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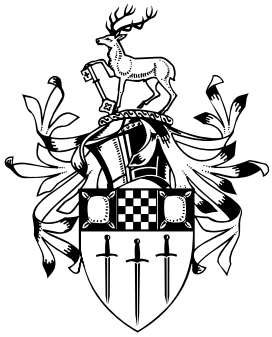

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# CENTRAL BANK INDEPENDENCE AND THE 'FREE LUNCH PUZZLE': A NEW PERSPECTIVE

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# Central Bank Independence and the 'Free Lunch Puzzle': A New Perspective *

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**Abstract**

A new perspective is provided on a puzzle that has emerged from the empirical literature suggesting that government-independent central banks provide a 'free lunch': lower inflation is apparently achieved at no cost in terms of greater output variance. We assess the various explanations provided by the theoretical literature. After revisiting the free lunch puzzle and confirming the empirical importance of open-economy effects, we develop a Rogoff-style delegation model that combines the latter with political monetary cycle effects. We show that if all countries delegate monetary policy to government independent banks, as economies become more integrated then a low inflation, higher output variance trade-off re-emerges.

**JEL Classification**: C72, E61.

**Keywords**: central bank independence, open economy, political uncertainty.

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# Contents

# 1 Introduction

This paper explains a stylized fact that has emerged from the empirical literature on central bank independence and its effect on economic performance. Apparently, government-independent central banks provide a free lunch; lower inflation and lower inflation variance are achieved at no cost in terms of greater output or employment variance. This contrasts with the prediction of Rogoff (1985b) that delegating monetary policy to an independent and inflation-averse central bank (CB) would result in lower average inflation but at a cost of an increase in the variances of output and employment. We provide a new perspective on the reconciliation of this empirical puzzle with theory that stresses the open-economy aspects of delegation.

The theoretical literature has explored a number of directions in order to understand this result. Two explanations specify equilibria in which zero inflation can be achieved without compromising the efficacy of stabilization policy in the face of shocks and consist of a trigger strategy equilibrium, as in Barro and Gordon (1983), or a banker's contract, as in Walsh (1995). Consider first the possibility of a trigger strategy equilibrium. Barro and Gordon confine themselves to the monetary policy game in the absence of shocks. In a repeated game, a zero inflation equilibrium can be sustained by a trigger strategy on the part of the public which specifies inflation expectations to be zero in the first period and thereafter, if the history of play is zero inflation. Otherwise they expect the non-zero discretionary inflationary bias for some length of time. Then provided that the punishment period is sufficiently long and the discount rate sufficiently low, the CB will not have an incentive to depart from zero inflation. Even in the absence of the stabilization dimension there are widely acknowledged problems with this proposed equilibrium; in particular, what determines the length of the punishment period during which the private sector expects high inflation, and how can an atomistic private sector coordinate on one particular strategy? Another problem is that even if the private sector could coordinate then the punishment is not 'recoordination-proof', and therefore not credible (al-Nowaihi and Levine (1994)).

A seminal approach to the credibility problem pioneered by Walsh (1995) proposes a contract that provides an incentive mechanism to eliminate the inflation bias whilst permitting the full use of stabilization policy. In terms of agency theory the principal (the

government) designs an incentive mechanism consisting of an income transfer contingent on inflation such that the agent (the CB) will pursue the desired policy. But does the Walsh contract in fact solve the credibility problem? What the contract certainly achieves is the 'relocation' of the problem as one of enforcing the contract (McCallum (1995)). The problem still remains that circumstances will arise when it will be in the interests of all concerned to renegotiate the contract rather than enforce it. This feature destroys the credibility of the Walsh contract in the absence of some other enforcement mechanism.

For Walsh contracts to work some mechanism is required to make them renegotiation-proof: for example institutional arrangements (implicitly assumed in Walsh (1995)) or reputational effects (see al-Nowaihi and Levine, 2000). However, even if neither of these devices exist and Walsh contracts do not eliminate the inflationary bias, al-Nowaihi and Levine (1998) point to another output variance-reducing role for contracts. Transparency is the key to their result: by providing an efficient signalling device to the electorate, bankers' contracts can eliminate the political monetary cycle even with government-dependent CBs. However, since Walsh contracts are not generally observed (New Zealand is the exception), the significance of this literature is more normative than positive.

We turn therefore to two other explanations of the puzzle that retain Rogoff-delegation of monetary policy to inflation-averse 'conservative' bankers, but modify Rogoff's model to include effects which offset the higher output variance. In the partisan political monetary cycle[1] closed-economy model of Alesina and Gatti (AG, 1995) government-independent conservative bankers engage in insufficient stabilization policy which increases output variance, but this can be outweighed by the reduction in output variance caused by eliminating political uncertainty. Currie *et al.* (CLP, 1996) examine the Rogoff delegation game in the open economy and highlight the free-rider effect when few countries are able to choose conservative independent central banks in a world of predominantly government-dependent CBs. It is possible that the empirical results are picking up this delegation disequilibrium in which, faced with symmetric shocks, those countries who delegate first enjoy the benefit

[1]Partisan monetary cycles arise from a change in government and preferences over inflation and output, whereas the political monetary cycles in al-Nowaihi and Levine (1998) arise from desire of a government to demonstrate its competence, or conceal its incompetence in the period before an election. Central bank independence has the effect of eliminating both forms of cycle and the analysis of this paper could equally be carried out using either.

of low average inflation whilst free-riding on other countries' monetary expansion.[2]

This paper presents a game of Rogoff-delegation modified to include both political business cycles, as in AG, and the open-economy effects of CLP. Before developing the theory, section 2 sets out the empirical motivation: first, the free lunch puzzle is confirmed. Second, we build on other studies to show the empirical support for an openness effect on the inflationary bias. Section 3 then sets out a Mundell-Fleming form of multi-country model with monetary policy conducted in terms of realized inflation targets, and fiscal policy consisting of fixed government spending and distortionary taxes following a tax rule aimed at achieving a fixed debt-GDP ratio in the absence of any supply-side shocks.

Section 4 describes a monetary policy game in the context of this multi-country world of economies each with two parties contesting elections and each subject to a random symmetric shock. This can be regarded as a generalisation of CLP to include political uncertainty. Others may prefer to see the model as a generalisation of AG to include open-economy effects. In section 5 we show that, by eliminating political uncertainty, CB independence for one country alone can result in a lower output variance for that country and a lower average inflation (i.e., the free lunch or 'gain without pain'). However, as economies become more open the incentive to engage in surprise inflation diminishes and with it the benefits of having an independent CB. Gain without pain is still possible but now less likely. Section 6 then asks the question: what happens if all countries choose an independent CB? We establish the 'bad news' for central bank independence: as economies become more integrated and subject to symmetric shocks, and if they all delegate monetary policy to government independent banks, then Rogoff's low inflation, high output variance trade-off re-emerges. Section 7 concludes.

[2]Numerous issues arising from the free lunch hypothesis have been discussed in the literature. Indicatively, other explanations of the free lunch 'puzzle' include Eijffinger and Hoeberichts (1998) and Hughes Hallett and Weymark (2002) who discuss the optimal degree of conservativeness of the independent central banker, and Demertzis *et al.* (2004) who stress the proactive role of fiscal policy when faced with rigid monetary objectives. The above literature suggests that the free lunch result appears in models where counter-cyclical fiscal policy and political uncertainty have not been accounted for. It also appears when preferences (relating to the degree of central banker's conservatism or political parties' preferences for output stability) are not endogenous.

## 2 The Evidence

In order to motivate our analysis, this section first confirms the empirical result found in the literature that central bank independence lowers inflation without cost in terms of higher unemployment or output variance.[3] We use data on real gross domestic income from the Penn World Tables and calculate the standard deviation of the series for the period 1980-1998, which we use as a measure of output variability. We also calculate the standard deviation of output growth. We regress these on measures of central bank independence obtained from Cukierman *et al.* (1992). In addition, we also examine the cost of delegation in terms of unemployment using data for the same period.[4]

Consistent with the empirical literature we have not managed to establish at any meaningful level of significance that higher degrees of independence are related to higher unemployment rates or lower and more variable rates of output growth. The data seem to be in favour of the 'free lunch' hypothesis. Estimation results are reported in Table 1 on the following page.

Our second set of results establish the empirical relevance of open-economy effects on the inflationary bias.[5] Table 2 on page 6 reports the estimated coefficients of a regression of inflation on openness, debt, past inflation, and a central bank dependence index for several subsets of countries, including non-OECD economies. We also report the estimated parameters dropping past inflation from the specification.

Our priors are that openness is negatively associated with inflation, whereas central bank dependence, the underlying structural or equilibrium unemployment rate and the debt-GDP ratio have the opposite effect. We use past inflation as a proxy for the equilibrium unemployment rate. We can see that the coefficients enter the equation with the right signs in all sub-samples, except for the coefficient of past inflation which has the wrong sign but is insignificant for the non-OECD countries and for the sample as a whole, which is dominated by this group. They are also significant at the 1 percent level in most cases.[6] Estimating the model without past inflation does not change the results signifi-

[3] See Grilli, Masciandaro, Tabellini (1991), Alesina and Summers (1993), and Alesina and Gatti (1995).

[4] Sources and definitions of the variables used in this section's estimations are reported in the notes of tables 1, 2 and 3.

[5] Related cross-countries studies of inflation are those of Romer (1993), and Campillo and Miron (1996).

[6] A criticism that is often made on empirical studies supporting the existence of a negative correlation

Table 1: Central Banks and Stabilization Losses

| | *CBO* | *CBL* | *Constant* |
|---|---|---|---|
| *Output Variability* | 0.142 | – | 0.117* |
| | (0.57) | – | (4.79) |
| | – | -0.024 | 0.138* |
| | – | (-0.44) | (5.83) |
| *Unemployment* | 0.082 | – | 0.069* |
| | (1.04) | – | (5.5) |
| | – | -0.054 | 0.095* |
| | – | (-1.02) | (3.87) |

*Notes.* Output data (in natural logarithms) are from the Penn World Table for the period 1980–1998; see Heston *et al.* (2002). *Unemployment* is average unemployment for the same sample period (source: OECD). *CBO* is an inflation-based indicator –see Table 11 in Cukierman *et al.* (1992)– which is also used in Romer (1993). Note that it is actually a *dependence measure*. *CBL* is Cukierman *et al.*'s legal central bank independence index. The sample consists of 24 OECD countries. Estimation method: OLS with robust errors (White estimator). The t-statistics are in parentheses. Superscripts *, ** and *** denote significance at the 1%, 5% and 10% levels respectively.

cantly except in the case of OECD countries where the coefficients of debt and openness lose their significance.[7]

The reason for including past inflation is to proxy for the equilibrium unemployment rate (although we have noted the alternative explanation of Campillo and Miron (1996) in footnote 7). We now test directly for this effect. We use four observations (1986, 1990, 1995, 1998) on the estimated non-accelerating wage rate of unemployment (NAWRU), but only for twenty OECD countries (we also carry out the estimation for a smaller sub-

between the degree of CB independence and inflation is that there may be a two-way causality in the results. However, Cukierman *et al.* (1992) find that two-stage least squares estimation does not affect their results. Using Data on 17 OECD countries, we have also tested for the possibility that it is the *deflatable* proportion of debt that creates inflation, but we find that it is the total level of debt to GDP that is inflationary and not the fraction of it that can be inflated away. We define government securities whose real returns can be eroded by surprise inflation (mainly nominal debt with maturity over a year) as deflatable.

[7]An alternative explanation for the result that average past inflation is positive and significant only for the rich countries is offered by Campillo and Miron (1996). They argue that it is possible that high inflation induces investments in technologies for avoiding the costs of inflation. Once these are developed they are not costly to use, and thus they reduce future aversion to inflation. Campillo and Miron claim that such technologies might be easier to develop in high income countries.

Table 2: Estimated Coefficients

| Variable | All | | OECD | | Non-OECD | | EU15 |
|---|---|---|---|---|---|---|---|
| *Constant* | -3.85* | -3.84* | -5.16* | -4.47* | -3.35* | -3.3* | -5.11* |
| | (-19.8) | (-19.8) | (-28.94) | (-14.9) | (-10.08) | (-10.04) | (-56.2) |
| *Openness* | -1.94* | -1.95* | -1.23** | -0.42 | -2.21* | -2.21* | -1.88* |
| | (-6.7) | (-7.6) | (-2.01) | (-0.9) | (-6.63) | (-7.51) | (-6.89) |
| *Debt 80* | 0.69* | 0.7* | 1.21* | 0.1 | 0.72* | 0.73* | 1.53* |
| | (3.68) | (3.7) | (3.55) | (0.26) | (3.38) | (3.33) | (11.92) |
| *CBO* | 8.1* | 8.1* | 8.47* | 10.93* | 6.22* | 5.88* | 8.65* |
| | (6.59) | (7.62) | (9.74) | (5.03) | (3.28) | (3.91) | (29.88) |
| *Past Infl.* | -0.09 | – | 11.71* | – | -0.15 | – | 13.15* |
| | (-0.11) | – | (5.07) | – | (-0.19) | – | (7.25) |
| Adj. R sq. | 0.56 | 0.57 | 0.76 | 0.5 | 0.47 | 0.49 | 0.67 |
| F-stat. | 20.95 | 29.35 | 18.99 | 8.74 | 9.44 | 13.47 | 10.69 |
| Sample | 63 | 64 | 24 | 24 | 39 | 40 | 15 |

The dependent variable is the log of the average inflation rate 1980-1998. *Openness* is the share of imports to GDP between 1980 and 1998; *Debt 80* is the level of government debt as a percentage of GDP in 1980; *CBO* is the central bank dependence index developed by Cukierman *et al.* (1992) for the 1980s; *Past infl.* is average inflation before 1980 (the beginning of the period varies across countries- but for most is early 1950s). The countries in the sample are those in Cukierman *et al.* (1992) for which we could obtain data on the rest of the variables. Estimation method: OLS with robust errors (White estimator). The t-statistic is in parentheses. Superscripts *, ** and *** denote significance at the 1%, 5% and 10% levels respectively.

sample of 13 EU countries, for which data were available). We use the mean of these four observations as a proxy for structural unemployment over our sample period, and we use this together with openness, debt, and the central bank index as explanatory variables. The results of Table 3 show a significant positive effect of NAWRU on the inflation rate, and the other variables have the effect predicted by our priors. The only qualification is that for the OECD as a whole, openness although correctly signed is now only significant at the 10% level.

Concluding the brief empirical analysis, we have revisited and confirmed the cross-country results of the literature: openness, low debt, low structural unemployment and central bank independence reduce inflation.[8] The apparent lower inflation which results

[8]Note, however, that the results on central bank independence are sensitive to the index used. A caveat

Table 3: The Role of NAWRU

| | *Constant* | *Openness* | *Debt 80* | *CBO* | *NAWRU* |
|---|---|---|---|---|---|
| OECD | -4.99* | -0.81 | 0.81** | 10.59* | 4.7* |
| | (-20.18) | (-1.10) | (1.95) | (13.21) | (3.07) |
| EU | -4.68* | -1.87* | 1.27* | 10.68* | 3.5* |
| | (-22.9) | (-6.3) | (6.24) | (9.99) | (4.6) |
| Adj. R-sq. | 0.66 (OECD) | 0.87 (EU) | F-stat. | 7.2 (OECD) | 20.8 (EU) |
| Sample | 20 (OECD) | 13 (EU) | | | |

*Notes.* NAWRU is the non-accelerating wage rate of unemployment (source: Elmeskov and Scarpetta, 1999). Other variables and estimation method same as in previous tables.

from a higher degree of independence of the monetary authorities does not come at a cost in terms of higher unemployment and output growth variance. We now develop the theory that can explain these stylized facts.

# 3 The Multi-Country Model

The model of output is of a Mundell-Fleming variety in which $n+1$ interdependent economies each specialise in the production of a distinctive composite good. These goods are imperfect substitutes in consumption. Capital stock and investment are exogenously fixed. All economies have identical economic structures, and are subject to a common supply shock.[9]

Label the countries with subscripts $0, 1, ..., n$ and drop the subscript for country 0. For country $i$ let $\pi_i$ be CPI inflation and $y_i = \log(Y_i/\overline{Y}_i) \approx (Y_i - \overline{Y}_i)/\overline{Y}_i$ be the proportional change in output relative to $\overline{Y}_i$, the steady-state natural rate path. All variables are dated at time $t$, a subscript $+1$ indicates the date $t+1$ and a subscript $-1$ indicates the date $t-1$. Denote CPI inflation surprise by $\tilde{\pi}_i = \pi_i - \mathcal{E}_{-1}(\pi_i)$. Then the reduced form of the model employed in the paper is given by an *output equation* for country 0, expressed

should also be issued that measurements of independence are somewhat dated. Even though one would not expect the institutional frameworks underlying the operation of central banks to change frequently, it needs to be mentioned that the index used may not represent the current status of all central banks in the sample.

[9]We ignore other shocks such as that to the government spending-GDP ratio.

in terms of inflation targets and tax rates, a *debt accumulation identity* and a *tax rule*. Output is given by

$$y = \xi[\phi\tilde{\pi} - \tau^v - \mathcal{E}_{-1}(\tau^w)] + \frac{1-\phi}{n}\sum_{i=1}^{n}\xi\tilde{\pi}_i - \epsilon \tag{1}$$

where $\phi \in [0,1]$ is a parameter such that $1-\phi$ expresses the degree of openness of the economies and measures the impact of a domestic inflation surprise on domestic output, $\tau^v$, $\tau^w$ are output and income tax rates respectively and $\epsilon$ is a supply shock. Analogous output equations apply to countries $i = 1, \cdot\cdot n$. Appendix A derives (1) from micro-foundations, but a more traditional formulation would lead to the same basic structure. The advantage of our treatment is that the parameters $\phi$ and $\xi$ can be expressed in terms of the underlying fundamental parameters and observed macro-economic variables; i.e.

$$\phi = \frac{\alpha + \gamma_2\xi}{\alpha + (n+1)\gamma_2\xi}; \quad \xi = (1-\beta)/\beta \tag{2}$$

where $\alpha = (\overline{C}/\overline{Y})/(1-\overline{G}/\overline{Y})$, $\overline{C}/\overline{Y}$ and $\overline{G}/\overline{Y}$ are consumption and government spending expressed as proportions of baseline output respectively, $\beta$ is capital's share of output, $\gamma_2$ is a consumer preference parameter for imported private (non-government) goods such that $n\gamma_2$ is the share of these goods in total consumption.

The mechanism through which the inter-country spillover effects in (1) occur is through surprise real exchange effects. A relative inflation surprise in country 0 causes a surprise real depreciation for country 0 relative to $i$. For country $i$ this is real appreciation which in turn lowers the cost of imported goods and causes its real product wage to fall. Thus a unilateral monetary expansion in the domestic country boosts foreign employment and output. This policy spillover plays a central role in the monetary policy game that follows.

*Government debt* as a proportion of GDP is given by

$$d_{+1} = \frac{1+R}{1+g}(1-m\tilde{\pi})d - \tau + G/Y \tag{3}$$

where $d$ is the beginning-of-period debt/GDP ratio, $R$ and $g$ are the expected real interest and GDP growth rates respectively, $m$ is the proportion of deflatable debt and $\tau = \tau^v + \tau^w$ is the total tax rate (assuming income and output tax are the sole sources of tax revenue). The model is completed with a *fiscal rule rule*

$$\tau = G/Y + \left[\frac{1+R}{1+g} - 1\right](1-m\tilde{\pi})d \approx G/Y + (R-g)(1-m\tilde{\pi})d \tag{4}$$

$$\tau^w = \mathcal{E}_{-1}(\tau^w) \tag{5}$$

for small $R$ and $g$. According to (5), the income tax rate is set one period ahead and from (4) the other tax rate, $\tau^v$, and government spending adjust in the current period to stabilize the current level of government debt.[10] This 'Ricardian' fiscal rule[11] implies that (3) becomes

$$d_{+1} = (1 - m\tilde{\pi})d \tag{6}$$

Thus taking expectations at the beginning of the period before the shock is observed, we have that $\mathcal{E}(d_{+1}) = d$.[12] In the absence of any inflation surprise the debt/GDP ratio is fixed. Expressing the tax rate and all variables in deviation form about the zero-inflation steady state and substituting into (1), output in country 0 in deviation form becomes

$$y = \xi[\phi + (\bar{R} - g)md]\tilde{\pi} + \frac{1-\phi}{n}\sum_{i=1}^{n}\xi\tilde{\pi}_i - \epsilon \tag{7}$$

where $\bar{R}$ is the steady state value of $R$. (7) forms the basis for our subsequent analysis.

The main aim of the paper is to contrast the results for a closed economy of AG with those for an increasingly integrated world economy. This contrast is facilitated by allowing the consumer preference parameter $\gamma_2$ to vary between $\gamma_2 = 0$ to the opposite extreme of *perfect integration* (or 'single market'), $\gamma_2 = 1/(n+1)$, where all private goods enter equally into the consumption basket. Corresponding variations in the openness parameter $1-\phi$ are then given in a useful lemma given in Appendix B which is used at various points in the subsequent analysis.

[10] Fiscal policy plays no direct role in stabilizing output.

[11] Such a tax rule implies a "consistent and conventional theory of the price level" –see Buiter (2005). Fiscal policy plays no direct role in stabilizing output. The particular form of the rule is chosen to make the analysis tractable. It implies that the variance of the primary surplus is small compared with $d$ (since the primary surplus $\tau - \frac{G}{Y} \simeq \delta d$, where $\delta < 1$ is the representative household's rate of time preference). However, it also implies that the variance of relative primary surpluses between countries equals that of debt-GDP ratios, which is not borne out by the data.

[12] See also Beetsma and Bovenberg (1998, 2003).

# 4 Political Uncertainty and Stabilization in the Open Economy

## 4.1 The Setup of the Game

We consider a world of $n+1$ identical interdependent economies. Output in country 0 is described by (1) and analogous equations describe output in the other countries. Reintroducing the time subscript for the moment, we assume that monetary authority $i$ at time $t$ adopts a standard intertemporal loss function at time $t$ of the form $\mathcal{E}_t(L_{it})$ where

$$L_{it} = \sum_{\tau=t}^{\infty} \left(\frac{1}{1+\delta}\right)^{\tau-t} [\pi_{i\tau}^2 + b_i(y_{i\tau} - \hat{y})^2] \tag{8}$$

where $\delta$ is both the authority's and the consumers' rate of time discount. Equation (8) says that the monetary authority has a bliss point at zero inflation and at an output level $\hat{y}$ relative to the baseline equilibrium rate which is thus assumed to be socially suboptimal. The inflation rate is the assumed monetary instrument. This can be regarded as inflation targets set by the CB and achieved without error. Random (but not systematic) monetary control errors can be easily introduced without changing anything of substance in the analysis.[13]

In the analysis of this section country 0 is assumed to have an independent CB with a degree of conservatism $b = b_0$. The remaining $n$ CBs are not independent and have preferences described by $b_i = b_L$ if the 'Left' are in power and $b_i = b_R$ if the 'Right' are in office where $b \leq b_R < b_L$. In each period there is an exogenous probability $p$, of a Right government being elected and a probability $(1-p)$ of a Left government being elected. For large $n$ these are also the approximate proportions of Right and Left governments.[14]

The sequencing of events is as follows:

**Event 1**. In the initial period $t = 0$ the CB in country 0 is appointed with a preference

[13]Thus the CBs are both instrument- and goal-independent, unlike the BoE which is only instrument-independent.

[14]The assumption of a constant and exogenous probability of winning, a standard one in the partisan political economy literature. Notice that it is the assumption about the current and future elections that matters in this model. The assumption says that $prob(Reagan\ wins\ in\ 84) = prob(all\ future\ Right\ governments\ win) = p$ with this probability formed in 84. An important future challenge for partisan political models is to allow for the endogeneity of the outcome of elections whilst maintaining the tractability of the analysis.

$b_0 = b$. Government 0 is *committed* to this choice in all future periods.

**Event 2**. Fiscal policy is set consisting of the tax rule (4) and a constant proportion of deflatable debt $m$. Initial debt and m is the same for all countries.

**Event 3**. In each country nominal wages are set based on expected inflation next period.

**Event 4**. The governments determining monetary policy in countries 1 to $n$ are elected.

**Event 5**. The common supply shock occurs in each economy.

**Event 6**. The CBs independently and simultaneously set inflation in response to observations of the shock.

### 4.2 The Equilibrium

We now solve the game from event 2 onwards, that is treating the choice of conservatism at event 1 as exogenous. Proceeding by backwards induction at event 6, using (6) the effect of unilateral inflation surprises, $\tilde{\pi}$, in country 0 at time 0, $\tilde{\pi}_1$ at time 1, $\tilde{\pi}_2$ at time 2 etc is make the debt/GDP ratio to accumulate according to: $d_1 = (1 - m\tilde{\pi})d$, $d_2 = (1 - m\tilde{\pi}_1)(1 - m\tilde{\pi})d \approx (1 - m\tilde{\pi}_1 - m\tilde{\pi})d$ etc, in the vicinity of a zero-inflation steady state.[15] From (7) we therefore have

$$y_{+1} = \xi(\phi + (\bar{R} - g)md_{+1})\tilde{\pi}_{+1} - \epsilon_{+1} + \text{spillovers} \tag{9}$$

where, using (6), the first term in (9) can be written $\xi(\phi + (\bar{R} - g)md)\tilde{\pi}_{+1}$ plus a second-order term in $\tilde{\pi}\tilde{\pi}_{+1}$. Minimizing $\mathcal{E}_{-1}(L) = \pi^2 + b(y - \hat{y})^2 + \frac{1}{1+\delta}\mathcal{E}(\pi_{+1}^2 + b(y_{+1} - \hat{y})^2) + \cdots$, we now can see that the contributions to the expected losses in the future are independent of the current inflation rate $\tilde{\pi}$. Therefore in a discretionary equilibrium, the first order condition with respect to $\pi$ given future inflation rates and all expectations including $\mathcal{E}_{-1}\pi$ (and recalling that $\tilde{\pi} = \pi - \mathcal{E}_{-1}\pi$) is simply

$$\pi + b\xi[\phi + (\bar{R} - g)md](y - \hat{y}) = 0 \tag{10}$$

Thus, with our assumed fiscal rule and the debt dynamics that follow from it a potentially intertemporal and intractable optimization problem reduces to a tractable single-period one. Equation (10) applies to country 0 with an independent central bank. Applying

[15] Following much of the dynamic stochastic general equilibrium (DSGE) literature we linearize in the vicinity of a zero-inflation steady state. See Appendix A for full details.

analogous reasoning to the other countries with non-independent central banks, we arrive at the first order conditions for countries 1, 2, ..., $n$:

$$\begin{aligned}\pi_R + b_R\xi[\phi + (\bar{R} - g)md](y_R - \hat{y}) = 0\\ \pi_L + b_L\xi[\phi + (\bar{R} - g)md](y_L - \hat{y}) = 0\end{aligned} \tag{11}$$

where (11) applies to $np$ Right and $n(1-p)$ Left administrations respectively.

We now decompose the inflation rates into two parts: an inflation bias $\bar{\pi}_i$ which depends on the type of monetary authority and beginning-of-period debt, and a term $\tilde{\pi}$ which is dependent on the current observed shock. Corresponding to this composition we write $y_i = \bar{y}_i + \tilde{y}_i$; $i = 0, 1, \cdot\cdot n$. We first solve for the inflation bias and equilibrium non-shock contingent output. At event 3 of the game expectations are given by

$$\mathcal{E}_{-1}(\pi) = \bar{\pi}; \quad \mathcal{E}_{-1}(\pi_i) = p\bar{\pi}_R + (1-p)\bar{\pi}_L),\ i = 1, 2, \cdot\cdot n \tag{12}$$

where from (10) and (11) we have

$$\bar{\pi} + b\xi[\phi + (\bar{R} - \bar{g})md](\bar{y} - \hat{y}) = 0 \tag{13}$$

$$\bar{\pi}_R + b_R\xi[\phi + (\bar{R} - \bar{g})md](\bar{y}_R - \hat{y}) = 0 \tag{14}$$

$$\bar{\pi}_L + b_L\xi[\phi + (\bar{R} - \bar{g})md](\bar{y}_L - \hat{y}) = 0 \tag{15}$$

For country 0 substituting (11), the second spillover term in (1) is given by

$$\sum_{j=1}^{n} \tilde{\pi}_i = \sum_{j=1}^{n} [\pi_i - \mathcal{E}_{-1}(\pi_i)] = n[p\tilde{\pi}_R + (1-p)\tilde{\pi}_L] \tag{16}$$

where $\tilde{\pi}_R = \pi_R - \mathcal{E}_{-1}(\pi_R)$ and $\tilde{\pi}_L = \pi_L - \mathcal{E}_{-1}(\pi_L)$. Hence using (1) we have that $\mathcal{E}_{-1}(y) = 0$. Then noting that the Ramsey-Keynes rule implies that $\bar{R} - \bar{g} = \delta$ (see Appendix A), and using the first order condition (12) for country 0 we arrive at

$$\bar{y} = 0; \quad \bar{\pi} = b\xi(\phi + \delta md)\hat{y} \tag{17}$$

Thus in the absence of an exogenous shock, for country 0 with an independent CB there is no political uncertainty. Output always remains at its natural rate and the inflation bias depends only on the beginning-of-period debt/GDP ratio and is not affected by the political uncertainty in the rest of the world.

For countries 1 to $n$ with government-dependent CBs, from (1) with $\bar{R}-g=\delta$, output in countries with a Right government is given by

$$y_R = \xi(\phi+\delta md)\left(\pi_R - \mathcal{E}_{-1}\left(\pi_i\right)\right)$$
$$+\frac{(1-\phi)\,\xi}{n}\left[\pi - \mathcal{E}_{-1}\left(\pi\right) + (np-1)\left(\pi_R - \mathcal{E}_{-1}\left(\pi_i\right)\right) + n\left(1-p\right)\left(\pi_R - \mathcal{E}_{-1}\left(\pi_i\right)\right)\right] - \epsilon \quad (18)$$

Hence using (12) we have

$$\overline{y}_R = -\xi(1-p)\left[\frac{[(n+1)\phi-1]}{n} + \delta md\right](\overline{\pi}_L - \overline{\pi}_R) \quad (19)$$

Similarly we have $\overline{y}_L = \xi p\left(\frac{[(n+1)\phi-1]}{n} + \delta md\right)(\overline{\pi}_L - \overline{\pi}_R)$ for Left governments. These two results together with (14) and (15) give us four equations for $\overline{y}_R$, $\overline{y}_L$, $\overline{\pi}_R$, and $\overline{\pi}_L$. Solving we arrive at

$$\overline{\pi}_R = b_R\left(\phi+\delta md\right)\xi\widehat{y}\left[1+\theta b_L\xi^2\right]/\Delta \quad (20)$$

$$\overline{\pi}_L = b_L\left(\phi+\delta md\right)\xi\widehat{y}\left[1+\theta b_R\xi^2\right]/\Delta \quad (21)$$

$$\overline{y}_R = -\left(1-p\right)\theta\left(b_L - b_R\right)\xi^2\widehat{y}/\Delta \quad (22)$$

$$\overline{y}_L = p\theta\left(b_L - b_R\right)\xi^2\widehat{y}/\Delta \quad (23)$$

where $\theta = \left[\frac{(n+1)\phi-1}{n} + \delta md\right][\phi+\delta md]$ and $\Delta = 1+\theta\left[\left(1-p\right)b_R + pb_L\right]\xi^2$ . From the lemma (ii) in section 3 we have that $\theta > 0$. It is then straightforward to show that corresponding to $b_L > b_R > b$ we must have $\overline{\pi}_L > \overline{\pi}_R > \overline{\pi}$ and that $\overline{y}_L \geq 0$ and $\overline{y}_R \leq 0$; that is the election of Left (Right) government results in output rising above (below) its natural rate. For a single closed economy we put $\phi = 1$ and all the results above reduce to those in the closed-economy partisan political monetary cycle literature. If elections are predictable at the time wages are set, then if $p=1$, $\Delta = 1+\theta b_l\xi^2$, $\overline{\pi}_R = b_R\left(\phi+\delta md\right)\xi\widehat{y}$ with output at its natural rate. Similarly if p=0, $\overline{\pi}_L = b_L\left(\phi+\delta md\right)\xi\widehat{y}$ and output, again, is at its natural rate. The main results up to this point are summarised as:

**Proposition 1.** *Assuming weights $b_L > b_R > b$ for a Left government-dependent CB, a Right government-dependent CB and an independent CB respectively, the corresponding inflation biases and output, in the absence of shocks, satisfy $\overline{\pi}_L > \overline{\pi}_R \geq \overline{\pi}$, $\overline{y}=0$, $\overline{y}_R \leq 0$ and $\overline{y}_L \geq 0$.*

These results reduce to those in the partisan political business cycle literature for closed economies, and AG in particular. Our results also reduce to those in CLP for the

open economy but without political business cycles. Given the inflation of other countries, our model predicts that the inflationary bias increases with openness, $1-\phi$, the inflatable debt-GDP ratio, $md$, central bank dependence, the conservativeness of the independent central bankers, $1/b$, and the bliss level of output relative to the equilibrium level which is approximately equal to the equilibrium unemployment rate, all consistent with the empirical evidence.

The open-economy effect on the inflationary bias is illustrated in Figure 1 on the following page which compares the inflation bias in the single open economy with that under the closed economy where $\phi = 1$. In employment-inflation space, since output in logarithms is proportional to employment in logarithms, we can see from (1) that the short-run Phillips Curve (SRPC) is steeper in the open-economy case. Given expectations, the policymaker chooses an indifference curve as close possible to the full-employment, zero inflation bliss point at $B$ at $C'$ and $C$ for the closed- and open-economy cases respectively. The rational expectations equilibria are on the vertical long-run Phillips Curve (LRPC) at $D'$ and $D$ respectively. Thus openness reduces the inflationary bias from $PD'$ to $PD$. If countries choose and are able to credibly cooperate, then this is equivalent to proceeding from the open- to closed-economy and the inflationary bias increases. This is an example of counterproductive cooperation first pointed out by Rogoff (1985a).

# 5 The Free Lunch (Gain without Pain) Explained

## 5.1 The Gain

The political gain from an independent CB, apart from a lower inflation bias, is the elimination of the output variance caused only by political uncertainty ($PG$). Thus $PG$ is given by

$$\begin{aligned} PG &= p\left[\overline{y}_R - \mathcal{E}\left(y_i\right)\right]^2 + (1-p)\left[\overline{y}_L - \mathcal{E}\left(y_i\right)\right]^2 \\ &= p\left(1-p\right)\left(\overline{y}_L - \overline{y}_R\right)^2 = p\left(1-p\right)\xi^4\theta^2\left(b_L - b_R\right)^2\widehat{y}^2/\Delta \end{aligned} \tag{24}$$

using (12) and the results above for $\overline{y}_L$ and $\overline{y}_R$. How is the gain $PG$ from eliminating political uncertainty affected by the degree of global integration? The latter is captured by $1-\phi$ which from the lemma (iii) increases if either the consumer preference parameter $\gamma_2$ increases and/or the number of countries in the trading bloc $n+1$ increases. Also

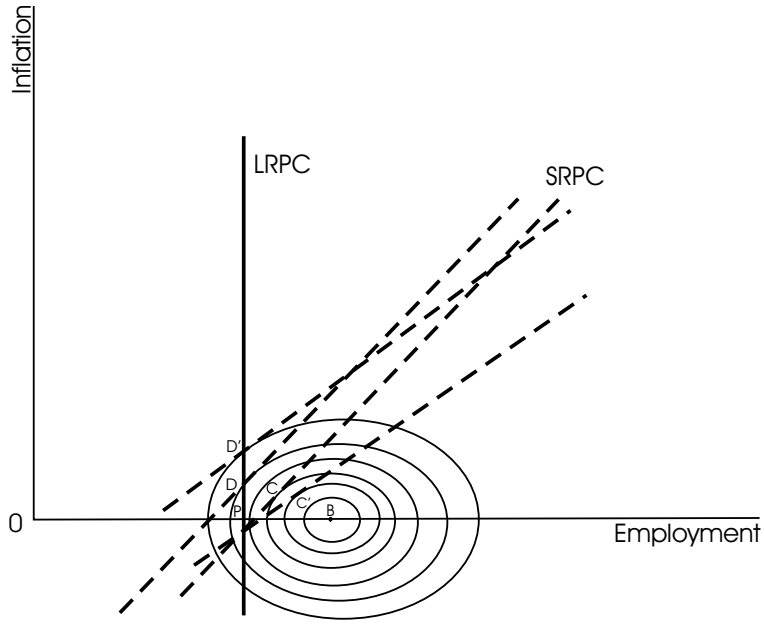


Figure 1: The Inflation Bias in the Open Economy: Cooperation and Non-Cooperation

from the lemma (iii) we can show that $\theta = \left[\frac{(n+1)\phi-1}{n} + (1+\delta)md\right][\phi + (1+\delta)md]$ is a decreasing function of $\gamma_2$ and $n$. Since $PG$ increases with $\theta$ we arrive at the proposition:

**Proposition 2.** *Global integration reduces the output variance caused solely by political uncertainty.*

The intuition behind this result follows from the previous insight that openness creates a disincentive to inflate because the boost to output caused by surprise inflation is partially offset by a real depreciation. As a result the increase (decrease) in output as a result of the election of a Left (Right) government falls and with it the output variance $PG$, given by (24) induced by political uncertainty.

### 5.2 The Pain

Now consider the downside, the 'pain' from CBI in the form of a stabilization loss. In order to simplify the subsequent analysis, we ignore debt (or, equivalently, assume that all debt is non-deflatable, i.e., $m = 0$). To find the stabilization loss, we need the shock-contingent components of inflation rates and output. From (10) and (11) these satisfy the first order

conditions

$$\widetilde{\pi} + b\phi\xi\widetilde{y} = 0 \quad (25)$$

$$\widetilde{\pi}_R + b_R\phi\xi\widetilde{y}_R = 0 \quad (26)$$

$$\widetilde{\pi}_L + b_L\phi\xi\widetilde{y}_L = 0 \quad (27)$$

for the independent CB, the $np$ Right government-dependent CBs and the $n(1-p)$ Left government-dependent CBs respectively. From (1) we have

$$\widetilde{y} = \phi\xi\widetilde{\pi} + (1-\phi)\,\xi\left[p\widetilde{\pi}_R + (1-p)\,\widetilde{\pi}_L\right] - \epsilon \quad (28)$$

$$\widetilde{y}_R = \phi\xi\widetilde{\pi}_R + \frac{(1-\phi)}{n}\xi\left[(np-1)\,\widetilde{\pi}_R + n\,(1-p)\,\widetilde{\pi}_L + \widetilde{\pi}\right] - \epsilon \quad (29)$$

$$\widetilde{y}_L = \phi\xi\widetilde{\pi}_L + \frac{(1-\phi)}{n}\xi\left[(np-1)\,\widetilde{\pi}_L + n\,(1-p)\,\widetilde{\pi}_R + \widetilde{\pi}\right] - \epsilon \quad (30)$$

giving us six equations in $\widetilde{\pi}$, $\widetilde{\pi}_R$, $\widetilde{\pi}_L$, $\widetilde{y}$, $\widetilde{y}_R$, and $\widetilde{y}_L$. Solving we arrive at the solutions

$$y = -\left(1+\theta b_L\xi^2\right)\epsilon/\Phi;\;\; y_L = -\left(1+\theta b\xi^2\right)\epsilon/\Phi;\;\; y_R = -\left(1+\theta b\xi^2\right)\Theta\epsilon/\Phi \quad (31)$$

where $\Phi = \left(1+b\xi^2\phi^2\right)\left(1+\theta b_L\xi^2\right)+\left(1+\theta b\xi^2\right)\left(pb_R\Theta+(1-p)\,b_L\right)\xi^2\phi\,(1-\phi)$, $\theta = \left[\frac{(n+1)\phi-1}{n}\right]\phi$ and $\Theta = \left(1+\theta b_L\xi^2\right)/\left(1+\theta b_R\xi^2\right) > 1$.

There are two possible ways of measuring the gain in terms of lower output variance from having an independent CB. The first, which we examine in this section, is to compare the output variance from having a single independent CB with that of the remaining $n$ countries with government-dependent CBs. This is not strictly the gain from the change in regime, but it does indicate observed differences which feature in the empirical section. The actual gain from the regime shift, examined in the next section, is the difference between the output variance of a country before and after it unilaterally makes its own CB government-independent. This is an indication of the incentive for an individual country to make this institutional change.

Gain without pain occurs in the first sense iff $\text{var}(y) \leq \text{var}(y_i);\; i = 1,...,n$. Since the two forms of uncertainty are independent the output variance for countries with government-dependent CBs decomposes into a political induced part $PG$ obtained above, and a shock-induced component given by $p\mathcal{E}_{-1}\left(\widetilde{y}_R\right)^2 + (1-p)\,\mathcal{E}_{-1}\left(\widetilde{y}_L\right)^2$. Since $var\left(\widetilde{y}\right) = \mathcal{E}_{-1}\left(\widetilde{y}\right)^2$ the condition for gain without pain becomes $PG > SL$ where $SL$ is the stabilization loss given by

$$SL = \left[\left(1+\theta b_L\xi^2\right)^2 - \left(1+\theta b\xi^2\right)^2\left(p\Theta^2+1-p\right)\right]\sigma_\epsilon^2/\Phi^2 \quad (32)$$

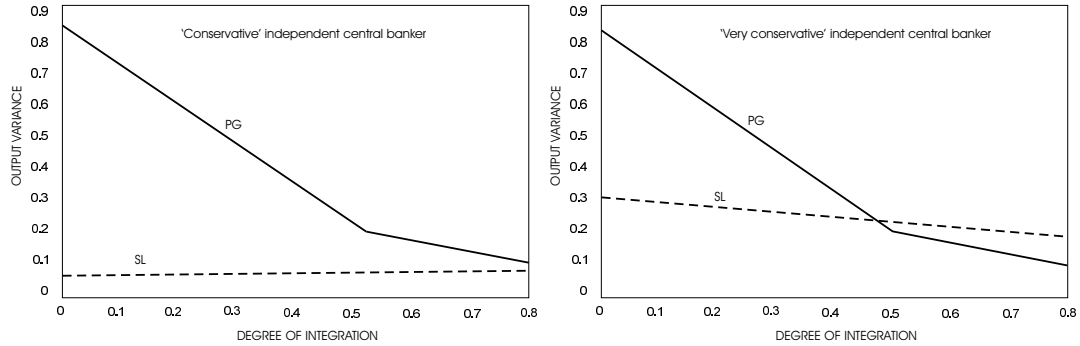


Figure 2: The Lower Output Variance Gain and Loss for a Single Independent CB Relative to $n$ Others.

Since $b \leq b_R$ it follows that $\Theta = \left(1+\theta b_L \xi^2\right)/\left(1+\theta b_R \xi^2\right) \leq \left(1+\theta b_L \xi^2\right)/\left(1+\theta b \xi^2\right)$. Hence since $b_L > b$ we must have that $SL > 0$. Thus we have the proposition:

**Proposition 3.** *In the open economy $SL > 0$; i.e. there is always some stabilization loss for the single independent CB.*

Thus the free-rider effect can never be sufficient to totally eliminate the stabilization loss caused by a single independent CB. Unlike the political gain $PG$ we cannot sign $SL$ unambiguously as integration increases. This is because there are two opposite effects operating. As integration increases, the spillover effect of a given monetary expansion (for a common negative supply-side shock) from the $n$ government-dependent CBs on the single independent CB increases. However integration also reduces the size of their expansion because they will be deterred by an increased exchange rate depreciation. We can see this ambiguity in some numerical results shown in figure 2. Figure 2 plots $PG$ and $SL$ against the proportion $n\gamma_2$ of imported goods entering the consumption basket which we refer to as the degree of integration.[16] As economies move from autarky to complete integration, where there is no bias towards the domestic good, then this portion increases through the range $n\gamma_2 \in [0, n/(n+1)]$. We examine a five-country trading bloc closed to the outside world (i.e. $n = 4$) and set the fundamental parameters $b_L$, $\widehat{y}$, $\sigma_\epsilon$, $\beta$, $\alpha$, and $md$ to reproduce observed behaviour in typical OECD countries. Appendix C on page 25 gives full details of this calibration. The remaining parameters are $b$ and $b_R$. We

[16]Note from the Lemma, part (iii), that openness $1-\phi$ increases with integration $n\gamma_2$

set $b_R = b_L/2$ and examine two cases: $b = b_R$ and $b = b_R/2$ corresponding to conservative and very conservative independent central bankers.

With our calibration in the case of autarky at $\gamma_2 = 0$ (corresponding to AG) the gain $PG$ from independent CBs in terms of less politically induced output variance by far outweighs the stabilization loss $SL$. As economies begin to trade $PG$ falls as required by proposition 2. The stabilization loss remains quite flat for the less conservative bankers but falls if bankers are very conservative. In the former case we still see gain without pain at high levels of integration; in the latter case CB independence results in higher output variance as economies begin to import around half their consumption needs. The main message from these results is that open-economy effects can drastically alter the balance between the gain from a reduction in political uncertainty, and the stabilization loss resulting from the appointment of an independent central banker in one country.

# 6 The Sting in the Tail: The Bad News for Central Bank Independence

We now address the question of what happens when all countries adopt independent CBs. We measure the gains or otherwise relative to the equilibrium where all CBs are government-dependent. If we put $b_R = b_L = b$ in the results of section 3 we in effect eliminate political uncertainty and arrive at the equilibrium with $n+1$ independent CBs. Using the previous results we find that

$$\overline{y} = 0; \;\; \overline{\pi} = b\xi\phi\widehat{y}; \;\; \widetilde{y} = -\epsilon/\left(1 + b\xi^2\phi\right) \tag{33}$$

which reduce to results obtained in CLP. We can now show that $var(\widetilde{y})$ increases as we proceed from one independent CB to $n+1$ independent CBs; i.e., we have the proposition:

**Proposition 4.** *The stabilization loss associated with central bank independence increases as we proceed from one to $n+1$ independent CBs.*

**Proof:** See Appendix D

Now let us compare the output variance for the two scenarios of proposition 4 with that for $n+1$ government-dependent CBs. For the latter the first order conditions and expectations

remain as before; that is (11) and (13) respectively. Output for a Right government is:

$$y_R = \xi\phi\left(\pi_R - E\left(\pi_i\right)\right) + \frac{\left(1-\phi\right)\xi}{n}\left[\left(\left(n+1\right)p-1\right)\left(\pi_R - E\left(\pi_i\right)\right) + \left(n+1\right)\left(1-p\right)\left(\pi_R - E\left(\pi_i\right)\right)\right] - \epsilon \quad (34)$$

Using (13) we find that $\overline{y}_R$, $\overline{y}_L$, $\overline{\pi}_R$, and $\overline{\pi}_R$ are as before and therefore output variance induced by political uncertainty is unchanged.

Turning to the shock-contingent component of output, first order conditions (25) are as before but now

$$\widetilde{y}_R = \xi\phi\widetilde{\pi}_R + \frac{\left(1-\phi\right)\xi}{n}\left[\left(\left(n+1\right)p-1\right)\widetilde{\pi}_R + \left(n+1\right)\left(1-p\right)\widetilde{\pi}_L\right] - \epsilon \quad (35)$$

$$\widetilde{y}_L = \xi\phi\widetilde{\pi}_L + \frac{\left(1-\phi\right)\xi}{n}\left[\left(\left(n+1\right)\left(1-p\right)-1\right)\widetilde{\pi}_L + \left(n+1\right)p\widetilde{\pi}_R\right] - \epsilon \quad (36)$$

replace (29) and (30). Solving our four equations in $\widetilde{\pi}_R$, $\widetilde{\pi}_L$, $\widetilde{y}_R$, and $\widetilde{y}_L$ gives

$$\widetilde{y}_L = -\epsilon/\Gamma; \;\; \widetilde{y}_R = -\Theta\epsilon/\Gamma \quad (37)$$

where $\Gamma = 1 + \theta b_L\xi^2 + \frac{n+1}{n}\left[pb_R\Theta + \left(1-p\right)b_L\right]\xi^2\phi\left(1-\phi\right)$, and $\Theta > 1$ is defined as before. The stabilization loss from central bank independence is now measured as:

$$SL = var(\widetilde{y}) - pvar(\widetilde{y}_R) - \left(1-p\right)var\left(\widetilde{y}_L\right) \quad (38)$$

where $SL = SL(one)$ for the case of one independent CB when is given by (32), obtained before, and $L = L(all)$ for the case of $n+1$ independent CBs in which case $\widetilde{y}$ is given by (33).

Figure 3 on the following page shows $PG$ (which is unchanged), $SL(one)$ and $SL(all)$ plotted against $n\gamma_2$. From proposition 4 we know that $SL(all) > SL(one)$ and this is confirmed by our numerical results. Our results indicate that 'gain without pain' when one country unilaterally appoints an independent CB can give way to a significant output volatility loss when all countries join the Rogoff delegation game. This delegation equilibrium for our identical economies requires that all countries do delegate and choose identical degrees of conservatism $b$ at event 1 of the game. The full delegation game with the endogenous determination of $b$ is examined in CLP for the case of monetary policy alone and in Levine and Pearlman (1997) with monetary and fiscal policy interactions, but in the absence of political uncertainty. Full examination of the full delegation equilibrium with political uncertainty would clearly be of interest, but would take us beyond the scope of this paper.

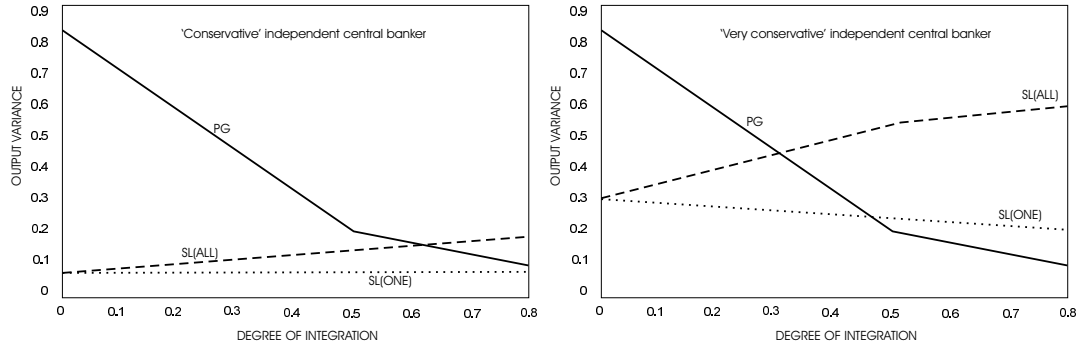


Figure 3: The Lower Output Variance Gain, $PG$, and Loss for One Independent CB, $SL(one)$, and $n+1$ Independent CBs, $SL(all)$, Relative to $n+1$ Government-Dependent CBs

# 7 Conclusions

Our brief survey of the theoretical literature in the introduction suggests four possible explanations for the apparent result that CB independence achieves lower inflation at no cost in terms of greater employment or output variability: we are a observing a trigger strategy equilibrium, Walsh-type contracts are at work, the Rogoff-delegation game is being played with either political uncertainty as in AG or with open-economy effects as in CLP. This paper focuses on the latter two more plausible explanations and provides a synthesis.

We find that open-economy effects significantly alter the results of AG and the effectiveness of Rogoff-style delegation to independent central banks. Whilst the positive conclusions are the same - the model is still consistent with the empirical findings of gain without pain - the normative conclusions to be drawn are quite different. Our results indicate that as more CBs become independent and economies become more integrated[17] A footnote has been added in the conclusions to this effect. then Rogoff's trade-off between low inflation and high output variance re-emerges. The policy implication of these findings is that alternatives to Rogoff-delegation discussed in the introduction, such as Walsh

[17]We focus on only some aspects of integration, namely those associated with a decreasing consumer bias for the home-produced good and an increase in trading partners. Other aspects of integration arising from, for example, more capital mobility would require a major reworking of our Keynesian short-run model with exogenous capital.

contracts that will enforce the first-best (or near-first best) monetary policy rules, may become increasingly attractive as the global integration of the world economy increases.

# A Derivation of Equation (1)

**The Demand Side**

In country $i$, $i = 0, j$, $C_{ij}$ units of good $j$ are imported from country $j$, $j = 0, ..., n$. All variables are dated at time $t$, a subscript $+1$ indicates the date $t + 1$ and a subscript $-1$ indicates the date $t - 1$. Given total consumption consumers in country $i$ choose to maximise an expected logarithmic utility function $\mathcal{E}_{-1}(U_i)$ where

$$U_i = \sum_{j=0}^{n} \gamma_{ij} \log C_{ij} + \eta_i \overline{G}\,; \quad \sum_{j=0}^{n} \gamma_{ij} = 1 \tag{A.1}$$

subject to $C_i = \sum_{j=0}^{n} E_{ij} C_{ij}$, where $\overline{G}_i$ is the exogenous government-provided good, assumed to exist solely of the domestic good (i.e. is non-traded), and $E_{ij}$ is the real exchange rate between country $i$ and $j$; that is, the price of good $j$ in units of good $i$. Standard analysis gives

$$C_{ij} = \gamma_{ij} C_i / E_{ij} \tag{A.2}$$

It follows that the demand for the output of country $i$ from consumers in country $j$ is $C_{ji} = \gamma_{ji} C_j / E_{ji} = \gamma_{ji} C_j E_{ij}$. With our logarithmic utility function (A.1), $\gamma_{ij}$ thus turns out to be the share of good $j$ in the consumption of the representative consumer in country $i$. We make the following assumptions about $\gamma_{ij}$. For the consumer in country $i$ no one imported good is preferred from countries $j = 0, \cdot \cdot n$; $j \neq i$; but the domestic good may be preferred to any foreign good. This may be interpreted as the result of a private non-traded sector (in addition to the government non-traded sector), or the idea that domestic producers can establish a special relationship with domestic consumers. Otherwise consumer preferences are identical in each country. To summarize:

$$\gamma_{ii} = \gamma\,; \quad \gamma_{ij} = (1 - \gamma_1)/n = \gamma_2\,; \quad \gamma_1 \geq \gamma \tag{A.3}$$

where $\gamma_1$ and $\gamma_2$ are constants. Hence total demand for the output of country $i$ is

$$Y_i = \sum_{j=0}^{n} \gamma_{ji} C_j E_i j + \overline{I}_i + G_i = \gamma_1 C_i + \frac{1 - \gamma_1}{n} \sum_{j=0, j \neq i} C_j E_{ij} + \overline{I}_i + \overline{G}_i \tag{A.4}$$

where $\overline{I}_i$ is exogenous private investment (note that $E_{ii} = 1$). Now express all exchange rates relative to country 0; i.e., put $E_{ij} = E_{i0}/E_{j0} = E_{0j}/E_{0i} = E_j/E_i$, dropping the country 0 subscript for notational convenience. Then for country 0 (A.4) is written simply as

$$Y = \gamma_1 C + \frac{1-\gamma_1}{n}\sum_{j=1}^{n} C_j E_j + \overline{I} + \overline{G} \tag{A.5}$$

The demand side of the model is not complete as we still need to determine total consumption; but we return to this closure later.

**The Supply Side**

The supply side is institutional in character. The representative wage-setter in country 0 has a target real disposable wage and, at time $t-1$, sets the one-period nominal wage contract for time $t$ to minimize an expected welfare loss $\mathcal{E}_{-1}(U)$ where

$$U = (w(1-\tau^w) - p^c - \hat{w})^2 \tag{A.6}$$

All variables in (A.6) are now expressed in logarithms apart from $\tau^w$, the income tax rate. $w = \log W$ is the log of nominal wage, $W$; the consumer price index (CPI) is $p^c = p + \gamma_2(e_1 + e_2 + \cdots + e_n)$, where $p$ is the log of the domestic price level, $\gamma_2$ has been identified as the share of each foreign good in consumption, $e_i$ is the log of the real exchange rate of country $i$ relative to country 0. Output is given by a Cobb-Douglas production function

$$Y = \overline{K}_{-1}^{\beta}(\bar{A}L)^{1-\beta}\exp(-u) \tag{A.7}$$

where $\overline{K}_{-1}$ is the exogenous end-of-period $t-1$ capital stock, $\bar{A}L$ are effective units of labour, $\bar{A}$ is human capital growing at an exogenous rate equal to the per capita GDP growth rate in a balanced-growth steady state, and $u$ is an $i.i.d$ mean zero negative output shock, the supply shock in the model. The representative firm maximizes post-tax profits $(1-\tau^v)PY - WL$, where $\tau^v$ is an output tax rate paid by firms[18] giving a labour demand relationship

$$w - p = f(\overline{K}_{-1}, \hat{A}) - \beta l - \tau^v - u \tag{A.8}$$

[18]We interpret output tax as VAT and any other tax levied on firms, expressed as a proportion of total revenue. This enables us to justify using this tax as a stabilization instrument responding automatically to changes in debt and inflation according to (4).

where $f(\overline{K}_{-1}, \hat{A}) = \log(1-\beta) + (1-\beta)\log\bar{A} + \beta\log\overline{K}_{-1}$ and we have approximated $\log(1-\tau^v) \approx -\tau^v$. The nominal wage, is found by minimizing (A.6) with respect to $w$ subject to (A.8). Performing this optimization we arrive at

$$w = \mathcal{E}_{-1}(p^c) + \mathcal{E}_{-1}(\tau^w) + \hat{w} = \mathcal{E}_{-1}(p) + \gamma_2\mathcal{E}_{-1}\left(\sum_{j=1}^{n} e_j\right) + \mathcal{E}_{-1}(\tau^w) + \hat{w} \tag{A.9}$$

Combining (A.8) and (A.9)we arrive at

$$l = \bar{l} + \{p^c - \mathcal{E}_{-1}(p^c) - \gamma_2\sum_{j=0}^{n}[e_j - \mathcal{E}_{-1}(e_j) + \mathcal{E}_{-1}(e_j)] - \mathcal{E}_{-1}(\tau^w) - \tau^v\}/\beta - \epsilon \tag{A.10}$$

where $\epsilon = u/\beta$ and equilibrium employment is given by $\bar{l} = [f(\overline{K}_{-1}, A) - \hat{w}]/\beta$.

The second term in (A.10) is the familiar effect of a CPI price surprise on employment. The next two terms are open-economy effects. An imported content in the consumption basket ($\gamma_2 > 0$) means that for a given credible consumer price target (i.e., $p^c = \mathcal{E}_{-1}(p^c)$) an unexpected real exchange rate appreciation enables the monetary authority to accommodate a surprise in the domestic price level, reducing the real product wage and increasing employment. The third term, which disappears in the rational expectations solution below, arises because an anticipated real exchange rate appreciation lowers the real product wage.

We close the model using the following standard results for country 0:

$$\mathcal{E}_{-1}\left(\frac{C(1+R)}{C_{+1}(1+\delta)}\right) = 1 \tag{A.11}$$

$$\mathcal{E}_{-1}\left(\frac{C}{C_{+1}}\left[\frac{E_{i,+1}}{E_i}(1+R_i) - (1+R)\right]\right) = 0 \tag{A.12}$$

(A.11) is the stochastic 'Keynes-Ramsey Rule' where $R$ is the real interest rate in country 0, $R_i$ in country i and $\delta$ is the representative consumer's rate of time preference. (A.12) can be obtained by maximising the expectations of (A.1) subject to a consumers' budget constraint. (A.12) equates (A.11) with an equivalent first order condition if the consumer keeps her wealth in foreign bonds. Equations (A.5), (A.7), (A.10), (A.11), (A.12) and their foreign counterparts give us $4(n+1)+n$ equations to determine the same number of macro-variables $\{C_i, Y_i, L_i, R_i\}, i = 0, \cdot\cdot n$; $\{E_i\}, i = 1, \cdot\cdot n$, given expectations and given the CPI and level of government spending in each country.

**The Rational Expectations Solution**

Let $\pi = p^c - \mathcal{E}_{-1}(p^c)$ be CPI inflation in country 0. We now express all variables as deviations about a baseline path consisting of the deterministic balanced-growth steady-state of the model.[19] In this baseline inflation rates are set at zero. Denote a country 0 CPI inflation surprise by $\tilde{\pi} - \mathcal{E}_{-1}(\pi)$ and similarly define surprises for other variables. The real exchange rate between country $i$ and country 0 in linear-deviation form is denoted by $e_i$ and that between country $j$ and country $i$ is therefore $e_j - e_i$. The country 0 model, linearized about a zero-inflation balanced trade and balanced growth steady state, is then

$$(1 - \overline{G}/\overline{Y})y = \overline{C}/\overline{Y}[\gamma_1 c + \gamma_2(e_1 + c_1 + \cdots + c_n + e_n)] + g \quad \text{(A.13)}$$

$$y = \frac{(1-\beta)}{\beta}[\tilde{\pi} - \gamma_2(\tilde{e}_1 + \cdots + \tilde{e}_n) - \gamma_2 \mathcal{E}_{-1}(e_1 + \cdots + e_n)] - \epsilon \quad \text{(A.14)}$$

$$\mathcal{E}_{-1}(c_{+1}) = c + r/(1+R) \quad \text{(A.15)}$$

$$\mathcal{E}_{-1}(e_{i,+1}) = e_i + (r - r_i)/(1+R) \quad \text{(A.16)}$$

(A.13) is (A.5) in linearized form. (A.14) is the open-economy Lucas supply curve obtained from (A.10) and using $y = (1-\beta)l - \beta\epsilon$. (A.15) and (A.16) are linearized forms of (A.11) and (A.16) respectively. The full information rational expectations solution follows by combining (A.15), its country $i$ counterpart, and (A.16) to obtain $\mathcal{E}_{-1}(c - c_i - e_i) = c_{-1} - c_{i,-1} - e_{i,-1}$ for which the saddlepath stable solution is $c = c_i + e_i$. Then equating demand and supply in the domestic country and foreign country and taking expectations of $y - y_i$ we have $\mathcal{E}_{-1}(e_i) = 0$ and

$$e_i - \mathcal{E}_{-1}(e_i) = \tilde{e}_i = e_i = \frac{\xi(\tilde{\pi} - \tilde{\pi}_i) - \epsilon + \epsilon_i}{\alpha + (n+1)\gamma_2(1-\beta)/\beta} \quad \text{(A.17)}$$

where $\alpha$ and $\xi$ are defined in (2). Substituting (A.17) into (A.14) gives (1).

# B Lemma Relating Integration and Openness

(i) Corresponding to the extremes of perfect integration and autarky we have

$$\frac{\alpha(n+1) + \xi}{(n+1)(\alpha + \xi)} < \phi < 1 \quad \text{(B.18)}$$

(ii) It follows from (B.18) that $(n+1)\phi > 1$.

(iii) Consider $\phi = \phi(n, \gamma_2)$ keeping remaining parameters fixed. Then $\frac{\partial \phi}{\partial n}, \frac{\partial \phi}{\partial \gamma_2} < 0$.

[19] Lower case variables denote proportional change relative to the steady state. For example, $c = \log(C/\bar{C}) \approx (C - \bar{C})/\bar{C}$ where $\bar{C}$ is the steady-state path. Note that in the steady state $\frac{1+\bar{R}}{1+\delta} = 1 + \bar{g}$. For small $\bar{R}$ and $\bar{g}$ we use the approximation $\frac{1+\bar{R}}{1+\delta} \approx 1 + \bar{R} - \delta$; i.e., $\bar{R} - \delta \approx \bar{g}$.

The left-hand-side (LHS) of (B.18) is the upper bound of openness, $1-\phi$ at the extreme of perfect integration. Result (ii) immediately follows from this and (iii) says that openness increases with the number of countries $n+1$ and the consumer preference for imported goods parameter, $\gamma_2$.

# C Calibration of Model

We have chosen parameter values to be based as far as possible on a representative world (i.e., OECD) economy. We choose $n+1=5$ which can be thought of as representing the EU without EMU or a world trading system consisting of 5 regions: the EU (with EMU), US, Japan, the rest of Asia, and the former Soviet Union. We choose a NAIRU, $\hat{l}=5$ so that with $\beta=0.3$, $\hat{y}=(1-\beta)\hat{l}=3.5$. We calibrate the weight $b_L$ to give an annual inflation rate of $\pi_L=5$ at a baseline degree of integration where economies import half their private consumption goods (i.e., $n\gamma_2=0.5$). A choice $\sigma_u=\text{var}(u)=1.5$ for the original supply shock in (A.7) with government dependent CBs leads to an output variance of 2.5 which corresponds to empirical estimates. Other details of the calibration are $\bar{C}/\bar{Y}=0.6$, $\bar{G}/\bar{Y}=0.6$. For these calculations, $md=0$ is assumed.

# D Proof of Proposition 4

We wish to show that $var\left(\widetilde{y}\right)$ with $\widetilde{y}$ given by (33) for the case when all CBs are independent, is greater that as given by (31) for a single independent CB. This is true iff

$$\left(1+b_L\xi^2\theta\right)\left[1+b\xi^2\phi\right]<\Phi \tag{D.19}$$

Using the definition of $\Phi$ after (31) we can rearrange the expression to give

$$\Phi=(1+b\xi^2\phi^2)(1+b_L\xi^2\theta)+\phi(1-\phi)\xi^2[(1+b\xi^2\theta)(p\Theta b_R+(1-p)b_L)-b(1+b_L\xi^2\theta)]$$

Therefore (D.19) holds iff

$$\left(1+b\xi^2\theta\right)p\Theta b_R+(1-p)\,b_L>b\left(1+b_L\xi^2\theta\right) \tag{D.20}$$

On LHS of (D.20) we have that $\Theta b_R=\left(1+\theta b_L\xi^2\right)b_R/\left(1+\theta b_R\xi^2\right)<b_L$ since $b_R<b_L$. It follows that the LHS is a decreasing function of $p$. Therefore if (D.20) holds at p=1 it must hold for all $p\in[0,1]$. At $p=1$ (D.20) becomes $\left(1+b\xi^2\theta\right)b_R>\left(1+b_R\xi^2\theta\right)b$ which is true since we assume that $b_R>b$.

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