

# THE POLITICAL ECONOMY OF INFLATION AND CENTRAL BANK INDEPENDENCE

**Berthold Herrendorf and Manfred J M Neumann**

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Centre for Economic Policy Research  
90–98 Goswell Rd  
London EC1V 7DB  
Tel: (44 171) 878 2900  
Fax: (44 171) 878 2999  
Email: [cepr@cepr.org](mailto:cepr@cepr.org)

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## ABSTRACT

### The Political Economy of Inflation and Central Bank Independence\*

We study monetary policy-making in an economy with many sector-specific monopoly unions. It is assumed that the senior union members are in the majority and – due to the practice of lay-offs by inverse seniority – face a lower unemployment risk than the junior members. Consequently, the unions' median voters are senior and set nominal wages that imply involuntary unemployment on part of the juniors. Thus, equilibrium unemployment is too high from a social welfare point of view. Nevertheless, an independent central bank is found not to produce an inflation bias because it is accountable to the majority of the population, which is not involuntarily unemployed. In contrast, government-dependence leads to an inflation bias and a higher variability of inflation, but has an ambiguous effect on employment variability. The reason is that democratic elections are about more than one policy issue, which is shown to give rise to political uncertainty about the monetary policy preferences of the elected government.

JEL Classification: E52, E58

Keywords: central bank independence, inflation bias, median voter, political uncertainty

Berthold Herrendorf  
Department of Economics  
University of Warwick  
Coventry CV4 7AL  
UK  
Tel: (44 1203) 523 482  
Fax: (44 1203) 523 032  
Email: b.herrendorf@warwick.ac.uk

Manfred J M Neumann  
Institute for International Economic  
Policy  
University of Bonn  
Lennestrasse 37  
D-53113 Bonn  
GERMANY  
Tel: (49 228) 739 232  
Fax: (49 228) 737 953  
Email: neumann@iiv.uni-bonn.de

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## NON-TECHNICAL SUMMARY

It is a fact that many central banks have been running monetary policy in an inflationary fashion. This has been a puzzling observation for a long time, given that inflation is costly and achieves no positive effects in equilibrium, apart from providing seigniorage. The seminal work of Barro and Gordon (1983) provided a game-theoretic explanation. Assuming that wage contracts are written in nominal terms and that the central bank has an employment target larger than the natural rate level (a so-called 'ambitious employment target'), they showed that the central bank has an incentive to create unexpected inflation so as to lower the real wage and boost the real economy. Since rational wage setters take this into account, they expect positive inflation and negotiate higher nominal wages to compensate for the expected price increases. This results in an inflation bias and no gain in employment, because in sub-game perfect equilibrium the central bank validates inflation expectations.

It is well known that the inflation bias is due to the assumption that the central bank is guided by social welfare considerations, which lead to an ambitious employment target larger than the natural rate level of employment. If the bank's employment target were the natural rate level, then the inflation bias would disappear, and with it a main point of the literature originated by Barro and Gordon. The key question, therefore, is whether the assumption that central banks are guided by social welfare is of descriptive value. This paper seeks to answer this question by deriving the central bank's policy objective as the outcome of majority voting. To obtain a non-trivial theory, we need to recognize that the work-force is heterogeneous. The reason is that if all individuals were assumed to be alike, involuntary unemployment would affect each individual in the same way and an ambitious employment target would inevitably emerge as the voting outcome.

In reality, the majority of the work-force is employed, whereas only a minority is (involuntary) unemployed. Our key idea is that the employed workers object to the creation of surprise inflation aimed at reducing involuntary unemployment. This is the case because, given pre-set nominal wages, surprise inflation decreases their real wage income. Furthermore it generates the standard costs of inflation, while it benefits the unemployed only. So if the monetary policy objective is determined by majority voting, it will not include an ambitious employment target. Consequently, there is no time consistency problem and no inflation bias. In addition, assuming that lay offs are by inverse

seniority, it turns out that the median voter with respect to monetary policy is conservative in that they care more about inflation and less about the stabilization of shocks than a welfare maximizing policy-maker would.

Having derived these results, we argue that monetary policy under an independent central bank resembles the voting outcome. The reason is that an independent central bank is accountable to Parliament, as a simple majority of Parliament can typically change the central bank law and thereby affect the office rent of the central banker. Note that this is true even for the most independent central bank, the Deutsche Bundesbank; a simple majority of Parliament can change the Bundesbank law that guarantees the Bundesbank's independence.

If the central bank is dependent on the government, then monetary policy is determined by the government's preferences. We argue that the government is elected on the basis of several issues, implying that its monetary policy preferences are likely to differ from those of the median voter with respect to monetary policy. To highlight the consequences of this we focus on the benchmark case in which monetary policy issues do not play a decisive role in the voting decision of individuals. Assuming further that individuals' preferences change stochastically, we show that uncertainty emerges about the future monetary policy stance. A dependent central bank therefore generates an inflation bias and a higher variability of inflation, but may increase or decrease employment variability. These results are consistent with the stylized facts from OECD countries on the correlation coefficients between the legal degree of central bank independence and average inflation, inflation variability and employment variability, respectively. Note that our model has the additional prediction that an independent central bank avoids the inflation bias, but does stabilize the real economy. While this prediction differs from that of the existing literature, it appears to be consistent with the record of the most independent central banks, e.g. the Bundesbank.

Assuming that the central bank is initially dependent, we finally analyse whether and when it becomes independent. Given that the policy of an independent central bank reflects the preferences of the median voter with respect to monetary policy, the median voter prefers an independent central bank over a dependent one, whereas other individuals may or may not prefer independence. In any case, independence wins in a majority vote and an independent central bank will remain independent. The question is then whether individuals can vote on central bank independence. This depends on whether the incumbent government puts the issue on the political agenda. Since, over time, the probability increases that the median voter with respect

to monetary policy gets elected as government, our model predicts that it becomes more and more likely that the central bank is made independent. This is consistent with the fact that the central banks of several OECD countries have gained (more) independence in the recent past, while no independent central bank has had to give up its independence.

# 1 Introduction

The seminal work of Barro and Gordon (1983) developed the ideas of Kydland and Prescott (1977) within a framework that permits studying the strategic interaction between an optimizing monetary policy authority and rational individuals. Key assumptions of Barro and Gordon were that individuals lock themselves into nominal wage contracts and that the monetary policy maker has an ambitious employment, or output, target, which exceeds the natural rate level. Given these assumptions, they showed that the sub-game perfect equilibrium is plagued by an inflation bias. Subsequently, much effort has been devoted to finding ways in which this bias can be mitigated by granting independence to the central bank; see e.g. Rogoff (1985), Lohmann (1992), Walsh (1995b) and Herrendorf and Lockwood (1997).

Although Barro and Gordon's model has become a standard textbook framework,<sup>1</sup> its major shortcoming is the lack of a convincing explanation of why the monetary authority should adopt an ambitious employment target. This issue is critical, as the inflation bias would disappear altogether when the natural rate level of employment were the central bank's bliss point [Persson and Tabellini (1990)]. A common justification for the existence of the ambitious employment target is that employment is too low from a social welfare point of view. In other words, the literature implicitly postulates that policy makers are concerned with social welfare.<sup>2</sup>

The assumption that social welfare is the policy objective has been criticized by several contributions to the recent political economy literature as being unsatisfactory for a positive, i.e. descriptive, theory of policy making; see Dixit (1996) for a more detailed discussion. Taking this point up, the present paper seeks to explain which policy objective other than social welfare the monetary authority adopts and what implications this will have for equilibrium monetary policy. To answer these questions, we need to introduce some heterogeneity into the workforce. The simple reason is that in representative-agent

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<sup>1</sup>Recent treatments include Obstfeld and Rogoff (1996) and Walsh (1997).

<sup>2</sup>Notable exceptions include Cukierman and Meltzer (1986) and Fratianni, von Hagen and Waller (1997). However, these papers do not explain how the policy objective function is related to the *individual* objective functions.

models, the representative individual's utility is the natural measure of social welfare. Furthermore, since, by construction of a representative agent model, involuntary unemployment affects all workers equally, an ambitious employment target emerges unless the policy objective is completely unrelated to the preferences of individuals.

In the real world, the majority of the workforce is typically employed, whereas involuntary unemployment affects only a minority. Our key idea is that the employed workers object to a creation of surprise inflation aimed at reducing involuntary unemployment. This is the case because surprise inflation decreases their real wage income and generates the standard costs of inflation. In order to make this point formally, we develop a highly stylized linear-quadratic setting with many identical sectors. In each sector of our economy, one trade union has the monopoly power to set the nominal wage to be paid to all workers in this sector. Heterogeneity is introduced by recognizing that workers differ in the seniority with their firm. We restrict attention to the simplest case: there are senior and junior workers in our economy. Assuming that the senior workers are in the majority and that union decisions are taken by majority vote, the representative senior worker is the median voter of the trade union and, hence, chooses the nominal wage.<sup>3</sup>

Seniority matters crucially for a worker's employment prospect, as real-world labor contracts typically contain provisions like "last in, first out" and lay-offs by inverse seniority, rather than by random draw [Oswald (1993)]. The main implication of lay-offs by inverse seniority is that the median voter of a trade union faces a lower unemployment risk than the more junior union members. We capture this by assuming that senior workers care less than junior workers about total employment. Given that lay-offs are by inverse seniority and that the senior union members are in the majority, they will set a nominal wage that reduces employment at the expense of the junior union members. In other words, the junior workers will be involuntarily unemployed and the presence

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<sup>3</sup>Note that we could introduce heterogeneity into the workforce in different ways. For example, we could model the distinction between insiders and outsiders, as was suggested by Lindbeck and Snower (1988). Alternatively, we could consider the effects of a minimum wage law, which increases the wage paid to workers facing monopsony employers, but tends to cause involuntary unemployment in competitive sectors.



of monopoly unions is distortionary. Hence, aggregate equilibrium employment is lower than is desirable from a social welfare point of view (where social welfare is defined as the sum of all individual utilities). We can therefore obtain from our model the familiar results of the Barro–Gordon literature if we are prepared to assume that the monetary policy maker is concerned with social welfare.

Our key point is that neither an independent nor a government-dependent central banker is guided by social welfare considerations. We argue instead that an independent central banker maximizes the utility of the median voter with respect to monetary policy. The reason is that while an independent central banker is independent from the government, ultimately she is subject to democratic control by the majority of voters, who can express their dissatisfaction with monetary policy by changing the central bank law. In our model, the senior union members are in the majority, implying that the representative senior is the median voter with respect to monetary policy. Given that the senior union members are not involuntarily unemployed, we find that central bank independence eliminates the time consistency problem and the inflation bias and that stabilization of employment is optimal from the median voter's point of view. Since the junior union members prefer a reduction in unemployment and a more active stabilization policy than the median voter, our independent central bank is more conservative than the junior workers and the benevolent dictator, but as conservative as the median voter. In sum, the first testable implication of our model is: (i) although an independent central bank does not create an inflation bias, it stabilizes employment.

If the central banker is dependent on the government, she maximizes the government's utility, because the government decides about her reappointment and/or has the power to immediately remove her from office. Since democratic elections are about several policy dimensions, the government's preferred monetary policy does not necessarily coincide with that of the median voter with respect to monetary policy. We capture this by introducing an additional policy dimension and by assuming that individuals' preferred policies are stochastic. This leads to ex-ante uncertainty about whether the senior or the junior union members' preferences will determine the elected government's monetary policy. As in related work by Alesina and Gatti (1995) and Waller and Walsh

(1996), political uncertainty gives rise to the following features of equilibrium monetary policy that add to the first testable implication of our model: (ii) a government-dependent central bank produces an inflation bias; (iii) inflation variability is higher under a government-dependent central bank; (iv) employment variability may or may not be higher under a government-dependent central bank.

All four predictions of our theory are consistent with the stylized facts. In particular, predictions (ii), (iii) and (iv) are confirmed by the empirical literature on the relation between macroeconomic variables and the degree of central bank independence for OECD countries. Cross-country regressions find that the degree of central bank independence (as measured by legal indices) is negatively correlated with the average level and the variability of inflation, and uncorrelated with the variability of employment – or equivalently output; see e.g. Grilli, Masciandaro and Tabellini (1991), Cukierman (1992) and Alesina and Summers (1993). While predictions (ii), (iii) and (iv) also follow from the models of Alesina and Gatti (1995) and Waller and Walsh (1996), our prediction (i) is different from theirs. They find that the inflation bias can be eliminated only if the monetary authority does not conduct stabilization policy. In contrast, our model implies that an independent central bank will stabilize unforeseen shocks without producing an average inflation bias. This is consistent with the widely studied track record of one of the most independent central banks, the German Bundesbank. In particular, for all practical purposes, the Bundesbank has achieved the goal of average price stability and, at the same time, has stabilized the real economy; see Clarida and Gertler (1997) and Neumann (1997) for further discussion.

The rest of the paper is organized as follows: in Section 2 we describe the labor market structure and analyze the unions' choice of the nominal wage; Section 3 shows that our framework can reproduce the standard results of the Barro-Gordon literature when the policy objective is taken to be social welfare; in Sections 4 and 5 we offer an alternative approach, which relates the policy objective of a government-dependent and an independent central bank to voters preferences; the results are discussed in Section 6; Section 7 concludes.

## 2 The Labor Market

Our economy has a continuum of measure one of identical sectors, each of which comprises one competitive firm and one trade union. We assume that all workers who supply labor in a sector are members of that sector's trade union and that workers cannot move across sectors (e.g. because of sector-specific skills). We also assume that each trade union has the monopoly power over wage setting in its sector, implying that it chooses the nominal wage to be paid to all workers in that sector. This wage is specified in a one-period labor contract, which also determines the normal working time of an employed worker, but leaves it to the firm to determine total employment ("right-to-manage").

Workers differ in their seniority. Here, we restrict attention to the simplest case in which there are only senior and junior workers. We assume realistically that the senior workers are in the majority, comprising an exogenously given share  $\alpha \in (1/2, 1)$  of the workforce. Note that senior workers are not necessarily old in age, but have been working with their company for more than a certain number of years. Assuming further that union decisions are taken by majority rule, the representative senior worker is the median voter of the trade union and, hence, chooses the nominal wage.

Seniority matters crucially for a worker's employment prospect when labor contracts contain provisions "like last in, first out" and lay-offs by inverse seniority, rather than by random draw.<sup>4</sup> Oswald (1993) provides evidence from real world labor contracts and from a postal survey, indicating that such practices are widely used in labor contracts in Canada, the UK and the US. A crucial implication of lay-offs by inverse seniority is that the median voter of a trade union faces a lower unemployment risk than the more junior union members. Oswald (1993) even argues that the median voter is *locally* isolated from any job risk and is therefore indifferent to the level of total employment. Other authors have challenged this claim. For example, Pencavel (1991) points out that even though senior workers may not be laid off when employment is reduced, reorga-

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<sup>4</sup>Possible reasons for lay-offs by inverse seniority include that senior workers (i) want to ensure themselves against future unemployment risk after a temporary expansion in employment; (ii) are more productive, as they have accumulated more firm-specific human capital; (iii) suffer a greater utility loss when sacked because they have a lower chance of finding a new job.

nization within their firm can lead to their reallocation to lower-paid or less-liked jobs. Furthermore, Pencavel stresses that Oswald's argument is valid only locally, implying that the senior union members will care about relatively large shocks to employment.

The important fact for our purposes is that the senior trade union members face a lower unemployment risk than the junior members. We capture this in a highly stylized linear-quadratic structure that allows us to study the strategic interaction between the policy maker and wage setters. In any period, economic issues are assumed to affect a worker in the following way:<sup>5</sup>

$$u_k = (w - p) - \frac{a_k}{2}(l - \bar{l})^2 - \frac{b}{2}\pi^2, \quad (1)$$

where  $k \in \{s, j\}$  indicates whether the worker is senior or junior,  $w$  represents the nominal wage,  $p$  the price level,  $l$  average per capita employment,  $\pi = p - p_{-1}$  the rate of inflation,  $a_k$  and  $b$  are positive relative weights, and  $\bar{l} > 0$  is the average per-capita employment level that corresponds to full employment. If not mentioned explicitly, all variables are in logarithms. Note that we do not need to distinguish between sectoral and economy-wide employment, because we have a continuum of measure one of identical sectors. Specification (1) implies that all workers prefer a higher over a lower real wage and suffer utility losses from inflation and deviations of actual from full employment. The consequences of lay-offs by inverse seniority are captured by the assumption that senior workers care less than junior workers about deviations of actual from full employment;  $a_s < a_j$ .

We assume the standard sequence of events for decisions of the trade unions and the monetary policy maker: (i) each trade union sets the nominal wage,  $w$ ; (ii) a zero mean productivity shock  $\epsilon$  occurs; (iii) the central banker chooses the inflation rate,  $\pi$ ; (iv) average per capita employment,  $l$ , is determined by firms' labor demand, which depends inversely on the real wage and positively on the productivity shock  $\epsilon$ . Choosing

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<sup>5</sup>Whenever it is not likely to cause confusion, time indices are suppressed so as to lighten notation. Moreover, it should be mentioned that (1) is not the complete utility function. In section 5.2 below, we will add an additional, non-economic issue to the analysis.

the appropriate normalizations, we have

$$l = p - w + \epsilon. \quad (2)$$

The median voter of a typical trade union picks the nominal wage that maximizes the expected value of her utility  $U_s$  - as given by (1) with  $k = s$  - subject to labor demand (2) and taking price expectations as given. This results in the following first-order condition:

$$w = E(p) - \bar{l}_n, \quad (3)$$

where  $E(p)$  is the rational price expectation formed at the beginning of the period and  $\bar{l}_n$  represents the natural rate level of employment,

$$\bar{l}_n \equiv \bar{l} - 1/a_s. \quad (4)$$

Note that  $\bar{l}_n$  is the smaller, the more the senior workers are sheltered from the consequences of fluctuations in employment, i.e. the smaller is  $a_s$ .

Substituting (3) into (2) yields a semi-reduced form for employment:

$$l - \bar{l}_n = \pi - E(\pi) + \epsilon, \quad (5)$$

where  $E(\pi) = E(p) - p_{-1}$  is the expected rate of inflation. While (5) is the Phillips curve relation typically used in the Barro-Gordon literature, the important point here is that we have related the natural rate level of employment to the underlying labor market structure. Hence, it will be possible to evaluate whether the natural rate is indeed too low from the policy maker's point of view, an assumption on which the whole literature initiated by Barro and Gordon (1983) critically rests.

### 3 The Standard Theory

In standard macro-models, all individuals are assumed to be identical and the utility of the representative individual is taken to be the measure of social welfare. We now characterize the equilibrium when the central bank's policy objective is social welfare. This serves to show that we can replicate the results of the Barro-Gordon analysis within our framework. In the following sections, we are going to extend the basic model in order to develop a different theory.

Applying the utilitarian notion that social welfare equals the sum of all individual utilities, we have:<sup>6</sup>

$$\begin{aligned} v &= \alpha u_s + (1 - \alpha)u_j \\ &= (w - p) - \frac{\alpha a_s + (1 - \alpha)a_j}{2}(l - \bar{l})^2 - \frac{b}{2}\pi^2. \end{aligned} \quad (6)$$

Given the assumed sequence of events, the central bank chooses  $\pi$  so as to maximize (6) subject to (3) and (5), while taking  $E(\pi)$  and the realization of  $\epsilon$  as given. This yields the first-order condition

$$0 = -bc_v + a_v[\pi - E(\pi) + c] + b\pi, \quad (7)$$

where

$$a_v \equiv \alpha a_s + (1 - \alpha)a_j, \quad (8a)$$

$$c_v \equiv (1 - \alpha)\frac{a_j}{b} \left[ \frac{1}{a_s} - \frac{1}{a_j} \right] > 0. \quad (8b)$$

Taking the expectation operator through (7) and rearranging gives a typical trade union's inflation expectation;  $E(\pi) = c_v$ . After substituting this back into (7) and using (5), we

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<sup>6</sup>Note that the essential properties of this section will go through for any welfare functions that attaches a positive weight to the juniors' utility.

obtain the equilibrium values of inflation and employment:

$$\pi_v = c_v - \frac{a_v}{a_v + b} \epsilon, \quad (9a)$$

$$l_v - \bar{l}_n = \frac{b}{a_v + b} c. \quad (9b)$$

Like Barro and Gordon, we find that equilibrium inflation exhibits a systematic inflation bias,  $c_v$ . From (8b) and (9a), we can see that the inflation bias depends positively on: (i) the share of junior workers in the total labor force, i.e.  $1 - \alpha$ ; (ii) the weight that junior workers attach to employment relative to inflation, i.e.  $a_j/b$ ; (iii) the difference between the natural rates that the juniors and the seniors prefer, i.e.  $(\bar{l} - 1/a_j) - (\bar{l} - 1/a_s) = 1/a_s - 1/a_j$ .<sup>7</sup>

Rogoff (1985) pointed out that the inflation bias can be reduced if the central bank assigns a relative weight  $b_r$  to the cost of inflation that is larger than that in the social welfare function, i.e.  $b_r > b$ . Replacing  $b$  by  $b_r$  in the previous solutions, the well-known result obtains that a weight-conservative central banker decreases the inflation bias, but stabilizes employment suboptimally. Furthermore, Rogoff (1985) proved that a finite degree of weight-conservatism  $b_r \in (b, \infty)$  optimally trades off credibility against flexibility. Note that we restrict attention to Rogoff's conservative central banker, although Walsh (1995b) has subsequently shown that providing the central banker with a performance contract permits both to eliminate the inflation bias and to avoid suboptimal stabilization. The reason for our way of proceeding is that as performance contracts are bound to be incomplete, it is optimal to appoint a weight-conservative central banker also when Walsh's contract is in place [Herrendorf and Lockwood (1997)].

It has become standard practice to equate Rogoff's conservative banker with central bank independence. However, this is not entirely satisfactory. First, there is no obvious reason why an independent central banker should adopt social welfare as the policy objective. Second, it is not clear how society can induce the independent central bank to adopt the correct degree of conservatism. Rogoff argued that weight conservatism is a question of the central banker's preferences. However, under this view it is not obvious

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<sup>7</sup>If the junior workers could set the wage, the natural rate level of employment would be  $\bar{l} - 1/a_j$ .

why the central banker should aim for a level of employment that exceeds the natural rate level. Finally, Rogoff's analysis rules out the possibility that an independent central bank achieves price stability and, at the same time, stabilizes employment. As argued in the introduction, this contradicts the policy record of the German Bundesbank. For these reasons, we now develop a different concept of central bank independence.

## 4 Towards a Descriptive Theory

### 4.1 Government-Dependence Versus Independence

We follow the literature in assuming that a government-dependent central bank behaves like a government agency, that is, maximizes the government's objective function. In democracies, the objective function of the government reflects the outcome of the political process, an important part of which are democratic elections. Since apart from monetary policy other economic and non-economic issues are at stake, the median voter theorem does not in general predict a unique outcome. One implication is that the elected government may run a monetary policy stance that the majority of the population dislikes. Another one is that uncertainty about voters' preferences in areas other than monetary policy can cause uncertainty about future monetary policy. We will argue that these two effects may be essential in understanding the monetary policy stance of a government-dependent central bank.

When the central banker is independent from government, she no longer behaves like a government agency, but runs monetary policy according to her own preferences. A necessary condition for independence is that the central bank is *institutionally* independent from the government, meaning that the government cannot directly interfere with the implementation of monetary policy.<sup>8</sup> Institutional independence requires that government representatives do not have a say on the central bank board and that the central bank cannot be forced to finance government debt directly or indirectly. However, institutional independence is not sufficient for central bank independence; rather

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<sup>8</sup>Note that our term "institutional independence" is equivalent to Fischer's (1995) "instrument independence".



the central banker needs to be *personally* independent as well. This is to say that the government cannot fire the central banker whenever it is not pleased with her performance; see Walsh (1995a) for a formal analysis of threats to fire the central banker. A further requirement for personal independence is that the government cannot decide whether the central banker is reappointed or not; see Neumann (1991) for further discussion.<sup>9</sup>

## 4.2 A Formal Model

In order to model the differences between government-dependence and independence just outlined, we introduce a second policy dimension, called  $x$ , which is assumed to affect individuals' utility according to  $-(x - \bar{x})^2$ . The bliss point  $\bar{x}$  may either be equal to  $-1$  or  $1$ . Hence, individual preferences are fully represented by the two parameters  $\bar{x}$  and  $a$ , the latter being the relative weight on employment fluctuations in (1). The shares of junior and senior workers with  $\bar{x} = -1$  are denoted by  $\gamma_j$  and  $\gamma_s$ , respectively, and are assumed to be independently uniformly distributed on  $(0, 1)$ . Consequently, the population is composed of  $\gamma_j(1 - \alpha)$  juniors with  $\bar{x} = -1$ ,  $(1 - \gamma_j)(1 - \alpha)$  juniors with  $\bar{x} = 1$ ,  $\gamma_s\alpha$  seniors with  $\bar{x} = -1$ , and  $(1 - \gamma_s)\alpha$  seniors with  $\bar{x} = 1$ . Finally, we assume that individual preferences are lexicographic in that the second policy dimension dominates monetary policy. This means that an individual with preferences  $(\bar{x}, a_k)$  prefers the policy pair  $(x_1, \pi_1)$  over  $(x_2, \pi_2)$ , if either  $-(x_1 - \bar{x})^2 > -(x_2 - \bar{x})^2$  or if  $-(x_1 - \bar{x})^2 = -(x_2 - \bar{x})^2$  and  $Eu_k(\pi_1) > Eu_k(\pi_2)$ . We have chosen this benchmark form for individual preferences, because it is convenient while being sufficient to illustrate the essential idea.

To give the second policy dimension a meaningful role, the sequence of events introduced in Section 2 above is generalized as follows: (i) each trade union sets the nominal wage,  $w$ ; (ii) the relative shares  $\gamma_j$  and  $\gamma_s$  are realized and nature draws one individual of each type as candidate; (iii) an election takes place, in which the candidate with the largest number of votes is elected as government and implements her preferred

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<sup>9</sup>These requirements are satisfied for the more independent central banks, such as the Deutsche Bundesbank, the Federal Reserve or the Swiss National Bank. In particular, the term length of their governors varies between eight and fourteen years and they can only be replaced if a higher court finds them insane or guilty of criminal action. Note that in Germany official term length is eight years but doubles due to the practice of unconditional reappointment.

policy  $x$ ; (iv) a zero mean productivity shock  $\epsilon$  occurs; (v) the central banker chooses the inflation rate,  $\pi$ ; (vi) average per capita employment,  $l$ , is determined by firms' labor demand; (vii) the government may suggest a change to the central bank law, which is accepted if it finds the support of a simple majority of the population; otherwise the status quo remains.

The steps (ii), (iii) and (vii) are new and need further explanation. We begin with (ii) and (iii). The first point to note is that since there is a positive mass of individuals of each type, the impact of any single individual's vote is negligible. Hence, strategic voting is only possible if individuals can coordinate their votes. It is typically agreed in the literature that this is an implausible possibility when individuals are atomistic. Thus, we assume that individuals vote sincerely, that is, they vote for their preferred candidate. Furthermore, with zero probability it is possible that more than one candidate has the same number of votes. We assume that a coin is then tossed to determine the winner of the election. Finally, in order to ensure that each candidate has a positive ex-ante probability of winning the election (and therefore finds it worthwhile to stay in the race), we restrict the parameter range for  $\alpha$ , the share of senior workers in the total labor force:  $\alpha \in (1/2, 2/3)$ . The assumption that  $\alpha > 1/2$  is as before and reflects that the seniors are in the majority, whereas the assumption that  $\alpha < 2/3$  ensures that each of the two junior candidate can win the election.<sup>10</sup> Given these assumptions, it can be shown (see the Appendix A for the technical details) that a junior worker will win the election with an ex-ante probability of

$$1 - \rho = \frac{2}{\alpha} + \frac{\alpha}{2(1 - \alpha)} - 4, \quad (10)$$

where  $1 - \rho \in (0, 1/2)$ . Thus, with ex-ante probability of  $\rho \in (1/2, 1)$ , a senior will be elected. Our model therefore provides an explanation for the emergence of political uncertainty about the future monetary policy stance under a government-dependent central bank. Note that the reduced form to which political uncertainty boils down here

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<sup>10</sup>If  $2/3 \leq \alpha \leq 1$  a senior worker will win with probability one, which is an uninteresting case in the present context.

is the same as that postulated in the seminal work of Alesina (1987).

We still need to specify precisely the changes in the central bank law that can be implemented in step (vii). First, if the central bank is independent from the government, the latter can propose to make it dependent. Second, if the central bank is government-dependent (which is assumed to be the default situation at the start of the game), then the government can propose to make it independent. We assume that if this proposal finds the support of the majority of the population, nature randomly draws a senior and a junior worker as candidates for the presidency of the independent central bank. Then there is a democratic vote and the candidate who gets the simple majority of votes becomes central bank president for as long as the central bank is independent. For the same reasons as explained above voting is assumed to be sincerely. These assumptions together with the fact that the senior workers are in the majority imply that, in the present model, an independent central banker will have the senior workers' preferences.

Before we solve the model, some remarks on the objective function of the independent central banker are at order. To avoid complications, we have implicitly assumed that a newly elected central banker has the same indirect utility function over real wages, employment and inflation as she had when being a senior worker. While most authors make a similar assumption, this is somewhat problematic. For example, in the current model, an independent central banker does not face a job risk; so, why should she be concerned with fluctuations in employment at all? The justification typically given is that the central banker cares about the utility of the individuals working in the sector from which she originally came, for instance because she still interacts with these individuals socially and/or because she is likely to return to this sector after her term of office will have ended.<sup>11</sup> In the present model, there is another possibility to justify that an independent central banker maximizes the seniors' utility. Simple majorities of parliament can typically change the central bank law, even for relatively independent central banks such as the Deutsche Bundesbank or the Federal Reserve. This allows the median voter

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<sup>11</sup>Note that to keep matters simple we assumed above that the central banker's term of office is infinite. In reality, office terms are of course finite. It can be shown, however, that the central bank board may behave like an infinitely-lived decision maker, if in each period only a minority of its members are in their last period.

with respect to monetary policy to threaten a “misbehaving” central banker with cuts of the latter’s operating budget, changes in the term length, and the introduction of more demanding reporting requirements. Since all of these measures would negatively affect the office rent of central bankers, one would expect that the threat of using them should be sufficient to induce the desired monetary policy stance. Grier (1991) provides empirical evidence for the US that this is indeed the case.

## 5 Results

### 5.1 Monetary Policy under Central Bank Independence

The equilibrium outcomes under central bank independence can be found by going through the same steps as above, with social welfare replaced by  $U_s$  – the utility of the senior trade union member. The results are

$$\pi_i = -\frac{a_s}{a_s + b} \epsilon, \quad (11a)$$

$$l_i - \bar{l}_n = \frac{b}{a_s + b} \epsilon. \quad (11b)$$

For future reference we also report the unconditional variances of inflation and employment when the central bank is independent:

$$\text{Var}(\pi_i) = \frac{a_s^2}{(a_s + b)^2} \sigma_\epsilon^2, \quad (12a)$$

$$\text{Var}(l_i) = \frac{b^2}{(a_s + b)^2} \sigma_\epsilon^2. \quad (12b)$$

The above solutions drive home the key result of our analysis, notably that there is no inflation bias when the central bank is independent. The reason is that the independent central bank does not attempt to systematically increase employment beyond the prevailing natural rate level, as the median voter has already picked the wage and employment levels that are optimal from her point of view. Any surprise inflation, created to raise employment systematically, would increase average employment but also give

rise to the standard cost of inflation and reduce the median voter's real wage rate. The only type of surprise inflation desired by the median voter is the one directed at dampening the impact of unanticipated productivity shocks. Solution (11b) indicates that this stabilization task is optimally fulfilled from the representative senior worker's point of view. In contrast, from the representative junior worker's point of view stabilization is suboptimally low.

Our independent central banker is weight-conservative in that her relative weight on stabilization is lower than that in the social welfare function (6),  $a_s < a_v$ . However, in contrast to Rogoff's interpretation, our central banker acts exactly as conservatively as the median voter is, rather than more conservatively. Consequently, the problem of finding a central banker with the correct degree of weight-conservatism in her preference function, which prevails under Rogoff's interpretation, does not arise here. Summing up, the first testable implication of our analysis is: (i) an independent central bank does not create an inflation bias and chooses a positive degree of employment stabilization.

## 5.2 Monetary Policy under Government-Dependence

We start solving for the equilibrium under government-dependence by calculating how the senior and the junior worker choose monetary policy when they are the elected government. Given an inflation expectation of  $E(\pi_d)$  (where the index  $d$  indicates central bank dependence) and a realization of  $\epsilon$ , maximizing the junior and the senior worker's utility functions subject to (3) and (5) yields<sup>12</sup>

$$\pi_{d,j} = \frac{a_j}{a_j + b} [E(\pi_d) - \epsilon] + c_j, \quad (13a)$$

$$\pi_{d,s} = \frac{a_s}{a_s + b} [E(\pi_d) - \epsilon], \quad (13b)$$

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<sup>12</sup>The indices  $d, j$  and  $d, s$  indicate the outcomes when the central bank is dependent and the representative senior worker and the representative junior worker determine inflation, respectively.

where

$$c_j \equiv \frac{a_j}{a_j + b} \left[ \frac{1}{a_s} - \frac{1}{a_j} \right] > 0. \quad (14)$$

Recalling that  $\rho$  is the probability that a senior will make monetary policy decisions, the unconditional inflation expectation formed at the beginning of the period must satisfy

$$E(\pi_d) = \rho E(\pi_{d,s}) + (1 - \rho) E(\pi_{d,j}). \quad (15)$$

(13b) and (13a) then imply

$$E(\pi_d) = dc_j, \quad \text{where} \quad d \equiv \frac{(1 - \rho)(a_s + b)(a_j + b)}{b[1 + (1 - \rho)a_s + \rho a_j]} > 0. \quad (16)$$

Substitution of (16) back into (13a) and (5) gives us the equilibrium when a junior government is elected:

$$\pi_{d,j} = \frac{a_j}{a_j + b} [dc_j - \epsilon] + c_j, \quad (17a)$$

$$l_{d,j} - \bar{l}_n = -\frac{b}{a_j + b} [dc_j - \epsilon] + c_j. \quad (17b)$$

We see that the junior government produces an inflation bias, which is the larger, the more weight  $a_j$  the juniors puts on the task of employment stabilization and the larger is the probability that a junior will be elected. Note that in exchange for the inflation bias the junior government achieves an employment gain relative to the natural rate level. The reason is that the election outcome is uncertain, which implies that wage setters rationally base their decisions on the unconditional expectation  $E(\pi_d)$ . If they were certain that a junior will be elected, wage setters would use the higher conditional expectation  $E(\pi_{d,j})$ , and the junior government would not be able to stimulate the economy.

Alternatively, when a senior government is elected the equilibrium is:

$$\pi_{d,s} = \frac{a_s}{a_s + b} [dc_j - \epsilon], \quad (18a)$$

$$l_{d,s} - \bar{l}_n = -\frac{b}{a_s + b} [dc_j - \epsilon]. \quad (18b)$$

A first important observation is that the senior government, too, produces an inflation bias, though a lower one than the junior government. Furthermore, absent the productivity shock, the senior government sets the inflation rate below the unconditional inflation expectation embodied in the wage rate,

$$0 < E(\pi_{d_s}) < E(\pi_d) < E(\pi_{d_j}). \quad (19)$$

Note that the senior government does not choose zero inflation because given that inflation expectations  $E(\pi_d)$  are positive, this would cause too severe a recession. (19) implies as a second result that, absent the productivity shock, a junior creates a boom and a senior creates a recession relative to the natural rate level of employment:

$$E(l_{d_s}) < E(l_d) = \bar{l}_n < E(l_{d_j}). \quad (20)$$

Again, these effects are entirely due to the electoral uncertainty. Summing up, in the presence of uncertainty about election outcomes, monetary policy will always be inflationary under central bank dependence while the level of inflation and employment will depend on who gains the power.

Finally, since senior workers are less concerned with total employment than junior workers, a senior government will choose less stabilization of employment shocks than a junior government. In other words, inflation in (18a) reacts less than in (17a) to the realization of the employment shock,  $\epsilon$ , implying that employment in (18b) is more volatile than in (17b). For future reference, we also report the unconditional variances of inflation and employment under central bank dependence:

$$\text{Var}(\pi_d) = \text{Var}(\pi_i) + \rho(1-\rho) \left[ E(\pi_{d_s}) - E(\pi_{d_j}) \right]^2 + (1-\rho) \left[ \frac{a_j^2}{(a_j+b)^2} - \frac{a_s^2}{(a_s+b)^2} \right] \sigma_\epsilon^2, \quad (21a)$$

$$\text{Var}(l_d) = \text{Var}(l_i) + \rho(1-\rho) \left[ E(l_{d_s}) - E(l_{d_j}) \right]^2 + (1-\rho)\delta^2 \left[ \frac{1}{(a_j+b)^2} - \frac{1}{(a_s+b)^2} \right] \sigma_\epsilon^2. \quad (21b)$$

### 5.3 The Political Economy of Central Bank Independence

So far, we have taken as given whether the central bank is government-dependent or independent. We now analyze the decision about this. To this end, recall the sequence of events from Section (4.2) above. In particular, we assumed that, in step (vii), the incumbent may propose a change in the central bank law, which is implemented when a majority of the population votes in favor of it. As argued above, if the central bank becomes independent, then a senior will be elected as central bank president. Hence, the proposal to make a government-dependent central bank independent is supported by all senior workers and, since they are in the majority, is accepted. Furthermore, any future proposal to go back to government-dependence will be blocked.

Starting from initial government-dependence as the natural “default” situation, our model therefore predicts that the central bank will be dependent until a government proposes independence. Since any government with senior preferences with respect to monetary policy prefers an independent central bank over a dependent one, it will propose independence if the bank still depends on the government.<sup>13</sup> In contrast, a government with junior preferences with respect to monetary policy may or may not prefer an independent central bank. This depends on the magnitude of two effects. On one hand, central bank independence eliminates the undesired inflation bias and the negative implications of political uncertainty. On the other hand, an independent central bank stabilizes suboptimally from the juniors’ point of view, whereas a government-dependent central bank does so only if a senior government is elected. A junior government therefore prefers a government-dependent central bank whenever the second effect dominates. Appendix B shows that this is the case if the variance of productivity shocks is sufficiently large.

Summing up, our model allows for two possibilities. First, if both senior and junior

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<sup>13</sup>Central bank independence is preferred by any senior government as it avoids the inflation bias, keeps average employment at the natural rate level, and provides the same degree of shock stabilization as the dependent central bank under a senior’s control. Moreover, central bank independence guarantees the preferred results indefinitely. Thus, the senior government is sure that losing the control of government to a junior will do no harm to the monetary policy stance.



workers prefer central bank independence, the central bank becomes independent in the first period of the game and remains independent forever. Second, and more interestingly, if senior workers prefer independence and junior workers prefer dependence, the central bank will then remain dependent as long as junior governments are elected. With the first senior government coming to power, the bank will gain independence and never return to dependence. This pattern is consistent with the post war experience in OECD countries: while several of them (particularly in Europe) have introduced institutional and legal reforms towards achieving a greater degree of central bank independence, none has gone in the other direction towards more dependence.

## 6 Discussion

### 6.1 Confronting our Theory With the Stylized Facts

Our theory leads to four main predictions that are empirically testable. To begin with, (11a) and (11b) imply: (i) an independent central bank does not create an inflation bias and stabilizes the real economy. Then, using (11a), (18a) and (17a), we have: (ii) average inflation is lower under central bank independence than under government-dependence. Moreover, comparing (12a) and (21a) and recalling that  $a_s < a_j$  we can see that our model predicts: (iii) the correlation between inflation variability and central bank independence is negative. Finally, (12b) and (21b) show that: (iv) employment variability may or may not be higher under a government-dependent central bank. More precisely:

$$\text{Var}(l_i) < \text{Var}(l_d) \iff b^2 \left[ \frac{1}{(a_s + b)^2} - \frac{1}{(a_j + b)^2} \right] \sigma_\epsilon^2 < \rho \left[ E(l_{d,s}) - E(l_{d,j}) \right]^2. \quad (22)$$

Whether this relation is satisfied depends on the parameter values of the model. For example, (22) is true when  $\sigma_\epsilon^2$  is relatively small, while it is violated when  $\rho$  is relatively small. As in Alesina and Gatti (1995) and Waller and Walsh (1996), whether (22) holds depends on the magnitude of two effects: on one hand, central bank independence leads on average to a less active stabilization policy stance, implying that employment is more

volatile; on the other hand, central bank independence eliminates political uncertainty about monetary policy, implying that employment is less volatile.

Prediction (i) of our model is consistent with the track record the German Bundesbank, which is widely viewed as the the most independent central bank and can therefore serve as a natural benchmark. Between 1950 and 1996, average German inflation has been 2.8%.<sup>14</sup> For all practical purposes this can be viewed as price stability. At the same time, the Bundesbank has stabilized the real economy to some extent; see Clarida and Gertler (1997) and Neumann (1997) for further discussion. The existing theoretical literature can explain this experience only by assuming that the Bundesbank has been subject to a Walsh (1995b) contract. For two reasons this is unlikely to have been the case. First, there is nothing in the Bundesbank law that resembles the features of a Walsh contract. In particular, the salaries of the policy makers are, like all salaries of German civil servants, automatically adjusted for inflation. Second, Herrendorf and Lockwood (1997) have shown that it is optimal to combine a Walsh contract with weight-conservatism, implying that having a Walsh (1995b) contract alone is sub-optimal. However, when the central bank is weight-conservative, the trade off between credibility and flexibility identified by Rogoff (1985) arises and the central bank cannot stabilize without generating an inflation bias.

Our predictions (ii), (iii) and (iv) are supported by a substantial body of empirical literature that has investigated whether macroeconomic variables are systematically related to the degree of central bank independence. By and large, cross-country regressions indicate for OECD countries that the degree of legal central-bank independence is negatively correlated with average inflation; negatively correlated with the variance of inflation; not correlated with the variance of employment; see e.g. Grilli et al. (1991), Cukierman (1992) and Alesina and Summers (1993).<sup>15</sup> To our knowledge, the only two theoretical contributions to the literature that are also consistent with these three empirical regularities are Alesina and Gatti (1995) and Waller and Walsh (1996). In all

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<sup>14</sup>This figure is the geometric mean inflation rate based on the figures calculated by the Bundesbank.

<sup>15</sup>Note that this does not imply that making the central bank of any one country independent has no effect on employment variability. Rather, it means that, within in the cross section of OECD countries, those with independent central banks do not systematically have higher employment variability.

other models, an increase in central bank independence is tantamount to an increase in weight-conservatism, implying the prediction that central bank independence be positively correlated with employment variability.

## 6.2 Future Research

A first interesting extension of our analysis would be to take into account other, potentially important, disadvantages of not granting independence to the central bank. To begin with, the government may force a government-dependent central bank to create a political inflation cycle [Lohmann (1995) and Fratianni et al. (1997)]. The basic idea is that a rational incumbent will use all available means to appeal to voters, who mistakenly take a boost in employment engineered by surprise inflation as a sign of the incumbent's economic competence. Moreover, public choice theory suggests that authorities and bureaucracies have a tendency to overspend [Niskanen (1971)]. Since seigniorage allows it to collect revenues without any effort, the government is likely to prefer more seigniorage than is optimal from the median voter's point of view. Adding these additional disadvantages of government dependence to the current analysis would increase the inflation bias and the variability of inflation under government dependence, whereas it is not clear whether the variability of employment would increase or remain unchanged.<sup>16</sup> Both of these extensions would therefore reconfirm the results derived above; see Herrendorf and Neumann (1996) for further discussion.

Another possibility for future research is to check the generality of our results. We suggest two main directions of investigation. First, while we have focused on the labor market characteristics of the median voter, Faust (1996) considers her credit market characteristics, i.e. whether the median voter is a net creditor or net debtor. Since Faust employs an overlapping generations model, the majority of the population in his model is necessarily young and indebted. This is bad news for our argument (as the median

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<sup>16</sup>This depends on the assumptions about the timing of events. On one hand, Fratianni et al. (1997) suppose that the government observes the realization of a competence shock *before* monetary policy is decided and find that the inflation cycle increases employment variability. On the other hand, employment variability is unaffected when one assumes that competence shocks are realized *after* monetary policy is decided [Lohmann (1995)].

voter with respect to monetary policy will then prefer unexpected inflation so as to reduce the real value of her outstanding debt). However, we doubt very much that, in OECD countries, the median voter is indeed a net debtor. As Faust does not provide any evidence, we cannot settle this issue here.

Second, in our model, involuntary unemployment results from the monopoly power of sector-specific trade unions. While trade unions play an important role in several OECD countries, different labor market distortions are important in other OECD countries. Our first guess is that our main results do not depend on the specific origin of the distortion, providing it gives rise to involuntary unemployment of only a minority of the labor force. This would be the case for insider-outsider theories [Lindbeck and Snower (1988)], a minimum wage law (which increases the wage paid to workers facing monopsony employers, but tends to cause involuntary unemployment in competitive sectors), or efficiency wage theories [Shapiro and Stiglitz (1984)]. In contrast, introducing a “keynesian” coordination failure along the lines of Cooper and John (1988) might lead to involuntary unemployment of all workers. While the creation of unexpected inflation could then be a way of coordinating economic activities across different sectors, it remains to be seen whether, from the point of view of the median voter, the positive consequences of unexpected inflation on employment outweigh the negative ones on inflation and on the real value of her salary.

## 7 Concluding Remarks

Subgame-perfect monetary policy exhibits an inflation bias if a government-dependent central banker maximizes a social welfare function with an ambitious employment target. A superior solution, it is frequently argued, is to appoint an independent and weight-conservative central banker. In this paper, we have presented an alternative theory. The key features have been that, instead of social welfare, a government-dependent central banker maximizes the utility of the government, while an independent central banker maximizes the welfare of the median voter with respect to monetary policy. Recognizing that democratic elections are about several issues, we have shown that the

elected government may favor a monetary policy stance that the median voter with respect to monetary policy dislikes. In contrast, central bank independence ensures that the monetary policy is implemented that would result under a single issue referendum about monetary policy.

In the real world, the median voter is likely to have various characteristics that can be explored. Our analysis has put the focus on the median voter's characteristic of being a senior trade union member, who sets an excessively high wage level and forces involuntary unemployment upon the junior workers. We have then found that an independent central banker does not produce an inflation bias at all, while it stabilizes too little from a social welfare point of view. In other words, our independent central banker is more conservative than a benevolent dictator, but as conservative as the median voter. Furthermore, we have shown that an inflation bias emerges under a government-dependent central bank because it is ex-ante uncertain whether a junior or a senior worker will gain control over the government's monetary policy.

## Appendix A: Derivation of Expression (12)

We first calculate the probability with which the junior with  $\bar{x} = -1$  gets more votes than any other candidate

$$\begin{aligned} & \Pr((-1, \pi_j) \text{ wins}) \\ &= \Pr(\{\gamma_j > 1 - \gamma_j\} \cap \{\gamma_j(1 - \alpha) > \gamma_s \alpha\} \cap \{\gamma_j(1 - \alpha) > (1 - \gamma_s)\alpha\}). \end{aligned} \tag{A.1}$$

Using that  $\gamma_j$  and  $\gamma_s$  are independently and uniformly distributed with support  $[0, 1]$ , we can express this as follows:

$$\Pr((-1, \pi_j) \text{ wins}) = 2 \int_{1/2}^{(1-\alpha)/\alpha} \int_{\gamma_s \alpha / (1-\alpha)}^1 d\gamma_j d\gamma_s = \frac{1}{\alpha} + \frac{\alpha}{4(1-\alpha)} - 2. \tag{A.2}$$

The probability that a junior wins is the sum of the probabilities that the junior with  $\bar{x} = -1$  wins and that the junior with  $\bar{x} = 1$  wins:

$$\Pr(\pi_j \text{ wins}) = \Pr((-1, \pi_j) \text{ wins}) + \Pr((1, \pi_j) \text{ wins}). \quad (\text{A.3})$$

Since  $\Pr((-1, \pi_j) \text{ wins}) = \Pr((1, \pi_j) \text{ wins})$ , we have

$$\Pr(\pi_j \text{ wins}) = 2\Pr((-1, \pi_j) \text{ wins}) = \frac{2}{\alpha} + \frac{\alpha}{2(1-\alpha)} - 4, \quad (\text{A.4})$$

which proves the claim.

## Appendix B: When Do Junior Workers Prefer Central Bank Independence?

Substituting (3), (4), (11a) and (11b) into (1) for  $k = j$ , the unconditional expectation of a junior's utility under central bank independence can be calculated:

$$E(U_j|z) = -\bar{l}_n - \frac{a_j}{2a_s^2} - \frac{b(a_j b + a_s^2)}{2(a_s + b)^2} \sigma_c^2. \quad (\text{B.1})$$

In order to calculate the unconditional expectation of a junior's utility under central bank dependence, we use (1), (3), (4), (18a), (18b), (17a) and (17b) together with the fact that a senior (junior) will run monetary policy with probability  $\rho$  ( $1 - \rho$ ). This gives

$$\begin{aligned} E(U_j|d) = & - \bar{l}_n \\ & - \rho \left[ \frac{a_j}{2} \left( -\frac{1}{a_s} - \frac{b}{a_s + b} dc_j \right)^2 + \frac{a_j}{2} \frac{b^2}{(a_s + b)^2} \sigma_c^2 \right. \\ & \quad \left. + \frac{b}{2} \left( \frac{a_s}{a_s + b} dc_j \right)^2 + \frac{b}{2} \frac{a_s^2}{(a_s + b)^2} \sigma_c^2 \right] \\ & - (1 - \rho) \left[ \frac{a_j}{2} \left( -\frac{1}{a_s} - \frac{b}{a_j + b} dc_j + c_j \right)^2 + \frac{a_j}{2} \frac{b^2}{(a_j + b)^2} \sigma_c^2 \right. \\ & \quad \left. + \frac{b}{2} \left( \frac{a_j}{a_j + b} dc_j + c_j \right)^2 + \frac{b}{2} \frac{a_j^2}{(a_j + b)^2} \sigma_c^2 \right]. \end{aligned} \quad (\text{B.2})$$

Since it is straightforward to show that

$$\frac{b(a_j b + a_s^2)}{2(a_s + b)^2} \sigma_\epsilon^2 > \left\{ \rho \left[ \frac{a_j}{2} \frac{b^2}{(a_s + b)^2} + \frac{b}{2} \frac{a_s^2}{(a_s + b)^2} \right] + (1 - \rho) \left[ \frac{a_j}{2} \frac{b^2}{(a_j + b)^2} + \frac{b}{2} \frac{a_s^2}{(a_j + b)^2} \right] \right\} \sigma_\epsilon^2, \quad (\text{B.3})$$

we have  $E(U_j|d) > E(U_j|i)$  when  $\sigma_\epsilon^2$  is sufficiently large.

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