Central Bank Independence, Centralized Wage Bargaining and Price Stability in a Monetary Policy Game

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Abstract

This paper addresses the usefulness of studying the interplay between central bank independence and centralized wage bargaining in the context of a repeated monetary policy game. Conventional macroeconomic wisdom suggests that because of increased credibility and the possibility to overcome inflationary bias, increased central bank independence has a negative effect on inflation rates. However, the benefits of increased central bank independence have lately been called into question. This paper seeks to answer whether the degree of CWB may affect the equilibrium in the monetary policy game and thereby also shed some light on the effect of CBI. The theoretical analysis considers two potential effects of CWB in the monetary policy game. The first stems from union inflation-aversion and the other from the effect of non-unionized wage bargainers. These effects are found opposing, which means that there is a possibility for a hump-shaped relationship between CWB and inflation. A small empirical study of 19 countries over three time-periods is also conducted. CBI turns out to have a negative effect on inflation. The hypothesis of a hump-shaped relationship between CWB and inflation also gains some support.

Contents

1   Introduction

The connection between central bank independence[1] (CBI) and low inflation rates has become close to an established fact within the field of monetary economics. Building on the work of Kydland and Prescott (1977), Barro and Gordon (1983a, 1983b) famously showed how *dynamic inconsistency*[2] renders discretionary policymaking unable to maximize social welfare when expectations are rational. In the standard Barro and Gordon (BG) monetary policy game, the government has an incentive to increase employment through surprise inflation, and cannot credibly convince the private sector to hold back on its inflationary expectations. The government's lack of credibility leads to an *inflationary bias* and eventually to an equilibrium with excessive inflation. This lack of credibility could potentially explain the relatively high and differing inflation rates throughout the world prior to the 1980's.

One way of overcoming inflationary bias is to appoint a conservative central banker who does not share the government's welfare function, but puts more weight on price stability instead (Rogoff, 1985). but who instead puts more weight on price stability (Rogoff, 1985). This will allow for the central bank to make a credible promise not to produce surprise inflation. Another approach is to introduce a contract that imposes a cost to the central banker when inflation is above the optimal level (Persson & Tabellini, 1993; Walsh, 1995). Both these approaches grant the central bank a certain degree of independence; the conservative central banker is given full control over monetary policy and the freedom to maximize his own welfare function,[3] while the contract-approach allows for the central banker to choose the method whereby a certain target may be reached.[4]

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[1] I will use the terms "central bank independence" and "central bank autonomy" interchangeably.

[2] Throughout this paper, the term "dynamic inconsistency" refers to a situation in which an optimal policy for some future period is no longer optimal once that period is actually reached. In the case of standard monetary policy games, the optimal strategy for the central bank may be to play a low-inflation strategy, and for the private sector to correctly anticipate this. However, because the private sector sets its expectations before the central banks policy takes effect, the optimal strategy for the central bank at that later point in time would be to deviate and play a high-inflation strategy (See for example Eijffinger & De Haan, 1996; and Fischer, 1990). Another way of expressing this is that the optimal monetary policy is not always subgame perfect.

[3] Note, however, that conservativeness and independence are two different concepts that should not be confused (see for example Berger et al., 2002; Cukierman, 1994; Hayo and Hefeker, 2002 and Lohmann, 1994

[4] The distinction between the conservative central banker-approach and the contract-approach visu-

If overcoming inflationary bias means granting the central bank a higher degree of independence from the government, we would expect a negative correlation between CBI and inflation. Indeed, such a relationship has gained support in several empirical studies (see Alesina and Summers, 1993 for a well-known example, and Arnone et al., 2007 for more recent data). However, the causal relationship of these findings has been called into question (Posen, 1993; Hayo, 1998). Does CBI cause lower inflation, or does some exogenous factor influence the design of monetary policy institutions and the priority given to price stability?[5] Furthermore, in the case of developing and transitional economies, there is relatively weak support for the negative correlation between CBI and inflation (Cukierman 1992; Hillman, 1999).

A related question is whether the decrease and stabilization of inflation rates throughout the world during recent decades (see figures 1 and 2) can be explained merely by an increase in CBI. There seems to have been a general decrease in inflation, both in countries that have moved towards greater CBI and in countries that have not (Ball & Sheridan, 2003). Partly on the basis of this observation, both the necessity and the sufficiency of CBI for price stability have been questioned (Hayo & Hefeker, 2007). The positive effect of instrument independence in the form of inflation targeting has also been challenged; there is little difference in economic performance between countries that recently have adapted inflation targeting and countries that have not (Ball & Sheridan, 2003). This would suggest that there is a need for additional explanations as to why inflation rates have decreased as well as stabilized since the 1970's; increased CBI may not tell us the whole story.[6]

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alizes the difference between goal independence and instrument independence (Debelle & Fischer, 1994). It is generally believed that central bankers should be given instrument independence, but not goal independence (de Haan & Kooi, 1997). Furthermore, it can be disputed to which degree a central banker that is given an already specified target is really independent (see for example Hayo and Hefeker, 2007); however, throughout this paper I will view both cases as different types of CBI. Finally, increasing CBI may only shift the credibility problem to another level, given that the government can revoke the central banks autonomy whenever deemed necessary (McCallum, 1995; Moser, 1999). We may assume, though, that the transaction costs of such actions are relatively large.

[5]Hayo (1998) stresses the role of the general public's attitude. In this view, Germany—with its experience of hyperinflation in the interwar period—is assumed to have a relatively inflation-averse culture and to design its monetary institutions accordingly.

[6]In a survey of central bankers own attitudes towards different means of achieving credibility, maintaining a reputation as committed to price stabilization was actually regarded as more important than CBI (Blinder, 2000). Moreover, the central bankers did not believe there were any shortcuts to increased credibility; the top rated method of achieving credibility turned out simply to be keeping a good track

Figure 1: Average Inflation rates in developed countries 1980-2010 (IMF, 2008).
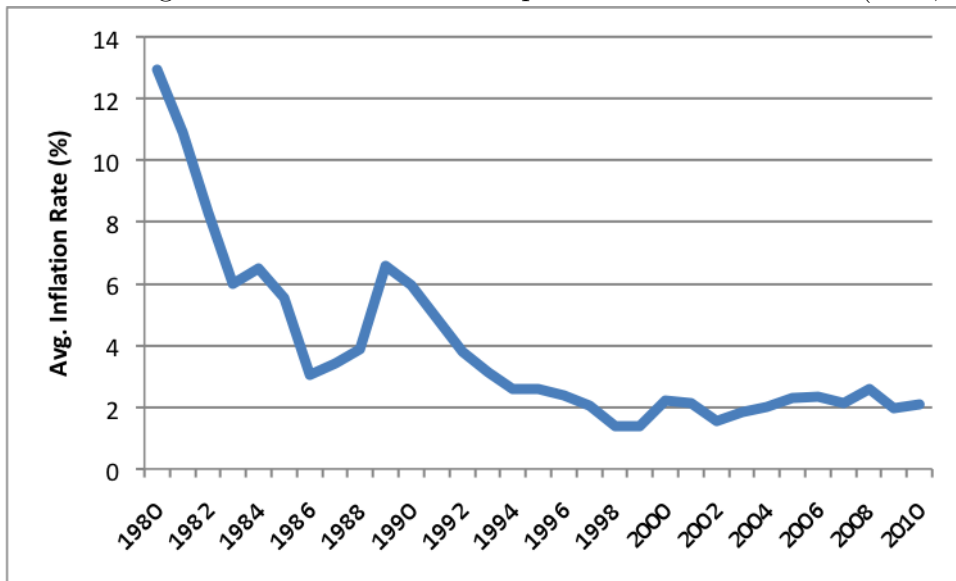

The present paper retains the idea that CBI does indeed have a positive effect on price stability. However, the moderation of inflation rates during recent years may not fully be explained by an increase in CBI alone. Instead, I consider an alternative interpretation of the BG monetary policy game, namely that legal constraints on monetary policy (such as CBI laws) are less important due to the reputational constraints imposed on the central bank by the private sector (see for example Rogoff, 1987; and Cukierman, 1992). By using a trigger strategy, the private sector can deter the central bank from resorting to surprise inflation.[7] Because the central bank cares about its reputation, it will not renege on its promises, and the dynamic inconsistency problem can be overcome. This mechanism enables an alternative explanation for how inflation can be reduced and sustained at low levels. However, game theoretic models such as the BG monetary policy game were originally developed for application in the field of industrial organization, where the number of actors is usually small. In monetary policy, these models suffer from the unrealistic assumption that a large number of actors can collaborate on one single

record of low inflation.

[7]The BG model builds on a variant of the infinite-horizon trigger-strategy equilibrium proposed by Friedman (1971). Playing a trigger strategy usually means that one player splays a cooperative strategy as long as the other player cooperates. If the opponent deviates, a player may resort to a punishment strategy that is less desirable for the opponenet. By using appropriate punishment strategy, a player can completely deter the opponent from deviating. How this works in the monetary policy game will be discussed in Section 3.

Figure 2: Average Inflation rates in devloping countries 1980-2010 (IMF, 2008).
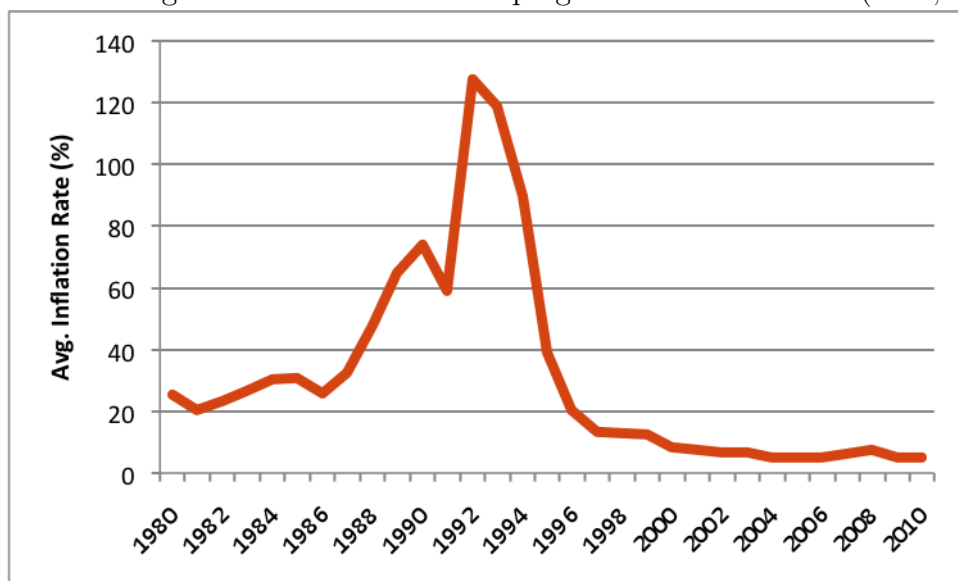
punishment strategy by coordinating their inflationary expectations. This weakness has frequently been pointed out in monetary policy literature (See for example Cukierman, 1992, chapter 11).

Nonetheless, there is a way of overcoming this coordination problem. By assuming centralized wage bargaining (CWB), the deterrence argument of the BG model seems more realistic (al-Nowaihi & Levine, 1994). If the private sector is represented by a limited number of unions, the numbers of actors that have to coordinate their strategies are fewer. Because fewer unions (higher CWB) means easier coordination, and possibly a change in the degree of inflation aversion among the remaining unions (see for example Cukierman & Lippi, 1999) we would expect that the structure of the labor market, and the way in which wages are negotiated, may affect the behavior of the central bank, and thereby also the equilibrium rate of inflation.

The purpose of this paper is to provide a critical assessment of the usefulness of introducing CWB in the monetary policy game in order to explain recent trends in inflation rates. What insights can be gained by studying the interplay between CBI, CWB and inflation rather than focusing exclusively on the degree of CBI alone? What effect can we expect from a change in the degree of CWB? Can shifts in these variables explain why inflation rates have lowered as well as stabilized during the 1980's and 1990's? A strand

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of literature has studied the effects of CBI and CWB on variables that reflect the macroeconomic outcome, such as inflation and unemployment. However, in contrast to many recent studies in this field (see for example Cukierman & Lippi; Guzzo & Velasco; and Lippi, 2002), I focus on the deterrence mechanism of the repeated monetary policy game and the reputational equilibrium as a model for how inflation can be moderated. The rest of the paper is organized as follows: Section 2 provides a brief survey on past studies on the relationship between CBI, CWB and inflation. Section 3 presents a basic monetary policy game and explains the workings of the deterrence mechanism. Thereafter, I move on to discuss some of the problems most frequently associated with the game-theoretic perspective on monetary policy and how centralization of wage bargaining can be treated in the model. Section 4 provides a brief empirical assessment of the issue with data from 19 OECD countries. Finally, section 5 concludes.

2   CBI, CWB and Inflation: A Brief Survey

This section outlines a short summary of past studies on the effects of CBI and CWB on inflation. Its purpose is to provide a background and justification for the present paper. Initially, I will discuss how the argument for how increased CBI may cause lower inflation evolved in theoretical, as well as empirical literature. Thereafter, I will remark on the use of game theory in analyzing monetary policy; in particular, I will comment on the problems associated with applying theories in monetary economics that originally have been developed in another field. Finally, I will consider some results from more recent studies on the interplay between central bank autonomy and labor market structure. As we will see, recent critique against the benefits of CBI may have underestimated the impact of variables such as CWB in monetary policy.

2.1   CBI and Inflation Rates

The case for why increased CBI may cause lower inflation evolved from what has become known as the "rules versus discretion debate"—a debate that gained prominence during

the first half of the 20th century, when Chicago school economists argued for the use of rules rather than discretion in monetary policy (see for example Friedman, 1959). The justification for imposing a policy rule on the central bank is the inflationary bias that would otherwise prevail—a bias usually attributed either to dynamic inconsistency, the revenue motive of the inflation tax, or both (Cukierman, 1992). However, early arguments suffered from the logical fallacy that discretion seemed to dominate rules in the sense that any rule can be followed as long as it is believed to maximize welfare, only to be abandoned when deemed necessary (Fischer, 1995). The first real demonstration of why rules may dominate discretion came with the dynamic inconsistency literature in the 1970's and 1980's. Kydland and Prescott (1977) and Barro and Gordon (1983a, 1983b) showed how dynamic inconsistency might cause serious problems when no institution that bolsters the central banks credibility exists. One such institution is CBI.

An independent central banker with different preferences than the government may credibly commit to a low inflation policy in a way that would be impossible without independence. If the central bank cares more about price stability relative to the government (in other words, if the central banker is what in monetary policy literature is referred to as "conservative"), it has simply no incentive to deviate from an already announced strategy (Rogoff, 1995). Because the private sector knows this, it can safely trust the central bank not to use surprise inflation. This provides a strong justification for why CBI may lead to lower inflation. Another way of increasing credibility is to tie the hands of the central bank with an explicit contract (see for example Persson & Tabellini, 1993 and Walsh, 1995).

The implications of these theoretical models that emerged in the late 1980's have been tested numerous times. A relatively early empirical test based on an average of legal and non-legal indices for central bank independence found a strong negative relationship between CBI and inflation (Alesina & Summers, 1993). This result has also been attained with the use of slight variations in the index of CBI (see for example Mangano, 1998 and Oatly, 1999). Eijffinger and De Haan (1996) surveyed the early case for CBI and concluded that empirical evidence matches the theoretical prediction. This conclusion gained support by a subsequent study by Berger et al. (2001), who included more recent

studies.[8]

However, empirical studies do not provide unambiguous support for the notion that increased CBI causes low inflation. Some have argued that the negative relationship is not robust with regards to certain control variables and the choice of countries (Campillo & Miron, 1997). In the case of transitional economies, some studies have even shown a positive relationship between CBI and inflation (Hillman, 1999), namely that an increase in CBI leads to higher inflation. Hayo and Hefeker (2007) highlight the case of Belarus, where the central bank enjoys a relatively high degree of independence, yet the country has experienced rampant inflation rates during recent years. Banian et al. (1998) argue that Russia serves as another example of such a phenomenon. Furthermore, it has been argued that the reduction in inflation due to central bank conservativeness is simply traded for greater output variability (Crosby, 1998).

By comparing seven countries that moved towards more CBI during the 1990's with thirteen countries that did not, Ball and Sheridan (2003) conclude that economic performance actually improved for *both* groups. Indeed, inflation rates fell by a larger amount for the group that moved towards more CBI. However, this group also started out with a higher-than-average inflation rate. The authors therefore argue that the relatively large fall in inflation rates can be explained simply as a regression-to-the-mean process.

A strand of literature has also questioned the theoretical basis for the benefits of CBI. Hayo and Hefeker (2007) survey this critique and conclude that granting CBI is neither sufficient nor necessary for low inflation. Instead, they suggest that the concept of CBI should be viewed in a two-stage process: first, countries choose how much emphasis should be put on price stability, then they choose whether or not CBI is the best way to achieve their chosen goal. Another perspective focuses on how the relative strength of particular sectors in the economy affect the weight given to price stability in monetary policy (Posen, 1993). In this view, countries with a powerful financial sector (which is assumed to be particularly inflation-averse) will become more concerned with fighting inflation. However, this argument has been challenged; it seems to fit some countries better than others (Fischer, 1995).

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[8]Blinder (1998, chapter 3) draws a similar conclusion.

Even though many studies have found a significant correlation between CBI and low inflation, there is without doubt disagreement about whether this relationship is causal.

2.2   Game Theory in Monetary Policy

One of the main themes in the early monetary policy game models was that previous analyses may have overestimated the monetary policymaker's credibility problems by focusing too much on single-period interaction (Rogoff, 1987). An alternative interpretation of the repeated BG monetary policy game is that legal constraints such as formal legal independence and official inflation targets are less important as long as the central bank cares about its reputation. The foundation for standard monetary policy games is built on theories for infinitely repeated games. Because monetary policy involves repeated interaction between the monetary policymaker (whether it is an independent central bank or a government) and the private sector, reputational considerations could possibly overcome the credibility problem associated with dynamic inconsistency and thereby make CBI less significant for price stability.

As we will see in section 3, the private sector of the BG model can use its inflationary expectations to force the central bank to behave in a desired way. Albeit seemingly abstract a method for achieving price stability, especially in comparison increasing CBI through legal means, this so called "deterrence mechanism"[9] provides an alternative perspective on how the central bank can increase its credibility.

This way of using game theory to model reputation in monetary policy became possible due to advancements in fields such as industrial organization and oligopoly theory. Naturally, there are some obstacles associated with applying the same reasoning when analyzing the strategic interaction between monetary policymakers and a private sector as when analyzing a "price war" between a limited numbers of firms. In the latter case, there is a small number of big actors that can easily coordinate their actions. This is rarely the case in monetary policy (Cukierman, 1992, pp. 209-211). One early attempt to overcome some unpractical traits of the monetary policy game was to focus on the

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[9]The private sector *deters* the central bank from trying to increase inflation above the expected level.

player's uncertainty about the opponent's behavior, rather than on the use of trigger strategies (Backus & Driffil, 1985). Another way is to consider a game between successive monetary policymaking regimes (al-Nowaihi & Levine, 1994). Finally, in order to make the deterrence mechanism more realistic, one can assume that the private sector is represented by a number of trade unions. Even though relatively few studies have considered the effect of unions on the deterrence mechanism in the monetary policy game, the interaction between CBI and labor market conditions, such as CWB, have been widely studied. We will know take closer look at this branch of literature.

2.3   The Interplay Between CBI and Labor Market Institutions

Many studies of the interplay between CBI, CWB and inflation agree that increased CBI lowers inflation independent of the degree of CWB (Berger et al., 2001). However, variations in the degree of CWB seem to have a more ambiguous effect on price stability. To a large degree, the ambiguity stems from whether or not unions are assumed to be inflation-averse. If unions do not care about inflation, a decrease in the number of unions (increase in CWB) leads to lower competition and substitutability between workers, higher real wages and higher inflation. On the other hand Cukierman and Lippi (1999) find that an increase in the degree of CWB also triggers an opposing effect when unions are inflation-averse. Apart from the competition effect, the unions' fear of inflation will have an effect on their real wage demand. In this context, the relationship between real wages and inflation is given through a combination of the results from the standard BG model and the Calmfors-Driffil[10] relation between CWB and real wages. The equilibrium inflation rate depends on the gap between the optimal and the natural level of output, which in turn is dependent on real wages.

When unions care about inflation, their willingness to trade off a higher real wage for lower inflation may have a stabilizing effect on prices. Cukierman and Lippi (1999) also find that, if unions are sufficiently inflation-averse, the two opposing effects cause a

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[10]A Calmfors-Driffil relation refers to a hump-shaped relation between to variables. Calmfors and Driffil (1987) considered the relation between centralization of wage bargaining and unemployment, and fund that unemployment was highest for low and high degrees of CWB and lowest for intermediate levels.

Calmfors-Driffil type relation between CBI, CWB and inflation. In other words, inflation is highest for intermediate levels of CWB. When the number of unions is relatively high, the competition-effect that causes high inflation will not be as strong. Similarly, when wage bargaining is relatively centralized, the effect of inflationary fears will dominate the competition-effect and stabilize prices. For moderate levels, neither effect will be strong enough, so that inflation will be relatively high. The intuitive explanation for this is that if unions dislike inflation, they are willing to hold back on their real wage demands in order to induce the central bank to produce a lower inflation rate (Jensen, 1997; Skott, 1997).

How realistic is the assumption of inflation-averse unions? In the case when there is only one all-comprising union, the motivation for introducing inflation aversion along with a high real wage into its preferences can be regarded as relatively innocuous. If there were only one union, it would extend its reach over most of society, which is inflation-averse according to standard monetary economics (Cubitt, 1992). Hence, a monopoly union is likely to be inflation averse (Cubitt, 1995; Agell & Ysander, 1993). However, the assumption that unions dislike inflation is also made in settings with more than one union (see for example Forteza, 1998; Guzzo & Velasco, 1999; and Skott, 1997). This may not be entirely obvious in the sense that inflation aversion can vary between different sectors of the economy.

If unions are inflation-verse, many of the positive and normative results from the standard models are turned upside down; a conservative central banker is not necessarily the best alternative, but rather one that puts no weight on inflation ("ultra-liberal" central banker). This can be seen as a "second-best" argument; introducing a second distortion in an economy where unions dislike inflation can improve the welfare outcome (Guzzo & Velasco, 1999). The basic explanation for this is that trade unions are more likely to internalize the inflationary consequences of higher wages if the central bank stops fighting inflation (Berger et al., 2001). However, the case for the ultra-liberal central banker has been criticized. As shown by Lippi (2002), when wages are negotiated in nominal terms, the result of Guzzo and Velasco (1999) is only true in the special case when there is only one singe all-encompassing union and that inflation increases linearly in the number of

unions.

On the basis of this brief survey of monetary policy literature, one can say that, by failing to take variations in CWB into consideration, recent studies critical against the beneficial effects of CBI (see for ecample Ball & Sheridan, 2005; and Hayo & Hefeker, 2007) may have been to quick to dismiss the results of the standard models. In the subsequent sections, I propose a way to view the BG monetary policy game that allows us to analyze potential effects of the degree of CWB. However, we will first take a closer look at the workings of the standard repeated monetary policy game.

3 Reputational Equilibrium in the Monetary Policy Game

This section provides a theoretical assessment of how the degree of CWB may be analyzed in the context of monetary policy game. Initially, I discuss the single period Nash equilibrium outcome. Thereafter, I show how the non-cooperative single period equilibrium can be overcome in the repeated game. Finally, some potential effects of variations in the degree of CWB are discussed.

3.1 Single Period Nash Equilibrium

In order to illustrate the single-period equilibrium, I use Backus and Driffil's (1985) simplified version of the BG monetary policy game. A conventional idea within macroeconomics is that employment and output can be affected by surprise inflation caused by an unanticipated growth of the money supply (see for example Fischer, 1977; Taylor, 1980; and Lucas, 1973). Assume that each period's output is determined by a surprise-supply function of the form

$$Y = Y_n + (\pi - \pi^e), \tag{1}$$

where π denotes inflation, π^e represents the private sector's inflationary expectations, Y represents output and Y_n denotes the natural rate. The central bank controls the inflation rate π through monetary policy. We make the bold simplification that the monetary policymaker is able to simply "choose" a value for π. Furthermore, the central bank dislikes inflation but strives to increase output. It prefers a level of output that is higher than the level determined through the nominal wages set by the private sector.[11] Suppose the central bank's single-period objective function is given by

$$z_c(\pi, \pi^e) = \alpha(\pi - \pi^e) - \frac{\pi^2}{2}, \qquad \alpha \in \mathbb{R}^+. \tag{2}$$

The first term represents the (linear) gain from one period of surprise inflation, while the second term represents the (quadratic) loss incurred by inflation. The private sector has an objective function similar to that of central bank:

$$z_p(\pi, \pi^e) = -(\pi - \pi^e)^2 - \beta\pi^2, \qquad \beta \in \mathbb{R}^+. \tag{3}$$

The first term in (3) indicates that the private sector suffers a quadratic loss from surprise inflation. The private sector prefers to correctly anticipate the central bank's choice of inflation π. Note that the loss due to inflation depends on the degree of inflation aversion β. Consider a "one shot game" between the central bank and the private sector. The central bank chooses an inflation rate π while the private sector chooses inflationary expectations π^e. As pointed out by Rogoff (1987), the aggregate inflation rate π is exogenous to individuals in the private sector, who can only affect thier own errors in predicting the inflation rate, $(\pi - \pi^e)$. In equilibrium, the collective actions of private agents have a strategic effect on the central bank's choice of monetary policy. However, individuals do not set their expectations strategically in the sense that it may be beneficial to intentionally make a wrong guess about the inflation rate.

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[11]This may be interpreted as a result of distortionary taxes on labor that has driven a wedge between the cost of labor to employers and the wage rate received by workers. In such a situation, the central bank's objective function can be viewed as a social welfare function (Cukierman, 1992, chapter 3). Alternatively, the preference for a level of employment above the natural rate can be seen as a result of political lobbying efforts (Woolley, 1984). The interpretation of the objective function will not, however, affect the mechanisms of the game itself

The players do not care about the future and are only concerned with payoff from the current period. Let π^* denote the *ideal policy*, i.e. the optimal policy from both the central bank's and the private sector's point of view. It is evident from the players' respective objective functions that the ideal policy is a zero inflation scenario π^* such that

$$\pi^* = \pi = \pi^e = 0. \tag{4}$$

However, (4) does not constitute a Nash equilibrium in the one-shot game. To see why, consider the optimal strategy for the central bank, taking the private sector's strategy as given. This means maximizing (2) given $\pi^e = 0$, which yields

$$\max\left\{z_c | \pi^e = 0\right\} \Rightarrow \pi = \alpha. \tag{5}$$

Because $z_c(\alpha, 0) > z_c(0, 0)$, the central bank clearly has an incentive to deviate from a potential zero-inflation strategy if it believes $\pi^e = 0$. The private sector, on the other hand, knows this and will take (5) as given when maximizing its own objective function, yielding

$$\max\left\{z_p | \pi = a\right\} \Rightarrow \pi^e = \alpha. \tag{6}$$

In this situation, both players are playing their best response to the other players strategy. By examining (2), we realize that the central bank's optimal strategy is to play $\pi = \alpha$, regardless of the the private sector's expectations. We denote the single period Nash equilibrium $\bar{\pi}$, such that

$$\bar{\pi} = \pi = \pi^e = \alpha \tag{7}$$

Since $z_c(\alpha, \alpha) = -\frac{\alpha^2}{2} < z_c(0, 0) = 0$ and $z_p(\alpha, \alpha) = -\beta\alpha^2 < z_p(0, 0) = 0$, $\bar{\pi}$ is clearly Pareto-inferior to the cooperative outcome π^*. This demonstrates the inflationary bias

resulting from discretionary policymaking when expectations are rational; the central bank lacks credibility to promise the private sector not to play $\bar{\pi}$. If the central bank was independent from political pressure, it may have cared less about increasing employment and could possibly make a credible promise. This provides the theoretical case for CBI. Also note that because the game is only played for one round, the players' reputation will not be damaged by their behaving uncooperatively. However, when the game is played for more than one round, the private sector can deter the central bank from playing the surprise inflation strategy. It is easy to show that introducing a finite number of rounds in this setting is not sufficient to overcome the inflationary bias; the game must be played over an infinite horizon in order for the deterrence mechanism to work.

To realize this, solve the game through backwards induction starting from the final round T where the central bank chooses an inflation rate π_T. Suppose the two players have managed to cooperate until round T. Playing the last round as an isolated game turns out to be essentially the same as playing the one-shot game. Hence the central bank's best strategy in the final round is apparently to play $\pi_T = \bar{\pi}$. In the penultimate round $T - 1$, the private sector knows that the central bank will try surprise inflation in round T, it will therefore play its best response $\pi^e = \bar{\pi}$. When the game unfolds backwards, the optimal strategy for both players turns out to be $\pi_t = \pi_t^e = \bar{\pi}$ in every round t.

3.2   Reputational Equilibrium

Building upon al-Nowaihi and Levine (1994), assume that the single-period game from the previous section is played repeatedly over an infinite number of periods, where the payoff for each period is given by the players' respective single-period objective function. The central bank's "dynamic" objective function is then given by

$$W_c = \sum_{t=0}^{\infty} (\delta_c)^t z_c, \tag{8}$$

where $\delta_c \in (0, 1)$ is a discount factor that represents the central bank's time preference. A low value of δ_c means that the monetary policymaker discounts the future heavily. The

private sector's multi-period objective function is defined in the same fashion:

$$W_p = \sum_{t=0}^{\infty} (\delta_p)^t z_p. \tag{9}$$

Let $\hat{\pi}$ denote the "best feasible" inflation rate such that

$$\hat{\pi} = k\alpha, \qquad k \in [0, 1]. \tag{10}$$

The best feasible inflation rate is the lowest possible inflation rate that can be supported as subgame perfect in the repeated game. Note that $k = 0 \Rightarrow \hat{\pi} = \pi^*$. Suppose the private sector uses a *trigger strategy* such that it expects the cooperative outcome $\pi_t = \hat{\pi}$ in period t, unless it has observed something else in period $t - 1$. Once it has seen a different value of inflation (such as $\pi_{t-1} = \bar{\pi}$), the private sector will play a punishment strategy $\pi_t^e = \bar{\pi} = \alpha$ for $\tau \in \mathbb{Z}^+$ rounds before returning to the cooperative strategy $\pi^e = \hat{\pi}$. This strategy leaves the central bank with two options. It may try to "cheat" the private sector in round t by deviating from the cooperative strategy and play $\pi_t = \bar{\pi}$.[12] Doing so, it knows that the private sector will retaliate by playing $\pi^e = \bar{\pi}$ for τ rounds. Hence, after deviating, the central bank will play its best response $\pi = \bar{\pi}$ in τ rounds. This yields the following payoff:

$$W_c^d = z_c(\alpha, k\alpha) + \sum_{t=1}^{\tau} (\delta_c)^t z_c(\alpha, \alpha) + \sum_{t=\tau+1}^{\infty} (\delta_c)^t z_c(k\alpha, k\alpha). \tag{11}$$

Alternatively, the central bank can cooperate and play $\pi = \hat{\pi}$ in every round, which yields

$$W_c^f = \sum_{t=0}^{\infty} (\delta_c)^t z_c(k\alpha, k\alpha). \tag{12}$$

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[12]Alternatively, we could allow for the central bank to cheat *only a little* by choosing an inflation rate $\pi = \beta\hat{\pi}, \beta \in [\alpha, 1]$. However, $\pi = \bar{\pi}$ yelds the highest single-period payoff for the central bank and can therefore be considered the *optimal deviation*. See al-Nowaihi & Levine, 1994, for a general model where small deviations are allowed.

In the latter case (12), the central bank follows a cooperative strategy because it is concerned with the consequences of cheating. This is what essentially constitutes a reputational equlibrium; the private sector utilizes the deterrence mechanism available in the repeated game in order to keep the central bank from resorting to surprise inflation. Whether the central bank will cooperate or deviate depends on the benefits that can be realized. A condition for successful deterrence is that the gain from cooperating has to be larger than the gain from defecting. This condition can be expressed in the following way:

$$W_c^d \leq W_c^f. \tag{13}$$

We are now going to consider two *extreme cases* of trigger strategies. The purpose of this is to analyze the effect of punishment length τ on the equilibrium rate of inflation.

3.2.1 Infinite Punishment Period

First, suppose the the private sector sets $\tau = \infty$. This means that it will play the cooperative strategy as long as it has observed $\pi = \hat{\pi}$, but once the central bank plays $\pi = \bar{\pi}$, the private sector will switch to the punishment strategy for the rest of the game. The central bank's payoff from deviating when the private sector uses this strategy is

$$W_c^d = z_c(\alpha, k\alpha) + \sum_{t=1}^{\infty} (\delta_c)^t z_c(\alpha, \alpha). \tag{14}$$

The payoff from not deviating is given by (12). It is now possible to solve for the lowest inflation rate that can be supported in a reputational equilibrium, given the players' respective strategy. The result is summarized by the following lemma:

Lemma 1. *If the private sector punishes non-cooperative strategies with an infinitely long punishment period (such that $\tau = \infty$), then the minimum sustainable inflation rate is $\pi^{min} = \alpha(1 - 2\delta_c)$*

Proof. See Appendix A.1 ☐

3.2.2 Single Punishment Period

Instead of an infinite punishment scenario, consider a case where the private sector plays the punishment strategy $\pi^e = \bar{\pi}$ for only one round ($\tau = 1$) after having observed $\pi = \hat{\pi}$ on behalf of the central bank. This leaves the central bank with the following payoff from cheating in period t:

$$W_c^d = z_c(\alpha, k\alpha) + (\delta_c)z_c(\alpha, \alpha) + \sum_{t=2}^{\infty}(\delta_c)^t z_c(k\alpha, k\alpha). \tag{15}$$

Similarly as in the previous case, the payoff from not deviating is given by (12).

Lemma 2. *If the private sector punishes non-cooperative strategies with one single punishment period (such that $\tau = 1$), then the minimum sustainable inflation rate is $\pi^{min} = \alpha\left(\frac{1-\delta_c}{1+\delta_c}\right)$*

Proof. See Appendix A. 2 ☐

3.2.3 Punishment Length and Inflation

We have now seen that the minimum rate of inflation that can be sustained in a reputational equilibrium differs between the infinite-punishment period case and the single-period punishment case. How is the minimum rate of inflation related to the length of the punishment period used by the private sector? It turns out that the rate that can be sustained in equilibrium depends on the punishment length in the following way:

Proposition. *Given the assumptions above, the minimum sustainable rate of inflation π^{min} decreases as the length of the punishment period τ increases.*

Proof. From Lemma and Lemma 2, we obtain

$$(1 - 2\delta_c)\alpha \leq \left(\frac{1 - \delta_c}{1 + \delta_c}\right)\alpha \qquad \alpha \in \mathbb{R}^+, \delta_c \in (0, 1) \tag{16}$$

$\square$

Condition (16) simply states that the minimum inflation rate with infinite punishment strategies will always be lower or equal than with single period punishment, for all defined levels of α and δ_c. By choosing an appropriate punishment strategy, the private sector can induce the central bank to behave in a desired way, avoid surprise inflation and thereby sustain a certain equilbrium inflation rate. However, this set-up also raises some questions. For example, when the private sector sets $\tau = \infty$, the optimal policy $\pi^* = 0$ can in fact be sustained given that $\delta_c \geq \frac{1}{2}$. In other words, that the central bank has to value payoff in the next period at least as much as half the value of the same payoff in the present. As pointed out by al-Nowaihi and Levine (1994), this is hardly a stringent condition for the central bank, and not very realistic (this would suggest that we never have to experience high inflation, which is certainly not the case). Furthermore, how can the private sector—which may consist of a very large number of actors—coordinate on a particular punishment strategy? We will now direct attention to these two issues.

3.3   Deterrence and Credibility

As pointed out in several studies (see for example Cukierman, 1992; Backus and Driffil, 1987; and Rogoff, 1987), the use of trigger strategies in the game-theoretic approach to monetary policy raises a number of problems. The equilibrium inflation rate π^{min} is very sensitive to the structure of the punishment strategy. According to the *Folk Theorem* for repeated games, if players are sufficiently patient, any outcome can be sustained as subgame perfect, where individually rational outcomes are played in each round, given an appropriate punishment strategy (see for example Fudenberg and Maskin, 1986). For the standard monetary policy game, this means that any inflation rate can be sustained as a subgame perfect equilibrium given that the private sector uses the right trigger strategy. This means that there exist an infinite number of Nash equilibria, but no mechanism for choosing among them (Cukierman, 1992, pp. 209-210). al-Nowaihi and Levine (1994)

suggest a way of overcoming this and other mathematical problems associated with the reputational approach.

Another—perhaps more serious—problem with a reputational equilibrium lies in how the private sector can coordinate on a certain punishment strategy. One commonly held belief about the deterrence mechanism in the previous section is that it may be unrealistic to assume that a whole sector can be treated as one unified actor. In contrast to an industrial organization setting, where the actors may use a certain pricing strategy as a deterrence mechanism, the private sector of the monetary policy game uses its expectations to induce its opponent to adopt a certain strategy. The "private sector" is likely to be composed of many different actors, and the assumption that they can collude on a certain punishment strategy is far from innocuous. In other words, if there is no institution that coordinates the private sector's expectations, the punishment strategy cannot be viewed as credible and the repeated game in the previous section breaks down.

One way of overcoming this problem is to consider a game between successive monetary policy makers (or in a case where the central bank is not independent, successive government administrations) (see for example al-Nowaihi & Levine, 1994). Another solution is to assume some degree of collective bargaining in the form of trade unions (Cubitt, 1995; Cukierman & Lippi, 1999). If the wage bargaining in the private sector is more centralized, the deterrence mechanism may be viewed as more realistic. In the subsequent sub-section, we will turn to the effect of centralized wage bargaining in the monetary policy game.

3.4   Centralized Wage Bargaining Effects on the Reputational Equilibrium

We are now going to consider two potential effects of introducing CWB in the monetary policy game. The first relates to the degree of inflation aversion versus the number of unions in the game. The second considers the role of individuals who are not members of any union.

3.4.1   Union Inflation Aversion

In the original BG monetary policy game, the private sector is only concerned with correctly anticipating the inflation rate set by the central bank.[13]   In other words, it does not care about the actual *level* of inflation as long as it expects that particular level. Introducing inflation aversion into the private sector's objective function, such as in (3), affects the foundations of the trigger strategy used by the private sector in the game. Inflation-aversion imposes a cost associated with punishing the central bank for non-compliance. In order to realize this, we can compare the private sector's payoff from playing the punishment strategy $\bar{\pi}$ with the payoff from playing the cooperative strategy $\hat{\pi}$, given that the central bank plays it respective best response: $z_p(\alpha, \alpha) = -\beta\alpha^2 \leq z_p(k\alpha, k\alpha) = -\beta(k\alpha)^2$. In other words, when unions are more inflation averse, it is also more costly to punish the central bank for deviating.

In a setting without private sector inflation-aversion (implying that $\beta = 0$), the payoffs are $z_p(\alpha, \alpha) = z_p(k\alpha, k\alpha) = 0$, meaning that the private sector is indifferent to continuing with the punishment period and to returning to the cooperative level. As β increases, it becomes less desirable to utilize a long punishment period. This would suggest that a higher degree of inflation aversion actually may *increase* the minimum attainable inflation rate π^{min}. This may seem contradictory to the argument of Cukeriman and Lippi (1999), which states that a higher degree of inflation-aversion moderates the unions' real wage claims. However, the unions' action may be seen as a tradeoff between maintaining a low equilibrium inflation rate and playing a credible punishment strategy.   In this sense, a strategy is "credible" if it is not against the private sector's best interest to play another strategy.[14]   Whether a strategy is credible or not depends on the out-of-equilibrium payoffs, i.e. payoffs that are realized at nodes of the "game tree" that are never reached when the game is played along the equilibrium path. This is a well-known feature of repeated games.

How does the degree of CWB affect unions' inflation aversion?   When CWB increases

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[13]This is evident from the fact that if $\pi_t^e = \pi_t$ when $\beta = 0$, z_p is always $= 0$.

[14]Alternatively, we could view the notion of credible punishment strategy as the fact that the opponent actually believes the punishment will be carried out.

(the number of unions decreases), the unions that remain will *ceteris paribus* comprise a larger share of the private sector and thereby be more inflation averse as a whole (see for example Cubitt, 1992; and Berger et al., 2001). When the degree of CWB is low and there are relatively many, smaller unions, the degree of inflation aversion may vary widely across branches (Berger et al., 2001). (Some unions may even be indifferent towards inflation.) A small union that only cares about its members may not consider the inflationary consequences of high real wage demands in the same way as a monopoly union.

This notion of a "reversed inflation-aversion effect" in the monetary policy game, meaning that an increase in the degree of CWB leads to higher inflation, may seem somewhat counterintuitive. The standard conception about this issue states that higher inflation-aversion lowers the unions' real wage demand and thereby the rate of inflation (Cukierman & Lippi, 1999). However, in this model, unions' ability to sustain a low inflation rate via the deterrence mechanism is circumscribed by the requirement to play a credible punishment strategy. This means that when unions' inflation-aversion increases, the lowest possible inflation rate that can be supported in equilibrium increases.

3.4.2 The Role of Non-Unionized Wage Bargainers

One aspect of the monetary policy game that has not yet been mentioned is the possibility that some individuals are not members of any union. The implications of such a situation certainly deserve some thought. Consider a situation where these individuals hold *adaptive expectations* of the inflation rate such that they set their expectations $\pi_t^e = \pi_{t-1}$. In other words, this part of the private sector plays a "strategy" where they simply expect the inflation rate of the present period to be the same as in the previous period.[15] The justification for this assumption may be that individuals for various reasons have an informational disadvantages that makes it harder to utilize a more complex strategy without the coordination made possible by unionization.

For the deterrence mechanism, the fact that some (non-unionized) portion of the private

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[15]An articulated strategy for the non-unionized wage bargainers might be: "Play the cooperative strategy $\pi^e = \hat{\pi}$ in the first round, then play $\pi_t^e = \pi_{t-1}$ in all subsequent t rounds."

sector holds adaptive expectations may have various effects. If the unions play the infinite punishment period strategy, it will not matter for the reputational equilibrium if some individuals always play $\pi_t^e = \pi_{t-1}$; the strategies will effectively yield the same outcome in terms of inflationary expectations. To realize this, suppose the central bank deviates in period t and plays $\pi_t = \bar{\pi} = \alpha$. Then, the unionized part of the private sector will start an infinite string of periods playing $\pi^e = \bar{\pi}$, starting in the subsequent period $t + 1$. In period $t + 1$, the non-unionized part of the private sector will expect the inflation rate to be the same as in period t, in other words α. Because the central bank will play its best response in period $t + 1$ and onwards, the non-unionized part of the private sector will continue to expect $\bar{\pi} = \alpha$. This yield the same outcome as having an entirely unionized private sector that plays the infinite punishment strategy.

If the unions use a single punishment period, the existence of a non-unionized wage bargainers *may*, however, affect the equilibrium. More precisely, if the non-unionized portion of the private sector is large enough, the aggregate expected level of inflation that the central bank takes into consideration may be higher than the level expected by the unions. (This stems from the fact that in the second round following a deviation, the unions expectation will be $\pi^e = \hat{\pi} = k\alpha$ while the non-unionized will expect the last period's inflation α.) If so, the single-period punishment strategy may break down into an infinite number of non-cooperative rounds.

Suppose that the aggregate expected inflation rate the central bank takes into consideration is given by the weighted average of the unions' (superscript u) and the non-unionized (superscript n) players' expectations:

$$\pi^e = q\pi^{e(u)} + (1 - q)\pi^{e(n)} \Rightarrow \pi_t^e = q\pi_t^{e(u)} + (1 - q)\pi_{t-1}, \qquad q \in [0, 1]. \qquad (17)$$

If the central bank deviates in round t, the unions return to play the cooperative strategy in round $t + 2$ (still assuming the the unions are playing the single period punishment strategy). However, the non-unionized part of the private sector will expect the same inflation as in period $t - 1$, which is α. Hence the inflation rate the central bank takes into consideration will be

$$\pi_{t+2}^e = \alpha(q(1-k) + k) \tag{18}$$

This inflation rate lies between the non-cooperative equilibrium and the least supportable rate, such that $k\alpha \leq (q(1-k) + k) \leq 1 \Rightarrow k\alpha \leq \alpha(q(1-k) + k) \leq \alpha$. If the share of non-unionized wage bargainers in the private sector $(1-q)$ is large enough, the central bank may not return to $\hat{\pi} = k\alpha$ in period $t + 2$, but rather set $\pi > \hat{\pi}$ in order to increase output. This would suggest that it may be harder for the private sector to establish an appropriate deterrence mechanism if a large portion acts as non-unionized wage bargainers with adaptive expectations, leading to a negative relationship between CWB and inflation.

We have now considered two potential effects of CWB in the monetary policy game. It turns out that they are opposing. The inflation-aversion effect suggests that an increase in CWB causes higher inflation, while the effect of non-unionized wage bargainers means that an increase in CWB leads to a *decrease* in inflation. How are these effects related? One possibility would be that for low levels of CWB, the inflation-aversion effect dominates the effect from non-unionized wage bargainers, while the reverse is true for high levels. This would create a hump-shaped relationship analogous to the one of Cukierman & Lippi, 1999. The rationale for this assumption would be that at low levels of CWB, inflation aversion is likely to be low because small unions (and non-unionized wages bargainers) will not consider aggregate inflationary consequences in the same way as an all-compirising union. The inflation aversion effect may increase quickly at low levels of CWB and diminish as CWB increases.[16] Nonetheless, in order to cast more light on the relationship, we may need an empirical assessment.

4   Empirical Evidence

This section looks at some empirical evidence of the relationship between central bank independence and centralization of wage bargaining, and the effect on inflation. The first

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[16]The increase in inflation-aversion when a small number of big unions get even fewer are not as likely to be as big as for when decentralized units centralize into unions.

sub-section discusses different ways of measuring CBI and CWB. We will see that there is some disagreement about the appropriateness of some empirical proxies used for this purpose. Thereafter, I will carry out a simple empirical assessment based on panel data from 19 countries during three different time periods.

4.1 Measurements of CBI and CWB

There are some obvious problems with trying to quantify measures of CBI and CWB. Neither concept is directly observable, so we have to rely on proxies. But what factors can be used as proxies for the independence of the central bank with accuracy? Even though formal legal measures are useful, they are often noisy and far from perfect (see for example Berger et al., 2001). For example, indices based on legal indicators may not give us an accurate picture of the central bank's real autonomy in cases where there is a significant divergence between a central bank's formal status and its actual independence. This problem may be even greater in developing countries where corruption and informal ties between central bank governors and the government can be significant. On the other hand, other measures also have drawbacks. There is fundamental disagreement about what criteria really provides a good measure of CBI (see for example Forder, 1999), and it is therefore not obvious which factors should be included in a non-legal index. As a result, non-legal indices inevitably suffer from a certain degree of arbitrariness. As pointed out by Berger et al. (2001), it may not be wise to base the analysis of CBI effect on just one indicator. However, the availability of reliable indices is limited, especially if we are interested in several time periods.

The two most widely used indexes for CBI are the Grilli-Masciandaro-Tabellini (1991) index (GMT) and the Cukierman (1992) index. The indices differ both in terms of included criteria and interpretation of central bank laws with regards to those criteria (Berger et al., 2001). Mangano (1998) points out that almost half of the criteria regarded as important in the GMT index is not regarded as important in the Cukierman index.[17] However, Berger et al. (2001) argue that the difference between the two indices lies

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[17]Berger et al. (2001) argue that this is due to the normalization process used by Mangano (1998).

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not so much in divergent definitions as in interpretation of different central bank laws. Nonetheless, one implication of the differences is obviously that the relationship between CBI and inflation will be dependent on the choice of index. The negative relation between CBI and inflation found by Alesina and Summers (1993), who used a variant of the GMT index, seems to be weaker when the Cukierman index is used (Fuhrer, 1997).[18]

Measures of CWB are usually constructed by categorizing countries with respect to what level the wage bargaining process predominantly takes place (see for example Cukierman & Lippi, 1999; Berger et al., 2001; and OECD, 2006). A natural assumption is that as wage bargaining becomes more centralized, the number of units who participate in the wage bargaining process decreases. This process of categorizing countries may seem crude and dubious. Indeed, countries may have widely different labor market structures, which may make them hard to compare. This has to be taken into account when analyzing data on CWB.

4.2   Description of Data

As evident from the discussion in the previous sub-section, the way in which CBI and CWB are measured implies that there is a relatively high risk of measurement errors associated with data on the subject. The limited availability of data also imposes a severe constraint on the analysis. Furthermore, recent data is particularly scarce.[19]

Nonetheless, the present data set contains data on CBI, CWB and inflation from 19 OECD countries for three time periods, giving a total of 57 observations. Because the data for the different periods are averages of a consecutive series of years rather than exclusively from the years explicitly shown, the notation "1990," "1995" and "2000" should be seen as representations of the time periods "early 90's," "mid-90's" and "early 2000's". Ideally, data from three specific years would have been used, implying three distinct cross-sections, but using approximate periods works as a second-best solution. As

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[18]See Cukierman, 1992; Berger et al., 2001; and Arnone et al., 2007; for extensive surveys of different ways of constructing indices of CBI. These studies provide a treatment of the debate on what really provides a good proxy for CBI.

[19]As pointed out by Cukierman and Lippi (1999) it is an important task for future empirical work in the field to mitigate these problems.

a proxy for the mid-1990s CBI index, I have used data for the year 1994 from Cukierman & Lippi (1999). Similarly, the underlying data on CWB are based on the three periods 1985-1990, 1990-1995 and 1995-2000. This may not be an ideal scenario, yet necessary due to the limitations in data availability. Table 1 summarizes the data in the sample.

Table 1: CBI, CWB and inflation in 19 countries during three time-periods.

Country	Period	CBI	CWB	Inflation
Australia	1990	0.56	4.0	5.26
	1995	0.56	2.0	2.24
	2000	0.63	2.0	2.84
Austria	1990	0.56	3.0	2.68
	1995	0.56	3.0	2.10
	2000	0.94	3.0	1.46
Belgium	1990	0.44	3.0	2.63
	1995	0.94	3.0	1.89
	2000	0.94	3.0	1.74
Canada	1990	0.69	1.0	4.18
	1995	0.69	1.0	1.48
	2000	0.63	1.0	2.05
Denmark	1990	0.50	3.0	3.29
	1995	0.50	3.0	1.93
	2000	0.75	2.0	2.41
Finland	1990	0.22	5.0	4.74
	1995	0.22	5.0	1.31
	2000	0.94	5.0	2.06
France	1990	0.44	2.0	3.03
	1995	0.94	2.0	1.78
	2000	0.94	2.0	1.36
Germany	1990	0.81	3.0	3.05

	Year	Col1	Col2	Col3
	1995	0.81	3.0	2.33
	2000	0.88	3.0	1.18
Italy	1990	0.31	2.0	5.74
	1995	0.31	2.0	3.99
	2000	0.81	2.0	2.23
Japan	1990	0.38	1.0	2.20
	1995	0.38	1.0	-0.40
	2000	0.44	1.0	1.36
Netherlands	1990	0.63	3.0	2.08
	1995	0.63	3.0	2.12
	2000	0.88	3.0	3.02
New Zeeland	1990	0.19	3.0	4.35
	1995	0.44	1.0	2.06
	2000	0.44	1.0	1.81
Norway	1990	0.27	4.5	4.22
	1995	0.27	4.5	1.99
	2000	0.75	4.5	2.40
Portugal	1990	0.19	3.0	11.17
	1995	0.81	4.0	3.94
	2000	0.81	4.0	3.05
Spain	1990	0.31	3.5	6.29
	1995	0.88	3.0	3.89
	2000	0.88	3.0	2.78
Sweden	1990	0.32	3.0	6.86
	1995	0.32	3.0	2.48
	2000	0.94	3.0	1.49
Switzerland	1990	0.75	3.0	4.07
	1995	0.75	2.0	1.46
	2000	0.94	2.0	0.80
UK	1990	0.38	1.0	5.71
	1995	0.38	1.0	2.29

	2000	0.64	1.0	1.24
USA	1990	0.75	1.0	4.31
	1995	0.75	1.0	2.73
	2000	0.75	1.0	2.30

The data for CBI is the GMT-index calculated by Arnone et al., (2007) combined with data from Cukierman and Lippi (1999). The index is measured as an average of *economic* and *political* autonomy[20] scores on a continuous scale from 0 to 1, where 1 indicates the highest degree of central bank independence. An evident problem emerges in that Arnone et al. (2007) only provide a GMT-index for the late 80's and 2003. In order to allow for an analysis that includes the mid 90's, data from Cukierman and Lippi's (1999) index for 1994 have been used.[21] The justification for choosing a legal measure of CBI rather than a behavioral index is that there are only developed countries (where the rule of law is assumed to be predominant) in the sample, and a legal measure should therefore be accurate enough. If developing countries were to be included, a behavioral index (such as the Cukierman index) would have been desirable.

Concerning the measure of CWB, I rely on data calculated by OECD (2006). Countries receive a score between 1 (least centralized) and 5 (most centralized) depending on where the wage bargaining process mainly takes place. This implies that centralized countries such as Finland receive a 5, decentralized Japan receives a 1, while the "intermediate" Netherlands receives a 3. As evident from the data, some countries have moved towards less centralized systems (as measured by the OECD), but only one (Portugal) has moved towards more centralization during the time period of of study.

Data on inflation rates have been obtained from the IMF World Economic Outlook Database (IMF, 2008). In order to correct for short-term fluctuations, the numbers on

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[20]See Arnone et al. (2007) for details about the distinction between economic and political autonomy score. The technical discussion is beyond the scope of the present paper, and has therefore been omitted.

[21]Arnone et al. (2007) uses use both a GMT and a "Cukierman index", while Cukierman and Lippi only use the latter. In order to overcome this problem, I have looked at *changes* over time in CBI. Cukierman and Lippi (1999) provide information about which countries that have remained on a constant level of CBI between the late 80's and mid-90's. For these countries, the same GMT index has been used for the two earliest time-periods. The 2003 GMT level has been used as a proxy for the mid-90's level for the 6 countries that according to Cukierman and Lippi (1999) changed the degree of CBI in the early 90's.

inflation are calculated as five-year average annual inflation rates, measured as average rate of change in consumer prices. The measures are centered around the years 1990, 1995 and 2000 (i.e. inflation for the mid-90's period is defined as the average inflation rate in the years 1993-1997).

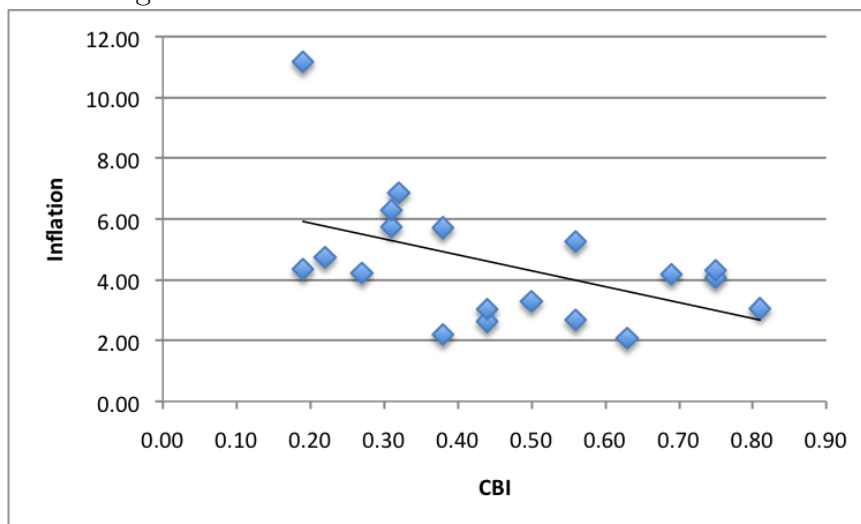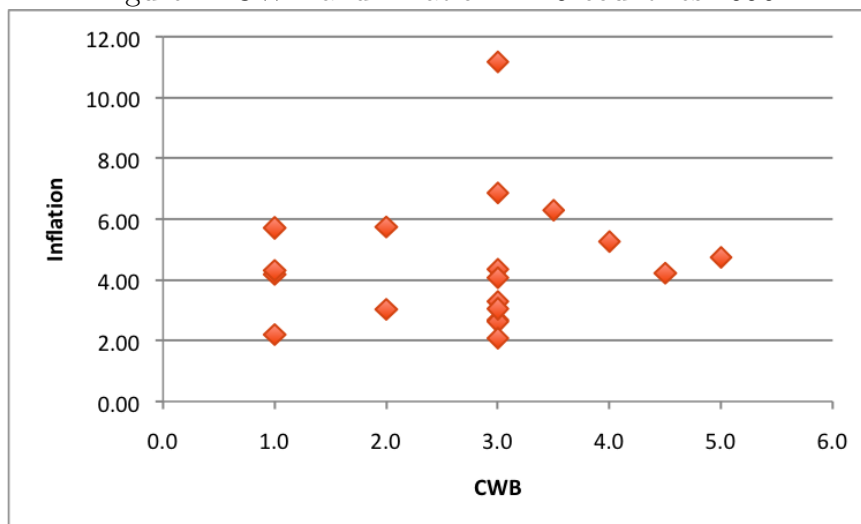Figure 3: CBI and inflation in 19 countries 1990.

Figure 4: CWB and inflation in 19 countries 1990.

As a preliminary analysis, consider figures 3 to 8, which show scatter plots of CBI, CWB and inflation in the three different time-periods. A few details are worth commenting on. Figure 3 shows the relationship between CBI and inflation during the early 1990's. The well-known negative relationship pointed out by Alesina and Summers (1993) and others is clearly visible. (However, note the high-inflation outlier Portugal.) It is harder

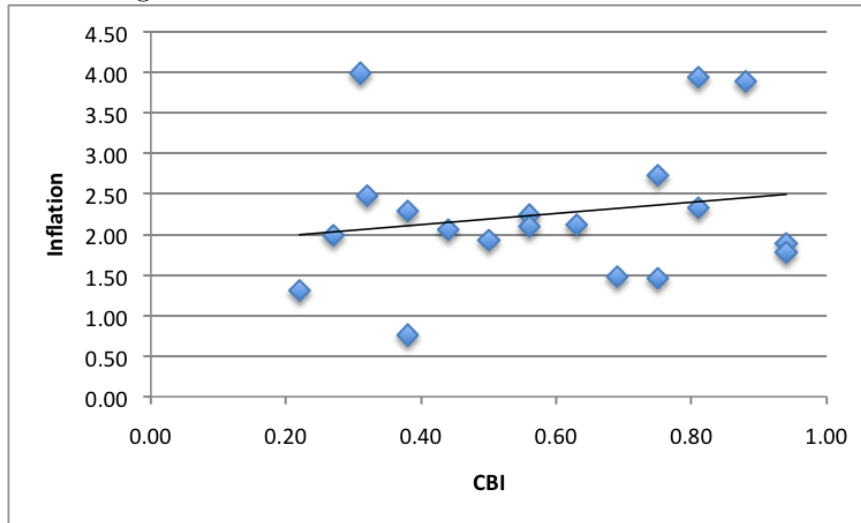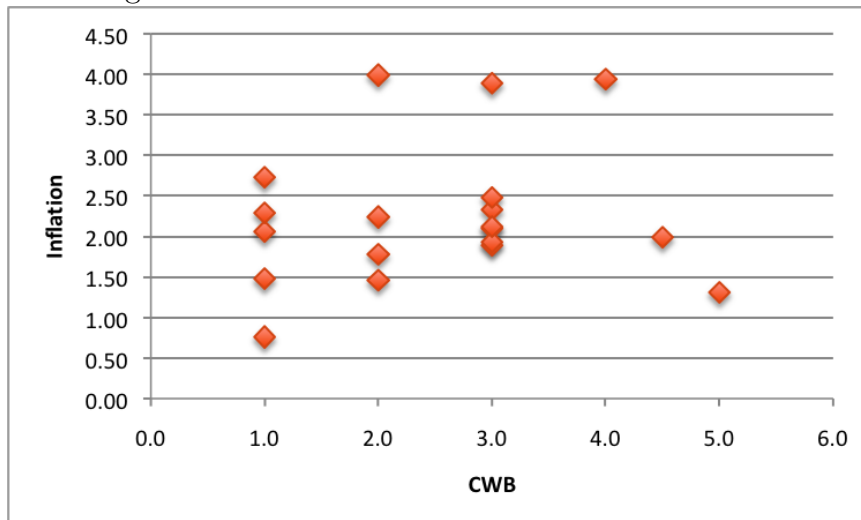Figure 5: CBI and inflation in 19 countries 1995.

Figure 6: CWB and inflation in 19 countries 1995.

to see any clear tendency in the CWB data for the same period (Figure 3). Note that, because the CWB index only takes values in .5 increments, graphical representations such as figures 4, 6 and 8 may be slightly harder to interpret.

The evident negative relationship between CBI and inflation seems to disappear in the 1995 and 2000 cross-sections (figures 5 and 7). This may be somewhat surprising, and would to some degree be consistent with the observations of recent critical studies of CBI. However, if Japan is dropped from the 2000 sample (figure 8), the relationship becomes clearly negative. It is also harder to say something meaningful about the relationship between CWB and inflation during the two later time periods purely on the basis of an

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Figure 7: CBI and inflation in 19 countries 2000.

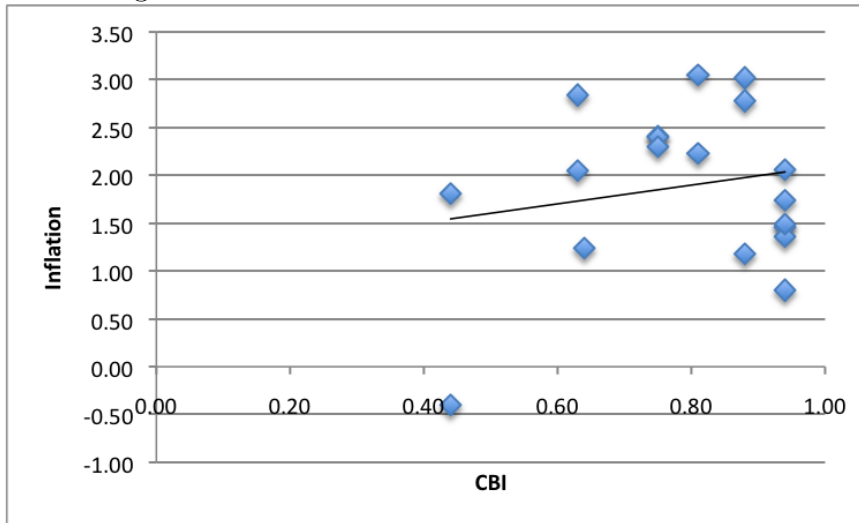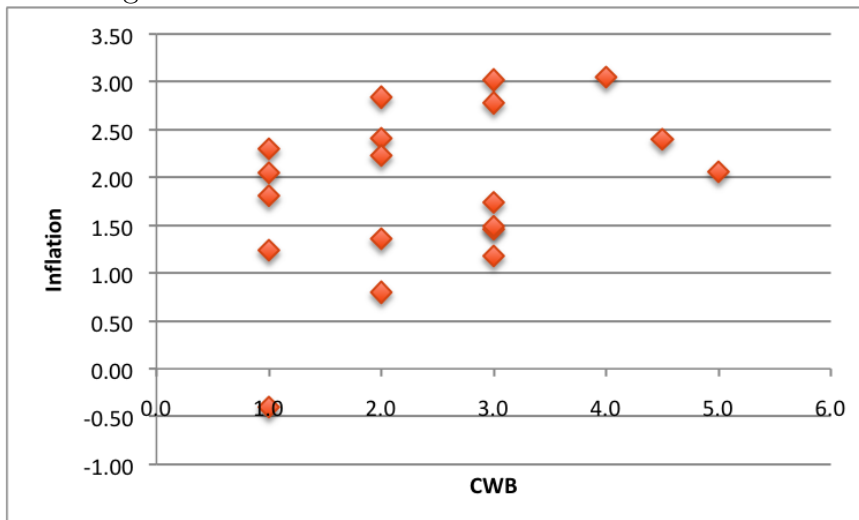Figure 8: CWB and inflation in 19 countries 2000.

examination of the scatter plots (perhaps due to the non-continous nature of the CWB measure). There seems to be a slight positive relationship in the 2000-period (figure 8). However, due to the negative-inflation outlier (Japan) and the fact that the observations are relatively evenly spread out, we should not draw too many conclusions on the basis of this observation.

4.3 Panel Data Regression Analysis

There is a number of possible ways to conduct a statistical assessment with the present data set. To run a simple pooled-OLS regression analysis would not be appropriate; the cross-sectional units (i.e. the countries) are likely to have different intercepts.[22] This leaves us with the option of either a *fixed* or *random* effects model. The fact that the panel data set comprises a relatively small set of units (19 to be precise) speaks in favor of using a fixed effects estimator (see for example Greene, 2002, pp. 291-295). However, a Hausman-test for consistency of the random effects (GLS) estimator yields a p-value of ≈ 0.49, meaning that we cannot reject that the GLS estimates are consistent. I therefore choose to rely on a random effects panel data regression analysis. Consider two alternative model specifications:

$$infl = \beta_1 + CBI\beta_2 + CWB\beta_3 + sq\_CWB\beta_4 + \epsilon. \tag{19}$$

$$infl = \beta_1 + CBI\beta_2 + CWB\beta_3 + sq\_CWB\beta_4 + dt\_1\gamma_1 + dt\_1\gamma_2 + \epsilon. \tag{20}$$

In (19) and (20), CBI and CWB represents the two variables we are interested in, and the β's are their respective coefficients. The variable sq_CWB is simply the square of the CWB variable. It is included in order to test for the possibility of a hump-shaped relationship between CWB and inflation (simlar to the results of Cukierman & Lippi, 1999). The variables dt_1 and dt_2 in (20) are the time-dummies for 1995 and 2000 respectively (1990 serves as base year).

4.4 Results

Table 2 shows the results from running a random effects regression analysis with the model specification given by (19). A Husman-test for consistency of the estimates yields a p-value ≈ 0.49, which means that we cannot reject the null-hypothesis that the estimates

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[22] An F-test for differing group intercepts yields a p-value ≈ 0.032

are consistent. The coefficient of CBI has a negative sign, which is consistent with most theoretical results discussed above. A low p-value (≈ 0) also indicates that the effect is statistically significant. The coefficient of CWB has a positive sign in this model, which could suggest that the inflation-aversion effect discussed in section 3 dominates the uncertainty effect. However, sq_CWB has a negative sign, which indicates a hump-shaped relationship between CWB and inflation. This is indeed an interesting finding. All explanatory variables are significant at the 5%-level.

Table 3 shows the results from running a regression using two time-dummy variables in addition to the variables included in the previous regression. A Husman-test for consistency of the estimates yields a p-value ≈ 0.17. The coefficients of the explanatory variables CBI, CWB and sq_CWB have the same signs as with specification (19). The hump-shaped relationship implied by the signs of the coefficients for CWB and sq_CWB is therefore still present. However, when the dummy variables are included, the effect of CWB and sq_CWB can no longer be regarded as significant (nontheless, they are not far from being significant at the 10%-level). Note that the effect of the time-dummies dt_2 and dt_3 is very significant.

Due to the limited availability of data, we should indeed be careful when drawing conclusions based on this small empirical investigation. Ideally, we would like to include more countries as well as a larger number of time periods. The quality of the data can also be questioned. The disagreement about the different CBI-indices' appropriateness suggests a need for caution when linking the empirical results to the theoretical predictions. Nevertheless, the results support the notion that central bank independence is associated with lower inflation. Particularly interesting, the results also suggest a hump-shaped relation between CWB and inflation. However, due to the low significance of this effect when time-dummies are included, it is hard to draw any definitive conclusions based on this empirical study.

Table 2: Random effects panel data regression using 57 observations

Variable	Cofficient	StdError	T-Stat	P-Value
const	2.68681	1.24428	2.159	0.03537
CBI	-4.07699	0.878123	-4.643	0.00002
CWB	2.19275	0.953585	2.299	0.02545
sq_CWB	-0.363013	0.172701	-2.102	0.04032

Table 3: Random effects panel data regression with time-dummies using 57 observations

Variable	Cofficient	StdError	T-Stat	P-Value
const	3.66592	1.24478	2.945	0.00485
CBI	-1.65728	0.944008	-1.756	0.08516
CWB	1.46320	0.955834	1.531	0.13200
sq_CWB	-0.273035	0.172491	-1.583	0.11963
dt_2	-1.85599	0.369389	-5.024	<0.00001
dt_3	-2.04393	0.472391	-4.327	0.00007

5 Summary and Concluding Remarks

The theoretical part of this thesis considered a repeated monetary policy game. Initially, we saw how a one-shot game resulted in a non-cooperative Nash equilibrium with excessive inflation. Then we considered a repeated game, and showed how the non-cooperative equilibrium of the repeated game may be overcome by the use of trigger strategies. There are without doubt some problems associated with the game-theoretical approach to monetary policy. As discussed in this paper, one of these problems, the coordination problem, can be overcome by assuming centralized wage bargaining.

In the theoretical analysis of the repeated game, the degree of centralized wage bargaining turned out to cause two opposing effects on the rate of inflation. First, there is the inflation-aversion effect that stems from the change in inflation-aversion which follows a change in the size o the unions. This means that an increase in CWB may lead to higher inflation. The opposing effect came from the existence of non-unioninized wage-bargainers with adaptive expectations. Assuming that some portion of the private sector holds adaptive expectations showed that increased CWB may also lead to lower inflation. This creates the possibility of a hump-shaped relationship between CWB and inflation.

In the empirical part of this paper, the existence of such a relationship was tested. Data from 19 OECD countries was analyzed, with they use of a random effects panel data regression analysis. The results provided support for the standard view that increased CBI has a negative effect on inflation rates. Moreover, the results also supported the notion of a Calmfors-Driffil relation between CWB and inflation. The significance of the latter was, however, not overwhelming; when time-dummies were included, CWB was only near significant. It shall be noted that the quality and availability of data imposes some constraints on to what extent we can draw any fruitful conclusions on the basis of this brief empirical study.

The main finding of this paper is that the two opposing effects of CWB in the monetary policy game could be viewed consistent with the result of Cukierman & Lippi (1999) and Lippi (2002). This provides an interesting alternative explanation to the phenomenon manifested in empirical results. Albeit its many weaknesses, the game-theoretical approach to monetary policy can be regarded as a helpful tool for explaining differences in inflation rates over time and across countries. A suggested avenue for future studies would be to further integrate game theory in studies of the interplay between monetary policy arrangements and labor market institutions. Another priority is to develop and refine the indices for CBI and CWB. The purpose with this should be to be able to perform broader empirical studies with more countries over a longer period of time.

This leaves us with the question how we can explain the moderation of global inflation rates during recent years. Recent studies critical to the beneficial effects of CBI may have a point in that there have been too much focus on one single variable when explaining lowering inflation rates and that we should broaden our focus. However, the present study have provided some support for the notion that increased CBI in fact lowers inflation rates. Furthermore, the effect of CWB on inflation would suggest that recent critical studies may have underestimated the positive effect of CBI on price stability. If there has been a general decrease in inflation rates, both for countries that have moved towards more CBI and countries that have not, we may gain many valuable insights by examining the pattern of change in CWB.

A   Mathematical Appendix

A.1   Proof of Lemma 1

Lemma 1. *If the private sector punishes non-cooperative strategies with an infinitely long punishment period (such that $\tau = \infty$), then the minimum sustainable inflation rate is $\pi^{min} = \alpha(1 - 2\delta_c)$*

Proof. Using (11), (12), (14), and the fact that $\sum_{t=0}^{\infty}(\delta_c)(-\frac{\alpha^2}{2}) = \lim_{X \to +\infty} -(\frac{\alpha^2}{2})\frac{1-\delta_c^X}{1-\delta_c} = -(\frac{\alpha^2}{2})\frac{1}{1-\delta_c}$, condition (13) can be rewritten as

$$\alpha^2 \left(\frac{1}{2} - k\right) - \frac{\alpha^2}{2}\left(\frac{\delta_c}{1 - \delta_c}\right) \leq -\frac{(k\alpha)^2}{2}\left(\frac{1}{1 - \delta_c}\right).$$

Multiplying both sides by $\frac{2}{\alpha^2}$ we obtain

$$(1 - k) - \left(\frac{\delta_c}{1 - \delta_c}\right) \leq -k^2 \left(\frac{1}{1 - \delta_c}\right)$$

Multiplying by $(1 - \delta_c)$ yields

$$(1 - 2k)(1 - \delta_c) - \delta_c \leq -k^2 \Leftrightarrow \frac{1 - 2k + k^2}{2 - 2k} \leq \delta_c \Leftrightarrow$$
$$\frac{1}{2}(1 - k) \leq \delta_c \Leftrightarrow k \geq 1 - 2\delta_c$$

It follows that $\hat{\pi} = k\alpha \Rightarrow \hat{\pi} \geq \alpha(1 - 2\delta_c)$. Thus the minimum sustainable inflation rate is $\pi^{min} = \alpha(1 - 2\delta_c)$. $\qquad \square$

A.2   Proof of Lemma 2

Lemma 2. *If the private sector punishes non-cooperative strategies with one single punishment period (such that $\tau = 1$), then the minimum sustainable inflation rate is $\pi^{min} = \alpha\left(\frac{1-\delta_c}{1+\delta_c}\right)$*

Proof. Similarly as in the proof of Lemma 1, by using (11), (12), (15), we can rewrite condition (13) as

$$\alpha^2 \left(\frac{1}{2} - k \right) - \frac{\alpha^2}{2}(\delta_c) - \frac{(k\alpha)^2}{2} \frac{(\delta_c)^2}{1 - \delta_c} \leq -\frac{(k\alpha)^2}{2} \left(\frac{1}{1 - \delta_c} \right).$$

Multiplying each side with $\frac{2}{\alpha^2}$ yields:

$$(1 - k) - \delta_c - k^2 \left(\frac{\delta_c^2}{1 - \delta_c} \right) \leq -k^2 \left(\frac{1}{1 - \delta_c} \right).$$

By multiplying this expression by $(1 - \delta_c)$ and rearranging the terms, we obtain

$$(1 - \delta_c^2)k + (2\delta_c - 2) \leq \delta_c^2 + 2 - 1 \Leftrightarrow k(-\delta_c^2 + 2\delta_c - 1) \leq \delta_c^2 + 2\delta_c - 1 \Leftrightarrow$$
$$k \geq \frac{\delta_c^2 + 2\delta_c - 1}{-\delta_c^2 + 2\delta_c - 1} \Leftrightarrow k \geq \frac{1 - \delta_c}{1 + \delta_c}$$

It follows that $\hat{\pi} = k\alpha \Rightarrow \hat{\pi} \geq \alpha \left(\frac{1-\delta_c}{1+\delta_c} \right)$. Thus the minimum sustainable inflation rate is $\pi^{min} = \alpha \left(\frac{1-\delta_c}{1+\delta_c} \right)$. $\qquad \square$

B   Lists of Figures and Tables

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