) + 2\psi_m \gamma_r (1+\gamma_y \mu_m)} \tag{44}$$

which will be greater than unity (and thus define the critical upper bound of the set of monetary policy parameters for which a unique saddle path equilibrium exists) for cases 2 and 3 in Section 4 of the main text.

By substitution of the underlying "deep" microeconomic parameters introduced in Section 3, we can rewrite this expression as:

$$\alpha^* = \frac{(\theta-1)\phi^{-1} + 2(1+\beta)}{(\theta-1)\phi^{-1}\left(1+2\bar{R}\Lambda\right)} \tag{45}$$

where:

$$\Lambda = \frac{u^*_{cm}}{u^*_{mm} + (1-\bar{R})u^*_{cm}} > 0$$

The inequality arises from the sign restrictions imposed in the main text to give plausible macroeconomic parameters. Recognize that, in contrast to the results obtained for the benchmark New Keynesian model above, $\alpha^*$ *does* depend on the functional form of the period utility function and (through the steady-state nominal interest rate, $\bar{R}$) on the central bank's desired steady-state rate of inflation, $\bar{\pi}$.

Note that as $u^*_{cm} \to 0$ (which – as shown by Ireland (2000) – implies that money plays no role in macroeconomic dynamics), $\alpha^*$ converges to the value of $\alpha^*$ obtained in the benchmark New Keynesian model discussed in Section 8.2. Furthermore, we can write the relationship between the two expressions for $\alpha^*$ as follows:

$$\alpha^*_{MONETARY} = \frac{\alpha^*_{NEW\,KEYNESIAN}}{(1+2\bar{R}\Lambda)} \tag{46}$$

[10] Note that for cases 1 and 2 in Section 5 of the main text, $\chi < 1$, whereas for case 3, $\chi > 1$. It can be shown that complex eigenvalues (which require $\vartheta < 0$) can only emerge in case 3 (although this point is not discussed further in this paper).

Given the sign restriction on $\Lambda$, two results emerge. First, for the same values of the "deep" parameters $\theta$, $\phi$ and $\beta$, $\alpha^*$ in the monetary DSGE model will always be lower than in the benchmark New Keynesian model. Hence the set of monetary policy parameters that will guarantee a unique saddle path equilibrium is always smaller in the monetary DSGE model. Second, for any given value of the monetary policy parameters $\alpha$, the set of parameter values $\{\theta, \phi, \beta\}$ for which macroeconomic stability would be maintained is always smaller in the monetary DSGE model than in the New Keynesian model. These two observations are natural corollaries of the result emphasized in the main text, namely that the Taylor principle is not sufficient to maintain macroeconomic stability in the monetary DSGE model.

# 9 References

Baumol, William (1952). “The transactions demand for cash: An inventory theoretic approach”. *Quarterly Journal of Economics* 66(4), pp. 545-556.

Blanchard, Olivier J. and Charles Kahn (1980). “The solution of linear difference models under rational expectations”. *Econometrica* 48(5), pp. 1305-1311.

Carlstrom, Charles T. and Timothy S. Fuerst (1999). “Timing and real indeterminacy in monetary models”. Federal Reserve Bank of Cleveland Working paper no. 99-10.

Clarida, Richard, Jordi Gali and Mark Gertler (1999). “Monetary policy rules and macroeconomic stability: Evidence and some theory”. NBER Working paper no. 6442.

The Economist (2001). “Chronic sickness”. 31 May 2001.

Gerdesmeier, Dieter, Roberto Motto and Huw Pill (2002). “Paradigm uncertainty and the role of monetary developments in monetary policy rules”. ECB: www.ecb.int/events/conf/other/mprules.

Hansen, Lars P. and Thomas J. Sargent (2000). “Wanting robustness in macroeconomics”, mimeo, Stanford University.

Ireland, Peter N. (2000). “Money’s role in the monetary business cycle”. NBER Working paper no. 8115.

Krugman, Paul (1999). “Japan heads for the edge”. *Financial Times* Personal view, 20 January 1999.

Mankiw, N. Gregory (2001). “U.S. monetary policy during the 1990s”. NBER Working paper no. 8471.

McCallum, Bennett T. (1999). “Recent developments in the analysis of monetary policy rules”. Federal Reserve Bank of St. Louis *Economic Review* Nov./Dec., pp. 3-11.

McCallum, Bennett T. (2000). “Alternative monetary policy rules: A comparison with historical settings for the United States, the United Kingdom and Japan”. NBER Working paper no. 7725.

McCallum, Bennett T. (2001). “Monetary policy analysis in models without money”. NBER Working paper no. 8174.

McKinnon, Ronald I. and Huw Pill (1997). “Credible liberalizations and overborrowing”. *American Economic Review* 87(2), pp. 189-193.

Onatski, Alexei and James Stock (2000). “Robust monetary policy under model uncertainty in a small model of the U.S. economy”. NBER Working paper no. 7490.

Porter, Michael E., H. Takeguchi and M. Sakakibara (2000). *Can Japan compete?* New York: Basic Books.

Rotemberg, Julio J. (1982). “Sticky prices in the United States”. *Journal of Political Economy* 90, pp. 1187-1211.

Svensson, Lars E.O. (2001). “How Japan can recover”. *Financial Times* Personal view, 25 September 2001.

Taylor, John B. (1993). “Discretion versus policy rules in practice”. *Carnegie-Rochester Series on Public Policy* 29, pp. 173-209.

Taylor, John B. (1999a). *Monetary policy rules*, Chicago: University of Chicago Press.

Taylor, John B. (1999b). “A historical analysis of monetary policy rules” in ed. John B. Taylor, *Monetary policy rules*, Chicago: University of Chicago Press, pp. 319-348.

Tobin, James (1956). “The interest elasticity of the transactions demand for cash”. *Review of Economic Studies* 38(3), pp. 241-247.

**Table 1** *Correlation matrix for Japanese short-term interest rates and Taylor rules*

| | *Japanese short-term nominal interest rates* | *Taylor rule (with potential output defined by a linear trend)* | *Taylor rule (with potential output defined by a quadratic trend)* | *Taylor rule (with potential output defined by a Hodrick-Prescott filter)* |
|---|---|---|---|---|
| *Japanese short-term nominal interest rates* | **1.00** | **0.87**<br>**0.70**<br>**0.93**<br>**0.63** | **0.86**<br>**0.79**<br>**0.94**<br>**0.31** | **0.87**<br>**0.85**<br>**0.93**<br>**0.30** |
| *Taylor rule (with potential output defined by a linear trend)* | | **1.00** | **0.93**<br>**0.98**<br>**0.99**<br>**0.78** | **0.93**<br>**0.90**<br>**0.99**<br>**0.82** |
| *Taylor rule (with potential output defined by a quadratic trend)* | | | **1.00** | **0.97**<br>**0.97**<br>**0.99**<br>**0.99** |
| *Taylor rule (with potential output defined by a Hodrick-Prescott filter)* | 1985:1 – 2001:3<br>1985:1 – 1988:4<br>1989:1 – 1993:4<br>1994:1 – 2001:3 | | | **1.00** |

The level of interest rates prescribed by the Taylor rule is given by: $3+1.5(\pi-2)+0.5x$, where the output gap $x$ is derived from various measures of potential output (based on a log linear trend, a log linear quadratic trend and a Hodrick Prescott filter). Note that the correlation between these various measures of the Taylor rule interest rate is very high. The level of the "neutral" real interest rate is taken from McCallum (1999).

**Table 2** *Explanatory power of Taylor rule for Japanese short-term nominal interest rates*

| Sample period | *Goodness of fit,* $R^2$ |
|---|---|
| 1985:1 – 2001:3 | 0.77 |
| 1985:1 – 1988:4 | 0.62 |
| 1989:1 – 1993:4 | 0.87 |
| 1994:1 – 2001:3 | 0.25 |

The level of interest rates prescribed by the Taylor rule is given by: $3+1.5(\pi-2)+0.5x$, where the output gap $x$ is an (unweighted) average of measures derived from various estimates of potential output (based on a log linear trend, a log linear quadratic trend and a Hodrick Prescott filter). The level of the "neutral" real interest rate is taken from McCallum (1999).

**Table 3** *Regression of Japanese short-term interest rates on inflation*

| Sample period | *Constant* | *Coefficient on inflation* |
|---|---|---|
| 1985:1 – 2001:3 | 2.18 *(0.15)* | 1.52 *(0.10)* |
| 1985:1 – 1988:4 | 3.53 *(0.17)* | 0.73 *(0.11)* |
| 1989:1 – 1993:4 | 2.27 *(0.39)* | 1.71 *(0.20)* |
| 1994:1 – 2001:3 | 0.53 *(0.10)* | 0.22 *(0.08)* |

Standard errors are shown in parentheses. All coefficients are statistically significant at the conventional 5% level.

**Figure 1** *Japanese short-term nominal interest rates compared to the prescriptions of the Taylor rule, 1985-2001*

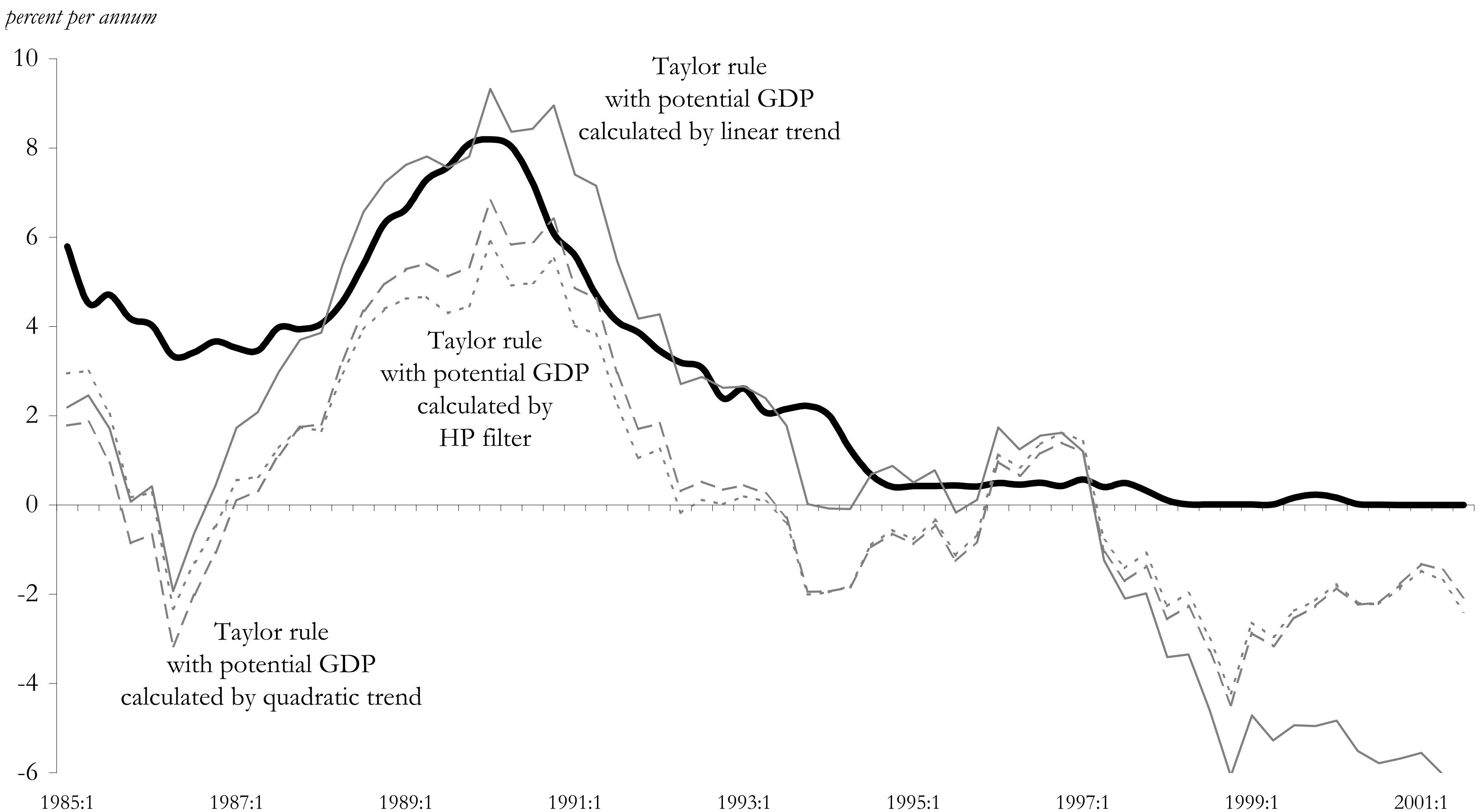

**Figure 2** *Eigenvalues in monetary DSGE model under case 1*

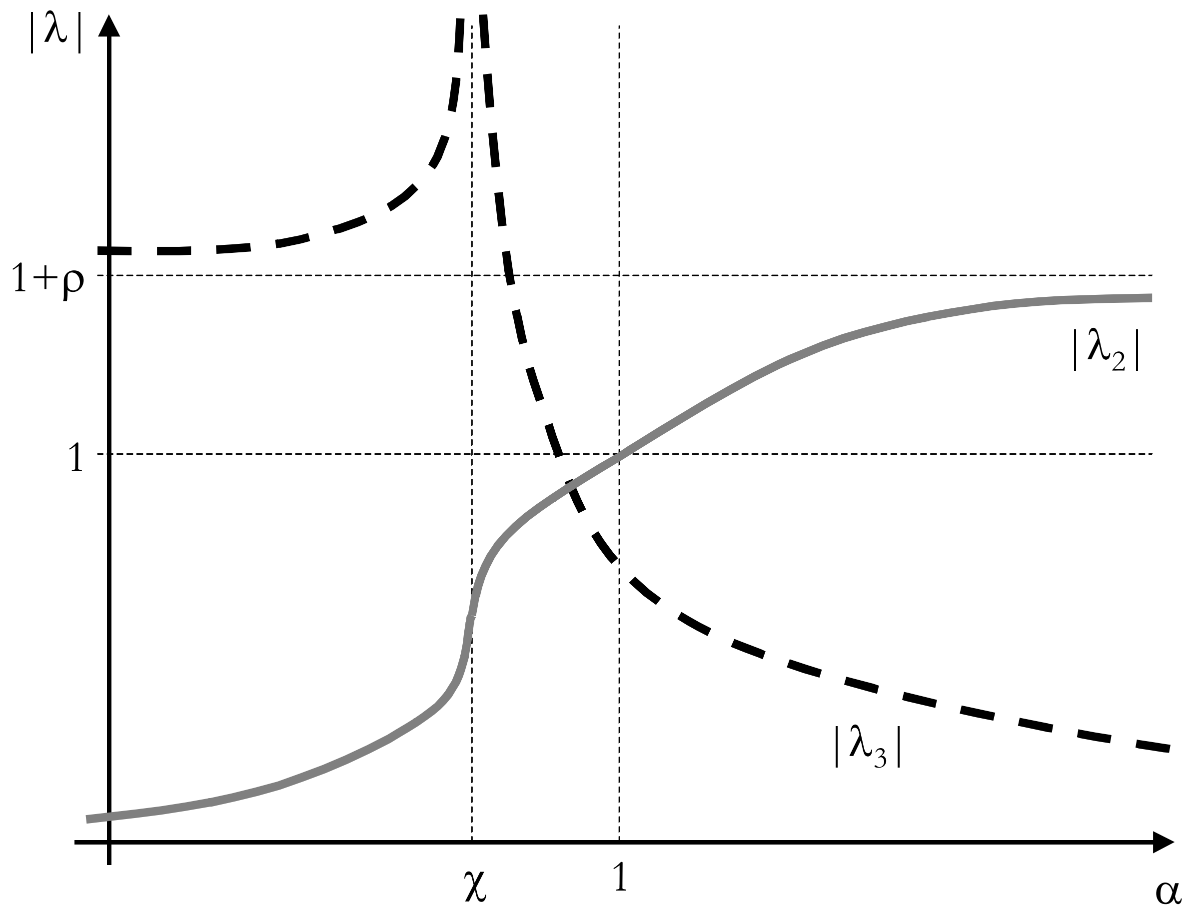

**Figure 3** *Eigenvalues in monetary DSGE model under case 2*

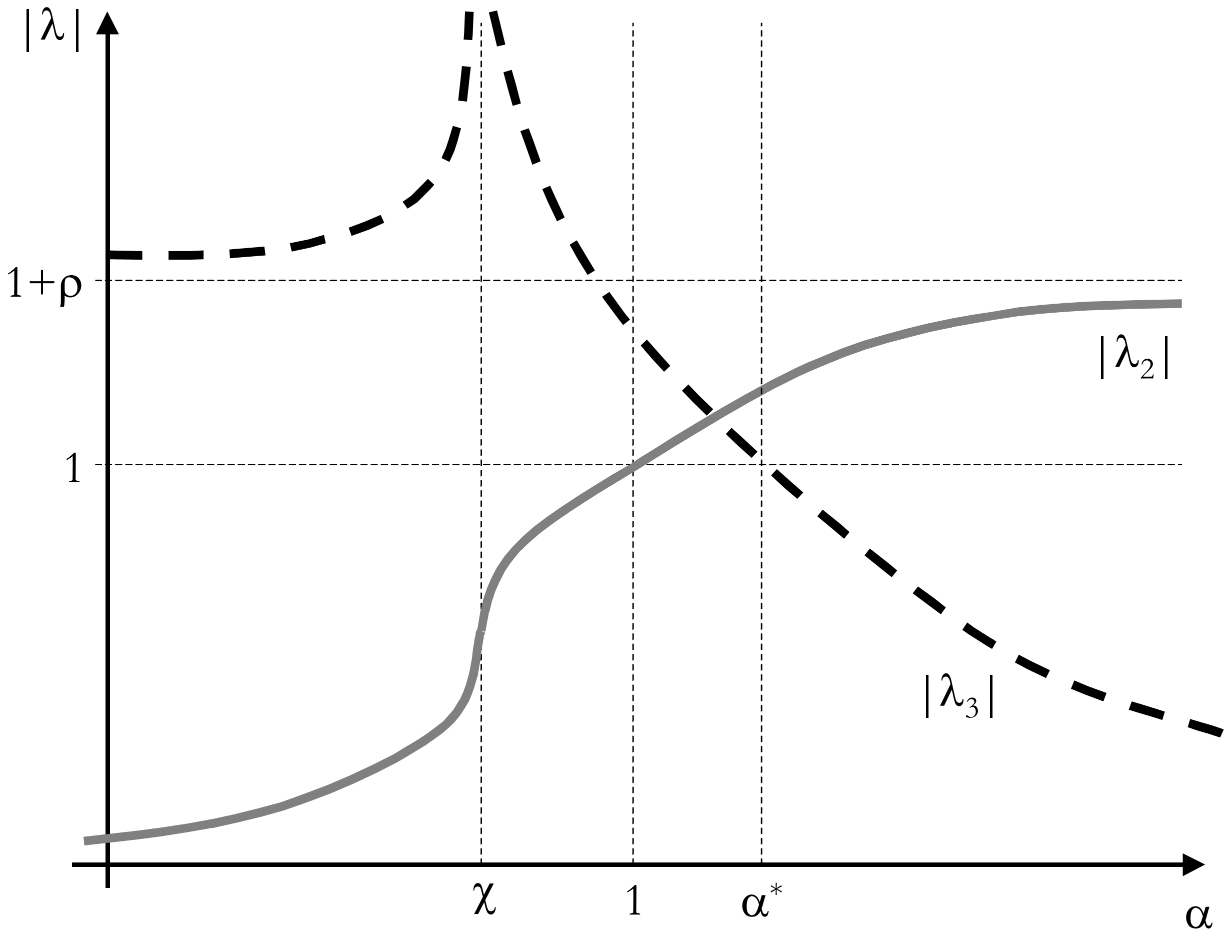

**Figure 4** *Eigenvalues in monetary DSGE model under case 3*

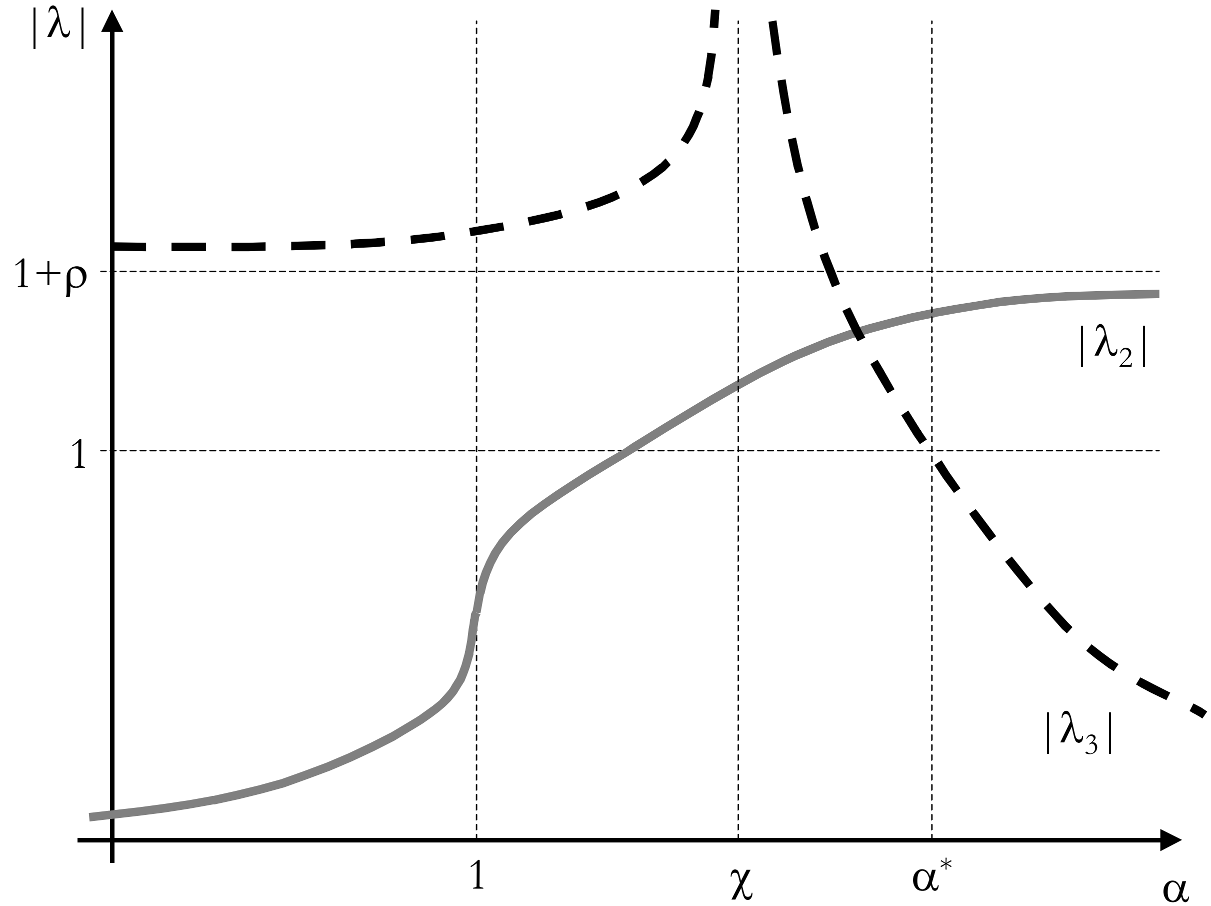

**Figure 5** *Eigenvalues in benchmark New Keynesian model*