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Contents

Abstract

Focusing on emerging market currency arrangements, we build a model of an exchange rate peg with escape clauses and output persistence. We first show how output persistence works as an additional "fundamental" so that an exogenous increase in persistence can make the currency peg more vulnerable to speculative attacks. We then endogenise output persistence as arising from capital market frictions that are caused by weak corporate governance institutions. It turns out that in emerging market economies, often characterised by credit constraints, a partial reform of corporate governance institutions may enhance a financial accelerator mechanism, which increases output persistence and deteriorates the credibility of the exchange rate peg. A conservative policymaker partially counters this adverse effect, but only a complete reform of corporate governance institutions fully eliminates persistence and reduces the risk of currency crisis on all levels of policy preferences.

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Keywords: Exchange rate pegs, speculative attacks, output persistence, capital market frictions, corporate governance.

1 Introduction

Recent academic work points to overwhelming evidence of that financial crises and currency crises seldom occur separately. In an analysis comprising 26 banking and 76 currency crises throughout the world from 1970's to mid-1990's, Kaminsky and Reinhart (1999) conclude that problems in the banking sector tend to precede a currency crisis, and that financial liberalisation often precedes a banking crisis.[1] A widely held view in the recent literature is that a "twin crisis" typically emerges after an open economy encounters an output shock that is amplified by financial market imperfections, or a *financial accelerator* (Bernanke, Gertler and Gilchrist, 1996).[2] However, it has been suggested that in addition to purely financial institutions, legal institutions also matter in currency crises. A recent study by Johnson, Boone, Breach and Friedman (1999) uncovers *weak corporate governance* as an issue that typically worsens currency crises in emerging market economies.

This paper analyses optimal exchange rate policy in an economy where a financial accelerator, arising from inadequate corporate governance institutions, increases the risk of a currency crisis. The model therefore explicitly allows for an analysis of exchange rate policy in an economy where both financial and legal institutions may be insufficiently developed.

Our starting point is to extend the model of optimal monetary policy under output persistence as used, for instance, in Svensson (1997, 1999), to incorporate the "escape clause" approach to currency crises. These "second generation" currency crisis models, often associated with Obstfeld (1994, 1996, 1997), have formalised the conventional wisdom that even though a reversible commitment to a currency peg makes monetary policy vulnerable to speculative attacks, it lowers the average rate of expected currency depreciation. In this context, we find that output persistence works as an additional "fundamental" so that an exogenous increase in persistence makes a speculative attack more likely, and that the likelihood of an attack can be reduced if the policymaker assigns a high weight on the exchange rate relative to real objectives such as output stability. Our main contribution is, however, to model the sources for output persistence following the research tradition on capital market imperfections and business cycles as initiated by Bernanke and Gertler (1989). In the spirit of this literature, persistence can be thought to originate from the constraints on the entrepreneurs' ability to obtain outside funds for investment. Inspired by the influential work by Holmström and Tirole (1997), Kiyotaki and Moore (1997), Aghion, Bacchetta and Banerjee (1999), Aghion, Banerjee and Piketty (1999), and Johnson, Boone, Breach and Friedman (1999), we justify the presence of the credit constraints by institutional capital market imperfections such as weak corporate governance, often present in emerging market economies.[3]

The novelty in our model is to use credit constraints as a link between the state of the capital market and the credibility of the exchange rate peg. Intuitively, in the presence of credit constraints, a reform that aims at improving the legislation for corporate governance increases the foreign supply of capital and boosts domestic investment. If the capital market institutions are initially sufficiently developed the reform reduces output persistence because the investors become less dependent on capital that is generated by domestic output. This has the effect of unambiguously improving the credibility of the exchange rate peg. If the capital market is, however, initially

[1] *The work linking financial market developments with exchange rate crises is sometimes classified as the "third generation" model of currency crises. See Jeanne (1999) for an excellent survey of currency crisis models and a discussion on the taxonomy. For early attempts to model twin crises, see Calvo (1995) and Goldfjan and Valdes (1995).*

[2] *Other names for this amplification mechanism have been proposed, such as the equity multiplier (Holmström and Tirole, 1998) and the credit multiplier (Aghion, Banerjee and Piketty, 1999). The term "credit channel" has also been used in this sense, but as explained by Bernanke and Gertler (1995), it is perhaps misleading to label an amplification mechanism as the credit channel.*

[3] *For evidence, see e.g., La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1997, 1998) Johnson, Boone, Breach and Friedman (1999), and Mitton (1999).*

seriously underdeveloped, a partial reform enhances the financial accelerator mechanism. The financial accelerator dilutes the credibility of the exchange rate peg, because even minor output shocks can accumulate in the system and force the policymaker over time to abandon the peg. While the adverse credibility effect arising from incomplete reform is partially countered if the policymaker is known to put a high emphasis on exchange rate stability, the most effective way of improving credibility is to aim at fully developed capital markets that do not allow amplifying mechanisms to arise. These results are in line with several recent contributions on the role of credit constraints in economic fluctuations in open economies, such as Edwards and Vegh (1997), Chang and Velasco (1998), Bris and Koskinen (1999), Caballero and Krishnamurthy (1999), Aghion, Bacchetta, and Banerjee (1999, 2000), and Burnside, Eichenbaum and Rebelo (1999, 2000). In all these models, various types of credit constraints increase the exposure of an open economy to output shocks suggesting that financial market imperfections are a significant source of instability in open economies.

The rest of this paper is organised as follows. The model of a self-fulfilling currency crisis with exogenous output persistence is introduced in the next section. In section 3, we analyse the role of persistence in determining the credibility of an exchange rate peg. In section 4, persistence is explicitly derived from capital market imperfections and weak corporate governance practices. The concluding remarks are in section 5.

2 The Basic Model

The macroeconomic equilibrium is described by means of a Barro and Gordon (1983) -type game between the private sector and the policymaker who controls inflation rate and, under the assumption that purchasing power parity (PPP) holds, the exchange rate. We extend the standard set-up by introducing output persistence as, for instance, in Jeanne (1997) and Svensson (1997, 1999). Output is thus generated according to the following modified Lucas supply function:

$$y_t = y_n + \rho y_{t-1} + \eta\left(\pi_t - \pi_t^e\right) + z_t \,. \tag{1}$$

In (1), y_t denotes output in period t, y_n is the natural rate of output, π_t is the inflation rate and π_t^e is expected inflation, η is a positive constant, and z_t is a stochastic output shock uniformly distributed on [$-Z/2$, $Z/2$].[4] The expected inflation is formed by the private sector one period earlier, i.e., $\pi_t^e = E_{t-1}(\pi_t)$ and, under PPP, the inflation rate is equal to the realised rate of currency depreciation. The autoregressive term, ρy_{t-1}, where $0 < \rho < 1$ denotes the degree of persistence, introduces past output as a state variable. The presence of such persistence is usually explained by labour market-based microfoundations as derived by Lockwood and Philippopoulos (1994), but it can also reflect other distortions that prohibit the markets from clearing every period. For instance, Kiyotaki and Moore (1997) show how credit constraints can generate substantial output persistence. For the moment we take ρ as exogenous, but in section 4 we resort to imperfections in capital markets to sketch an explanation for persistence that might be especially relevant in emerging market economies.

Given the supply function and the institutional set-up of the game, the policymaker chooses the rate of currency depreciation in order to minimise a standard loss function that is quadratic in both output and inflation (or currency depreciation). We assume that the economy's transmission mechanism is known and such that the policymaker can directly control the inflation rate and, due to the PPP assumption, the exchange rate. The policymaker's loss function is then given by

$$L_t = \frac{1}{2}\left[\lambda \pi_t^2 + (y_t - y^*)^2\right] + C(\pi_t)\,, \tag{2}$$

[4] *To be precise, lower-case letters y, π, and z denote the logarithms of output, inflation rate and output shock.*

where $\lambda > 0$ is the relative weight assigned by the policymaker on the respective policy objectives. The standard time-inconsistency problem is captured by assuming that the policymaker's target level of output is higher than the natural rate of output, that is, $y^* > y_n \geq 0$. In that case, under a finite λ the policymaker has an incentive to generate policy surprises. Under an *exchange rate peg*, however, the policymaker commits *ex ante* to a zero rate of depreciation so that $\pi_t = 0$.[5]

In practice, a binding commitment to an exchange rate peg is hardly possible. Instead, the policymaker can usually utilise an escape clause that allows her to abandon the currency peg in the aftermath of an exceptionally large output shock. Such a "partial" commitment will, however, still temper the credibility problem because it renders the exercise of the escape clause costly. These costs are captured by the last term $C(\pi_t)$ in the policymaker's loss function (2). More specifically, the policymaker places herself in a position where any upward change in the exchange rate (a devaluation, implying that $\pi_t > 0$) has a cost of $C(\pi_t) = c_d$ whereas any downward change in the exchange rate (a revaluation, implying $\pi_t < 0$) has a cost of $C(\pi_t) = c_r$.[6]

The timing of events is as follows. (i) The private sector rationally forms its expectations on the future rate of depreciation, knowing the policymaker's preference parameter λ, output target y^* and the realignment costs c_r and c_d. (ii) The output shock is realised. (iii) The policymaker makes the realignment decision. (iv) The optimal rate of exchange rate depreciation is determined.

We begin by analysing the set of actions following a decision to *maintain* the currency peg. By definition, the rate of depreciation is then zero, and from (1) it is trivial to see that output when the peg is kept is equal to

$$\bar{y}_t = y_n + \rho y_{t-1} - \eta \pi_t^e + z_t \cdot \tag{3}$$

If the policymaker *abandons* the peg she opts for discretionary monetary policy (floating exchange rate), and the external value of the currency will be determined by private sector expectations.[7] In other words, the policymaker simply chooses the rate of depreciation, after observing the shock and taking the expectations as given. The policymaker's strategy can thus be expressed as a function of y_{t-1}, that is, the intertemporal decision problem has the following form:

$$V(y_{t-1}) = E_{t-1} \min_{\pi} \left[L_t + \delta V(y_t) \right] \cdot \tag{4}$$

When making the optimal policy decision, the policymaker takes into account that changes in *current* output will affect *current expectations* of future inflation through $V(y_t)$. To solve (4), we employ the method of undetermined coefficients. Because the problem is linear-quadratic, we can conjecture that the value function takes a quadratic form

$$V(y) = \gamma_1 y + \frac{1}{2} \gamma_2 y^2, \tag{5}$$

5 *The literature on optimal central bank institutions (Rogoff 1985, Lohmann 1992, Walsh 1995, Svensson 1997 and others) analyses the case where the policymaker tries to move from the discretionary equilibrium towards the time-inconsistent optimal policy rule by explicitly delegating monetary policy to an agent with different preferences or targets. The equilibrium time-consistent inflation rate under an optimally designed monetary institution is lower than under the policymaker's discretion.*

6 *Following the bulk of the literature in escape clauses (e.g., Obstfeld 1994, 1996, 1997, Jeanne, 1997, 1999) we regard these fixed costs as exogenous. An exception is De Kock and Grilli (1993) who demonstrate how the costs can be interpreted as the political cost for the policymaker from breaking the commitment to the exchange rate peg. Their argument, however, builds on a punishment strategy that violates the assumptions underlying the Markov-perfect equilibrium concept used below (cf. footnote 7). An alternative explanation for the fixed cost term could be that a deviation from the rule incurs a direct cost on policymaker if she has issued foreign currency debt denominated in domestic currency (for a related argument, see Bohn, 1990).*

7 *Recall that the autoregressive term ρy_{t-1} will introduce past output as a state variable. In the discretionary equilibrium, we restrict our attention to Markov-perfect equilibria where strategies at date t depend on the past only through this payoff-relevant state variable y_{t-1}. Making this common restriction involves a substantial advantage of excluding the strategies that directly depend on the realignment decision.*

where coefficients γ_1 and γ_2 are to be determined later. Upon inserting (1), (2), and (5) into the right-hand side of (4) and minimising with respect to π_t, we obtain that in period *t*, the optimal rate of depreciation under a floating exchange rate regime is

$$\tilde{\pi}_t = \frac{\eta(y^* - \delta\gamma_1) - b\bar{y}_t}{\lambda + \eta b}, \tag{6}$$

where $\bar{y}_t$ is given by (3) and $b = \eta(1+\delta\gamma_2)$. Parameter *b* measures the degree of complementarity, or supermodularity, between output and the rate of depreciation in the policymaker's value function, that is, $b = \partial^2 V/\partial y \partial \pi$. Several of the primary insights below can simply be obtained by isolating the impact of output persistence on this complementarity parameter. The equilibrium output under a free float can now be obtained by substituting (6) back into equation (1):

$$\tilde{y}_t = \bar{y}_t + \eta\tilde{\pi}_t. \tag{7}$$

The policymaker's expected *per period* welfare loss under the peg and under the floating exchange rate regime can be written by using (2) (3), (6) and (7) as

$$\bar{L}_t = \frac{1}{2}(\bar{y}_t - y^*)^2, \tag{8a}$$

$$\tilde{L}_t = \frac{1}{2}\left[\lambda(\tilde{\pi}_t)^2 + (\eta\tilde{\pi}_t + \bar{y}_t - y^*)^2\right] \tag{8b}$$

Note that the costs of currency realignment can be ignored at this stage. The equilibrium intertemporal loss functions under the two regimes can now be expressed in terms of (3), (7) and (8a, b) as

$$\bar{V}(y_{t-1}) = E_{t-1}\left(\bar{L}_t + \delta\bar{V}(\bar{y}_t)\right), \tag{9a}$$

$$\tilde{V}(y_{t-1}) = E_{t-1}\left(\tilde{L}_t + \delta\tilde{V}(\tilde{y}_t)\right). \tag{9b}$$

We now turn to analyse the optimal realignment decision. Given the fixed costs of currency realignment, c_d and c_r, the authorities would deviate from the exchange rate peg only when the output shock is low enough, so that $\bar{V}$ - $\tilde{V}$ > c_d, leading to a devaluation, or high enough so that $\bar{V}$ - $\tilde{V}$ > c_r, leading to a revaluation. Invoking the unimprovability principle of dynamic programming, it is sufficient to consider one-period deviations only. Consequently, we can rewrite both intertemporal loss functions in (9a, b) by employing the same functional form given by (5):

$$\bar{V}(y_{t-1}) = E_{t-1}\left[\bar{L}_t + \delta\left(\gamma_1\bar{y}_t + \frac{1}{2}\gamma_2(\bar{y}_t)^2\right)\right], \tag{10a}$$

$$\tilde{V}(y_{t-1}) = E_{t-1}\left[\tilde{L}_t + \delta\left(\gamma_1\tilde{y}_t + \frac{1}{2}\gamma_2(\tilde{y}_t)^2\right)\right]. \tag{10b}$$

Substituting (3) and (8a) for (10a) and (7) and (8b) for (10b), the conditions $\bar{V}$ - $\tilde{V}$ > c_r and $\bar{V}$ - $\tilde{V}$ > c_d can be simplified to

$$z_r = \frac{\eta(y^* - \delta\gamma_1) + \sqrt{2c_r(\lambda + \eta b)}}{b} - \rho y_{t-1} - y_n + \eta\pi_t^e, \tag{11a}$$

$$z_d = \frac{\eta(y^* - \delta\gamma_1) - \sqrt{2c_d(\lambda + \eta b)}}{b} - \rho y_{t-1} - y_n + \eta\pi_t^e. \tag{11b}$$

Equations (11a, b) determine the "trigger shocks" that make it optimal to switch from the peg to a floating regime. If the shock realisations are sufficiently small, $z_t \in [z_d, z_r]$, the exchange rate peg is maintained. On the other hand, for given expectations, a revaluation occurs when $z_t > z_r$ and devaluation occurs when $z_t < z_d$. Assuming that the policymaker's decision rule is fully transparent, the trigger shocks have to be incorporated in the private sector's rational expectations for inflation and thus depreciation. Recalling that the output shock z_t is uniformly distributed on [-Z/2, Z/2], the equilibrium expected depreciation is given by

$$E_{t-1}\pi_t = \int_{-Z/2}^{z_d} \tilde{\pi}_t(z) f(z)dz + \int_{z_r}^{Z/2} \tilde{\pi}_t(z) f(z)dz \cdot \tag{12}$$

From (6) and (3) we see that $\tilde{\pi}_t(z)$ depends on expected inflation. In other words, inflationary expectations enter here both in determining the inflation rate conditional on realignment *and* in determining the probability of realignment. As shown in Obstfeld (1994, 1996), this inherent feature of the escape clause regime gives rise to the possibility of multiple equilibrium expected inflation rates, although Morris and Shin (1998) point out that the existence of multiple equilibria requires the strong assumption of perfect information. It is, however, easy to show that even in the context of perfect information there may be a unique equilibrium. For this, the expected rate of inflation and depreciation need to be derived explicitly. The substitution of (6) for $\tilde{\pi}_t(z)$ and (11a, b) for z_r and z_d in (12) gives, upon somewhat involved algebra, an explicit form for the expected rate of depreciation under the escape clause regime:

$$E_{t-1}\pi_t = \alpha - \beta y_{t-1} + \frac{\Delta c}{\chi}. \tag{13}$$

In (13), we label the term $\alpha = [\eta(y^* - \delta\gamma_1) - by_n]/\lambda$ as *the average inflation bias*, $\Delta c = (c_r - c_d)/Z\lambda$ as *the devaluation premium*, $\beta = b\rho/\lambda$ as *the optimal policy response to past output* and, accordingly, $\chi = b/(\lambda + \eta b)$ as *the optimal policy response to output shocks*. This labelling becomes more useful when we substitute (13) for π_t^e in (6), which yields the optimal rate of depreciation under the escape clause regime:

$$\tilde{\pi}_t^* = \alpha - \beta y_{t-1} + \Delta c - \chi z_t\,. \tag{14}$$

The *average* rate of depreciation can now be obtained by substituting (14) for $\tilde{\pi}_t(z)$ in (12). This exercise confirms that in the rational expectation equilibrium the actual average depreciation rate equals the expected depreciation rate shown in (13). Moreover, equations (13) and (14) illustrate how the existence of multiple equilibria actually hinges on cost asymmetry, $c_r \neq c_d$. If the costs are of equal size, there is a unique equilibrium under perfect information where the expected rate of depreciation simply equals to the rate of depreciation under a free float, which can be obtained by setting $c_r = c_d$ in (13) and (14).

To complete the model we need to determine coefficients γ_1 and γ_2. Because the identification procedure associated with the method of undetermined coefficients is tedious, we relegate the details to Appendix 1. As a result of this exercise, parameters α and b read as

$$\alpha = \frac{\eta y^* - by_n}{\lambda - \delta\rho(\lambda + \eta b)}, \tag{15}$$

and

$$b = \frac{\lambda(1-\rho^2\delta) - \sqrt{\lambda^2(1-\rho^2\delta)^2 - 4\eta^2\lambda\rho^2\delta}}{2\rho^2\delta\eta}\,. \tag{16}$$

With suitable modifications, equation (16) gives the optimal policy responses to past output and output shocks through β and χ, respectively. We postpone the detailed evaluation of equations (13)-(16) in the subsequent section where the optimal exchange rate policy is characterised.

3 Stability of the exchange rate peg in the Presence of Output Persistence

Equations (13)-(16) fully characterise the expected and optimal rates of depreciation in the escape clause regime with output persistence. However, when the model includes output persistence, there is always a possibility that the dynamic system does not converge to a stationary state. To avoid such a possibility, we must first impose a stability restriction on the parameters. Substituting (13) into (1) shows that the stability condition $dy_t/dy_{t-1}<1$ holds only under the following restriction.

STABILITY CONDITION: $\rho + \eta\beta < 1$.

This is an equivalent (but slightly less tight) restriction to the one employed by Svensson (1997). The Stability Condition amounts to requiring that either η or ρ is sufficiently small or, alternatively, that the policymakers is sufficiently "conservative" so that λ is not too small. Operating under this parameter restriction, we can summarise the relevant properties and consequences of equations (15) and (16). We begin from equation (16).

LEMMA 1. It follows from the Stability Condition that (i) $b \geq \eta$, (ii) $\partial b/\partial\rho > 0$, and (iii) $\partial b/\partial\lambda < 0$.

Proof: In Appendix 2.

The main implication of part (i) in Lemma 1 is that b is positive. This confirms the conjecture from the previous section that the policymaker's value function is supermodular in output and depreciation rate. Note from part (ii) that the degree of supermodularity is increasing in output persistence.

Combining the Stability Condition and Lemma 1 yields our first result.

PROPOSITION 1. (i) The optimal policy responses to past output and output shocks are positive and increasing in the level of output persistence (ii) The average inflation bias is positive and increasing in the level of output persistence if the target level of output is not too low (iii) Under the exchange rate peg with escape clauses, the average rate of depreciation is increasing in the devaluation premium Δc.

Proof. (i) Because $b > 0$ by part (i) of Lemma 1, $\beta = \rho\beta/\lambda \geq 0$ and $\chi = b/(\lambda+\eta b) > 0$. Because $\partial b/\partial\rho > 0$ by part (ii) of Lemma 1, $d\beta/d\rho = [b+\rho(\partial b/\partial\rho)]/\lambda > 0$, and $d\chi/d\rho = (\partial b/\partial\rho)\lambda/(\lambda+\eta b)^2 > 0$.

(ii) It immediately follows from the Stability Condition that the nominator of (15) is positive. Thus, the sign of α is given by the sign of $\eta y^*\text{-}by_n$, and taking the derivative of (15) with respect to ρ reveals that the sign of $d\alpha/d\rho$ is given by the sign of

$$\alpha\delta\left(\lambda + \eta b + y_n\rho\frac{\partial b}{\partial\rho}\right) - y_n\frac{\partial b}{\partial\rho}\cdot \tag{17}$$

Because $\partial b/\partial\rho > 0$ by part (ii) of Lemma 1, a necessary and sufficient condition for $d\alpha/d\rho > 0$ and a sufficient condition for $\alpha > 0$ is that y^* not too small so that (17) is positive. The proof of part (iii) follows immediately from equation 13.

Q.E.D

The results of part (i) are standard, as the behaviour of the optimal policy responses reflect the message in Svensson (1997). If the economy shows output persistence, a stronger response to supply shocks is required in the current period to avoid shocks to accumulate in the future. In contrast, part (ii) warrants more attention. To understand the behaviour of the average inflation bias, note that if $\rho > 0$, the natural rate of output has a direct impact on future output through (1), whereas the target level of output has no impact in equilibrium. As a result, if the natural rate is large, the presence of output persistence may mitigate the time-inconsistency problem of creating positive inflation surprises. Part (iii) also invites a few words of explanation. The devaluation premium Δc is positive if the cost of devaluation is lower than the cost of revaluation, since in that case the policymaker is *ex ante* known to be more prone to devaluations than revaluations. The devaluation premium is incorporated in the expectations as can be seen from (13) and therefore, in the case of positive premium, the policy surprises must be relatively large to raise output above the natural rate. In other words, even though the rate of depreciation is zero in the escape clause regime under small output fluctuations caused by shocks z_t such that $z_t \in [\underline{z}, \overline{z}]$, the average rate of depreciation will be higher due to the devaluation premium. Therefore, an exchange rate peg with escape clauses may lead to a lower average rate of inflation only when it is known that the devaluation premium is negative, i.e., $\Delta c < 0$.

We are now ready to analyse the effect of output persistence on the credibility of the exchange rate peg or, in terms of Obstfeld, on the vulnerability of the peg on speculative attacks. For the remaining of the paper we assume without loss of generality that $c_r = c_d = c$. Equations (11a, b) determine the range of output shocks in which the exchange rate peg is optimally defended, providing thus a practical measure of the credibility of the peg.

DEFINITION 1. Let $c_r = c_d = c$ in (11a, b). The credibility of the exchange rate peg can then be measured by the following expression:

$$\Phi \equiv z_r - z_d = 2\left(\frac{2c}{\chi b}\right)^{1/2}.$$

Observe first that Φ is increasing in the cost of currency realignment. An exogenous reduction in the cost thus makes speculative attacks more likely. In addition to the realignment cost, the credibility measure is merely a function of output persistence and the policymaker's preferences. Proposition 2 summarises the respective effects of these two parameters on the credibility of the exchange rate peg.

PROPOSITION 2. The credibility of the peg is decreasing in the degree of output persistence and increasing in the weight assigned on the exchange rate stability objective, i.e., $d\Phi/d\rho < 0$, $d\Phi/d\lambda > 0$.

Proof: Part (ii) of Lemma 1 and part (i) of Proposition 1 establish that $\partial b/\partial\rho > 0$ and $d\chi/d\rho > 0$. It therefore immediately follows from Definition 1 that $d\Phi/d\rho < 0$. To see that $d\Phi/d\lambda > 0$, let us first split $d\Phi/d\lambda$ in two:

$$\frac{d\Phi}{d\lambda} = \frac{\partial\Phi}{\partial\lambda} + \frac{\partial\Phi}{\partial b}\frac{db}{d\lambda}. \tag{18}$$

Because $\partial\chi/\partial\lambda < 0$, the first term in the right-hand side is positive. Because $\partial b/\partial\lambda < 0$ by part (iii) of Lemma 1, the second term in the right-hand side is also positive.

Q.E.D

The finding in Proposition 2 is easy to explain. Output persistence increases the costs of insufficient shock stabilisation, because the shocks that are not stabilised in a given period will have a bearing on future output and, accordingly, on the expected rate of currency depreciation. Under such conditions even small additional shocks to output can trigger a speculative attack that forces the policymaker to abandon the currency peg. Under output persistence, a conservative policymaker (who shows a high λ) is particularly credible, as she neglects not only the usual short-run output effects of the shocks but also the long-run output considerations. This is highlighted by equation (18) where the first and second terms in the right-hand side depict the short-run and the long-run credibility effects, respectively. Because of the long-run credibility effect, the public further scales down its devaluation expectations, increasing the sustainability of the peg.

However, an excessively strong preference for exchange rate stability may have a negative side effect, as accumulated shocks tend to lead to severe long-run output distortions. If monetary policy is delegated to a "conservative" agent, who may be less exposed to speculative attacks, the regime may nevertheless be more exposed to overruling on the behalf of the principal policymaker if the principal does not share the agent's preferences. Following Lohmann (1992) it is actually possible to show that the incentive of a policymaker who has a stronger preference for output stabilisation to overrule the monetary authority is increasing in the level of output persistence.[8] This suggests that the only *sustainable* way of enhancing the credibility of an exchange rate peg is to improve the economic fundamentals, including a reduction in output persistence. To achieve meaningful policy recommendations, however, we need to specify the mechanism creating output persistence in more detail. This is the topic of the next section.

4 Corporate Governance Institutions and the Stability of Exchange Rate Pegs

This section provides financial market microfoundations for the formulation of the output function (1). More specifically, we show how output persistence can arise from institutional capital market imperfections such as weak corporate governance practices. In so doing, we establish a link between the state of the capital market and the credibility of the exchange rate peg. It turns out that the impact of corporate governance on output persistence is non-linear; minor improvements in corporate governance practices may increase persistence, whereas major reforms tend to result in reduced persistence. This happens because an insufficient reform may enhance the *financial accelerator mechanism,* rendering the economy vulnerable to a currency crisis.

Our starting point is the standard expected-market-clearing model (see, e.g., Fischer, 1977, Taylor, 1999) but instead of the usual one-period wage contracts, we use debt contracts governing capital supply over a period. The complete model is solved in Appendix 3, with the main equations provided below. Assume first that the output of a representative firm is determined by means of a Cobb-Douglas production function of the form

$$Y_t = A_t K_t^n , \tag{19}$$

where, in period *t*, Y_t and K_t are the output and investment levels, *n* is the elasticity of output with respect to the investment level, and A_t is a random productivity shock with mean $E_{t-1}(A_t)=1$ and variance σ_A^2. The profit function of the representative firm is given by

$$P_t = \Pi_t A_t K_t^n - R_t K_t , \tag{20}$$

[8] *The calculations that prove this argument are available from the authors upon request.*

where Π_t and R_t denote the price level and the cost of capital, respectively. The timing of events is as follows. (i) The cost of capital is determined. (ii) The productivity shock and the price level are realised. (iii) The demand for capital is determined. The cost of capital is set in such a way that the market for capital is expected to clear; after the cost of capital is determined, it remains fixed during the market period.

The expected demand for capital is the solution to the problem in which the expected value of (20) is maximised with respect to K_t. The problem is solved in equations (A3.1)-(A3.4) in Appendix 3, and the solution can be expressed in the logarithm form as

$$k_t^d = \frac{\log n + \pi^e + \xi - r_t}{1-n}, \tag{21}$$

where ξ is a negative constant capturing the covariance of random variables A_t and Π_t. The supply of capital in the credit-constrained open economy is determined by the following relationship:

$$K_t^s = D_t + F_t, \tag{22}$$

where D_t and F_t denote the domestic and foreign supply of capital. We assume that the availability of domestic funds solely depends on output, i.e.,

$$D_t = Y_{t-1}^{\varepsilon}, \tag{23}$$

where $\varepsilon < 1$ measures the elasticity of domestic capital supply with respect to output.[9] An interpretation of (23) is that in the absence of a domestic banking sector the entrepreneurs resort to internal financing, i.e., finance their investments by their revenue flows.

In contrast, the availability of foreign capital depends on the state of domestic legal rules and corporate governance. Following Holmström and Tirole (1997), the amount of foreign funds available, F_t, can be called *pledgeable income*, i.e., the maximal amount of revenues that the entrepreneurs can promise to put aside to pay back their loans. The pledgeable income can be derived from the entrepreneur's participation constraint:

$$E_{t-1}P_t(K_t) - F_t \geq E_{t-1}P_t(K_t) - G(K_t, g) \tag{24}$$

In each period, the entrepreneurs can choose whether to pay back their loans to foreign investors or divert the funds to private projects. The weaker is investor protection, the easier it is to divert funds. In (24), $E_{t-1}P_t(K_t)$ is the entrepreneurs' expected discounted profit and $G(K_t, g)$ captures the cost of diverting funds, which is increasing in g, the state of corporate governance. As in Holmström and Tirole (1997), Aghion, Bacchetta and Banerjee (1999), and Aghion, Banerjee and Piketty (1999), we hypothesise that the cost is also related to the size of the investment, and, for reasons of tractability, we postulate that G takes a specific form of $K_t(1-K_t^{-g})$. From (24) we now immediately see that

$$F_t \leq G(K_t, g) \equiv K_t\left(1 - K_t^{-g}\right). \tag{25}$$

Clearly, when g approaches infinity, the economy encounters no credit constraints. In contrast, when g approaches zero, the threat that all funds will be diverted to private projects prohibits the access to the international capital market. In other words, when g = 0 no foreign financing takes

9 *The size of ε is assumed to depend on entrepreneurs' consumption and investment decisions only, as an explicit derivation of the capital supply by domestic financial intermediaries is beyond the scope of this paper. However, it is realistic to assume that ε is strictly less than one, as typically a fraction of current output is consumed.*

place in equilibrium and, consequently, the liquidity is scarce in the economy. In such circumstances only few projects can go ahead because the entrepreneurs can only resort to internal financing as specified in (23).

Substituting (23) and (25) for (22), and solving for the logarithm form of K_t^s yields the expression for expected supply of capital:

$$k_t^s = \frac{\varepsilon y_{t-1}}{1-g} \tag{26}$$

Equating (21) and (26), the expected demand for and supply of capital, and solving for the equilibrium price of capital, gives

$$r_t = \log n + \xi + \pi^e - \frac{\varepsilon}{1-g}(1-n)y_{t-1}. \tag{27}$$

On the other hand, the *ex post* demand for capital is given as a solution to the problem in which K_t solves (20) when A_t and Π_t are known and when the cost of capital is determined by (27). As shown in equations (A3.5)-(A3.8) in Appendix 3, solving the *ex post* demand for capital, substituting the resulting expression for K_t in equation (19), and taking logarithms, gives the Lucas supply curve with output persistence,

$$y_t = y_n + \rho y_{t-1} + \eta(\pi_t - \pi^e) + z_t. \tag{28}$$

In (28), $y_n = -\eta\xi$, $\rho = n\varepsilon/(1\text{-}g)$, $\eta = n/(1\text{-}n)$, and $z_t = a_t/(1\text{-}n)$. Note first that the natural rate of output is strictly positive. The reason is that the cost of capital is based on the expected demand of capital before the realisation of the shocks and price level. Because the covariance of random variables A_t and Π_t is negative, it follows from Jensen's Inequality that actual demand of capital is on average higher than the expected demand. If the shocks and price level were uncorrelated, or the cost of capital were based on the actual demand, the natural rate would remain zero.

As the comparative statics regarding the other parameters are well understood, the new insights here emerge from the evaluation of parameter ρ. It is evident that for sufficiently small values of g, output persistence is increasing in the state of corporate governance as captured by the term $1/(1\text{-}g)$ in ρ. Under the worst state of corporate governance ($g = 0$), there is no access to foreign capital and the investment level hinges on the supply of domestic capital. However, when the state of corporate governance improves foreign capital also becomes available. Consequently, for a given level of domestic financing there is initially a higher level of investment. When the conditions for availability of foreign capital improve further, the investment demand eventually reaches the desired level due to the fact that the marginal productivity of investment is decreasing. The optimal *ex ante* demand for capital equals R^*/Π^e where R^* denotes the rate of return on an outside option, e.g., the international rate of return. Letting k_t^s from (26) be equal to $r^*\text{-}\pi^e$, and solving for g then yields the following threshold level of corporate governance

$$\bar{g}_t = 1 - \frac{\varepsilon y_{t-1}}{r^* - \pi_t^e}. \tag{29}$$

We define an economy where $g \in [0, \bar{g}_t]$ as an *emerging market economy*. In this region, ρ is increasing in g, that is, all improvements in corporate governance that end in g being less than $\bar{g}_t$ certainly increase output persistence. As Caballero and Krishnamurthy (1999) point out, emerging market economies are almost by definition characterised by, on one hand, profitable investment opportunities and, on the other hand, severe financial constraints. In our model a partial relaxation of such constraints boosts investments, but also enhances the financial accelerator mechanism.

Above the threshold level of corporate governance given by (29) the improvements in corporate governance only affect the financial composition of the investment, decreasing the dependence on domestic financing and thus reducing output persistence.[10] In other words, when $g > \bar{g}_t$ the elasticity of domestic capital supply, ε, is decreasing in *g*. However, when *g* is above the threshold level the *ex ante* demand for capital is at the desired level while the *ex post* investment activity is still constrained by the domestic capital supply and, accordingly, the output of the previous period. Only when *g* approaches infinity credit constrains are completely eliminated and the supply of capital is solely determined by the real international rate of return. Under such "perfect" capital markets $K^s = R^*/\Pi^e$ or, equivalently, $k^s = r^*\text{-}\pi^e$, and the entrepreneurs invest until $r = r^*$. It is easy to show that using $k^s = r^*\text{-}\pi$ instead of equation (26) results in the standard Lucas supply curve where the economy encounters no persistence.

Because the threshold level of corporate governance as specified in (29) turns out to be below unity, the Stability Condition from section 3 is likely to hold and, consequently, the analysis of this section can be directly connected with the findings of the previous sections. Armed with this result, we are finally able to characterise the optimal exchange rate policy under capital market imperfections. Our first conclusion reads as:

PROPOSITION 3. In emerging market economies, the optimal policy responses to past output and output shocks, β and χ, are increasing in the state of corporate governance. Furthermore, given Proposition 1, the average inflation bias is positive and increasing in the state of corporate governance.

Proof: By our definition of an emerging market economy, $d\rho/dg > 0$. By part (i) of Proposition 1, β and χ are increasing in ρ, and, hence, in an emerging market economy, in *g*. Similarly, an implication of part (ii) of Proposition 1 is that when y^* is not too small, both α and $d\alpha/d\rho$ are positive.

Q.E.D

The dynamics underlying Proposition 3 are well in line with earlier literature, including in particular Aghion, Bacchetta and Banerjee (1999), that, however, uses a very different framework. The improvements in the legal institutions for corporate governance initially enlarge the entrepreneurs' capacity to obtain outside funds per unit of the current output, thus raising the level of output persistence in the economy. As shown in Proposition 1, increased persistence leads to a tradeoff between increased and decreased policy activity. On the one hand, persistence increases the natural rate of output which stimulates future output and diminishes the discrepancy between the target level and the average level of output, thus alleviating the time-inconsistency problem and reducing the need for policy activity. On the other hand, persistence provides the policymaker with an incentive to react rather aggressively to the output shocks so as to dampen the effect of the financial accelerator. Only in fully developed economies with a good state of corporate governance the optimal policy response may be relatively insensitive to output shocks, as the entrepreneurs' investment behaviour is independent on current output in the absence of credit constraints and the financial accelerator.

Next, we define *corporate governance reform* as changes to law and institutions regarding investor protection so as to improve the efficiency of capital markets. In our model such reform means

[10] *The underlying assumption here is that the entrepreneurs prefer foreign credit to domestic. For an elegant justification for such a preference, see Bris and Koskinen (1999).*

actions that increase g. Of course, in reality a variety of actions fall into this category. For instance, improving revenue collection and opening up the domestic financial market would probably also result in an effect similar than an increase in g. Proposition 2 together with equation (28) now yields our key finding:

PROPOSITION 4. An incomplete corporate governance reform may reduce the credibility of the exchange rate peg if the reform is not accompanied by an appointment of a monetary authority with higher preference for the exchange rate stability objective.

Proof: Suppose that a corporate governance reform takes place that increases g in the region where $d\rho/dg > 0$. The rest of the proof immediately follows from Proposition 2.

Q.E.D

Proposition 4 suggests that a partial reform of corporate governance practices may actually render the exchange rate peg vulnerable to speculative attacks. The reasoning is as follows. When corporate governance rules are very underdeveloped, the entrepreneurs cannot rise foreign capital. In that case, shocks to the revenues do not to matter much because the financial accelerator is weak. After a partial reform, the entrepreneurs can obtain foreign capital against their current revenues (pledgeable income), but, as a side effect, the financial accelerator is enhanced. Under a currency peg, the policymaker can not eliminate the impact of the shocks by adjusting the exchange rate. The shocks are thus multiplied by the financial accelerator, increasing expectations of the currency peg collapsing and thus diluting the credibility of the peg. A "conservative" policymaker will induce the private sector to scale down such expectations and thus enhances the credibility of the peg as indicated by the credibility measure in Definition 1.

Corporate governance reform tends to be almost by definition a part of financial liberalisation programmes and in that respect, our model provides support to the widely held view that poor design of financial liberalisation may be a source of currency crises. Kaminsky and Reinhart (1999) and Allen and Gale (2000) conclude that a common origin of such "twin crises" is the boom in foreign currency lending that follows financial liberalisation, along similar lines as predicted by our model.[11] Moreover, in the studies looking deeper into the causes of the currency crises, corporate governance has recently received increasing attention. Johnson, Boone, Breach and Friedman (1999) and Mitton (1999) report how the weak corporate governance worsened the 1997 East Asian currency crises. In Burnside, Eichenbaum and Rebelo (2000), the policymaker can eliminate self-fulfilling speculative attacks by reforming the bailout guarantees of domestic borrowers. In comparison with these studies, our argument on the role of corporate governance is complementary. Weak corporate governance can work in a similar way than worsening of the "traditional" economic fundamentals, possibly triggering a crisis and forcing the policymaker to abandon the exchange rate peg in the first place.

The final point emerging from the analysis above is that, although reforming corporate governance legislation may increase output persistence in emerging market countries, it always has the positive effect of increasing the average level of output. This tradeoff between good and bad outcomes is consistent with the jet-airplane analogy of financial innovations offered by Summers (2000). In emerging market economies, financial innovations such as improvements in corporate governance practices tend to have similar consequences to the invention of the jet airplane that boosted the volume of travelling but made the crashes spectacular.

[11] *For a detailed account of this experience in some individual countries, see, e.g., Sachs, Tornell and Velasco (1996) for Mexico in mid-1990's, Corsetti, Pesenti and Roubini (1999) for the East Asian countries in 1990's, and Honkapohja and Koskela (1999) for Finland in late 1980's and early 1990's.*

In assessing the reliability of the observations here, however, a caveat should be borne in mind. Our simple model is limited in that the role of domestic financial intermediation is not explicit, as incorporating the profits and credit losses of a domestic banking sector would substantially complicate the analysis of the optimal exchange rate policy. Nonetheless, previous work by Holmström and Tirole (1998) and Caballero and Krishnamurthy (1999) suggests that financial intermediation cannot improve the responsiveness of an economy to aggregate output shocks. As a result, in our framework where the shocks are economy-wide the introduction of domestic financial intermediaries should only reinforce our argument. The improvements in corporate governance practices would in that case substantially increase persistence as domestic lending would also be boosted for a given level of output. A model that permits the evaluation of the optimal exchange rate policy in an economy where the domestic financial intermediation plays a welfare-improving role nevertheless provides a formidable challenge for future research.

5 Conclusion

Previous research on currency crises detects two basic causes for abandoning the exchange rate peg. First, the fundamentals may have deteriorated to the extent at which switching to a floating rate regime becomes a tempting alternative. The second cause follows from the private sector's rational devaluation expectations that, by affecting the economy's output, may create an incentive for the policymaker to validate the expectations *ex post* by manipulating the exchange rate. In this paper we show how insufficient capital market development and weak corporate governance institutions can generate a mechanism that increases the vulnerability of the currency peg to self-fulfilling expectations and speculative attacks.

We find, in line with recent literature, but applying an original approach that if the economy is characterised by severe credit constraints, a partial reform that aims at improving the corporate governance institutions may not necessarily be beneficial under an exchange rate peg. Although such a reform stimulates investment by allowing foreign lenders to enter the market, it is shown to also increase output persistence and thereby the vulnerability to a currency crisis. These adverse effects can be alleviated if the policymaker puts a relatively high weight on the exchange rate stability objective. Nevertheless, only if the capital market frictions are eliminated completely, in the context of our model by creating efficient institutions for corporate governance, persistence may disappear and the credibility of the peg strengthen on all levels of the policymaker's preferences.

Our analysis sheds some light on the links between weak corporate governance, financial market frictions and exchange rate policy in emerging market economies. In particular, we were able to combine results from several branches of literature and build a connection between the financial market microstructure and the policymaker's decision problem on the macro level. A straightforward policy recommendation arises from our analysis. Since the probability of a speculative attack against the currency peg is higher when the legal and financial institutions of the economy are insufficiently developed, and since an incomplete reform may further increase such probability, high emphasis should be assigned on reforming both economic and legal institutions prior to entering any policy regime that involves fixing the exchange rate.

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Appendix 1: *The determination of coefficients γ_1 and γ_2*

The exposition here loosely follows Svensson (1997). Let us write the recursive value functions explicitly as

$$V_t(y_t) = \gamma_{1t} y_t + \frac{1}{2}\gamma_{2t} y_t^2 \tag{A1.1}$$

and

$$V_{t-1}(y_{t-1}) = E_{t-1} \min_{\pi}\left(L_t + \delta V_t(y_t)\right) \cdot \tag{A1.2}$$

Taking the derivative of (A1.2) by using the envelope theorem and (A1.1) yields

$$\gamma_{1t-1} + \gamma_{2t-1} y_{t-1} = \frac{\rho(\lambda + \eta b_t)}{\lambda\eta}\left[b_t(\rho y_{t-1} + y_n) - \eta(y^* - \delta\gamma_{1t})\right], \tag{A1.3}$$

where $b_t = \eta(1+\delta\gamma_{2t})$. Equation (A1.3) has a solution only if

$$\gamma_{1t-1} = \frac{\rho}{\lambda\eta}(\lambda + \eta b_t)\left[b_t y_n - \eta(y^* - \delta\gamma_{1t})\right] \tag{A1.4}$$

and

$$\gamma_{2t-1} = \frac{\rho^2 b_t}{\lambda\eta}(\lambda + \eta b_t) \cdot \tag{A1.5}$$

In the stationary state $\gamma_{it-1} = \gamma_{it} = \gamma_i$ for $i \in \{1, 2\}$ and, accordingly, $b_t = b$. After manipulating (A1.4) in the stationary state, the solution for γ_1 can be expressed in terms of α as

$$\alpha = \frac{\eta y^* - b y_n}{\lambda - \delta\rho(\lambda + \eta b)} \cdot \tag{A1.6}$$

Corresponding manipulation of (A1.5) gives an implicit solution for γ_2 in terms of b as

$$\delta\rho^2\eta b^2 - b\lambda\left(1 - \delta\rho^2\right) + \lambda\eta = 0 \cdot \tag{A1.7}$$

Equation (A1.7) has two positive solutions but, as $b = \eta$ when either ρ or δ equals 0, we can apply *L'Hôpital's rule* to exclude the larger root. Solving (A1.7) for the smaller root gives

$$b = \frac{\lambda(1-\rho^2\delta) - \sqrt{\lambda^2(1-\rho^2\delta)^2 - 4\eta^2\lambda\rho^2\delta}}{2\rho^2\delta\eta} \, . \tag{A1.8}$$

Equations (A1.6) and (A1.8) corresponds equations (16) and (17).

Appendix 2: *The proof of Lemma 1*

i) The proof of part (i) has two main steps. We first prove that the Stability Condition is a sufficient condition that b has a real solution. We then prove that the solution has to be at least as large as η.

Step 1. From (A1.8) we can observe b has a real solution if and only if

$$\lambda(1-\rho^2\delta)^2 - 4\eta^2\rho^2\delta \geq 0. \tag{A2.1}$$

We now show that if the Stability Condition holds, then (A2.1) holds. The Stability Condition is equivalent to $\rho+\beta\eta < 1$ or, by using (A1.8), to

$$\frac{1-\rho}{\eta} > \frac{\lambda(1-\rho^2\delta) - \sqrt{\lambda^2(1-\rho^2\delta)^2 - 4\eta^2\lambda\rho^2\delta}}{2\rho\lambda\delta\eta}. \tag{A2.2}$$

Simplifying and rearranging (A2.2) gives

$$\sqrt{\lambda^2(1-\rho^2\delta)^2 - 4\eta^2\lambda\rho^2\delta} > \lambda(1-\rho^2\delta) - (1-\rho)2\rho\lambda\delta \cdot \tag{A2.3}$$

Clearly, if the right-hand side is positive, the left-hand side also has to be positive. After some manipulation, the right-hand side of (A2.3) turns out to be equivalent to

$$(1-\rho\delta)^2 + \rho^2\delta(1-\delta) > 0, \tag{A2.4}$$

which clearly holds. In sum, as far as the Stability Condition is valid, b has a non-negative real solution.

Step 2. From (A1.8) it is easy to see that condition $b \geq \eta$ is equivalent to

$$\lambda(1-\rho^2\delta) - 2\rho^2\delta\eta^2 \geq \sqrt{\lambda^2(1-\rho^2\delta)^2 - 4\eta^2\lambda\rho^2\delta} \cdot \tag{A2.5}$$

Squaring both sides of (A2.5) gives

$$\left[\lambda(1-\rho^2\delta) - 2\rho^2\delta\eta^2\right]^2 \geq \lambda^2(1-\rho^2\delta)^2 - 4\eta^2\lambda\rho^2\delta \cdot \tag{A2.6}$$

Recall from Step 1 that the right-hand side is positive. A straightforward simplification of (A2.6) then yields

$$\rho^2\delta(\lambda+\eta^2) \geq 0 \cdot \tag{A2.7}$$

Q.E.D

ii) Rewriting b from (A1.8) as

$$b = \frac{\lambda(1-h) - \sqrt{\lambda^2(1-h)^2 - 4\eta^2\lambda h}}{2h\eta} \tag{A2.8}$$

where $h = \rho^2\delta$ captures the impact of output persistence on b. Take next the derivative of b with respect to h to get

$$\frac{\partial b}{\partial h} = \frac{1}{2h\eta^2}\left[-\lambda + \frac{(\lambda^2(1-h+2\eta^2\lambda)h}{\sqrt{\lambda^2(1-h)^2 - 4\eta^2\lambda h}} + \sqrt{\lambda^2(1-h)^2 - 4\eta \right. \cdot \tag{A2.9}$$

Equation (A2.9) is positive if the term in the square-brackets is positive, i.e., if

$$-\lambda\sqrt{\lambda^2(1-h)^2-4\eta^2\lambda h}+\left(\lambda^2(1-h)+2\eta^2\lambda\right)h+\lambda^2(1-h)^2 \cdot \tag{A2.10}$$

Simplifying and rearranging (A2.10) gives

$$\lambda(1-h)-2\eta^2 h>\sqrt{\lambda^2(1-h)^2-4\eta^2\lambda h}\cdot \tag{A2.11}$$

Because (A2.11) is equivalent to (A2.5), the rest of the proof is given by equations (A2.6)-(A2.7).

Q.E.D

iii) Taking the derivative of *b* from (A2.8) with respect to λ yields

$$\frac{\partial b}{\partial \lambda}=\frac{1}{2\eta h}\left[1-h-\frac{\left(\lambda(1-h)^2-2\eta^2 h\right)}{\sqrt{\lambda^2(1-h)^2-4\eta^2\lambda h}}\right]\cdot \tag{A2.12}$$

Equation (A2.12) is negative if the term in the square-brackets is negative, i.e., if

$$\lambda(1-h)^2-2\eta^2 h>(1-h)\sqrt{\lambda^2(1-h)^2-4\eta^2\lambda h} \tag{A2.13}$$

Squaring both sides of (A2.13) and simplifying gives

$$4\eta^4 h^2>0\cdot \tag{A2.14}$$

Q.E.D

Appendix 3: *Derivation of the Lucas supply function with output persistence*

The exposition here loosely follows Turnovsky (2000, pp. 101-104). The output and profit function of a representative firm are given by equations (19) and (20). We now explicitly derive the expected demand for capital given by equation (21). The expected demand for capital is the solution to the problem in which the expected value of profits is maximised with respect to K_t. Maximising the expected value of (20) with respect to K_t gives the first-order condition

$$nK_t^{n-1}E_{t-1}(\Pi_t A_t) = R_t \cdot \tag{A3.1}$$

Using the definition of covariance,

$$E_{t-1}(\Pi_t A_t) = \Pi^e\left[1 + \frac{\operatorname{cov}_{t-1}(\Pi_t, A_t)}{\Pi^e}\right]. \tag{A3.2}$$

By substituting (A3.2) for (A3.1), the expected demand for capital can be expressed in terms of logarithms as

$$k_t^d = \frac{\log n + \pi^e + \xi - r_t}{1-n}, \tag{A3.3}$$

where

$$\xi = \log\left[1 + \frac{\operatorname{cov}_{t-1}(\Pi_t, A_t)}{\Pi^e}\right]. \tag{A3.4}$$

Under the standard assumptions on the policymaker's objective function, the covariance of P_t and A_t is negative and, consequently, $\xi < 0$. Equation (A3.3) is equation (21).

We next derive equation (28). The *ex post* demand of capital is given as a solution to the problem in which K_t solves (20) when A_t, Π_t, and R_t are known. In the logarithm form the solution of this problem can be written as

$$k_t = \frac{\log n + \pi_t + a_t - r_t}{1-n}. \tag{A3.5}$$

Inserting (27) into (A3.5) yields

$$k_t = \frac{\pi_t - \pi^e + a_t - \xi}{1-n} + \frac{\varepsilon}{1-g} y_{t-1} \cdot \tag{A3.6}$$

Note next that taking logarithms of (19) gives

$$y_t = nk_t + a_t \cdot \tag{A3.7}$$

By substituting (A3.6) for (A3.7) we obtain

$$y_t = \frac{n}{1-n}\left(-\xi + \pi_t - \pi^e\right) + \frac{n\varepsilon}{1-g} y_{t-1} + \frac{a_t}{1-n}, \tag{A3.8}$$

which is equivalent to (28).

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