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The Institutional Design of Central Banks

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An abstract of
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Abstract

The Institutional Design of Central Banks
By Caitlin T. Ainsley

In three essays, this dissertation analyzes how the institutional design of central banks affects policymaking strategies and economic performance. Each essay focuses on a different aspect of monetary institutions and considers both theoretically and empirically its implications for monetary policymaking. Of central interest throughout is the role played by policymaking uncertainty and how it factors into the decision-making strategies of governments, central banks, and private markets.

In the first essay, I consider how policymaking uncertainty affects central bank decision-making and, in turn, governments' central bank appointments. Uncertainty — and critically changes in uncertainty during the long terms of appointment which have become a landmark of central bank independence — can result in the appointment of central bankers likely to pursue excessively inflation tolerant strategies. I provide evidence of this relationship with a novel dataset collected from the central bank of Hungary.

The second essay explores how central bank voting transparency affects market expectations. I propose and test a theory which suggests individually attributing votes undermines both the accuracy of market expectations and central banks' ability to influence expectations with official announcements. Support for this claim is provided in an analysis of data from the Central Bank of Brazil, where since the release of attributed voting records, market expectations are less accurate and react less to official central bank communication.

Finally, in the third essay I examine how the definition of inflation targets affects decision-making and propose they are a potential solution to the problem of policy drift associated with delegation to independent agencies. When an inflation target is defined according to a target zone rather than target rate, I argue the degree of policy drift and deviation from target should be smaller. I demonstrate evidence of this result in a sample of six inflation targeting central banks, including the Czech Republic, Hungary, Poland, South Korea, Sweden, and the United Kingdom.

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Central Bank Appointments and Decision-Making Under Uncertainty

Abstract

Monetary delegation to independent central banks is the institutional standard for responsible monetary policymaking. Governments overcome their own high inflation biases by delegating policymaking discretion to central bankers with political independence and long terms of appointment. With a formal model of central bank appointments and monetary policymaking, I provide results that suggest this canonical result hinges on widespread, empirically false assumptions about the nature of central bank preferences and the economic environment in which monetary policy is conducted. During periods of heightened monetary uncertainty, central bank independence is a less effective institutional solution to achieving inflation goals than extant theory suggests. Under realistic economic conditions, monetary delegation can result in economic outcomes even worse than those we would expect if the government had maintained discretion. I test several predictions from the model drawing on voting data from the central bank of Hungary, the Magyar Nemzeti Bank (MNB), from 2005-2014.

1.1 Introduction

The delegation of policymaking authority is a political phenomenon that spans multiple disciplines and nearly all subfields of political science. With the rise of the administrative presidency (Lewis 2008) and growing role played by international organizations (Nielson and Tierney 2003), questions of whom to grant what authority have received substantial scholarly attention. While our theories cover an impressive scope of complicated institutional contexts, they often rely on a common set of stylized first principles about the behavior of individuals and the policymaking environments in which they operate (Bendor and Meirowitz 2004). Though these assumptions may be empirically valid or innocuous in some applications, they are not always. In this paper, I examine how a pair of assumptions about the shape of preferences and uncertainty facing policymakers can critically change our expectations over the effects of central bank independence.

Based on theoretical arguments (Adolph 2013, Rogoff 1985, Walsh 1995) and extensive empirical evidence (Alesina 1988, Alesina and Summers 1993), scholars have concluded low-inflation and macroeconomic stability are best achieved by delegating monetary policy authority to an independent central bank (Forder 2005). By tying the government's hands and insulating monetary policy from political pressure, CBI prevents output stimulating, high-inflation policies believed detrimental to sustainable economic growth. I revisit this conclusion and present theoretical and empirical results that cast doubt on the unqualified benefits of monetary delegation to an independent central bank. Not only can the institution fail to mitigate the high-inflation outcomes, but CBI can in practice lead to even higher levels of inflation than expected in its absence. A central result in this article — that increased monetary uncertainty facing the central bank induces the government to make more inflation-seeking appointments — implies monetary delegation and CBI can inhibit recovery from periods of high-inflation as well as prolong instances of persistent deflation. Simply put, under

plausible conditions the institution can exacerbate the exact problems it was designed to cure.

I build on the existing literature on monetary delegation and policymaking by focusing on the inherently political decisions elected officials face when staffing monetary policymaking committees. Extant literature provides a strong theoretical and empirical foundation for our understanding of how and why governments establish (Bernhard, Broz and Clark 2002, Bodea 2010) and preserve (Bodea and Hicks 2015, Mukherjee and Singer 2008, Stasavage 2003) central bank independence, but relatively less attention has been given to governments' retained influence through the appointment process.[1] In response to the economics literature that largely champions the unqualified advantages monetary delegation and CBI, this line of political science research highlights how in practice the constellation of supporting political institutions can mitigate the theoretical benefits of CBI on economic performance. In this article I demonstrate how even in an optimal institutional environment in which a government can credibly commit to sustaining the central banks' independence, allowing politically motivated elected officials the influence to make long-term appointments to the central bank can undermine the perceived benefits of monetary delegation. Further, not only can the political nature of the appointment process mitigate the improved performance attributed to central bank independence, it can exacerbate precisely the problems it sought to cure.

To develop this argument I relax two widespread restrictive assumptions common in both general theories of delegation as well as the literature on central bank appointments and monetary policymaking. First, I relax the assumption that the central bank can perfectly determine the inflation rate through its monetary policy instruments. This assumption is inconsistent with a cursory review of historical inflation trends, anecdotal statements from central bankers,[2] and the increasing practice

[1] For exceptions, see Chang (2001), Adolph (2013), and Schnakenberg and Turner (2014).

[2] Both Alan Greenspan and Alan Blinder of the Federal Reserve have referred to uncertainty as

of central banks publishing assessments of uncertainty over future inflation (Elder 2005). As I demonstrate, incorporating the central bank's "monetary uncertainty" — i.e., their uncertainty over future inflation rates — has a critical second order effect on government appointment strategies. Second, I relax the assumption that central bankers have perfectly symmetric preferences around their inflation target. Instead, I allow for an inflation-averse, conservative central banker to find inflation outcomes above their target more costly than equidistant deviations below their target, and vice versa. While the direction and degree of this asymmetry is ultimately an empirical question for which I will provide additional evidence, there is already both qualitative (Blinder 1997) and quantitative (Ruge-Murcia 2002, 2003) evidence inconsistent with perfectly symmetric central bank preferences. Taken together, relaxing these assumptions generates predictions about monetary policymaking and central bank appointments that are at odds with existing theory and have important substantive implications. Not only can monetary delegation to a politically independent central bank fail to provide a solution to the problem of undesirably high inflation, but under plausible conditions, inflation outcomes are even higher under delegated monetary authority.

I evaluate the theory's predictions by drawing on data from the central bank of Hungary, the Magyar Nemzeti Bank (MNB), from 2005-2014. I provide the first quantitative empirical support that individual central banker preferences are asymmetric and sensitive to uncertainty.[3] In a sample of twenty-five central bankers spanning almost a decade, none demonstrate voting behavior consistent with symmetric preferences. Additionally, I test the model's prediction that heightened monetary uncertainty leads to more inflation-seeking appointments. The results are highly supportive of the theoretical prediction: controlling for the appointing government, more

"the defining feature" of monetary policymaking (Blinder 1999, Greenspan 2004).

[3]Existing quantitative work has demonstrated that central bank reactions functions are *in aggregate* asymmetric about an inflation target (Ruge-Murcia 2002, 2003), but not directly shown evidence of individual central bankers possessing asymmetric preferences.

inflation-seeking central bankers are appointed during times of increased monetary uncertainty.

The article is organized as follows. The next section describes the model, borrowing heavily in structure from existing theory while highlighting the aforementioned departures. The third section presents the equilibria and provides a discussion of the model's substantive implications. In the fourth section, I present a novel measure of monetary uncertainty followed by a test the model's empirical implications. The fifth and final section concludes.

1.2 Theory of Monetary Delegation

Existing models of monetary delegation and central bank appointments highlight the government's inability to commit itself to low-inflation monetary policy. Governments that maintain policy discretion cannot resist the incentive to stimulate economic output with loose monetary policies. To moderate this inevitable high-inflation bias, the government ties its hands by appointing individuals less concerned with economic output to an independent central bank (Adolph 2013, Rogoff 1985). Delegating monetary authority to individuals who assign disproportionate importance to pursuing low-inflation outcomes provides a commitment mechanism.[4]

Since the seminal theoretical (Barro and Gordon 1983, Rogoff 1985, Walsh 1995) and empirical (Alesina 1988, Alesina and Summers 1993) work on the inflation reducing impact of central bank independence, the literature on monetary politics has largely taken this result as given and focused on the constellation of political insti-

[4]Consistent with the extant literature on central bank appointments (see Rogoff (1985), Chang (2001), Adolph (2013)), I treat central bank independence exogenously. Thus, the focus here is not on the initial delegation of monetary policymaking authority or design of the institution, but rather how a government optimally appoints individuals to a previously established independent central bank. Alternative motivations for delegation — such as an effort to lock-in policies for future, potentially oppositional, governments (Goodman 1991) — exist, but do not change the underlying tensions explored here. For a more detailed discussion of this theoretical assumption and modeling choice, see Keefer and Stasavage (2003).

tutions supporting continued independence of the central bank. For example, both (Moser 1999) and Keefer and Stasavage (2003) consider the credibility of the government's decision to delegate and how the presence of checks and balances and veto players, respectively, serve to safeguard the independence of the central bank and the presupposed desirable inflation outcomes such an institution entails. Bodea and Hicks (2015) make the argument that central bank independence can be preserved if states face pressure to maintain competitive for foreign direct investment and sovereign borrowing. While the theory presented in this article abstracts away from any broader political institutional context, the conclusions drawn from this extant literature remain relevant. The results that follow suggest even in the most ideal political environment where monetary delegation to an independent central bank ought to unambiguously improve inflation performance according to existing theories, the delegation process coupled with an uncertain economic environment can still undermine this central result. That is, even in the presence of multiple veto players (Keefer and Stasavage 2003), high quality domestic institutions (Hielscher and Markwardt 2012), and demand for global finance (Bodea 2013), credible monetary delegation to an independent central bank can have a pernicious effect on monetary policymaking and inflation outcomes.

In this paper, I build on the findings from this extensive literature on the institutional design and efficacy of central bank independence by incorporating formally the potential role played by two defining features of the monetary policymaking and central bank appointment processes. Extant theories of central bank appointments reduce the government's decision to the explicit choice of a utility-maximizing level of inflation, thereby assuming the appointed central bank can perfectly determine inflation outcomes (Adolph 2013, Barro and Gordon 1983, Rogoff 1985, Schnakenberg and Turner 2014). Speaking on this class of models, Alan Blinder noted that "to a theorist, it may seem innocuous to pretend that monetary policy can control either u

[unemployment/output] or π [inflation] perfectly on a period-by-period basis. But to a practical central banker, it seems downright silly, for it assumes away most of the uncertainties that define everyday life" (Blinder 1997). In the model here, the effect of monetary uncertainty is twofold. First, it directly impacts central bankers' policy choices. Second, though relatedly, a government's appointment strategy is a function of the future uncertainty which it believes appointees will face.

In addition to introducing monetary uncertainty to the canonical models, I relax the assumption of perfectly symmetric central bank preferences over inflation and model a single-mandate central bank interested only in inflation outcomes.[5] Following the presentation of the equilibrium, I offer a discussion of the results that shows these simplifying assumptions are not innocuous.

Government Preferences

Consistent with extant literature, a government has preferences over the inflation rate (π) and economic output (y). These preferences are formalized by an additive quadratic loss function:

$$U_g(\pi, y) = -(\pi - \pi_g)^2 - \phi\left(y - (y^* + y_g)\right)^2. \tag{1.1}$$

The first term reflects the losses the government faces for deviations away from their most-preferred inflation rate (π_g), while the second term captures the government's economic output goals ($y^* + y_g$) and the relative importance assigned to achieving them ($\phi > 0$). The preferred rate of output is $y^* + y_g$, where y^* represents the natural rate of output and y_g is a positive constant corresponding to the amount of output above the natural rate the government prefers.[6] Without loss of generality,

[5] By forcing the central bank to derive no utility from output considerations, this represents the hardest case to demonstrate monetary delegation need not be strictly inflation-reducing.

[6] This specification of government preferences is common throughout the literature. For examples, see Bodea (2010), Clark and Hallerberg (2000), Copelovitch and Singer (2008), Mukherjee and Singer

the natural rate of output can be normalized to zero, $y^* = 0$.

Economy

The economy in the model is described by a Philips curve, where economic output (y) is a function of the natural rate (y^*) and the difference between the expected (π_e) and actual (π) inflation rates, such that:

$$y = y^* + (\pi - \pi_e) - u, \tag{1.2}$$

where $u \sim N(0, \sigma_u^2)$ represents a stochastic shock to output. Formalizing the economy in this way captures the explicit trade-off the government faces between its inflation and output objectives: realized economic output (y) is increasing in the amount the inflation rate (π) exceeds the private sectors (π_e). For similar specifications, see Bodea (2010), Clark and Hallerberg (2000), Mukherjee and Singer (2008), Stasavage (2003). In practice, this corresponds to a world in which wage-setters and employees enter long-term wage contracts that extend beyond the period in which monetary policy decisions are made. While workers want to write contracts that cover the future price levels, the government can attempt to stimulate output by setting the inflation rate above the expected level that informed long-term contracts.

This trade-off between two competing objectives creates what the existing literature highlights as a defining feature of monetary politics. Governments with preferences over inflation and output find themselves unable to commit to forgoing potential output gains in favor of low-inflation that promotes long-run economic growth. We can see this explicitly by solving for the equilibrium inflation outcome if the government were to maintain discretion over monetary policy rather than delegating to a central bank. As in the canonical models, assume the private sector sets its inflation

(2008), Stasavage (2003).

expectations π_e without observation of the stochastic shock u. The government then observes both the fixed π_e and the stochastic shock and chooses an inflation rate, π. In the absence of delegation to an independent central bank, the inflation outcome in equilibrium is given by the following result. All proofs are provided in the appendix.

Lemma 1. *When the government maintains discretion over monetary policy, the equilibrium inflation outcome is:*

$$\pi^*_{\neg delegate} = \pi_g + \phi y_g + \frac{\phi u}{1+\phi}.$$

This result provides the government's motivation for monetary delegation to an independent central bank.[7] Inflation outcomes will in expectation exceed the government's ideal inflation rate due to the positive trade-off between inflation and output and the government's preference for increased economic output. The potential gains from increased economic output lead the government to implement expansionary monetary policies that drive inflation rates above their desired level, π_g. In contrast, by delegating to a central banker who weighs output considerations *less* than the government — i.e., $\phi' < \phi$ — inflation outcomes will in expectation be closer to the government's target policy. Taking this logic to its limit, it follows that a single-mandate central bank who derives no utility from output considerations — i.e., $\phi' = 0$ — would produce inflation outcomes in expectation *at* the government's target rate (π_g).

[7]For the entirety of the paper, the "government" refers to the political actor charged with appointing individuals to serve on the central bank. In a survey of 71 central banks conducted by Cukierman, Webb and Neyapti (1992), monetary policy committee members are appointed by some combination of political actors in the executive and/or legislative branches in all but 4 countries. Thus, while control over the appointment process is one component of central bank independence, the tension captured in this model results from the presence of government appointments to the bank, a nearly ubiquitous feature of independent central banks.

Central Bank Preferences

This is an important result. Monetary delegation to a "conservative" inflation-fighting central bank provides an institutional solution to achieving monetary stability and low-inflation outcomes considered necessary for stable economic growth. However, this argument relies on two assumptions. First, monetary uncertainty is of no consequence in existing theories of central bank decision-making and appointments. This continues to be true despite the mounting anecdotal accounts by central bankers themselves (Blinder 1999, Greenspan 2004) in addition to the growing practice at central banks to publish alongside their policy decisions and forecasts explicit statements of their uncertainty over future inflation rates. For example, the MNB Inflation Report includes a "fan chart," which indicates the central bank's uncertainty over future inflation rates around their central projection (see Figure 1.3). To capture this, I assume that the interest rate decision imperfectly determines the inflation rate.

To capture central bankers' sensitivity to this monetary uncertainty, I model central bank preferences with a linear-exponential (linex) loss function (Varian 1974, Zellner 1986). Defined by two parameters, the linex function allows for asymmetric preferences over inflation outcomes. The first parameter is an inflation ideal point (π_c). In addition to the ideal point, the function incorporates a shape parameter (α_c), which determines the direction and magnitude of asymmetry in an actor's utility function. The central bank's utility function is given by,

$$U_c(\pi) = -\frac{e^{\alpha_c(\pi-\pi_c)} - \alpha_c(\pi - \pi_c) - 1}{\alpha_c^2}. \tag{1.3}$$

The mechanics of this function are demonstrated in Figure 1.1. When a central banker has an α_c shape parameter of nearly zero ($\alpha_c \to 0$), the utility function approximates the quadratic with symmetric preferences about an ideal point. For central bankers with positive shape parameters ($\alpha_c > 0$), utility declines more sharply

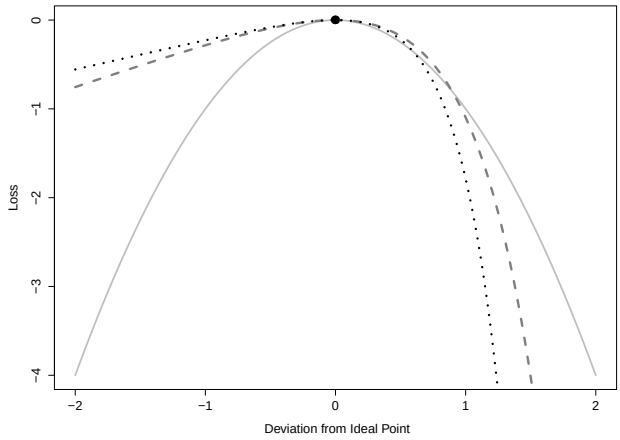

Figure 1.1: Linear Exponential Utility Function for Central Bank Preferences.
The solid line corresponds to a linex utility function with $\alpha_c \approx 0$, or approximately symmetric losses. The dashed and dotted line correspond to $\alpha_c = 2$ and $\alpha_c = 3$, respectively. For $\alpha_c > 0$ ($\alpha_c < 0$), deviations above an individual's ideal point are considered more (less) costly than those below.

with inflation exceeds their ideal rate than when it falls below it. As the shape parameter increases in magnitude, the degree of this asymmetry becomes stronger, meaning an even steeper drop in utility above their target. Figure 1.1 shows this for increasingly positive values of α_c, moving from the dashed to the dotted line. The opposite effect holds for negative shape parameters ($\alpha_c < 0$).

While this generalization of central bank preferences is consistent with the aforementioned qualitative (Blinder 1997) and quantitative (Ruge-Murcia 2002, 2003, Surico 2003, 2007, Sweidan 2008) work on central bank decision-making, it departs from a common conceptualization of central bank conservatism. Existing research distinguishes between "conservative" and "liberal" central bankers based on their preferred level of inflation, i.e. the ideal point. However, when the assumption of perfectly symmetric preferences is relaxed, variation in conservatism can also be thought of as the shape of the utility function for bankers with the same preferred inflation rate. That is, a *liberal* central banker, as compared to a *conservative* central banker, is one who is comparatively tolerant of outcomes above a mutually agreed upon target.

Which of these concepts of central bank conservatism better describe actors' preferences is ultimately an empirical question. In the theoretical model, I collapse these two dimensions of central bank conservatism into a substantively motivated pairing of ideal points and shape parameters. Thus, an inflation-tolerant, *liberal* central banker is one with (a) a higher inflation ideal point and, that (b) is, compared to a conservative banker, more tolerant of inflation outcomes above this target rate. Conversely, a *conservative* central banker has a lower inflation ideal point and finds inflation outcomes above this rate more costly than does their more liberal counterpart. In addition to keeping to a single dimension of conservatism, this modeling choice is also appealing because it does not require the government to have any more information about hypothetical appointees than previously assumed. However, the results hold (see Appendix) when the parameters are allowed to move independently.

1.2.1 Structure of the Model

The timing of the game is as follows. Nature moves first, drawing a level of future uncertainty unknown to all three actors at this point. Uncertainty, defined more precisely shortly, captures how confident the central bank is concerning future inflation rates after they make a monetary policy decision. The government forms beliefs about this value and chooses a central banker conditional on these beliefs. Uncertainty is then revealed to the private sector and appointed central banker. Having observed the appointed central banker, the private sector forms rational expectations over inflation outcomes and writes wage contracts conditional on expected inflation. Finally, the central bank chooses an inflation rate and outcomes are realized.

Appointment Stage. Not knowing the degree of uncertainty (σ_ε) its central bank appointee will face, the government first forms beliefs about this value ($B(\sigma_\varepsilon) = \hat{\sigma}_\varepsilon$). This is the second-order effect of introducing monetary uncertainty into the central bank's decision calculus; because monetary uncertainty affects policy choices, a gov-

ernment's optimal appointment is conditional on the environment in which it believes an appointee will operate. While the government might be able to assess reasonably well the instantaneous monetary uncertainty facing the central bank and appointees given their access to the bank's published reports and forecasts, the long terms of appointment to central banks coupled with observed variability in uncertainty nearly ensure deviations from their expectations over an appointees tenure.

The appointment of a central banker is modeled as a choice of central bank conservatism ω_c, where high (low) values correspond to liberal (conservative) central bankers. Two functions map this single choice variable ω_c on to a pairing of a central banker's ideal point and shape parameter, (π_c, α_c). The ideal point (π_c) is given by a function $f : \mathbb{R}_+ \to \mathbb{R}_+$, which is a direct mapping to an inflation ideal point: $f(\omega_c) = \pi_c$. Therefore, to reflect the intuition given above concerning the relationship between central bankers' ideal points and shape parameters, ω_c and α_c are negatively related. I define the function $g : \mathbb{R}_+ \to \mathbb{R}$ such that $g(\omega_c) = b - \omega_c$, where b corresponds to the ideal point of the central banker with symmetric preferences $(\alpha_c = 0)$.[8]

Private Sector Expectations. Following the government's appointment, the uncertainty facing the central bank in a given period is revealed. This information asymmetry between the government and other two actors captures the duration of central bankers' tenure and uncertainty about future economic conditions at the time of appointment. The private sector sets its inflation expectation, π_e, conditional on the observed uncertainty (σ_ε) and preferences of the central bank (π_c and α_c).[9]

Central Bank Policy-Making. With inflation expectations fixed, the central bank manipulates the inflation outcome through its choice of interest rate, i.[10] A key

[8] See Appendix for derivation when government chooses parameters independently.

[9] While this operationalization is common in the literature (Keefer and Stasavage 2003, Nobay and Peel 2003, Ruge-Murcia 2002), the results are not dependent on the existence of an information asymmetry or a private sector with perfect information.

[10] By effectively reducing the central bank to a single decision-maker appointed by the government, I follow the existing literature on central bank appointments (Adolph 2013, Chang 2001, 2003, Rogoff 1985, Schnakenberg and Turner 2014).

assumption in the model is the central bank cannot perfectly determine inflation outcomes with its policy choices. Thus, inflation outcomes are modeled as the sum of the policy choice (i) and an economic shock $\varepsilon \sim N(0, \sigma_\varepsilon^2)$: $\pi = h(i) + \varepsilon$, where $h(\cdot)$ is a monotonic, continuous function mapping an interest rate i onto an inflation outcome π. The variance of the distribution from which the economic shock is drawn reflects the level of monetary uncertainty facing central bankers. The model is intentionally agnostic about the source of uncertainty, allowing this term to encapsulate everything from risk associated with instrument and forecast model uncertainty to truly exogenous shocks from external economic forces (Greenspan 2004). When this variance is high (large σ_ε), the central bank is more uncertain about future inflation as the likelihood of drawing a large economic shock is greater. Conversely, when the variance is small, central bankers face less monetary uncertainty as they are more confident in how any given interest rate translates into an inflation outcome.

1.2.2 Equilibrium

I now present the solution to the model in which the government delegates monetary policymaking authority to an independent central bank. Working backwards, I first consider the equilibrium inflation rate given the central banker's policy choice. After laying out the critical properties of inflation outcomes and central bank decision-making, I present the equilibrium appointment by the government. The expected inflation outcome is given by the following result.

Lemma 2. *In equilibrium, the expected inflation outcome for a central banker with preferences π_c and α_c is:*

$$\pi^*(\sigma_\varepsilon; \pi_c, \alpha_c) = \pi_c - \frac{\alpha_c}{2}\sigma_\varepsilon. \tag{1.4}$$

When monetary uncertainty is introduced and the central bank is allowed to pos-

sess asymmetric preferences, the expected inflation outcome is no longer necessarily at the ideal point of the central bank.[11] With this lemma in hand, we can state the first main result.

Proposition 1. ***Monetary Policymaking and Uncertainty.*** *Inflation outcomes deviate in expectation from the central banker's targeted rate when faced with uncertainty. The magnitude of this deviation ($\pi^* - \pi_c$) is increasing in the amount of uncertainty (σ_ε) and central bank aversion to over-shooting the target (α_c).*

Consider a conservative central banker who finds inflation rates above their target comparably costly, i.e. they have a large α_c shape parameter. Because overshooting the inflation ideal point (π_c) is more costly, the presence of uncertainty induces the banker to hedge their policy choices below their target, guarding against a potential adverse economic shock. Thus, we expect such an inflation-averse central banker to systematically choose policies that produce a low-inflation bias relative to their target in order to provide insurance against the possibility of drawing a costly positive shock. Conversely, for a less inflation-averse central banker — i.e., one with a smaller α_c, thus a shallower utility drop above their most-preferred rate — outcomes will in expectation still deviate from their most-preferred rate as long as $\alpha_c \neq 0$, but by a smaller amount for any given level of uncertainty. Facing a less severe cost to drawing a large positive shock, there is less incentive for a comparatively inflation-tolerant central banker to hedge their policy choices below their target.

We can now consider the government's appointment strategy. Given the expected inflation outcome in Equation 1.4, the government's equilibrium appointment is given by the following.

[11] The result central to previous theoretical work that inflation outcomes are in expectation at the ideal point of the central bank ($\pi^* = \pi_c$) is contained as a special case in this model. In the absence of uncertainty, the central bank perfectly determines inflation outcomes with their choice of interest rate. Formally, this amounts to the case in which $\varepsilon \sim N(0, 0)$, or $\sigma_\varepsilon^2 = 0$. By Lemma 2, in this case $\pi^* = \pi_c$. Additionally, recall a central banker with shape parameter of nearly zero ($\alpha_c \approx 0$) has approximately quadratic, symmetric preferences. In this case, the expected inflation rate again equals the most-preferred inflation rate of the central banker: $\pi^* = \pi_c$.

Lemma 3. *In equilibrium, the government will appoint a central banker with preferences:*

$$\omega_c^*(\hat{\sigma}_\varepsilon; \pi_g) = \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2 + \hat{\sigma}_\varepsilon}. \tag{1.5}$$

Consistent with the existing literature, the government's equilibrium appointment strategy is in part a function of their own preferences over inflation (π_g). Recall higher values of ω_c correspond to more inflation-tolerant, liberal central bankers. Thus, inflation-tolerant governments with high inflation targets (π_g) are going to appoint more inflation-seeking central bankers, and vice versa. This is both logically what we expect to observe and consistent with the existing models of central bank appointments that highlight the partisan nature of central bank appointments (Adolph 2013, Chang 2001, 2003, Schnakenberg and Turner 2014).

Appointments and Uncertainty

In addition to recovering this result from the existing literature, the model presented here provides additional predictions concerning the appointment process. Monetary uncertainty, or the confidence the central bank has in predicted inflation outcomes, not only affects central bank decision-making (Proposition 1), but also has a second-order effect on the government's appointment strategies. Because monetary uncertainty affects policy outcomes, the government's decision calculus must take into account the environment in which its appointees will operate. After considering the implications of monetary uncertainty for the government's appointment strategy, I turn in the following section to the implications these results have for real economic outcomes.

I focus on the case in which the appointing government's ideal point is such that $0 < \pi_g \leq b$. In practice, this condition has two implications. First, the government's most-preferred inflation rate is non-negative. The implications of a government targeting negative inflation ($\pi_g < 0$), though difficult to rationalize substantively, are

noted in the Appendix. The second condition — that $b \geq \pi_g$ — speaks to a substantively motivated and testable restriction on the universe of hypothetical central bank appointees the government chooses among. In practice, this means for any given government inflation target, potential central bankers with that same target are more inflation-averse than the government.[12] Focusing on this case implies the following testable prediction.

Lemma 4. *When $\pi_g \leq b$, all central bank appointments have preferences such that $\alpha_c \geq 0$ in equilibrium.*

In the following section I provide direct empirical evidence that this is in fact the relevant case, but the implications of the alternative case are noted in the appendix.

I now turn to a central result of the model, considering the effect of expected monetary uncertainty on government appointment strategies.

Proposition 2. ***Government Appointments and Uncertainty.*** *When $0 < \pi_g \leq b$, increased expected uncertainty ($\hat{\sigma}_\varepsilon$) leads a government to appoint less conservative central bankers. Under lower expected economic uncertainty, the government will prefer to appoint more conservative central bankers.*

Consider the intuition behind this result. Aware of a central banker's preference to hedge its policy choices when faced with increased uncertainty, the government's appointment strategy depends in part on the expected economic climate in which the central banker will operate. When expecting an environment of nearly zero monetary uncertainty, the government wants to appoint a central banker with an ideal point close to their own because, by Proposition 1, the incentive for bankers to hedge against adverse shocks is marginalized under limited uncertainty. However, should monetary uncertainty increase, this induces this same central banker to hedge expected inflation

[12]Recall b corresponds to the ideal point of the central banker with symmetric preferences over their targeted inflation rate, or $\alpha_c \approx 0$. When $b \geq \pi_g$, a central banker with the same target as the government ($\pi_g = \pi_c$) is equally or more conservative in the sense that overshooting this target is considered equally or more costly than undershooting it.

outcomes below their ideal point. Because increased uncertainty drives down the expected inflation rate, the government prefers to appoint less inflation-averse central bankers when they expect higher monetary uncertainty. While it might seem logical that conservative appointments implementing cautious policy strategies would most appeal during times of heightened monetary uncertainty, the exact opposite arises in equilibrium.

The inverse of this relationship also holds. When governments expect relatively low levels of monetary uncertainty, they prefer to appoint comparatively inflation-fighting, conservative central bankers. Facing little uncertainty, central bankers are more confident about future inflation outcomes and thus the magnitude of hedging away from their target policy is marginalized. Because appointing such an inflation-averse central banker does not have the same costly low-inflation bias that results under high-uncertainty, the government appoints comparatively conservative central bankers when they expect an environment of low monetary uncertainty to prevail.

Taken together, these results suggest the incentive structure underlying the appointment process leads to the appointment of central bankers likely to exacerbate existing economic conditions. In the expectation of heightened monetary uncertainty characterized by large shocks to inflation, we ought to observe appointments that are relatively tolerant of a weaker currency. Further, this relationship is true for all types of governments, irrespective of their own economic preferences. That is, even a right-leaning monetary conservative would prefer to appoint less inflation averse central bankers during periods of monetary uncertainty than they would otherwise. Having established the impact of monetary uncertainty on central bank decision-making and the appointment process, I now turn to the implications these results have for inflation outcomes.

1.3 Theoretical Implications

Propositions 1 and 2 demonstrate that monetary uncertainty affects both policymaking at the central bank and the appointment process. However, if the government's assessment of uncertainty is correct ($\hat{\sigma}_\varepsilon = \sigma_\varepsilon$) and constant for the duration of an appointment's tenure, these results of course hold but have no effect on real outcomes. Recall that the government appoints a central banker who, when $\sigma_\varepsilon = \hat{\sigma}_\varepsilon$, will choose policies resulting in inflation outcomes in expectation at their target rate, π_g. Therefore, when the government's assessment of uncertainty is correct, inflation outcomes are identical ($\pi^* = \pi_g$) for a more inflation-tolerant appointment under periods of greater monetary uncertainty and a more inflation-averse appointment under periods of less monetary uncertainty.

That said, given the increasingly long term lengths at central banks so often deemed desirable by advocates of CBI, it is nearly impossible for a government to perfectly anticipate future climates their appointee will face. When monetary uncertainty directly affects policy choices, changes in the environment facing central bankers result in outcomes that deviate from the appointing government's policy goals in the following ways.

Proposition 3. ***Monetary Delegation Exacerbating Inflation Biases.*** *If the government overestimates monetary uncertainty at the time of an appointment ($\hat{\sigma}_\varepsilon > \sigma_\varepsilon$), monetary delegation can result in inflation outcomes with an even higher inflation bias than expected if the government maintained monetary policy discretion. If the government underestimates monetary uncertainty ($\hat{\sigma}_\varepsilon < \sigma_\varepsilon$), inflation outcomes are in expectation below the government's inflation target.*

Recall the intuition from Proposition 2 in which a government that expects high levels of uncertainty (i.e., large $\hat{\sigma}_\varepsilon$) prefers to appoint a less inflation-averse central banker. At the time of appointment (when $\hat{\sigma}_\varepsilon = \sigma_\varepsilon$), the government is able to

achieve its most-preferred inflation rate (π_g) in expectation by delegating monetary discretion. In Figure 1.2, this is reflected in the black point on the line, corresponding to an inflation outcome at the government's ideal point $\pi_g = 2$ when $\hat{\sigma}_\varepsilon - \sigma_\varepsilon = 0$. However, suppose during a relatively inflation-seeking central banker's tenure the economy begins to recover and stabilize, leaving less uncertainty among monetary policymakers (decreasing σ_ε). Because in the absence of such high uncertainty this central banker no longer hedges its policy choices as much as it was, inflation outcomes are in expectation strictly greater than the government's target. Further, under the following condition, monetary delegation and CBI can result in inflation outcomes higher than would have occurred in their absence.

Lemma 5. *When* $\frac{(b-\pi_g)(\hat{\sigma}_\varepsilon - \sigma_\varepsilon)}{2+\hat{\sigma}_\varepsilon} > \phi y_g$*, the expected inflation when monetary policy is delegated to an independent central bank is greater than if the government had maintained monetary policy discretion in the absence of delegation.*

Thus, depending on the magnitude of the difference between expected and realized uncertainty ($\hat{\sigma}_\varepsilon - \sigma_\varepsilon$) and the government's degree of high-inflation bias when it maintains discretion over monetary policy (ϕy_g), monetary delegation may result in even higher inflation outcomes than expected under government discretion. Therefore, these institutions can in theory exacerbate precisely the problem they sought to cure.

Exactly how likely is this to occur in practice? In Figure 1.2, I plot the relationship between expected inflation outcomes in equilibrium and the difference between expected and realized uncertainty.[13] The shaded area denotes the region in which inflation outcomes expected under monetary delegation exceed the high inflation bias expected when the government maintains policy discretion. In this region, central bankers that were optimal for the government at the time of appointment face an

[13]To identify an inflation level we might hypothetically observe the absence of delegation, the government's preference parameters are held fixed at $\pi_g = 2$, $y_g = .5$, $\phi = .5$. These values, though somewhat arbitrary, provide a reasonable approximation of government preferences given observed inflation targets and preferences for increased output above the natural rate.

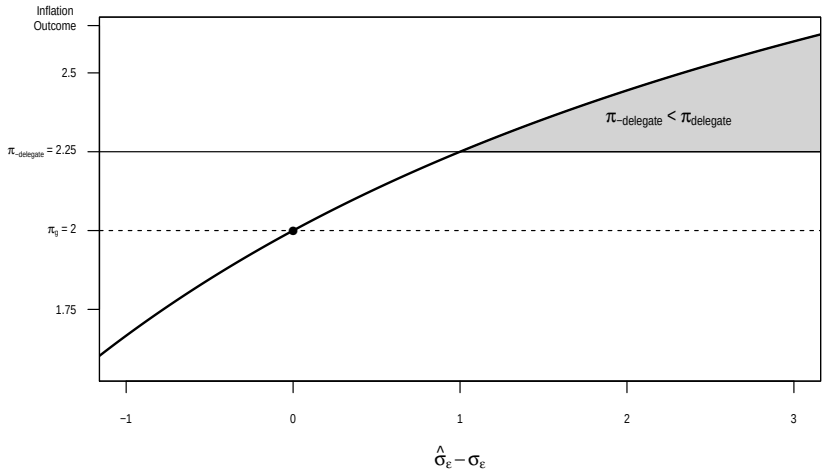

Figure 1.2: Equilibrium: Monetary Delegation & Inflation Outcomes

Expected inflation outcomes for the government's equilibrium appointment strategy are plotted against the difference between expected and realized economic uncertainty ($\hat{\sigma}_\varepsilon - \sigma_\varepsilon$).

environment that leads them to choose policies that result in higher inflation than we would expect had that government not delegated monetary policy. In the section that follows, I provide a measurement of monetary uncertainty and demonstrate for the case of Hungary, a non-trivial number of cases likely fall in this range.

This result is particularly pernicious when we consider the circumstances in which it is likely to hold. In the following section, I present empirical evidence to suggest monetary uncertainty peaks during times of economic crises. For example, in Figure 1.4 we observe surges in monetary uncertainty reported by the MNB during the 2009 and 2012 financial crises. Thus, by Proposition 2, appointments to the central bank during these times are likely to be relatively inflation-tolerant. While during the crisis these appointments might be optimal, they stand to obstruct economic recovery once the crisis induced uncertainty resolves itself. This result highlights how the incentives underlying the appointment process coupled with long terms of appointment could lock-in periods of high-inflation and stall economic recovery.

The opposite of this relationship also holds and is salient in light of an era of

persistent deflation. Relatively conservative, inflation-averse appointments optimal during times of economic stability may prolong crises or delay recovery when faced with heightened uncertainty during their terms. Should uncertainty increase above expected levels with these appointments serving out their terms, expected inflation outcomes will fall below the government's most-preferred rate. While the unintended consequence here is a low- rather than high-inflation bias, it similarly demonstrates how these institutions can hinder a government's ability to achieve its monetary objectives and do so in both times of recovery and crisis.

In short, a central implication of the model presented here is the same tying of their hands mechanism that in theory overcomes politically motivated monetary inefficiencies can serve to lock-in central bank strategies that outlive the economic environment for which they were desirable. Long terms of appointment at central banks, which are often considered indicators of institutional independence, stand to nearly ensure this is the case in practice.

1.4 Empirical Analysis

In this section, I test several assumptions and discriminating predictions derived in the preceding sections. First, I consider the implications for monetary uncertainty on decision-making at central banks (see Proposition 1).

Hypothesis 1. ***Central Bank Preferences.*** *Central bankers' policy choices are a function of uncertainty at the policymaking stage; or, equivalently by Lemma 2, central bank preferences are asymmetric:* $\alpha_c \neq 0$.

This prediction contrasts with previous theories which, either by assumption or omission, assume there is no impact of uncertainty at the monetary policymaking stage. Additionally, bringing data to this question allows me to empirically validate several

assumptions made in the preceding model. First, the model assumes away the possibility that a government can choose a central banker with symmetric preferences ($\alpha_c = 0$) and an ideal point identical to their own ($\pi_g = \pi_c$). If this were an option available to the government, this would of course be their utility maximizing choice. Therefore, if my assumption is realistic, no central bankers should have statistically insignificant estimates of the coefficient on the uncertainty term. Further, I focus the discussion of theoretical results on the case when $b \geq \pi_g$, which implies all central bank appointments should find inflation outcomes above their target more costly than those below. Therefore, the assumption yields a directional prediction for the coefficient on uncertainty. If this is in fact the relevant case, it should be true that the coefficient on uncertainty is positive for all appointed bankers in the sample, or $\alpha_c \geq 0$.

Next, I test the second discriminating prediction that defines the relationship between monetary uncertainty and central bank appointments.

Hypothesis 2. ***Central Bank Appointments.*** *Governments will appoint more inflation-tolerant central bankers when faced with high uncertainty and more inflation-averse central bankers when faced with low uncertainty.*

Again, this contrasts with the existing literature on central bank appointments which assumes both monetary policymaking at the central bank and in turn government appointments are unaffected by monetary uncertainty.[14]

[14]Recall that uncertainty in this context stems from the central bank's uncertainty at the time of their policy choice surrounding future inflation. It is worth pointing out that in recent work by Schnakenberg and Turner (2014), the result that we should observe more liberal appointments in the presence of greater inflation variability is derived. Their concept of inflation variability is, however, fundamentally different. In their model, output shocks are realized prior to monetary policymaking and central banks perfectly determine inflation outcomes. Increased variability, also referred to as economic uncertainty, leads to more liberal appointments because employment/output is more stable for liberal central bankers who take advantage of output shocks rather than mediating them like their conservative counterparts.

1.4.1 Data

To test these hypotheses, I draw on the individual voting records at the MNB from October 2005 to June 2014. In this period the Monetary Council voted monthly on changes to their primary interest rate, resulting in records from 107 meetings by 25 central bankers. The MNB is among a limited set of central banks that publishes attributed voting records of individual central bankers at monetary policy meetings. While some banks release unattributed votes that cannot be tied to individual central bankers, since 2005 voting records at the MNB include the stated alternative interest rates preferred by members voting against the majority. These stated preferred interest rates are the dependent variable in the first model. As with any estimation strategy that draws on individual voting records, there is the possibility that strategic votes will infringe on our ability to infer sincere preferences from this data. However, central bankers themselves having stated that strategic voting on MPCs is less prevalent than academics suggest (Yellen 2005) and the use of voting data to infer preferences is common among researchers at the MNB (Jung 2013, Jung and Kiss 2012). For examples of MPC voting data used similarly in the extant literature to estimate individual preferences as well as a more complete discussion of these considerations, see Chang (2001, 2003), Hix, Hoyland and Vivyan (2010), Jung (2013), Jung and Kiss (2012).

In addition to data availability considerations, Hungary provides a generalizable case to test empirically the implications of the preceding theory. According to measures of institutional independence provided by Cukierman, Webb and Neyapti (1992) and Polillo and Guillen (2005), the MNB is representative of a central bank with average levels of CBI.[15] Further, while it has been shown the credibility of monetary

[15]Hungary's level of CBI falls within one standard deviation of the mean for the entire sample of 71 countries. While recently there have been concerns about the operational independence of the bank since the Fidesz Party regained control in 2010, all results that follow hold when observations for this time period are dropped from the sample. See Empirical Appendix, Table A2.

delegation and sustained CBI affects inflation performance (Keefer and Stasavage 2003, Moser 1999), we should expect the institutional independence in this case to be relatively credible insofar as Hungary's membership in the European Union is contingent on the continued protection of central bank independence. The MNB also exhibits high levels of institutional transparency, another feature which has drawn considerable attention in the extant literature on the conditional efficacy of central bank independence (Crowe and Meade 2008, Stasavage 2003). Within a group of peer countries, Hungary is consistently ranked among the most democratic (Bodea 2013) as well as one of the major foreign investment success stories of Central and Eastern Europe (Bodea and Hicks 2015).

Critically, Hungary also experienced significant variation in economic conditions during the studied period. Recall that for an empirical test of this model's implications we must identify a case with meaningful variation in the economic environment across a series of appointments ideally by a government(s) with similar preferences, *not* variation in CBI itself. Thus, while looking at a single case raises questions of external validity which the above discussion aims to address, leveraging additional data from a cross-national sample only introduces variation in institutions or norms of appointment which could confound the ability to test the implications of the model. For the sample under consideration, the Hungarian economy endured periods of stability and growth as well as turbulence and uncertainty stemming from both domestic economic policy changes as well as global financial crises. This variation in economic circumstance — which is demonstrated in the following section to significantly affect the central bank's statements of forecast uncertainty — coupled with the appointment of three governors and twenty-two monetary council members by only three different prime ministers makes Hungary a strong case for an empirical test of the model's implications.

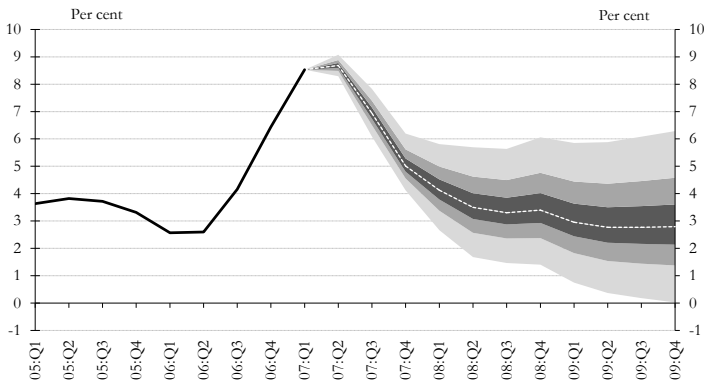

Figure 1.3: Inflation Fan Chart from MNB, May 2007 Inflation Report

The white dashed line corresponds to the central projection for inflation. The bands reflect the degree of uncertainty (30, 60, and 90% confidence) around this projection. To measure uncertainty at any given time horizon, I am recording the vertical distance from the 90% interval around the central inflation projection.

1.4.2 Measuring Monetary Uncertainty

The uncertainty over future inflation facing MPC members is the primary explanatory variable. Another advantage of focusing on the MNB is their inflation forecast reporting practices, which make possible a measure of uncertainty that maps particularly well to the preceding theory's conceptualization of monetary uncertainty. An increasingly common though not yet universally adopted practice by central banks is the publication of a "fan chart" to convey the central bank's forward-looking uncertainty around its projected inflation forecast. Figure 1.3 provides an example of a fan chart published by the MNB. The solid black line tracks the historical inflation rate up until the report's publication. Where this line stops, there is a white dashed line corresponding to the central bank's "central projection" for inflation moving forward. The increasing bands around this line correspond to the central bank's uncertainty. According to the MNB, the variance for a fan chart is calculated according to historical forecast errors and then modified "in the light of the relevant risk factors for a given forecast horizon, changes in our risk perception and the extent to which these risk factors influence inflation" (MNB 2004). Critically, the width of the fan charts is

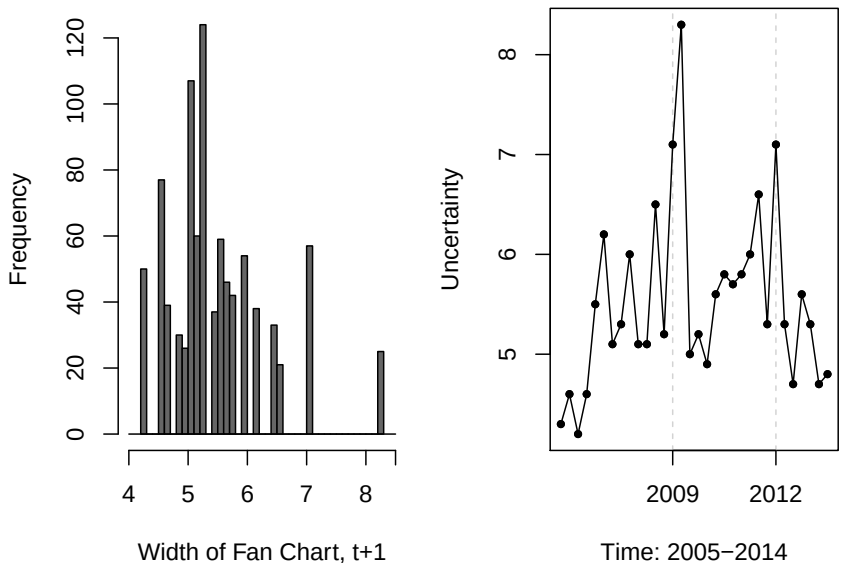

Figure 1.4: Measures of Monetary Uncertainty: Hungary 2005-2014

Uncertainty measured from the MNB's Quarterly Inflation Report by recording the distance between the upper and lower bands of the 90% confidence interval one year from the time of the meeting. On the left the distribution of uncertainty present for individual votes is shown. The figure on the right shows uncertainty measure over time.

allowed to vary by publication, reflecting the amount of perceived risk and uncertainty around their projection specific to that point in time. At the Bank of England, the institution which the MNB considers its fan chart methodology most similar (MNB 2004: 108), they explicitly recognize that in assessing the width of the fan chart, the MPC is considering "whether uncertainty looking forward is likely to be greater or less than that of past experience" (Elder 2005).

To construct a measure of uncertainty from the fan chart data I record the width of the widest (90%) band around the central projection one year from the time of that meeting. The distribution of this measure is presented graphically in Figure 1.4. While the modal width of a band around the forecast one year out is 5.3, it ranges from 4.2 to 8.3 units.[16] Unsurprisingly, uncertainty peaks during the 2009 financial

[16]While Hungary undoubtedly experienced significant monetary uncertainty at times as well as meaningful variation in this sample, it is far from a unique case on this dimension. At the Bank of England, for example, the mean measure of uncertainty for the same time period was 4.8, compared to 5.5 at the MNB.

crisis, where the wide forecast bands reflect the considerable economic uncertainty during the bailouts. There is, however, no evidence to suggest a constant trend towards greater or less variability around the bank's central projections. Finally, it is worth pointing out this conceptualization and measure of uncertainty is not just a proxy for other commonly incorporated economic indicators for inflation performance or economic output. This measure of uncertainty is only weakly correlated with the inflation rate (-0.35) and output gap (-0.33).

Control Variables

In addition to this measure of uncertainty, I include the standard battery of controls common in the literature. To account for interest rate smoothing, the prevailing interest rate is included. Previous anecdotal (Blinder 1999) and quantitative (Jung and Kiss 2012) evidence suggests there exists significant individual-level variation with respect to policy activism, or how much central bankers prefer to adjust their primary monetary instrument from meeting-to-meeting. Because of this, the estimated coefficient on the lagged interest rate is allowed to vary by individual. Further, three measures of macroeconomic performance commonly believed to influence interest rate choices are included. Consistent with a standard Taylor monetary policy rule, I include measures of the inflation and output gaps (Taylor 1993). The inflation gap is measured as the difference between Hungary's explicitly stated inflation target and their two-year inflation forecast. Consistent with similar empirical work, I use the two year policy horizon as it is believed this is the benchmark central banks consider (Jung and Kiss 2012). Output gap estimates are drawn from the OECD, which calculates the output gap as the deviation of actual gross domestic product (GDP) from potential GDP, as a percent of potential GDP. Lastly, given Hungary's status as a small open economy whose inflation outcomes may be sensitive to fluctuations in the exchange rate, I follow Taylor and include a measure of their real exchange rate

(Taylor 2001).

1.4.3 Estimation of Central Bank Preferences

Individual central bank preferences are estimated with a Bayesian Random Coefficient Model (RCM). Each central banker i's stated preferred interest rate at meeting t ($R_{i,t}$) is modeled as a function of uncertainty ($\bar{\sigma}_t$), the current interest rate ($\bar{R}_{t-1}$), the inflation gap ($\tilde{\pi}_{t+24} - \pi^T$), the exchange rate ($\mathrm{XR}_t$), and the output gap ($Y_t$). The model is specified as:

$$\begin{aligned} R_{i,t} \quad &\sim \quad N(r_i^* - \beta_{1[i]} * \bar{\sigma}_t + \beta_{2[i]} * \bar{R}_{t-1} + \beta_3 * (\tilde{\pi}_{t+24} - \pi^T) + \\ &\qquad \beta_4 * \mathrm{XR}_t + \beta_5 * Y_t, \sigma_R^2), \end{aligned} \tag{1.6}$$

for $i = 1, ..., n$ central bankers where,

$$\begin{pmatrix} r_i \\ \beta_{1i} \\ \beta_{2i} \end{pmatrix} \sim N \left(\begin{pmatrix} \mu_r \\ \mu_{\beta_1} \\ \mu_{\beta_2} \end{pmatrix}, \begin{pmatrix} \sigma_r^2 & \rho\sigma_r\sigma_{\beta_1} & 0 \\ \rho\sigma_r\sigma_{\beta_1} & \sigma_{\beta_1}^2 & 0 \\ 0 & 0 & \sigma_{\beta_2}^2 \end{pmatrix} \right).$$

Approaching data of this structure with a Bayesian RCM is appealing for several reasons. Though such models are less common in the political science literature, their advantages particularly in application to comparative politics are well-documented. (Beck and Katz 2007) demonstrate with Monte Carlo simulations Bayesian RCMs are better able to handle issues that arise with time series cross-sectional data than the more common approach to employ ordinary least squares regression with corrected standard errors (Beck and Katz 1995) and serial correlation. While unit effects and non-independence are often treated as statistical nuisances for which we wish to correct for and ignore, they are instead the quantities of interest in this application. Thus, a Bayesian RCM is particularly appealing here because it allows for and esti-

mates the unit heterogeneity (i.e., preference heterogeneity across individual central bankers) expected from the theory, but does not necessarily assume its presence or magnitude. Instead, this modeling technique first estimates individual unit effects, but then allows the data itself to determine appropriate shrinkage to a grand mean that is proportional to the homogeneity across units and the estimated confidence in the unit specific estimates (Beck 2001). Thus, unlike a classical regression which assumes independence across unit and time, this non-independence in the data in which we are explicitly interested is directly incorporated in the estimates.[17]

Two additional features of this model specification are worth emphasizing. First, the estimate of central banker i's random intercept (r_i^*) should be thought of as a unit effect for that central banker, similar to the ideal point π_c in the preceding theory. Note, however, the unit here is a preferred *interest rate* rather than *inflation rate*.[18] Therefore, an inflation-seeking *liberal* central banker (large π_c) is one with a lower preferred interest rate (small r_i^*). Similarly, the random coefficient on the uncertainty term $\beta_{1[i]}$ maps on to the shape parameter α_c in the theoretical model. Second, consistent with the claim these two terms (r_i^* and $\beta_{1[i]}$) ought to be correlated preference parameters, I allow for (but do not assume) such correlation by estimating the parameter ρ in the model above.

The posterior distribution of each parameter was simulated using Markov chain Monte Carlo. WinBUGS 1.4 (Spiegelhaltery et al. 2000) was used for the Bayesian computation with all other data processing completed using R and the R2WinBUGS package (Sturtz, Liggs and Gelman 2005). The results are based on three MCMC chains of 100,000 iteration simulations with 25,000 burn-in periods. I assign uninformed normal priors for each parameter. Chains converged quickly and completely

[17]For a more complete discussion of the advantages of Bayesian RCMs and their applications in political science, see Beck (2001), Beck and Katz (2007), Gelman and Hill (2006), **?**.

[18]This shift in the unit of analysis is trivial in terms of testing the implications of the theory because of the mean-zero error term $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ and common functional form $h(\cdot)$ given by the equation $\pi = h(i) + \varepsilon$.

	Variable	Coefficient Mean	95% Credible Interval	
r_i^*	Intercept	-2.37	-2.72	-2.04
		(0.17)		
$\beta_{1[i]}$	Uncertainty	-0.06	-0.08	-0.03
		(0.01)		
$\beta_{2[i]}$	Current Interest Rate	0.99	0.98	1.01
		(0.01)		
β_3	Inflation Gap	0.077	0.046	0.108
		(0.016)		
β_4	Exchange Rate	0.007	0.006	0.008
		(0.001)		
β_5	Output Gap	0.057	0.049	0.065
		(0.004)		
N=925; Deviance = -529.1; DIC = -485.4				

Table 1.1: Bayesian Random Coefficient Estimates of Central Bank Preferences
Results from Bayesian random coefficient model defined in Equation 1.6. Posterior standard deviations in parentheses. Dependent variable is preferred interest rate stated by central banker i at meeting t ($R_{i,t}$).

for all parameters, as measured by the Gelman-Rubin R-hat statistic. See Appendix for robustness checks.

The results are presented in Table 1.1. Estimated effects for the macroeconomic control variables are statistically significant and signed consistent with previous work and prior expectations. There is a high degree of policy inertia as demonstrated by a mean coefficient of nearly 1 for the existing interest rate. Consistent with a Taylor rule, the estimated coefficients on the inflation (β_3) and output (β_5) gaps are positive (Taylor 1993). When the two year inflation forecast increases above the target rate, central bankers prefer to increase the interest rate. Similar results follow with respect to the output gap, where increasing output above potential output leads to interest rate increases. Lastly, a real currency depreciation (increase XR_t) corresponds with increased interest rates (Taylor 2001).

In Figure 1.5, I plot the fitted R_i for each central banker, holding values of all independent variables at their mean. The results are consistent with prevailing wisdom about MPC member preferences. Recall that given the dependent variable is the

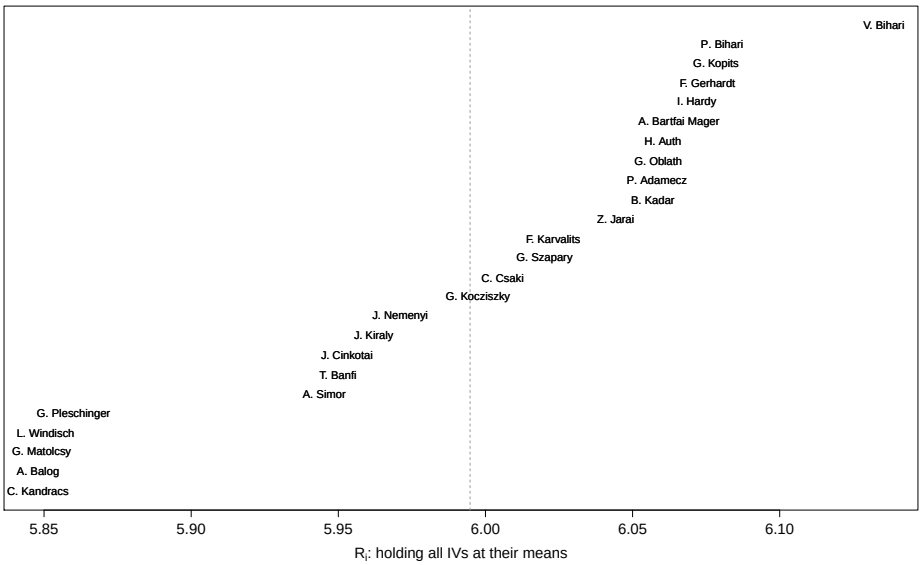

Figure 1.5: Estimates of Central Bank Preferences

Holding all independent variables at their means, I plot the estimated preference variation in the preferred interest rate R_i for the twenty-five central bankers in the sample. Sample mean is denoted by the dashed line.

preferred interest rate, lower (higher) estimates correspond to more inflation-seeking (inflation-averse) central bankers. The relative positions of two former governors of the MNB — György Maltolscy and Zsigmond Járai — provide an illustrative validity check. Járai, a "trusted free-marketer" whose tenure on the Monetary Council was marked by a strengthening domestic currency and resistance to inflation in the face of mounting political demands, is estimated to be much more inflation averse than current Governor Maltolcsy, whose appointment was surrounded by much concern given his apparent tolerance for a weaker currency (The Economist 2001). The model successfully captures this variation in central bank preferences.

Estimating the effect of uncertainty in this model allows for a test of Hypothesis 1, which states that uncertainty affects central bankers' policy choices and, equivalently, their monetary policy preferences are asymmetric. In addition to the grand mean coefficient on uncertainty being statistically significant with 99% confidence (see Table 1.1), the 95% credible intervals for the individual level coefficient estimates on

uncertainty ($\beta_{1[i]}$) are strictly less than zero for all twenty-five central bankers in the sample. This is supportive of the assumption in the preceding theory that the relevant case for consideration was $b > \pi_g$. All appointed central bankers in this sample exhibit voting patterns consistent with asymmetric preferences and they prefer to hedge against uncertainty in an inflation-averse direction.

Uncertainty has a substantively meaningful effect as well despite the seemingly small coefficient. Consider a central banker with the coefficient on uncertainty (β_1) at the grand mean, or -0.06. A one standard deviation increase in uncertainty (0.84) corresponds to, all else equal, this central banker preferring an interest rate interest rate vote 0.05 points higher. In this sample of 925 votes cast, 517 of the votes are for a change of 0.1 points or less. Thus, given the incremental nature of interest rate policy changes, a 0.05 point difference is non-trivial. Finally, while the theory makes predictions about individual policy choices and appointments, it is worth noting the estimated individual preferences aggregate in a way that suggest realized policy outcomes reached by majority vote are similarly sensitive to monetary uncertainty. Equivalently, this implies the MNB's monetary reaction function is asymmetric about its target. Controlling for the same standard battery of indicators of economic performance, a one standard deviation increase in uncertainty corresponds to the central bank choosing an interest rate 0.04 points higher.[19] That is, regardless of whether policy outcomes at the MNB are guided by committee consensus, chairman dominance, or truly individualistic voting in which the committee median dictates policy choices, monetary uncertainty as it is conceptualized and operationalized here has a substantively meaningful impact on policy choices and, in turn, appointment strategies.

[19] See supplemental appendix for complete aggregate results.

Variable	(1)	(2)
Uncertainty	-0.14	-0.08
	(0.02)	(0.02)
Orbán		-2.02
		(0.16)
Medgyessy		-1.86
		(0.14)
Gyurcsány		-1.86
		(0.12)
N	21	21
Adjusted-R^2	0.74	0.99

Table 1.2: Regression Results: Central Bank Appointments and Monetary Uncertainty
Results from linear regression model defined in Equation 1.7. Standard errors in parentheses. Dependent variable is individual intercept estimated from Equation 1.6.

1.4.4 Monetary Uncertainty and Central Bank Appointments

Drawing on variation in the estimated preferences as a dependent variable, I now test the second hypothesis that increased uncertainty leads to the appointment of more inflation-tolerant central bankers. Following the government's equilibrium appointment strategy given by Equation 1.5, I estimate a model where the preferences of the appointed central banker at time t (r_t^*) are a function of monetary uncertainty *at the time of appointment* ($\bar{\sigma}_t$) and the appointing government preferences (γ_j). To account for the appointing governments' inflation preferences, I include fixed effects for the three appointing prime ministers: Viktor Orbán, Péter Medgyessy, and Ferenc Gyurcsány. I estimate the following model:

$$r_t^* = \beta_1 \bar{\sigma}_t + \sum_{j=1}^{J} \gamma_j z_{j[t]} + \varepsilon_t; \qquad \varepsilon \sim N(0, \sigma_r^2), \tag{1.7}$$

where $z_{j[t]}$ is an indicator such that $z_{j[t]} = 1$ if the appointment at time t is by Prime Minister j, and $z_{j[t]} = 0$ otherwise. Thus, γ_j represents a Prime Minister specific intercept shift. Because the MNB only began publishing the fan charts in 2002, the sample is reduced to twenty-one appointments.

The results presented in Table 1.2 are both consistent with the existing empirical literature on central bank appointments and support Hypothesis 2. Recall lower values of the dependent variable correspond to lower preferred interest rates, or more inflation-tolerant preferences. The inclusion of the Prime Minister fixed effects recovers an ordering of the Prime Ministers' monetary preferences consistent with the received wisdom: Orbán appears more tolerant of inflation than his predecessors. However, even controlling for this variation across the appointing governments' preferences, increased monetary uncertainty leads to the appointment of a more inflation-seeking central banker. A one standard deviation increase in uncertainty (0.87) at the time of appointment corresponds to *any given Prime Minister* appointing a central banker who will vote all else equal for an interest rate 0.066 points lower. Thus, while the results are consistent with the existing empirical literature on appointments that focuses primarily on the influence of the appointing government's preferences, they point to a statistically and substantively meaningful influence of monetary uncertainty on central bank appointments.

Inflation Outcomes

In light of such empirical support for the first two hypotheses, I return to the implications of monetary delegation for inflation outcomes. Recall from Proposition 3 (and Figure 1.2) there exists a monotonically increasing relationship between the government's overestimation of monetary uncertainty and expected inflation outcomes. While any overestimation of uncertainty makes CBI less inflation-reducing than previously argued, in theory the inflation outcomes under monetary delegation can exceed the high-inflation bias that arises when the government maintains policy discretion.

Whether such conditions occur in practice is an empirical question that can be addressed in part with the measure of uncertainty employed here. In Figure 1.6 the density of $\hat{\sigma}_\varepsilon - \sigma_\varepsilon$ is shown for each vote cast by an individual central banker,

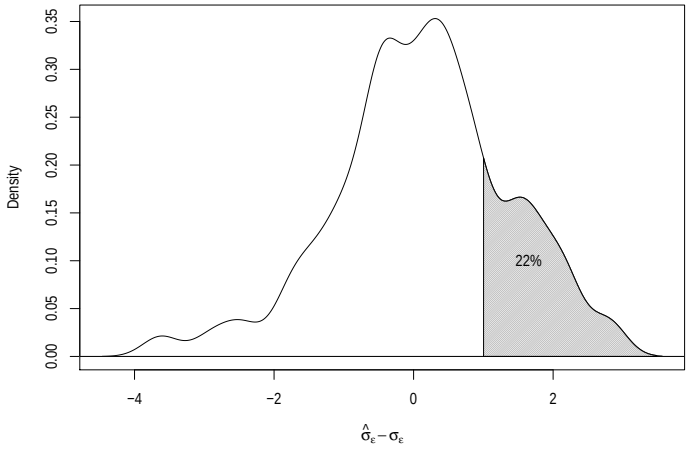

Figure 1.6: Difference Between Expected and Realized Uncertainty.
Expected uncertainty for a given central banker is measured as the monetary uncertainty at the time of that individual's appointment, while realized uncertainty is recorded as the uncertainty at the time of the vote. For a government with preferences $\pi_g = 2$, $y_g = .5$, and $\phi = .5$, 22% of the votes from the sample are cast by central bankers who in theory target inflation outcomes above what the government would have had they maintained discretion.

where expected inflation ($\hat{\sigma}_\varepsilon$) is measured by the monetary uncertainty *at the time of appointment* for a given central banker and realized uncertainty (σ_ε) corresponds to the monetary uncertainty *at the time of a vote*. For a government with the same realistic (but unmeasurable) preferences from Figure 1.2, 22% of the votes cast should in theory target expected inflation outcomes higher than we would expect to observe in the absence of delegation. Thus, in addition to providing direct evidence of the first two hypotheses, the data on monetary uncertainty in the case of Hungary suggests the conditions in which monetary delegation stands to exacerbate the problem of high-inflation are quite plausible.

1.5 Conclusion

Despite the widespread consensus surrounding the desirability of monetary delegation to independent central banks, I demonstrate both theoretically and empirically this consensus should be qualified in fundamental ways. When one accounts for the

uncertainty endemic to this policymaking environment, delegation to a politically insulated central bank is no longer strictly inflation reducing. In short, the government's incentive to appoint individuals with biased inflation preferences creates the potential for central banks pursuing undesirable monetary policy strategies as the environment of uncertainty changes. While these results may cast some doubt on the desirability of CBI, monetary delegation can under certain conditions enable the government to better achieve their policy goals. Future work on CBI ought to reintroduce the institutional context in which the central banks operate and consider with this theoretical foundation how other features of these institutions interact with monetary uncertainty and can potentially mediate the deleterious effects highlighted in this article. Finally, building on the simplistic characterization of the central bank presented here, important questions remain surrounding the optimal design of the institution including the presence of inflation targets, central bank mandates, and central bank term lengths.

While this is an important result that challenges a central finding in the literature on monetary delegation and central bank independence, it is illustrative of a more general feature of delegation and appointment models. In applications of standard delegation models where policymakers face uncertainty over policy implementation and do not evaluate losses symmetrically, these simplifying assumptions are not innocuous and can bias our inferences in systematic and important ways. For example, we might think bureaucrats' partisan biases determine the direction and degree of their preference asymmetries as they might prefer to err in one direction over the other. If this were the case, in an agency like the Environmental Protection Agency which faces variable but meaningful uncertainty across policy areas, uncertainty ought to have implications for both observed policy outcomes as well as the characteristics of appointed agents.

2
Central Bank Transparency and the Performance of Market Expectations

Abstract

Whether central banks should publish individually attributed voting records from monetary policy committee meetings is among the most contested areas of debate in monetary policymaking today. Though more and more banks are making this shift in the name of individual accountability and transparent policymaking, many central banks continue to shield their voting policymakers from such public scrutiny. In this paper, I argue that while unattributed vote outcomes are potentially beneficial as a communication mechanism to coordinate market expectations, publishing complete voting records undermines both the accountability of central banks and their ability to manage market expectations. Empirically, I leverage the recent implementation of a freedom of information law in Brazil which required the release of individually attributed central bank voting records. The evidence shows that not only has this policy change worsened the accuracy of market expectations, but it also reduced the ability of the central bank to influence market expectations with their official communications. This result has important implications for the ongoing debates over the merits of central bank transparency and provides a cautionary tale for the application of broad political reform efforts to monetary policy institutions.

2.1 Introduction

Once shrouded in mystery, monetary policymaking at central banks has undergone a transparency revolution in the past several decades (Blinder et al. 2001, Blinder 2004, Goodfriend 1986, Issing 2005). A growing consensus about the benefits of transparent monetary policy decision-making has been met by a institutional overhaul at central banks around the world (Chortareas, Stasavage and Sterne 2002, Crowe and Meade 2007, Dincer and Eichengreen 2014). These institutions have reformed once standard best practices of only providing opaque and significantly delayed announcements of final policy outcomes, now releasing minutes and transcripts of their meetings alongside detailed real-time forecasts and voting records. This dramatic change in procedure and definition of 'best practices' coupled with the resulting surplus of data and information has drawn considerable scholarly interest in the past two decades.

This growing consensus surrounding the benefits of central bank transparency stems primarily from two objectives. First, transparent central bank decision-making provides a mechanism by which central bankers can be held accountable for their policy choices. While central banks historically believed reporting requirements compromised their independence from government influence, it is now argued the publication of reports and minutes from meetings offers central banks necessary institutional legitimacy and closes a perceived democratic deficit, insuring the bank pursues socially optimal policies (Blinder et al. 2001, Blinder 2004, Buiter 1999). Second, transparent decision-making procedures and reporting practices provide markets with valuable information which helps to anchor and coordinate their expectations (Blinder et al. 2001, Blinder 2004, Gerlach-Kristen 2004, King 2000). In a domain like monetary policy where the efficacy of policymaking is highly dependent on coordinating market expectations, heightened levels of transparency that serve to make policy more predictable are attractive to policymakers and private sector interests alike (Blinder 2004, King 2000, Woodford 2003).

Focusing specifically on the publication and attribution of voting records from monetary policy committees (MPCs), I consider in this paper how such transparency policies can undermine precisely the objectives of improved democratic accountability and coordinated market expectations they are designed to achieve. When identified voting records are released, central bankers are exposed to private interests and face the incentive to use their votes as an opportunity to credit claim and send a costly signal of their loyalty to a narrow industry or group (Adolph 2013). Because such potentially conflicting motivations now factor into a central banker's decision calculus when casting a vote, the MPC voting record is a noisier signal upon which markets form expectations. Therefore, not only does procedural transparency in the form of publishing individually-attributed voting records stand to undermine the accountability of central bankers by making them susceptible to capture, it hinders their ability to affect and manage market expectations with one of their primary means of communication. Critically, this second order effect that worsens the predictability of monetary policy can occur regardless of whether central bankers are in fact captured so long as there is a perception of insincere and strategic voting.

To examine empirically the identified effects of transparency with respect to published voting records, I employ data from the central bank in Brazil, the Banco Central do Brasil (BCB), from 2003-2016. During this period the BCB was mandated by national legislation to change their practice of publishing anonymous final votes from meetings of their MPC (Copom) and begin releasing individually identified voting records. Drawing on a uniquely rich dataset which compiles real time surveys on market expectations for the duration of this time period, I examine how releasing attributed voting data affects the formation, accuracy, and coordination of market expectations. Not only has the heightened procedural transparency of this form corresponded with worse monetary policy and inflation forecast accuracy, but perhaps even more importantly it has lessened the reaction of market expectations to central

bank announcements.

The results presented in this paper contribute to the unresolved debate over the optimal design of monetary institutions. Though there remains significant cross-national variation in procedural transparency with respect to the publication of votes, the overwhelming trend towards opening up the decision-making process to outsiders makes this an area demanding increased attention. The remainder of the paper proceeds as follows. In the next section I discuss the extant literature on central bank transparency and accountability and develop an argument about the implications of procedural transparency for the formation of market expectations. In the third section, I test a series of hypotheses using data on monetary policy decision-making and market expectations in Brazil. This dataset and research design provides one of the first empirical analyses of how a specific aspect of central bank transparency measure can undercut the overarching objective of improved policy predictability and coordination of market expectations. In the final section, I summarize the empirical results and discuss their implications for existing and future research.

2.2 Transparency, Accountability, and Market Expectations

The "transparency revolution" at central banks has drawn substantial scholarly interest in both the causes and consequences of opening the monetary policymaking process to public scrutiny (Blinder 2004). Large, cross-national transparency indices demonstrate an undeniable and nearly universal trend towards heightened transparency (Crowe and Meade 2007, Dincer and Eichengreen 2014, Geraats 2009). Critically, however, these aggregated patterns are hardly indicative of institutional convergence. In practice, there remains considerable variation in how governments and their central banks have become more transparent.

The focus here is on a specific aspect of what Geraats (2002) refers to as *procedural transparency*, which includes "the monetary policy strategy and an account of policy deliberations, typically through minutes and voting records." Compared to other dimensions of transparency, central banks have been most reluctant to disclose detailed reports of the decision-making process including minutes and voting data. Only ten of ninety-eight central banks publish attributed voting records according to a 2009 survey, though this is twice the number of countries adopting this practice just eight years earlier in 1998 and the number has continued to grow (Geraats 2009). This hesitance to release voting records and individually attributed minutes has been met by growing demands for public disclosure and an ensuing debate over the merits of publishing voting records from central banks.[20]

The perceived virtues of procedural transparency are two-fold. First, transparency with respect to the decision-making process provides a mechanism for achieving the accountability necessary to maintain legitimacy under central bank independence. Keech (2013) suggests in the context of delegation to bureaucratic agencies, accountability — and thus credibility — can be achieved either by requiring bureaucrats to explain and defend their policy choices or providing opportunities and mechanisms for dismissal and override of policy choices. Because the success of monetary policy is believed to hinge on the independence of central bankers and their protection from political interventions like early dismissal and policy overrides (Persson and Tabellini 1993, Rogoff 1985, Walsh 1995), the central bank's soul source of accountability is derived from their procedural transparency.

In addition to providing a mechanism by which the central bank can be held accountable for its policy choices, publishing details concerning the nature of the debate and votes on MPCs enhances the predictability of monetary policy. A large

[20]This intensity of this debate is perhaps clearest in the case of the European Central Bank, which has since its inception denied calls for improved transparency in the monetary policymaking process. For a detailed description of this ongoing debate at the ECB, see Buiter (1999) and Haan and Eijffinger (2000).

and growing collection of empirical research provides evidence of a significant relationship between minority dissents and future policy outcomes. This result is intuitively appealing and has been demonstrated with data from a variety of central banks including the US Federal Reserve, Bank of England, and Sweden, among others (Gerlach-Kristen 2004, Horvath, Smidkova and Zapal 2012*a*,*b*). Thus, the argument is made that since voting data improves the predictability of future policy shifts for researchers, it should (if released in a timely manor) provide novel information to markets that similarly improves the accuracy of their expectations.

It is worth emphasizing the critical importance of policy predictability and market expectations for effective monetary policymaking. In contrast to the historical understanding that central bankers could leverage their informational asymmetry with markets in order to generate surprise policy and market reactions to spur the economy, there is now a widespread consensus that central banking should be "boring" in the sense that markets perfectly predict both policy and economic outcomes (King 2000). Reiterating this commonly held belief among today's macroeconomists, Michael Woodford has said that, not only do expectations about policy matter, but, at least under current conditions, very little else matters" (Woodford 2003). If the empirical research cited above is correct that transparency in the form of released votes informs market expectations and improves predictability, such transparency policies provide a potentially invaluable mechanism to anchor expectations in times of economic instability and uncertainty.

While transparent monetary policymaking has many virtues, one widely noted concern is that it exposes supposedly independent central bankers to being monitored (and potentially pressured) by outside interests. That is, when votes are recorded and individually attributed, they can be used by central bankers as signals and concessions to outside interests including the appointing President, Congress, and organized special interests (Belden 1989, 1991, Havrilesky and Gildea 1991, Havrilesky and

Schweitzer 1990). Early empirical work on voting at central banks focused almost entirely on the Federal Open Market Committee (FOMC) of the US Federal Reserve, where for the entirety of the period under examination, FOMC voting records were being published in the form of individually-attributed votes. Building on this literature focused narrowly on the Federal Reserve, Adolph (2013) presents and tests cross-nationally a theory of monetary policymaking in which career-motivated central bankers use published votes as an opportunity to send costly signals to potential future employers in the financial sector. Working with this cross-national sample, Adolph (2013) demonstrates a robust relationship between the publication of voting records and voting behavior consistent with signaling to financial interests.

In addition to raising concerns about institutional legitimacy, the influence of private interests on voting behavior at otherwise independent central banks creates a second order effect which is potentially even more costly. Recall that central bank transparency in the form of published voting records is intended to inform and manage market expectations by providing additional information about the current and future state of the economy as well as the nature of the deliberations (Ehrmann, Eijffinger and Fratzscher 2012, Geraats, Giavazzi and Wyplosz 2008). This mechanism functions because when the market observes a dissenting vote in favor of a tighter policy, for example, they believe there is a greater probability of tightening at the following meeting than loosening (Gerlach-Kristen 2004). However, when votes are individually attributed and made public record, it can undermine the ability of the central bank to communicate to the market this otherwise clear, quantitative information because the central bank cannot credibly commit that dissenting votes are not insincere signals directed at outside interests. That is, when votes are individually attributed, the market becomes uncertain about the informational content of dissenting votes and no longer considers the voting record a sincere signal upon which they can accurately form and coordinate their expectations.

Critically, the attribution of votes can undermine the coordinating effect of publishing the voting record even if central bankers aren't captured by private interests so long as there is a perception by the market of this possibility. For example, even sincere dissenting votes intended to inform the market of likely future rate changes can be meaningless — or worse, confusing — as the market understands the possibility of conflicting interests and disagrees on the informational content and intent of the vote.

2.2.1 Empirical Implications

While this theoretical argument is plausible, it remains to be seen whether there is any empirical support suggesting attributed voting records are less effective than anonymous votes at informing market expectations. To investigate this question, I explore how the accuracy, period-to-period updating, and dispersion of market expectations change when a central bank changes its publication policy from anonymously reporting the final vote to attributing votes by name to individual central bankers. If the argument presented above is correct and attributing votes exposes central bankers to outside pressure in a way that undermines there ability to communicate information about future policy and economic outcomes, then I should find support for the following set of hypotheses.

The first hypothesis speaks to the argument that publishing individually attributed votes reduces the predictability of policy outcomes. While anonymous votes are predictive of future policy choices and thus provide informative signals that improve the accuracy of market expectations, competing incentives that arise when votes are attributed to individuals increase the likelihood the market is surprised by the policy outcome. This relationship provides the first testable hypothesis:

Hypothesis 3. *Increasing central bank transparency by releasing attributed voting*

records leads to less predictable policy outcomes.

A corollary to this hypothesis concerns how market expectations react to information released from central banks. That is, when voting records are released, does the market internalize this information and update their expectations? I propose that because the market perceives voting records which are individually attributed as noisier and less sincere signals of policy outcomes, market expectations should update less following the release of attributed voting records than they do following anonymously reported vote outcomes.

Hypothesis 4. *Increasing central bank transparency by releasing attributed voting records leads to less updating of market expectations over the policy choice following the publication of the policy and vote outcome.*

In addition to predicting monetary policy outcomes, the market forms expectations over a variety of economic indicators including long-term inflation, output, and the exchange rate. Through the same channel discussed in the first hypothesis, increased transparency should similarly affect market expectations over inflation outcomes.

Hypothesis 5. *Increasing central bank transparency by releasing attributed voting records leads to less accurate inflation expectations.*

Finally, if publishing attributed votes affects market expectations because there is uncertainty about the intent and target of the signal sent with a dissenting vote, then there is likely greater disagreement about the interpretation of voting records. This disagreement, in turn, should manifest itself in the data as increased dispersion of inflation forecasts and market expectations.

Hypothesis 6. *Increasing central bank transparency by releasing attributed voting records leads to less coordinated inflation expectations.*

In the next section, I turn to empirical tests of these expectations. However, before moving to that task, it is worth noting explicitly how these hypotheses are inconsistent with predictions derived in the existing literature. First, in one of the few formal theoretical treatments of the interaction between procedural transparency and the formation of inflation expectations, Gerlach-Kristen (2004) provides a heuristic model in which dissenting votes are informative of future policy changes and improve the accuracy of inflation expectations. However, both theoretically and empirically, she assumes there is a common informative effect whether votes are attributed or remain anonymous as long as the rate of dissent is released. Thus, the shift from anonymous to individually attributed votes should not affect the accuracy, updating, or coordination of expectations predicted by my argument and tested below.

Similarly, opponents of enhanced procedural transparency often cite the concern that publishing dissents results in a "cacophony" that increases market uncertainty about the policy trajectory of the central bank. Again, these authors make no distinction between anonymous and individually attributed dissents, predicting no support for the above hypotheses so long as increased procedural transparency does not coincide with increased rates of dissent. I will address and dismiss this possibility empirically in the following section. Finally, there is an often cited empirical regularity in the extant literature that increased scores on aggregate transparency indices correspond to improved performance of forecasters (Ehrmann and Fratzscher 2007, Mariscal and Howells 2007). Further, even those studies within this set which disaggregate transparency according to the Geraats (2002) typology find a statistically significant and positive association between procedural transparency scores and the performance of private sector forecasts. Thus, this literature predicts with the increase of procedural transparency from anonymous to individually attributed voting records, the accuracy of market expectations should improve. Evidence to the contrary of an opposing effect suggests the results from studies using composite additive

indices are actually lower bounds on the effect of increased procedural transparency up until the point of publishing attributed votes.

2.3 The Data

To test these hypotheses, I draw on central bank voting data from the central bank of Brazil, the Banco Central do Brasil (BCB), from 2003-2016, as well as a national survey of market expectations over a variety of economic indicators. In this section, I discuss the choice of Brazil and provide background information on the evolution of central bank transparency at the BCB. In addition, I describe the relevant measures of market expectations and provide basic sample statistics.

Monetary Policy at the Banco Central do Brasil

The primary advantage of examining the case of Brazil is that the central bank has in recent history changed their transparency procedures from reporting anonymous voting records to attributing votes to individual central bankers by name. While Brazil is not alone in their adoption of this transparency policy and reporting practice, the change in policy at Brazil critically occurred in the absence of more extensive reforms of the central bank's mandate or operating procedures. That is, unlike many other central banks who have similarly undergone a transparency revolution, the institutional structure and policymaking process at the BCB has remained otherwise constant since the period prior to the publication policy change. Further, for the duration of the sample under consideration, the BCB has conducted their extensive and award-winning Market Expectations Survey, which provides real-time updates of 120 of the country's top banks, forecasting firms, and asset management groups, among others.

While the BCB is not among the central banks which have drawn the most atten-

tion from scholars (i.e., the Federal Reserve, Bank of England, and Swedish Riksbank), it is in many ways structurally similar to these institutions. All monetary policy decisions at the BCB are made by the Comitê de Política Monetária (Copom), a nine person committee composed of a single Governor and group of Deputy-Governors representing a variety of monetary and economic policy issue areas. Since Brazil adopted an inflation targeting regime in 1999, the primary objective of Copom has been to conduct monetary policy and open market operations necessary to achieving this explicitly stated inflation target. Though Copom initially convened monthly, they began in 2006 meeting only eight times a year. At these pre-scheduled, two-day meetings, they discuss the state of the economy and vote on any necessary adjustments of their primary monetary policy instrument, the Selic interest rate.[21]

With the adoption of an inflation target, Copom began the practice of releasing minutes from their meetings. In these minutes, Copom included the committee's final vote count for the Selic target and the alternative preference of any dissenting voters, but did not disclose by name which members cast which votes. This reporting practice, established as a measure to increase the transparency of monetary policymaking but insulate members of Copom from political pressure, would continue until 2012 with the passage of the Access to Information Act (Lei de Acesso à Informação) under President Dilma Rousseff. The AIA of 2012 was the result of eight years of legislative debate and effort to promote government-wide transparency. It provides the foundation for information request procedures applicable across government institutions and includes obligations for disclosure and the provision of data in a non-proprietary format. While the law explicitly intended to put pressure on the legislature to make all votes open, it would similarly effect the monetary policy committee. In accordance with the national legislation, Copom began including in their minutes not only the

[21]The Selic (Sistema Especial de Liquidação e de Custódia, or Special System for Settlement and Custody) interest rate is the average interest rate on overnight interbank loans backed by government securities. Copom sets a target for this rate, which the open market desk of the BCB then conducts operations to hold the daily Selic rate at the target level.

final vote count on the setting of the Selic interest rate, but also attribute by name any dissenting votes to individual members of the committee. This shift in reporting practices from anonymous vote counts to individually attributed records is the primary independent variable in this study.

Before turning to the measurement strategy, a brief discussion of this legislation and its implications for policymaking at central banks is in order. Though the implementation of the AIA provides the impetus for the policy change which is of primary interest here, it is worth highlighting the implications of its passage being part of a much broader national movement towards political transparency. In the law's conception and the heated debate that surrounded its passage, there is hardly any mention of its application to monetary policymaking at the BCB. I will revisit this issue of central bank transparency arising tangentially out of broadly defined Freedom of Information laws in the concluding section. However, with respect to the research design, that this policy shift emerged in the absence of a sweeping reform of the central bank's mandate and policymaking process is helpful in this context for isolating its effect on market expectations.

2.3.1 Measurement of Market Expectations

To consider the effect decision-making transparency has on the predictability of monetary policy and formation of market expectations, I draw on data from an ongoing survey conducted by the Investor Relations and Special Studies Department (Gerin) at the BCB. Beginning with their adoption of the inflation targeting regime in 1999, Gerin started fielding the Market Expectations Survey (MES) in an effort to more carefully and systematically monitor market expectations over primary macroeconomic indicators. What began as a relatively small survey of 50 financial institutions and consultancies, the MES now draws regular forecasts from over 100 Brazilian

Table 2.1: Sample Statistics for Market Expectations Series

Variable	Description	Mean	Median	Std. Dev.	Min	Max
SelicError	Absolute difference between the mean Selic target rate expectation 1 day prior to Copom announcement and the announced Selic target rate.	0.082	0.030	0.103	0	0.5
RateUpdateX	Absolute difference between the mean Selic target rate expectation 1 day prior to Copom announcement and the mean Selic target rate expectation X day following the announcement.	0.272 0.288 0.293	0.245 0.270 0.285	0.229 0.232 0.238	0 0 0	0.980 1.120 1.180
InflationError	Absolute difference between the mean IPCA inflation expectation 1 day prior to Copom announcement and the realized IPCA inflation.	0.888	0.610	0.800	0.010	3.830
Inf.Dev	Standard deviation of IPCA inflation expectations.	0.400	0.400	0.092	0.240	0.670

Descriptive statistics for each of the market expectation series which will be the dependent variables in the proceeding analyses are provided.

economists, research firms, and the like.[22] Approved forecasters log-in to the access-controlled online system at any time and provide updates of their short-, medium-, and long-term forecasts over a variety of price indices, exchange rates, the Selic target rate, and balance of payments variables. While individual forecasts are not identifiable, the MES provides daily updates of the sample statistics (median, mean, standard deviation, coefficient of variance, maximum, and minimum) for the aggregated forecasts.

The first set of dependent variables I examine are constructed from the market expectations of the target Selic rate. The series SelicError corresponds to the absolute difference between the mean of the expected Selic rate the day before the meeting and the realized outcome following the Copom vote.[23] While the average

[22]For more detailed information about the history and scope of the MES, see Marques (2012).
[23]Results using the median of the expected Selic rate to construct SelicError forthcoming.

magnitude of the difference between the expected and realized Selic rate for the sample is 0.15 points, the mean market expectation is within 0.02 points of the voted on value for 36% of the meetings.

In addition to the accuracy of market expectations over policy outcomes, I also include a series of dependent variables corresponding to the amount of updating in expectations following the publication of a vote. The variables RateUpdate1, RateUpdate2, and RateUpdate3 correspond to the change in the mean of market expectations over the future Selic rate one, two, and three days after the decision, respectively. While RateUpdate1 provides a measure of any change in expectations that is least likely to incorporate new sources of information other than the policy choice and vote outcomes, I include the longer two- and three-day time horizons to allow for the fact that participants voluntarily log-in at there convenience to update their expectations and there is no incentive or reason to expect them to do so immediately. Though the measures vary slightly, results are consistent across all three variables.

In addition to expectations over Copom's setting of the Selic target rate, the MES provides similar information on the inflation expectations of participating firms. Though the survey collects forecasts for eight different inflation indexes, I focus primarily on the Extended National Consumer Price Index, or IPCA, which is Brazil's official inflation measure and price index.[24] Similar to the dependent variables for policy expectations discussed above, I construct a variable InflationError, corresponding to the absolute difference between expected and realized inflation. Using market expectations for this same inflation indicator, I include a final dependent variable InflationVar which captures the variance in inflation expectations among participating firms. Sample statistics for each of these variables are provided in Table 2.1.

[24]Results for the National Consumer Price Index (INPC) and General Price Index-Internal Availability (IGP-DI) are provided for robustness checks (forthcoming).

2.4 Analysis and Findings

First, I must address the time structure of the data before moving to the analysis of how the attribution voting records effects the accuracy, formation, and coordination of market expectations. Two concerns emerge when working with time series data like each of the dependent variables here. First, the modeling techniques employed in this section rely on the assumption that the data is stationary, meaning the mean and variance of the series do not change conditional on time (Box-Steffensmeier et al. 2014, Monogan 2015). While plotting the data does not reveal any discernible trends worthy of concerns regarding stationarity, I also conduct Augmented Dickey-Fuller tests on each series which help diagnose whether the series have unit roots (Dickey and Fuller 1979). These results are presented in Table 2.2 and suggest each series is in fact stationary.

Second, I diagnose and address any serial autocorrelation in the series. Measures constructed from repeated measures at sequential points in time often have serially correlated errors, which left ignored leads to overconfidence in parameter evidence (Box-Steffensmeier et al. 2014, Monogan 2015). Thus, before concluding which method is appropriate for estimating the effect transparency policies have on the market expectations series, I follow the Box-Jenkins approach for identifying the appropriate error process in the data (Box, Jenkins and Reinsel 2008). The central objective of this approach is to filter series of trends and error processes before estimating an inferential model. This filtering — or "prewhitening" — involves capturing the error process with autoregressive integrated moving average (ARIMA) models, in which an ARIMA(p, d, q) process incorporates p autoregressive terms, differences the series d times, and accounts for q moving average components. The appropriate ARIMA model of each series is identified in Table 2.2.[25] In each series, the autocor-

[25] In addition to the Box-Jenkins approach, I confirm these ARIMA structures by implementing the step-wise algorithm developed by Hyndman and Khandakar (2008) for determining the appropriate ARIMA model. Both techniques produce the same results for each series.

Table 2.2: Univariate Time Series Diagnoses Test

		Augmented Dickey-Fuller		**Ljung-Box Q-test**	
Variable	ARIMA(p,d,q)	D-F	p-value	χ^2	p-value
SelicError	(0,0,0)	-3.90	0.02	1.887	0.170
InflationError	(2,0,0)	-5.40	<0.01	0.240	0.624
InflationVar	(1,0,0)	-3.57	0.04	0.004	0.95
RateUpdate1	(3,0,0)	-5.53	<0.01	0.022	0.881
RateUpdate2	(2,0,0)	-6.29	<0.01	0.0001	0.993
RateUpdate3	(0,0,2)	-6.40	<0.01	0.045	0.832

For each market expectation series dependent variable, the results of the Dickey-Fuller test for stationarity are given as well as the identification of the appropriate ARIMA(p, d, q) structure. The Ljung-Box Q-test results test for remaining correlation given the assigned ARIMA(p, d, q) structure, and with $p > 0.05$ we cannot reject the null hypothesis of independence.

relation and partial autocorrelation functions of the residuals from their respective ARIMA specifications indicate no lags reach standard levels of statistical significance. Finally, I include the results of the Ljung-Box Q-test, which computes a joint test across lags to examine whether there remains any evidence of serial correlation. The null hypothesis of independence cannot be rejected for any of the series, suggesting there is no evidence of remaining serial correlation.

While the series on updated rate expectations (RateUpdate1-3) as well as inflation forecast accuracy (InflationError) and variance (InflationVar) exhibit serial correlation which must be accounted for prior to estimating an inferential model, the series of Selic target rate surprises (SelicError) does not. Therefore, this series can be appropriately analyzed with standard regression techniques. Before describing the methodology and estimating models for the serially correlated series, I first estimate the following model which tests for the hypothesized relationship presented in Hypothesis 3: when vote records become individually attributed, market expectations of monetary policy outcomes should be less accurate than they were when dissents

Table 2.3: Regression Analysis: Market Expectations Selic Rate

Variable	Parameter	(1)	(2)	(3)
Dissent_{t-1}	β_1	0.036	0.035	0.007
		(0.03)	(0.03)	(0.03)
I_T	β_2	-	-0.012	-0.035
		-	(0.02)	(0.03)
$\text{Dissent}_{t-1}*$	β_3	-	-	0.138*
I_T		-	-	(0.06)
Constant	β_0	0.073*	0.076*	0.082*
		(0.01)	(0.01)	(0.01)
N		102	102	102
Breusch-Godfrey		0.206	0.245	0.3805
		[0.650]	[0.620]	[0.537]
Durbin-Watson		1.966	1.966	2.0425
		[0.431]	[0.393]	[0.547]

The dependent variable is SelicError, which corresponds to the absolute difference between the mean expected Selic target rate and the announced rate at the Copom meeting. Standard errors are provided in parentheses. For the Breusch-Godfrey and Durbin Watson tests, p-values are given below test statistics in brackets. Note: $*p < .05$.

remained anonymous.

$$\text{SelicError}_t = \beta_0 + \beta_1 * \text{Dissent}_{t-1} + \beta_2 * \text{I}_\text{T} + \beta_3 * \text{Dissent}_{t-1} * \text{I}_\text{T} + \varepsilon \quad (2.8)$$

In Equation 2.8, the amount which market expectations inaccurately predict the policy choice at meeting t (SelicError_t) is a function two binary indicator variables: (1) whether there was a dissenting vote cast in the previous meeting ($\text{Dissent}_{t-1} = \{0, 1\}$); and (2) whether Copom individually identified voting records from that meeting ($\text{I}_\text{T} = 1$), or votes remained anonymous ($\text{I}_\text{T} = 0$).

All results are presented in Table 2.3. First, it is worth noting post-estimation diagnostics on the model's residuals confirm autocorrelation is not a problem in this series. Test statistics for both the Durbin-Watson and Breusch-Godfrey Tests fail to reject null-hypotheses that there is no autocorrelation (Box-Steffensmeier et al. 2014, Monogan 2015, Zeileis and Hothorn 2002).

Substantively, two important relationships emerge from this analysis. First, anonymous dissenting votes (i.e. $I_T = 0$) do not have a statistically significant effect on the accuracy of market expectations over Copom's policy choice. This result alone is inconsistent with the existing literature on monetary policy transparency, which suggests dissenting votes should improve the predictability of policy choices and thereby *reduce* the amount of surprise policy outcomes. While this literature has used the fact that dissenting votes are often predictive of future policy change to infer market expectations should therefore be more accurate, there is no evidence of this transmission mechanism when directly examining the accuracy of market expectations.

Further, the results indicate that when votes become individually attributed ($I_T = 1$), one or more reported dissents in the previous meeting ($\text{Dissent}_{t-1} = 1$) leads to a statistically significant increase in the difference between the expected Selic target rate and the policy choice. Specifically, the presence of a dissenting vote increases the amount of Selic rate surprise at the following meeting by 0.15 points. Though a seemingly small quantity, given that the mean magnitude of Selic rate target changes when they occurred is only 0.5 points an increase of 0.15 points is a meaningful increase in the inaccuracy market expectations. This pattern is consistent with the argument that attributing voting records to individual central bankers motivates voting behavior that distorts market expectations.

2.4.1 Time Series Intervention Analyses

In the remaining analyses, I consider the impact this change in procedural transparency had on the updating of market expectations of policy outcomes as well as the accuracy and coordination of market expectations of inflation. Because the time structure of these series identified in Table 2.2 makes estimates from a the static model like that given by Equation 2.8 inefficient, I employ time series intervention analysis

to test the hypotheses concerning the effect moving from anonymous to attributed MPC voting records has on market expectations. Introduced by Box and Tiao (1975), this class of models examines whether the occurrence of an event (or "intervention") has an impact on the time series. Extremely common in the health sciences policy literature, this method has been employed in the political science literature on trends in public opinion (Flemming, Bohte and Wood 1997, Ura 2009) as well as the process of economic integration (Caporaso and Pelowski 1971) and emergence of revolutions (Lewis-Beck 1979). In this application, I conceptualize the change in the transparency of voting records as a punctuated intervention of interest and examine how this policy shift changes the remaining series of market expectations.

Time series intervention analysis allows me to explicitly account for serially correlated errors in the dependent time series before considering the effect(s) of an intervention. Specifically, the Box and Tiao (1975) approach estimates auto-regressive and moving average components of the time series according to an ARIMA error processes identified in Table 2.2. In practice, doing this reduces a dynamic, dependent series to white noise before estimating the impact of an intervention. Thus, for a given time series of market expectations (Y_t), the effect of the intervention is estimated by the following equation:

$$Y_t = f(I_t) + N_t, \tag{2.9}$$

where I_t is the effect of the policy change and N_t is the ARIMA error process. Having already identified the appropriate ARIMA model structure for each time series dependent variable, I model the policy intervention with a binary indicator equal to 0 at all meetings when votes were cast anonymously and equal to 1 when the reporting policy changed to individually attributed voting records. This variable structure assumes a "step," rather than "pulse," intervention. Substantively, this implies the

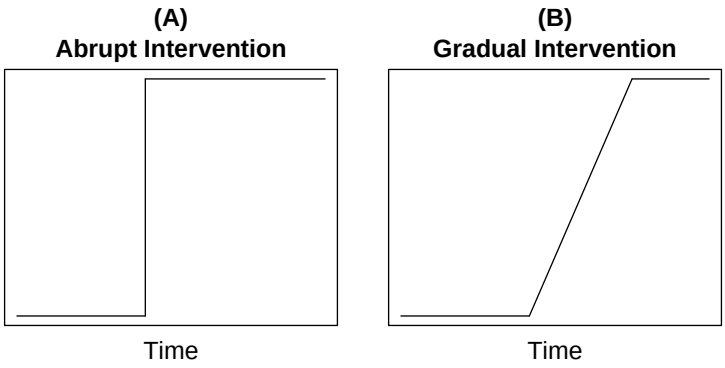

Figure 2.1: Transfer Functions.
This figure illustrates the structure of two hypothetical transfer functions estimated in each of the time series intervention analyses.

intervention creates a policy change that continues for the duration of the data and has a permanent effect on the series. Though the distinction between step and pulse interventions and the sometimes subjective task of choosing the proper specification is often wielded as a critique of Box-Tiao analyses, the substantive application here provides a natural theoretical justification for a step structure. That is, there is no reason to suspect switching from anonymous to attributed voting records would have an immediate, but impermanent, effect on market expectations.

Though the theory and nature of this empirical application provides direction in the choice between the types of interventions, I consider and estimate two alternative specifications of the transfer function which could reasonably describe how this policy shift affects each series. The simplest specification of a transfer function characterizes an *abrupt* effect of a step intervention, demonstrated graphically in Figure 2.1A. In terms of this application, this would correspond to the shift to attributed minutes in October 2012 having an immediate and complete impact following implementation that permanently shifts the underlying market expectations data-generating process. This intervention model and transfer function take the following form when the white

noise component N_t is subtracted from Equation 2.9:

$$Y_t^* = f(I_t) \quad = \quad \omega_0 I_t, \tag{2.10}$$

where ω_0 is the effect of the intervention. Alternatively, the effect of the intervention could appear more gradually, though still have a permanent effect on the series. For example, since the series InflationError corresponds to the mean of the sample of reported expectations, there may be a more gradual intervention as individual survey participants update at different rates how they decide to incorporate the new Copom voting records into their forecasts. Alternatively, holding market expectation formation constant, if the theory that attributed votes present an opportunity to private interests holds, there may be a stalled or delayed effect of the intervention as Copom members establish these relationships and begin voting opportunistically. A *gradual* intervention like these described appears in Figure 2.1B. This specification requires the estimation of an additional rate parameter, δ, such that:

$$Y_t^* = f(I_t) \quad = \quad \frac{\omega_0}{1 - \delta B} I_t. \tag{2.11}$$

As $\delta \in [-1, 1]$ increases in absolute value, the steepness of the transfer function increases.[26]. In the absence of a theoretical justification for the appropriate transfer function specification in each series, I choose based on which performs better according to the Akaike Information Criterion (AIC).

2.4.2 Target Rate Updates

The first set of time series intervention analyses correspond to the implications provided by Hypothesis 4, which predicts the market will update their expectations about

[26]This can equivalently be written without the backshift operator B as $Y_t^* = \delta Y_{t-1}^* + \omega_0 I_t$

Table 2.4: Time Series Intervention Analyses: Market Expectations Selic Rate Updating

Variable	Parameter	(1) RateUpdate1	(2) RateUpdate2	(3) RateUpdate3
Intervention	ω_0	-0.115**	-0.121**	-0.102*
(step)		(0.069)	(0.066)	(0.08)
Mean (constant)	μ	0.298	0.319	0.319
		(0.04)	(0.03)	(0.04)
Autoregressive Terms				
First Order	ϕ_1	0.791	0.859	-
		(0.10)	(0.09)	-
Second Order	ϕ_2	-0.254	-0.395	-
		(0.13)	(0.09)	-
Third Order	ϕ_3	-0.056	-	-
		(0.10)	-	-
Moving Average Terms				
First Order	θ_1	-	-	0.852
		-	-	(0.09)
Second Order	θ_2	-	-	0.342
		-	-	(0.09)
AIC		-67.51	-74.5	-66.51
N		101	101	101

These estimates are for the time series intervention analyses on the series RateUpdate1, RateUpdate2, and RateUpdate3. Standard errors are provided in parentheses.

the target Selic rate less following MPC meetings and announcements when votes are individually attributed than when they remain anonymous. In Table 2.4, I present the results of the intervention analysis on the three series that correspond to changes following meetings in the market expectations of the target Selic rate.

The estimated effect of the intervention is in the predicted direction and statistically significant for all three series. Since the BCB increased their procedural transparency by publishing individually attributed votes following Copom meetings, market expectations became less sensitive to the announcements of policy outcomes and voting records. This relationship is consistent with the expectation that voting records are perceived by the market as less informative of future policy outcomes when they are individually attributed than when they remain anonymous. Further,

the magnitude of this effect is substantively meaningful. For example, referring to the results from model (1) on the series RateUpdate1 in the first column, the market updates its Selic rate expectations by 0.115 fewer points following announcements when voting records were individually attributed.

The results are similar across the three series and the information criterion favors modeling the transfer function as an abrupt intervention with no decay term like that given in Equation 2.10. I plot the estimated intervention for each series in Figure 2.2. The solid black line corresponds to the observed data from each series while the blue points are the predicted values from the full model. Overall, these predicted values track reasonably well with the observed data suggesting the model fits well in-sample. The solid blue lines reflect the estimate of the effect of the intervention on the series. In each series, the transparency policy shift to releasing attributed voting records from MPC meetings coincides with a decisive decline in the amount the market updates their expectations over future policy outcomes in response.

I have now provided empirical evidence in support of both Hypotheses 3 and 4. Both sets of results indicate increased procedural transparency at the BCB coincided with systematic changes in the formation of market expectations over monetary policy outcomes. While it is certainly worrisome that market expectations over the central bank's primary monetary policy instrument appear less accurate under heightened procedural transparency policies, it is equally concerning that the market becomes less responsive to information released by the central bank. If a primary purpose of central banks is to manage market expectations as many contemporary central bankers have argued, that this policy of releasing attributed voting records undermines the central bank's ability to affect expectations with their primary source of official communication has tremendous consequences for the policymaking efficacy.

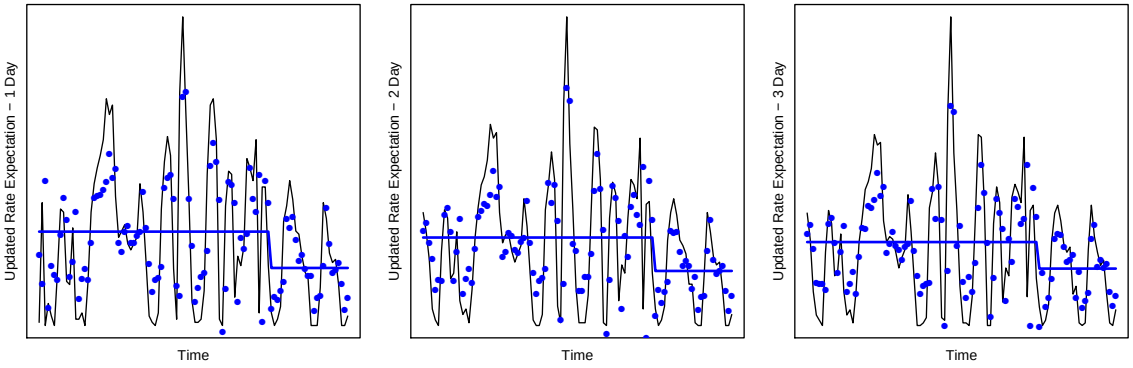

Figure 2.2: Time Series Intervention Analyses: Market Expectations Selic Rate Updating

Each plot shows the estimated effect of the intervention given for Models (1)-(3) in Table 2.4. From left to right, the solid black lines reflect the observed data for the series RateUpdate1, RateUpdate2, and RateUpdate3. The blue points are the predicted values from the model and the solid blue line is the estimated effect of an abrupt step intervention.

2.4.3 Inflation Expectations Series

Next, I estimate the effect changing from anonymous to attributed voting records has on the market expectations series for the accuracy and variance of inflation expectations (InflationError and InflationVar, respectively). The results are presented in Table 2.5. While I will address further below concerns about the estimated effects of the intervention failing to achieve standard levels of statistical significance, they are both signed in the expected direction. Consider the results of model (4) in the first column, which correspond to the series on inflation forecast errors (InflationError). The results indicate that publishing attributed voting records increased the magnitude of the error in inflation expectations by 0.315 points in the first month it was implemented, October 2012. The relatively large estimate of $\delta = 0.652$ indicates this effect accumulates and persists beyond the initial intervention, with a prediction of an increased inflation expectations error of 0.520 points at the following meeting and 0.449 points the meeting after that.

Figure 2.3 illustrates this effect more clearly. Again, I plot the actual observed InflationError series in the solid black line alongside predicted values at each

Table 2.5: Time Series Intervention Analyses: Market Expectations Inflation Accuracy and Variance

Variable	Parameter	(4) InflationError	(5) InflationVar
Intervention	ω_0	0.315	0.013
(step)		(0.37)	(0.042)
	δ	0.652	-
		(0.51)	-
Mean (constant)	μ	0.56	0.404
		(0.34)	(0.026)
Autoregressive Terms			
First Order	ϕ_1	1.37	0.723
		(0.09)	(0.07)
Second Order	ϕ_2	-0.47	-
		(0.09)	-
AIC		-73.53	-259.21
N		101	101

These estimates are for the time series intervention analysis on the series InflationError and InflationVar. Standard errors are provided in parentheses.

time period with the blue dots. The in-sample fit of the model is decent, as the predicted values map on to the observed data reasonably well. The solid blue line corresponds to the dynamic effect of the change from anonymous to attributed voting records in October 2012. Following the initial surge in the inaccuracy of market inflation expectations, the intervention the effect tapers off slightly; however, there is a persisting effect of a greater absolute difference between expected and realized inflation under heightened procedural transparency.

A similar result emerges in the series for the variance of inflation expectations InflationVar, though the effect is comparatively smaller. In this series, the information criterion indicate an abrupt intervention is more appropriate than the gradual intervention. Releasing attributed voting records corresponds to a 0.013 increase in the variance of market expectations over inflation. Given a mean value of about 0.4, this is a fairly marginal increase in the spread of the distribution of market

expectations. However, as I will discuss in more detail below, the relatively short post-intervention series makes it difficult to rule out in this case the possibility of a delayed, gradual effect in the series.

While the quasi-experimental nature of this design is appealing for a variety of reasons discussed above that relate to the quality of inference, the lack of control over the timing of the intervention makes for a sample to date that is unlikely to recover statistically significant estimates of the effect. With only twenty-six meetings after the treatment, it is difficult to speak confidently about a persistent shift in the mean of the data generating process. Further, this issue of a small post-intervention sample compounds the problem when we are interested in considering the implications of gradual interventions beyond a strict mean-shift. This is, however, a promising direction to continue. The nature of the data means there is a predictably steady growing sample of post-intervention observations and, critically, the fixed series prior to the intervention is more than sufficiently long. Additionally, the rate of dissent appears roughly unchanged with the intervention, eliminating any concern that there will not be enough post-intervention observations with dissent in due time. In the Appendix, I provide the power computations for these series as derived by McLeod and Vingilis (2005). These estimates reveal the probability of a "true" effect of an intervention reaching statistical significance given the pre- and post-intervention sample sizes and the autocorrelation in the existing series. In addition to revealing there is a relatively low probability of achieving statistical significance for the estimates in these series regardless of the true effect size, this exercise demonstrates how quickly this probability increases as the sample steadily grows over the next two years.

2.4.4 Robustness Checks

While some of the issues related to inference can only be addressed with time and increased sample size, there are opportunities to conduct robustness checks with the

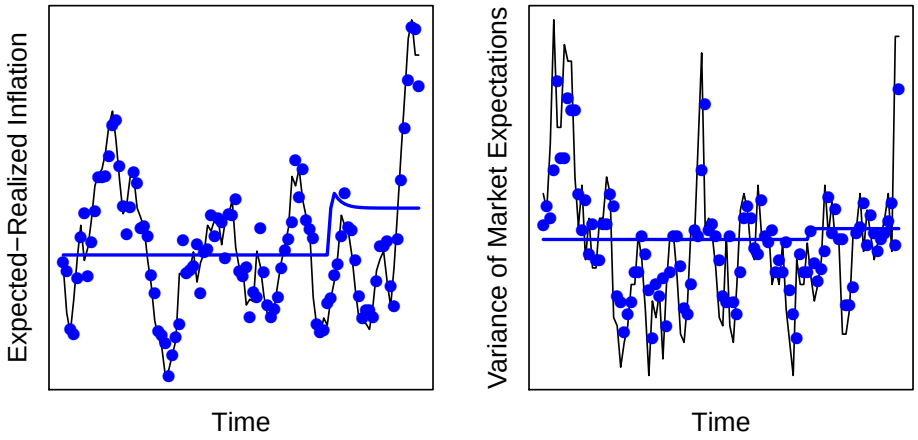

Figure 2.3: Time Series Intervention Analyses: Market Expectations Inflation Accuracy and Variance

Each plot shows the estimated effect of the intervention given for Models (4) and (5) in Table 2.5. From left to right, the solid black lines reflect the observed data for the series InflationError and InflationVar. The blue points are the predicted values from the model and the solid blue line is the estimated effect of a a gradual (left) and abrupt (right) step intervention in each series.

data currently available that stand to provide further support for the theoretical insights motivating this analysis. For example, one might be concerned there is an alternative explanation for the observed patterns and suggest the procedural transparency intervention merely coincides with some other underlying trend or relationship in the data generating process. To address this possibility, I conduct a series of placebo tests on the pre-intervention series in which the timing of a placebo "intervention" is a randomly drawn point in the series.[27] There is, of course, still no serial correlation to model in a truncated series of SelicError, so the robustness checks are on traditional models given by Equation 1. The effect of including a placebo intervention eliminates the conditional effect of casting a dissenting vote pre- and post-intervention. Further, in several cases the results even reverse, with the earlier "fake" pre-intervention period exhibiting (insignificantly) higher values for the effect of a dissent than the latter.

[27]Complete results of this exercise are provided in the Appendix, Table A2.

Alternatively, one may suspect the observed changes in market expectations over the Selic rate and inflation could be explained by factors entirely unrelated to the central bank and monetary policy. For example, the result concerning less updating of market expectations following meetings could reflect the fact that agents began cutting back on the frequency of updating their forecasts, which has nothing to do with a perception that monetary policy minutes are less informative. If this were the case, we would expect to observe similar changes in the market expectations series for unrelated (or at least more tangentially related) forecasts, such as those for industrial production also provided by the MES. Thus, I repeat the intervention analysis on the series of market expectations for industrial production in an effort to examine whether changes in the updating of market expectations are unique to monetary policy expectations. If the shift in procedural transparency has no effect on the market expectation series for industrial production, we should be more confident in the claim that the content of central bank communication is driving the observed pattern in market expectations over monetary policy.

The results for the intervention analyses on the market expectations over industrial production are provided in the Appendix, Table B.1. As expected, the implementation of individually attributed voting records following Copom meetings has no statistically significant effect on the amount which the market updates their industrial production expectations. Though it would be difficult to provide a theoretical explanation for why attributed voting records *would* lead to more or less reaction from markets' industrial production forecasts, this provides a robustness check by confirming a unique relationship between changes in procedural transparency and monetary policy expectations that cannot be explained by general trends in expectation formation across issue areas.

2.5 Conclusion

Central bank transparency is intended to enhance the accountability of central bankers and improve the predictability, and in turn efficacy, of monetary policymaking. This same justification is reiterated throughout the academic literature (Crowe and Meade 2007, Geraats 2002, Issing 2005), by central bankers themselves (Blinder 2004), and even international institutions like the International Monetary Fund in their development of institutional "best practices." Though transparency measures broadly conceived may in aggregate produce these outcomes, the empirical findings presented here identify an important caveat about applying this reasoning and justification for the publication of individually attributed voting records. Central bank transparency of this form can not only undermine the accountability to the public interest as suggested in previous research, it also appears to diminish the central banks ability to manage and coordinate market expectations.

These results have a number of additional implications. First, while the results most obviously present a cautionary tale for central banks facing pressure to release individually attributed voting records, they simultaneously suggest some findings in the existing literature may actually be lower bounds on potential gains from heightened procedural transparency. Previous analyses of procedural transparency and its relationship with quantities of interest like market expectations and policy transmission use a composite measure which includes four additive components: whether there is an explicit policy rule, release of minutes, timeliness of minutes, and the attribution of voting records (Dincer and Eichengreen 2014, Geraats 2002). Therefore, if the intuition and results here are believed, because the attribution of voting records has an opposite effect on central bank accountability and in turn policy predictability, the potential benefits of these other components are understated in these analyses.

In addition, there is an important lesson for scholars to be drawn from the comparison of these results with much of the literature focusing on the relationship between

dissents and the predictability of monetary policy. The data and analyses employed in this analysis not only fail to recover the market's ability to better predict future rate changes following a dissenting vote, they uniformly identify the opposite relationship with varying degrees of statistical significance. While this is in direct opposition to the interpretation of the results in the existing literature, there is an important difference between the actual tests. I examine the single case of Brazil in no small part because of a truly uniquely rich dataset on market expectations which provides daily updates of a variety of measures from a large number of private market forecasters. The theoretically comparable tests conducted on a variety of other central banks use proxies of market expectations (i.e., changes in the prices of money market contracts) which are regularly updating (Neuenkirch 2012), market expectations surveys conducted comparatively infrequently (often quarterly) (Hubert 2014), or infer from their own ability to estimate a model that dissents predict future policy changes that rational markets can and will do the same (Gerlach-Kristen 2004, Horvath, Smidkova and Zapal 2012*a*). As with any single country test there are concerns with extrapolating beyond the case at hand, but testing this relationship in most other domains or for a large cross-national sample forces researchers to work with comparatively weak measures of the primary quantity of interest.

Finally, the results speak most directly to the ongoing policy debate over the publication of voting records and central bank accountability. Though currently most actively debated at the European Central Bank by EU member states, similar policy changes are under active consideration elsewhere. The theoretical intuition and empirical results presented in this paper indicate there is nothing to be gained from the shift from anonymous to individually attributed voting records. Perhaps interestingly given the fervor of the current debate in political circles, this is not inconsistent with foundational literature that advocates of procedural transparency cite that equates anonymous vote outcomes with individually attributed records. In the absence of

market expectations data prior to the advent of anonymous Copom voting records in 1999, this empirical analysis cannot speak directly to the comparative performance of expectations when there was not even an anonymous vote outcome publicly released. However, neither can the existing literature which only looks at the shift from no voting record to attributing voting records. This is an area which hopefully can be explored in future research as the opportunity presents itself empirically.

As it appears there is little opportunity for policy reversion at central banks who begin publishing attributed voting records, this is an area which demands immediate attention from scholars and more thorough consideration in policy spheres. A worrisome trend in the evolution of central bank transparency which does seem to disproportionately affect procedural transparency policies is the application of broad national legislation like Freedom of Information laws to central banks. The experience in Brazil at the BCB where the shift to attributed voting records was mandated by national legislation that was neither directly related to the central bank nor concerned in design with monetary policymaking is far from unique. For example, voting records from Federal Open Market Committee meetings were attributed as a result of the Freedom of Information Act. In light of these results which suggest the individual attribution of votes can undermine the efficacy of monetary policymaking, greater care should be taken in considering how these laws are applied across a variety of institutions.

3
Inflation Targeting Regimes and the Implications for Monetary Policymaking

Abstract

How can governments ensure central banks pursue a desirable monetary policy strategy without infringing on their autonomy and independence? Though there is an unprecedented academic consensus surrounding the benefits of central bank independence, delegation to independent central banks presents the same classic delegation problems facing most independent agencies of bureaucratic drift and agency capture. In this article, I propose that the definition of inflation targets according to target inflation zones rather than target rates can effectively curb the policy drift away from target observed under target inflation rates. I test this claim with the analysis of original data on monetary policymaking and inflation performance at six central banks. The results suggest not only that the structure of the inflation target affects policymaking at central banks, but it provides a potentially valuable opportunity for governments to constrain policymaking without undermining institutional independence.

3.1 Introduction

How can governments ensure central banks pursue a desirable monetary policy strategy without infringing on their autonomy and independence? There is an unprecedented academic consensus surrounding the benefits of monetary delegation to independent central banks (Forder 2005). This reality is further reflected in a near universal delegation of authority over monetary policy instruments to individuals or committees housed in politically insulated central banks. Though there is ample empirical evidence expounding its benefits, delegation to independent central banks presents the same classic delegation problems facing most independent agencies of bureaucratic drift and agency capture (Keech 2013). For example, recent theoretical and empirical research has focused on how central bankers may be captured by the financial sector interests (Adolph 2013) as well as the potential for monetary policy drift due to changes in the economic climate over long terms of appointment (Ainsley 2016). While revoking the independence of central banks is hardly a viable solution to these concerns, the existing literature falls short of offering alternatives to mitigate such undesirable outcomes.

In this article, I address this gap in the literature by developing and testing a theory of decision-making at inflation targeting central banks. Specifically, I focus on the differential effect target zones and target rates have for monetary policy choices and inflation outcomes. When central banks choose policies according to a target inflation zone, their preferences over inflation outcomes are augmented in such a way that it mitigates the potentially deleterious relationship between uncertainty and monetary policy drift. By contrast, implementing inflation targets defined by a single target rate of inflation is an ineffective measure to address the policy drift which emerges due to changes in uncertainty. Thus, despite the seeming greater flexibility accorded to a target zone, this target structure can in practice constrain policymakers more than a single target rate. After demonstrating this counterintuitive

result theoretically, I present empirical evidence drawn from a sample of six central banks with varying inflation target structures.

The remainder of the article proceeds as follows. In the next section I briefly review the existing literature on inflation targeting and develop a heuristic model of monetary policymaking which yields a series of empirical implications. In the third section, I test the central claims using original data on monetary policymaking at the inflation targeting central banks in the Czech Republic, Hungary, Poland, South Korea, Sweden, and the United Kingdom. This dataset and analysis not only allows me to test claims in the existing literature on a larger set of countries, but also provides the opportunity to examine cross-nationally the implications the design of inflation targets has for policymaking. In the fourth and final section, I summarize the results and conclude with a discussion of their broader implications.

3.2 Delegation, Inflation Targeting, and Constrained Discretion

The Reserve Bank of New Zealand became the first central bank to adopt a formal inflation targeting framework in 1990. By 2005, over twenty emerging and industrial countries had followed suit and adopted explicit inflation targets. Much as the name suggests, an inflation targeting framework requires the "public announcement of medium-term numerical targets for inflation" (Mishkin 2008). In practice, the government, central bank, or some combination of the two is responsible for setting the target, which then commits monetary policymakers to striving for inflation outcomes at or near the specified target. Beyond this statement of a numerical target which is a common feature of all inflation targeting regimes, there is considerable cross-national variation in the structure and definition of targets. For example, the time horizon on targets varies considerably as well as the measure of inflation and specification of a

target point or range.

Scholars have focused primarily on two aspects of inflation targeting regimes: when and why countries adopt targets, and the effect of adopting a target on inflation performance. Given the rapid expansion of inflation targeting regimes, it is unsurprising the decision to adopt an inflation target has received such scholarly interest. In theory, scholars have argued inflation targets are an effective mechanism to lower inflation (King 2002) and inflation variability (Svensson 1997), coordinate (Bernanke et al. 2001) and lower (Johnson 2002, Mishkin 1999) inflation expectations, and establish a strong reputation and central bank credibility (Cukierman 2000, Tanuwidjaja and Choy 2006). However, in order to reap these perceived benefits of an inflation targeting framework, several institutional and market conditions must be met prior to the target's adoption (Carare et al. 2002, Mishkin 2008). Based on these preconditions for adoption, there is a continuously evolving literature examining whether specific countries "are ready" for the implementation of an inflation target (Akyurek, Kutan and Yilmazkuday 2011, Perera 2010, Saleem 2010).[28]

Setting aside this question of necessary preconditions, the empirical evidence of these perceived benefits is quite mixed even under optimal circumstances. While some have purported to demonstrate superior inflation and economic performance in developing countries with inflation targets compared to those without (de Mendonca and de Guimaraes e Souza 2012, Mishkin 2000), others have found just the opposite once controlling for the selection bias of which developing countries have chosen to adopt targets in the first place (Ball and Sheridan 2005, Brito and Bystedt 2010). There is, however, a growing consensus surrounding the efficacy of inflation targets as a means for coordinating market expectations and enhancing central banks' credibility. This advantage of inflation targeting has been of particular importance and well-documented in Latin America countries including Brazil and Chile (Capis-

[28]For a more thorough review of this literature on the adoption of inflation targets, their theoretical benefits, and the role of preconditions, see Samarina and Haan (2014) and Sterne (2002).

tran and Ramos-Francia 2010, Minella et al. 2003, Mishkin 2000, Nahon and Meurer 2009).[29]

While considerable debate remains, scholars have made tremendous strides in understanding the implications such monetary policy frameworks like inflation targeting regimes have for inflation performance. Much of this work, however, sets aside how the presence of an inflation target affects central bank decision-making in order to focus exclusively on real economic quantities of interest (i.e., inflation rates, output variability, etc.). Thus, somewhat surprisingly given the intense scholarly interest in measuring and identifying the influence of individual central bank preferences, the extant literature largely black boxes the policymaking process by examining only the relative performance of inflation targeting central banks.[30]

The degree to which this matters either theoretically or empirically for our understanding of inflation targeting hinges on the channel(s) by which we believe an inflation targeting framework affects real outcomes. If, on the one hand, the claim is that an inflation target affects inflation performance only by improving the efficacy of monetary policy through its coordination of market expectations, then understanding the implications for decision-making on monetary policy committees is of less interest and relevance for performance. However, if there are reasons to believe the presence of an inflation target alters the decision calculus of policymakers and effectively augments their preferences over inflation outcomes, this omission in the literature becomes of greater intrigue and importance. In a rare empirical paper on the issue, Bleich, Fendel and Rulke (2012) demonstrate for a sample of twenty countries that the adoption of an inflation target affects monetary policy strategies of central banks. Specifically, the authors demonstrate with an analysis of data before and after the implementation of the target that central banks place greater emphasis on inflation

[29]Both Walsh (2009) and Miller, Fang and Eren (2014) provide extensive surveys of this empirical literature on the effects of inflation targeting.

[30]For an important recent exception, see Creel and Hubert (2015), which looks specifically at monetary policymaking strategies and the response to inflation at inflation targeting central banks.

stabilization once an inflation target is in place. Though this work makes little distinction among types of inflation targets and is not concerned with understanding why this change may or may not occur, it provides important cross-national evidence to suggest inflation targets influence the decision calculus of central bankers.

Despite the relative dearth of empirical evidence on how an inflation target affects policy choices, there is in fact ample anecdotal evidence to suggest central bankers themselves are sensitive to inflation targets and adjust their policymaking strategies accordingly. As Gordon Thiessen, former Governor of the Bank of Canada, put it:

> "There is no question that the targets really did help us bring our inflation below that of the US. I think it is just another indication that the target system really did work very well. But in assessing inflation targets, we do not just want to look at the success of bringing down inflation, although that is terribly important. [...] it changes the way you make decisions and the way you describe decisions" (in Mahadeva and Sterne (2000)).

Thiessen highlights the seemingly overlooked aspect of inflation target evaluation this article seeks to address. While substantial attention has been and continues to be devoted to evaluating the impact of inflation targets on a country's inflation performance, we understand relatively less about the second facet of how adopting an inflation target changes decision-making and strategies on monetary policy committees. This same sentiment is reiterated by Ben Bernanke, former Chairmen of the Federal Open Market Committee (FOMC) of the US Federal Reserve. He and his co-authors describe monetary policymaking with an inflation target as the exercise of "constrained discretion." Inflation targets, they argue, simultaneously provide central banks the necessary flexibility to conduct monetary policy effectively while keeping them "disciplined" and accountable (Bernanke et al. 2001).

If monetary policymakers operate with such constrained discretion in the presence of an inflation target, is it possible to structure inflation targets in such a way that

overcomes some of the issues that emerge with delegation to an independent agency? According to the extant literature on monetary policymaking, one source of monetary policy drift is uncertainty that leads inflation averse central bankers to pursue a hedging strategy that results in inflation outcomes below targeted rates (Ainsley 2016, Nobay and Peel 2003, Ruge-Murcia 2002). In other words, when there is a threat of a large inflationary shock, central bankers prefer to choose policies well-below their target in an effort to protect themselves against the possibility of this costly outcome. As we often assume central bankers are more inflation-averse than governments à la Rogoff's "conservative central banker," this sort of hedging inherently leads to inflation outcomes drifting from the government's preferences (Adolph 2013, Rogoff 1985).

Focusing specifically on this source of theoretically unbounded policy drift, I suggest the implementation of a target in the form of an inflation zone can effectively constrain policy choices and curb central banks' tendencies to increasingly hedge against high-inflation in the presence of heightened uncertainty. The results concerning policy drift in the presence of uncertainty from the previously cited literature either explicitly assume a point inflation target or define objectives according to an individual's inflation ideal point, which we can reasonably interpret as a point target. With a point target defined as an inflation rate in the absence of a band of tolerance, there is a constant cost to hedging outcomes away from the target rate. By contrast, establishing an inflation target zone may serve to simultaneously augment these preferences in two ways. First, the presence of a zone lessens some of this incentive to hedge against inflationary shocks by increasing the relative cost of doing so beyond a certain point. Additionally, a target zone can increase the central bank's tolerance for outcomes in a narrow range above target by lowering the relative disutility of these outcomes. Thus, while the fundamental incentives and policymaking strategies are the same for central bankers operating under target points and zones, we should

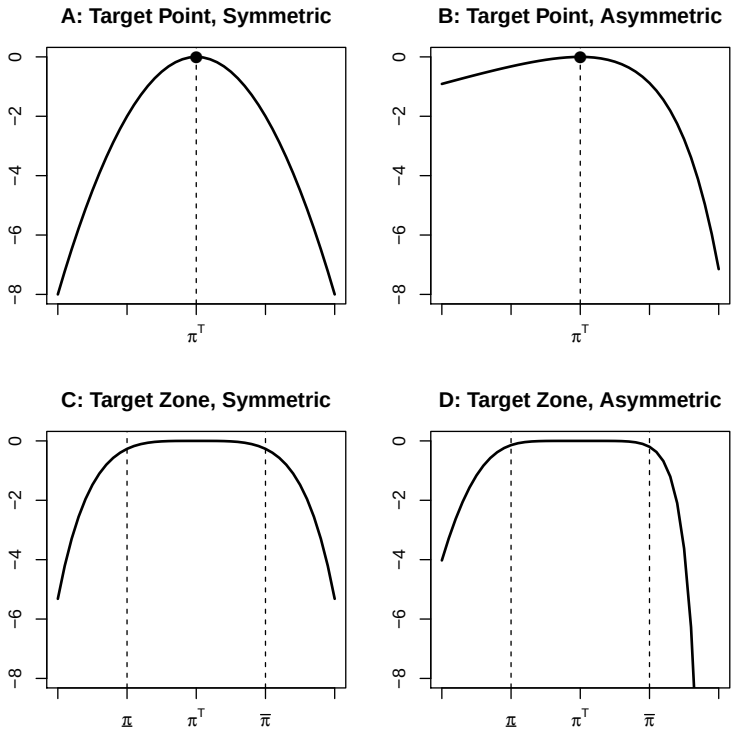

Figure 3.1: Inflation Targets and Utility Functions

This figure illustrates four hypothetical central bank utility functions across different types of inflation targeting regimes. In each figure, utility losses are plotted on the y-axis and inflation outcomes across the x-axis. Point targets are denoted π^T and target zones are given by their lower ($\underline{\pi}$) and upper ($\overline{\pi}$) bounds.

expect less policy drift in the presence of uncertainty under target zones.

While it is perhaps not immediately clear how defining central bank objectives according to a target inflation zone rather than a target inflation rate affects their decision calculus and interacts with uncertainty, the following heuristic model provides some intuition and traction on these relationships. Assume in an inflation targeting regime, central bankers' objectives can vary on two, discrete dimensions: (1) targets specified as a point or zone, and (2) the symmetry or asymmetry of their preferences over outcomes above/below this target point or zone. Taken together, these dichotomous pairs yield the four different central bank preference structures, which are depicted graphically in Figure 3.1.

First, consider the description of preferences in Figures 3.1A and 3.1B, which

reflect the more common definition of an inflation target as a target rate of inflation. In practice, these could reflect an inflation target like that currently implemented at the Bank of England, which is defined as a "2% increase of the annual rate of inflation based on the consumer price index" (Bank of England). In this case, the policymakers' target-induced preferences can hypothetically be represented by a point on a single dimension. The difference between Figures 3.1A and 3.1B is of course how they evaluate outcomes deviating above and below this target rate. While in Figure 3.1A the target is specified such that a policymaker ought to be indifferent between equidistant deviations above and below target, in Figure 3.1B inflation outcomes above target are considered more costly than those below.

By contrast, if as is often the case an inflation target is defined by an acceptable zone of inflation outcomes, it may be more appropriate to describe policymaker preferences and central bank objectives like those depicted in Figures 3.1C and 3.1D. Here, rather than assuming a unique target rate at which the central bank faces no costs, we can define a range of inflation outcomes which policymakers find equally desirable and derive no disutility. Just as before, it is possible for policymakers to have symmetric (Figure 3.1C) or asymmetric (Figure 3.1D) preferences about this target zone.

Given this set of inflation targets and the structure of induced preferences, how does the definition of the inflation target affect policy choices and in turn inflation outcomes? To answer this question, I numerically simulate utility maximizing policy choices and the resulting expected inflation outcomes for each preference specification. Each of these preference distributions is contained as a special case of a generalized form of the linear-exponential function.[31] While it is clear from Figure 3.1 a pol-

[31]The utility function takes the following form:

$$u(\pi) \quad = \quad \frac{exp[\alpha(\pi - \pi^T)^\beta] - \alpha(\pi - \pi^T)^\beta - 1}{\alpha^2\beta},$$

where π is the inflation outcome, π^T is the inflation target, and α and β determine the shape of

icymaker's most-preferred outcome is either inflation at the point target or within the target zone, I assume policy instruments (i.e., interest rates) only imperfectly determine inflation outcomes. Specifically, policy choices are affected by an additive shock drawn from a mean-zero distribution with known variance. Consistent with the existing literature, the variance of the distribution of the error term is substantively interpreted as the magnitude of uncertainty facing policymakers (Ainsley 2016, Nobay and Peel 2003, Ruge-Murcia 2002).[32] When the variance of the distribution is high (low), there is a higher (lower) probability of a large positive or negative shock affecting the transmission of the interest rate into the inflation outcome, making a policymaker less (more) uncertain about inflation outcomes.

In Figure 3.2, I plot the results of the simulations which demonstrate the relationship between the expected rate of inflation and uncertainty facing policymakers for each of the four inflation targeting specifications. Several observations emerge from this exercise. First, results for point targets reflect those from standard models which define central bank preferences with an ideal point. Under a symmetric point target, inflation outcomes are in expectation always at the target rate. This result captures a well-known property of symmetric utility functions known as certainty equivalence, which leads decision-makers to behave as if they faced no uncertainty (Blanchard and Mankiw 1988). Introducing asymmetry into the decision-makers' preferences over inflation outcomes breaks the property of certainty equivalence and leads to policy choices deviating from the target in expectation. Further, the magnitude of this deviation is conditional on the uncertainty environment: as uncertainty increases and

the utility function. When $\beta = 1$ and $\alpha \to 0$, the utility function approximates a quadratic loss function with a unique inflation target, π^T. When $\beta = 1$ and $\alpha \neq 0$, the utility function collapses to the standard linear-exponential function with a unique ideal point. Finally, when $\beta = 2$ and $\beta = 3$, the utility function corresponds to the symmetric and asymmetric (respectively) target zones. For other examples of its use, see Boinet and Martin (2008), Naraidoo and Raputsoane (2010, 2011), Srinivasan and Kumar (2012).

[32]Formally, I define the inflation outcome (π) by the following equation: $\pi = f(i) + \varepsilon$, where $\varepsilon \sim N(0, \sigma^2)$. For a more thorough discussion of this interpretation and further applications, see the work cited above.

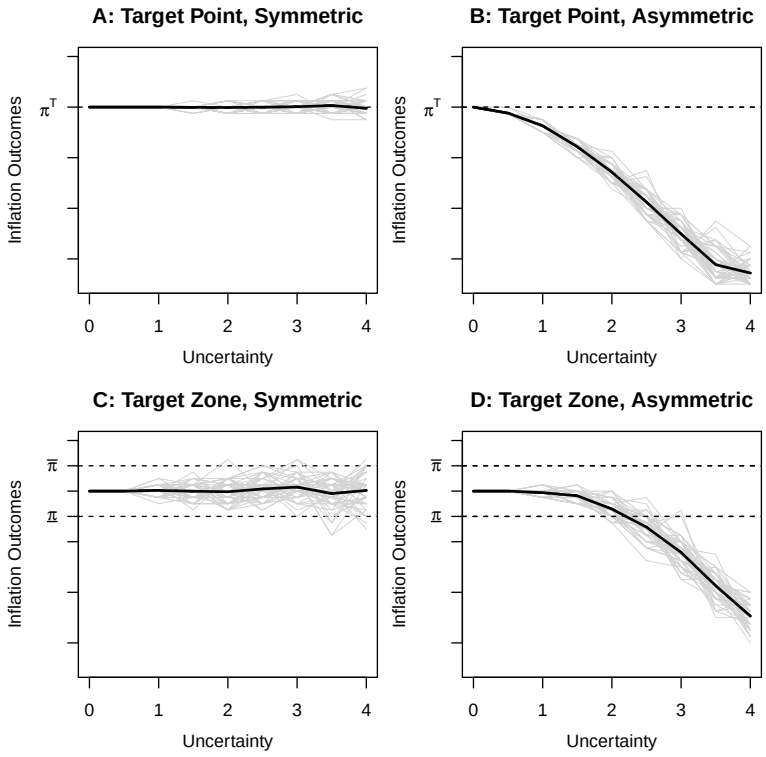

Figure 3.2: Inflation Outcomes in Different Inflation Targeting Regimes

This figure illustrates the expected inflation outcomes (on the y-axis) simulated across levels of uncertainty (on the x-axis) for each specification of inflation targets defined in Figure 3.1. The mean of the 1000 simulations is given by the solid dark line and each individual simulation is plotted in the light grey lines. Target inflation outcomes on the y-axes are denoted by either the target rate π^T or target zone, $\underline{\pi}$ and $\overline{\pi}$. Finally, uncertainty is given by the standard deviation on the error term ε which affects the transmission of a interest rate policy choice into an inflation outcome.

the probability of a costly inflationary shock increases, the central banker prefers to choose policies below target that guard against this possibility.[33] In the case of an asymmetric inflation point target (Figure 3.2B), the observed relationship between uncertainty (on the x-axis) and inflation outcomes (y-axis) captures the hedging behavior discussed in greater detail in Ainsley (2016) and Ruge-Murcia (2002). This comparison between symmetric and asymmetric targets leads to the first observation:

[33]There is a substantial literature on assessing the degree of asymmetry in central bank reaction functions and preferences. For a more thorough review of this work and examples of applications specific to inflation targeting regimes, see Nobay and Peel (2003), Srinivasan, Mahambare and Ramachandran (2006), Schaling (2004), and Kim and Seo (2008).

Observation 1. *Monetary uncertainty does not affect policy choices when inflation targets, with respect to either a point or zone, are symmetric.*

Much of the same intuition emerges in the comparison of inflation zones with symmetric (Figure 3.2C) and asymmetric preferences (Figure 3.2D). Though predictably there is greater dispersion around the midpoint of the symmetric zone target than there is for the symmetric point target, inflation clearly adheres closely to this target level for all levels of uncertainty. This reflects the same property of certainty equivalence which appears for the symmetric point target. It follows that when a central bank faces low levels of uncertainty, outcomes are at or near the target regardless of preference symmetries and how the target is defined. Just as before, hedging behavior only emerges as uncertainty increases and the probability of an inflationary shock increases. This gives way to a second observation concerning the relationship between uncertainty, inflation outcomes, and the design of inflation targets:

Observation 2. *Under low levels of monetary uncertainty, inflation outcomes should be at or near their targets across all types of targeting regimes.*

As uncertainty increases, central banks with asymmetric preferences about their target have the incentive to strategically hedge and choose policies which produce inflation outcomes below the target in order to guard against an increasingly likely inflationary shock. Thus,

Observation 3. *Under high levels of monetary uncertainty, central banks with asymmetric targets (defined by a point or zone) should choose policies that result in inflation outcomes deviating further from their targets than those with symmetric inflation targets.*

In addition to these similarities across target points and zones, a critical difference emerges that suggests the ability to curtail excessive hedging by defining targets according to inflation zones rather than point rates. Under asymmetric preferences

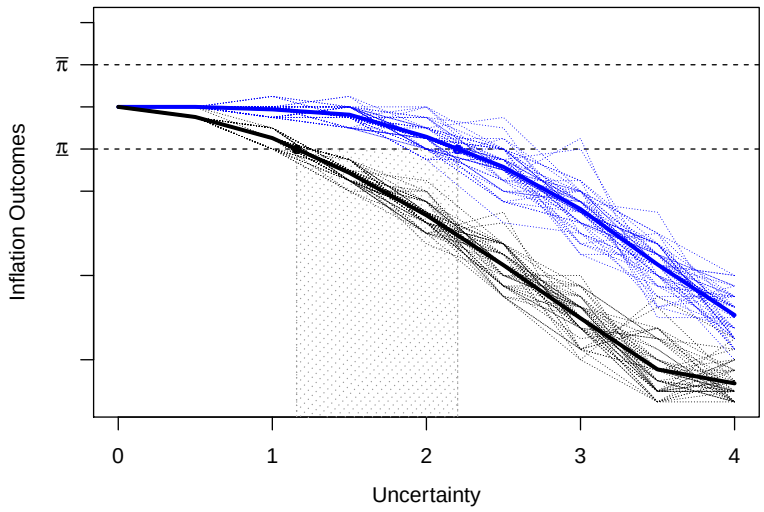

Figure 3.3: Inflation Outcomes with Asymmetric Inflation Targets

This figure reproduces the simulation results given in Figures 3.2B and 3.2D for asymmetric inflation target points (black) and asymmetric inflation target zones (blue). The grey shaded region highlights the range of corresponding uncertainty environments in which an inflation zone targeting central bank outperforms a point targeting central bank by achieving inflation outcomes within the zone, on average.

with an inflation target point (Figure 3.2B), the induced hedging results in a near-linear, decreasing relationship between uncertainty and inflation outcomes. However, when preferences are asymmetric with respect to an inflation target zone (Figure 3.2D), we observe inflation outcomes in the target zone (and closer to the midpoint of this range) for higher values of uncertainty before the incentive to hedge leads to larger deviations. This comparison is reproduced in Figure 3.3, where the inflation outcomes with a point target are given in black and those with a zone target are in blue. It is clear from this depiction of the results that there exists a range of uncertainty environments (shaded in grey) for which policies pursued according to a target zone outperform those chosen according to a single target rate. Therefore, the final two observations speak to these differential relationships between uncertainty, policy choices, and inflation outcomes for central banks with point and zone inflation targets.

Observation 4. *Monetary uncertainty should affect policy choices in targeting*

regimes with point targets more than it does in targeting regimes with zone targets.

Observation 5. *While at the highest levels of uncertainty inflation outcomes should nearly converge for those with zone and point inflation targets, the magnitude and degree of hedging away from target should be less when the target is defined by an inflation zone.*

Intuitively, this is the relationship we ought to expect. Inflation targeting zones decrease the relative disutility of deviations as long as outcomes remain within the lower and upper bounds. Critically, this is true even if we assume central banks operating under a target zone implicitly target the midpoint of that range and find inflation outcomes within the zone but deviating from the midpoint costly. Because an inflation outcome just outside the lower bound, for example, is more costly than one on or just inside it, there is less incentive to hedge policy choices in that neighborhood of expected inflation outcomes. Thus, implementing a target inflation zone curbs the degree of monetary policy hedging for intermediate levels of uncertainty, effectively delaying and mitigating the dramatic policy drift we observe under extreme levels of uncertainty.

3.3 Empirical Analysis

To examine empirically these expected relationships between uncertainty, policymaking, and inflation outcomes, I draw on novel data collected on monetary policymaking and uncertainty in six inflation targeting countries: the Czech Republic (2008-2016), Hungary (2005-2015), Poland (2011-2016), South Korea (2010-2016), Sweden (1998-2016), and the United Kingdom (1998-2016). In this section, I discuss both the sample of countries and their inflation targeting experiences during these times as well as measurement techniques for estimating monetary uncertainty and preference asymmetries.

Table 3.1: Inflation Targeting Central Banks Sample

Country	Years	Stated Target	Point or Zone?	Who Sets?
Czech Republic	2008-2010	2-4%	Zone	Gov and CB
	2010-	1-3%	Zone	
Hungary	2005-2015	3%	Point	Gov and CB
Poland	2011-	2.5%	Point	CB
South Korea	2010-13	2-4%	Zone	Gov and CB
	2013-16	2.5-3.5%	Zone	
Sweden	1998-	2±1%	Point	CB
United Kingdom	1998-	2%	Point	Gov

This table includes each central bank in the sample and the years and definition of their inflation targets. While the Czech Republic, Poland, and South Korea all established inflation targets prior to the included years in the table, the absence of inflation forecasts and corresponding fan chart necessary to measure uncertainty restrict the sample to the following years. All inflation targets are given in terms of the annual percentage increase in the consumer price index, or CPI.

3.3.1 The Data

The primary criterion for the selection of this sample is the adoption and maintenance of an inflation target in not too recent history coupled with data availability. Further, while this represents a small sample of all inflation targeting regimes and even smaller proportion of central banks, within this sample of countries there is critical variation in the structure of inflation targets that allows for relevant cross-national comparisons. In addition to the implementation of an inflation target, each central bank in the sample publishes statements of uncertainty around their inflation forecast, which provides the data to construct the common and comparable measures of monetary uncertainty discussed in the following section.

The critical feature of this sample worth highlighting prior to presenting the measurement strategies is the variation in how each central bank has chosen to define their inflation targets. In Table 3.1, I summarize the definitions of each central bank's inflation target(s). Central banks in both the Czech Republic and South Korea define

their targets according to zones of inflation. In contrast, the inflation target in Sweden is given as 2%, with an explicit tolerance band of 1% above and below this point. Though widely described as a point target, this structure may be considered somewhat of a hybrid between a true point target (like Hungary and Poland) and the inflation zones in the Czech Republic and South Korea. While for theoretical clarity it is easiest to think about inflation targets being either a point or a zone, in practice these are likely extreme poles which many observations fall in between. The degree to which this variation in the definition of targets affects behavior is ultimately an empirical question I aim to address.

Measuring Monetary Uncertainty

To measure the key explanatory variable, I draw on each central bank's self-reported statements of uncertainty over their inflation forecast. While central banks provide a variety of information intended to convey their policy uncertainty, one increasingly common method of reporting monetary and inflation uncertainty is the publication of "fan charts."[34] These fan charts, which are often included for several of the major economic indicators, accompany the central banks' forecasts and typically illustrate varying levels of confidence (i.e., 30%, 60%, and 90%) around a central projection up to three years from publication. Thus, when looking at an inflation forecast presented in a fan chart, one can, for example, infer with 90% confidence a range in which inflation is likely to fall one year in the future.

The information central banks incorporate in the construction of these confidence intervals makes them a valuable piece of data for measuring uncertainty as it is conceived here. While a central bank's assessments of uncertainty necessarily include a baseline level of forecast error, they also incorporate "whether uncertainty looking forward is likely to be greater or less than that of past experience" (Elder 2005). That

[34]For a more thorough discussion of the publication of fan charts and central banks' statements of uncertainty, see Hampton, Philip and Stephens (2003).

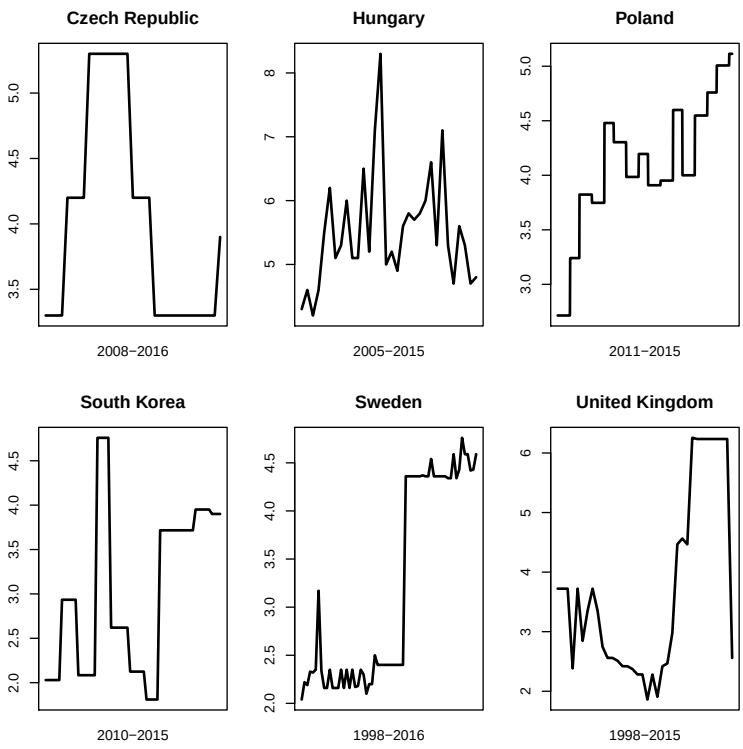

Figure 3.4: Monetary Uncertainty Measurement

This figure illustrates the time series for measures of monetary uncertainty for each country in the sample. The y-axis corresponds to the width of 90% band on inflation fan charts one year from the time of the meeting.

is, from the perspective of the policymakers themselves, fan charts reflect the relative level of uncertainty central banks face in their policymaking moving forward. In addition to having the advantage of being self-reported from the decision-making body being studied, this data also provides the necessary temporal variation in uncertainty which motivates the research question at hand. While none of the central banks in this sample update and publish inflation forecasts and corresponding fan charts at every meeting, this data is typically released alongside monetary policy reports no less than four times a year.[35]

To systematically quantify these central bank assessments of uncertainty, I mea-

[35]In most cases, the data used to create the fan charts is published alongside the report in which they are included. However, for both Poland and South Korea there is no accompanying data from which I was able to directly recreate the plot and calculate the width of the confidence interval. Instead, I relied on the R package digitize to extract the relevant data points (Poisot 2011).

sure the widths of the bands of uncertainty around central banks' inflation forecasts. Specifically, I record uncertainty as the difference between the upper and lower bounds of the 90% confidence interval around the inflation forecast one year from the time of publication. This is the same measurement approach first employed in Ainsley (2016) on data from central bank of Hungary. Figure 3.4 shows the time series of uncertainty measures for each country in the sample. This measurement approach is is particularly attractive in this comparative application because it allows for the cross-national comparisons which would be limited by other, less systematic records of uncertainty. For example, while the Bank of Japan is another inflation targeting central bank which publishes forecasts along with assessments of uncertainty, it does so only with ordinal statements of whether they perceive more or less uncertainty than in previous periods. Though this information provides similar insights into the policymaking process of the monetary policymaking committee, it does not provide a measure we can as easily compare cross-nationally. In the remainder of the analysis, I normalize these measures of uncertainty to enable direct, cross-country comparisons.

Identifying Central Bank Asymmetries

In addition to the distinction between inflation target points and zones, the theory presented here yields expectations concerning the relationship between preference (a)symmetry, policy choices, and inflation outcomes. Ideally, we would construct a sample of inflation zone and inflation point targeting central banks who have both explicitly symmetric and asymmetric targets. The European Central Bank, for example, has an explicitly asymmetric target defined as "up to 2%" inflation, while in Sweden the inflation target is symmetric by definition, at 2±1%. Unfortunately, the necessary data from the forecasts and fan charts is not made publicly available by all inflation targeting central banks and none of the central banks in this sample have explicitly asymmetric targets. However, defining an inflation target as symmetric

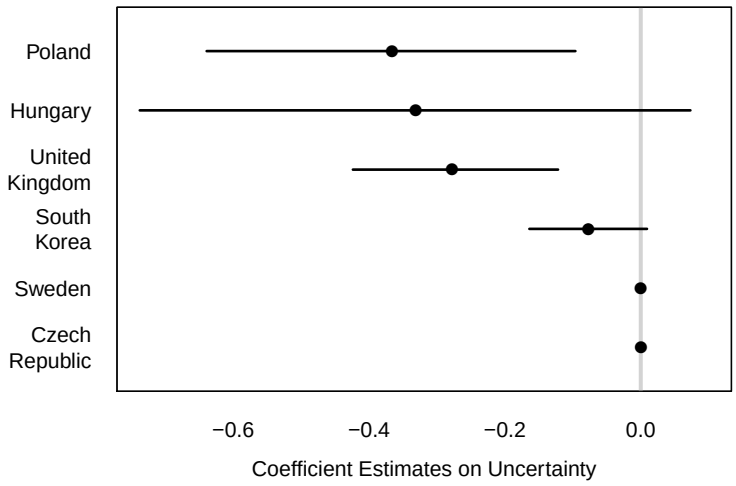

Figure 3.5: Central Bank Preference (A)symmetries

The coefficient estimates for the estimated effect of uncertainty (β_1) from the model given in Equation 3.12 are plotted for each central bank. The band around each coefficient corresponds to the 95% credible interval. When the estimates approach zero, given by the vertical grey reference line, uncertainty has no affect on policy choices and we will assume preference about an inflation target are symmetric.

does not necessarily mean individuals and the committee as a whole will pursue the target point or zone as if they have perfectly symmetric preferences. Rather, as I will demonstrate empirically, preference asymmetries enter into the central banks' as well as individual policymakers' decision calculus even in the pursuit of a target defined as symmetric.

Recall from Observation 1 and the aforementioned research on preference asymmetries and certainty equivalence that uncertainty should only affect policy choices if preferences are asymmetric. In other words, the effect of uncertainty is conditional on the degree to which preferences are asymmetric. I can, therefore, leverage this result to categorize each of the six formally symmetric inflation targeting central banks according to whether they appear to possess more symmetric or asymmetric preferences about their targets.

To quantify the effect of uncertainty on policy choices and infer the degree of (a)symmetry in central bank preferences, I estimate reaction functions for each of

the six central banks in the sample. The dependent variable, R_t, is the interest rate outcome from meeting t and I model it as a function of uncertainty (as measured from the fan charts) and the lagged interest rate, R_{t-1}. This equation takes the following form:

$$R_t \sim N(r^* + \beta_1 * \text{Uncertainty}_t + \beta_2 * R_{t-1}, \sigma_R^2), \tag{3.12}$$

where r^* is an intercept which in the absence of uncertainty results in inflation outcomes at the inflation target, and the second term ($\beta_1 * \text{Uncertainty}_t$) corresponds to the effect of uncertainty on the monetary policy choice. This interpretation of the intercept is theoretically motivated and consistent with the existing literature. Thus, as $\beta_1 \to 0$, we can say the central bank has approximately symmetric preferences with respect to the inflation target.

Results are presented graphically in Figure 3.5. For each central bank, I plot the 95% credible interval for the estimated coefficient on uncertainty (β_1). Notably, there is considerable variation in the sample with respect to the effect of uncertainty on policy choices and, in turn, the estimated degree of asymmetry. The central banks in Poland, the United Kingdom, and Hungary appear to exhibit the most asymmetric preferences, while in both Sweden and the Czech Republic preferences appear to be near perfectly symmetric. In South Korea the interval just barely crosses the zero threshold. While we cannot reject the possibility of symmetric preferences, it suggests at the very least the central bank is more sensitive to uncertainty than the other inflation zone targeting central bank in the sample, the Czech Republic.

With these empirical estimates I can now crudely classify each central bank according to the dichotomous typology defining inflation targets and their symmetry. While the distinction between point and zone targets is relatively straightforward, it is less clear how to classify the continuous dimension of asymmetry exhibited by

Table 3.2: Classification of Inflation Targeting Central Banks

	Point Target	Zone Target
More Symmetric	Sweden Hungary	Czech Republic
More Asymmetric	United Kingdom Poland	South Korea

Each inflation targeting regime is classified according to whether it defines its target by a single inflation rate (point) or a range of inflation outcomes (zone) as well as the degree of asymmetry in their preferences according to the reaction function estimated from Equation 3.12.

several of the banks. In Table 3.2, I propose a categorization of each central bank into one of the four categories of inflation targeting regimes identified at the outset. It seems rather uncontroversial to conclude from the results that central banks in both Sweden and the Czech Republic exhibit symmetric preferences. Similarly, the statistically significant effects of uncertainty for the central banks in both Poland and the United Kingdom suggest they are likely to exhibit asymmetric preferences about the inflation target. For both Hungary and South Korea, the argument for inclusion in one group of the other is less clear. As demonstrated in Table 3.2, I choose to classify these borderline cases as having asymmetric preferences despite the fact that both credible intervals cross the threshold for being symmetric preferences. I do this for several reasons. In the case of South Korea, the credible interval narrowly fails to remain significant, so much so that the estimate *is* statistically distinguishable from zero with 90% confidence. Though for Hungary this is not the case, the standard deviation is so large (0.21) it would have to exhibit the largest estimated coefficient across countries in order to achieve significance at standard levels. Thus, while it is

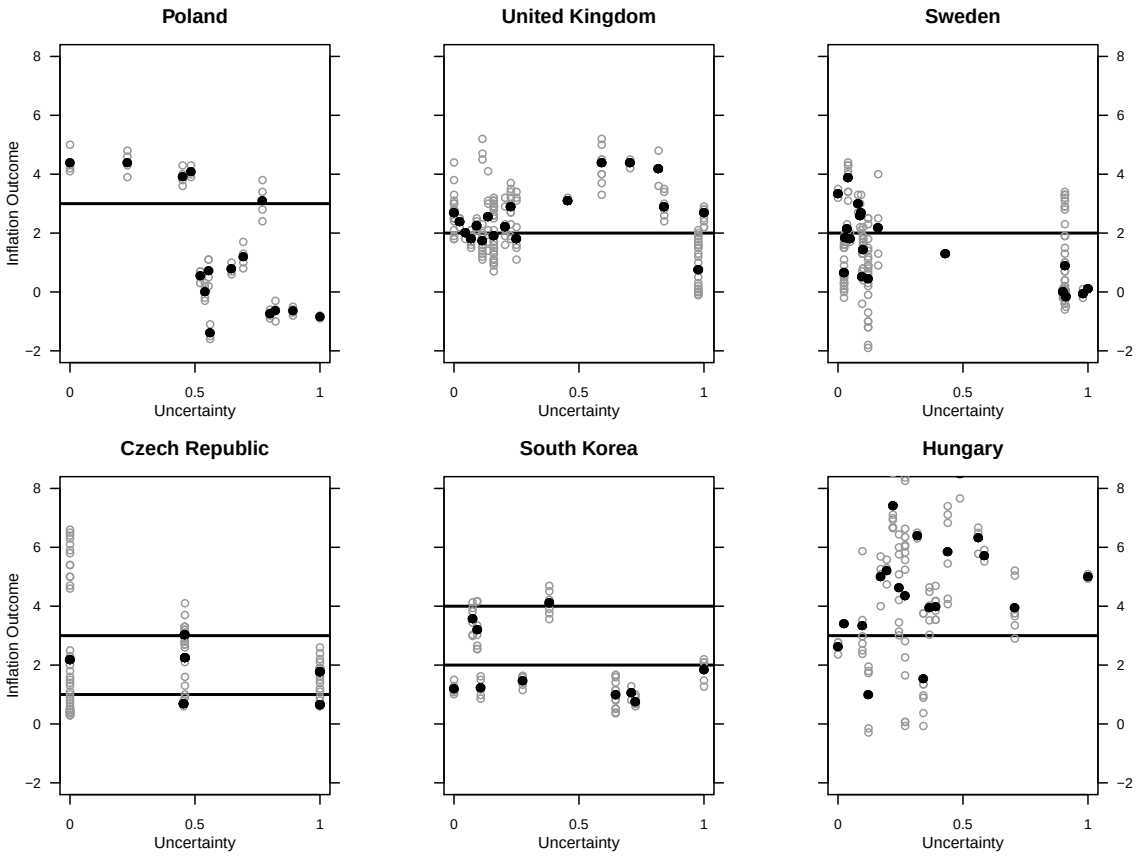

Figure 3.6: Raw Data: Inflation Outcomes and Uncertainty

For each central bank in the sample, I have plotted the relationship between inflation outcomes (on the y-axis) and uncertainty (on the x-axis). The raw data is plotted in the open grey points while the solid black points correspond to the mean inflation outcome for a given level of uncertainty. The horizontal reference line reflects the stated inflation target for that central bank.

important to keep these more subjective placements in mind moving forward, it is reasonable to assume these central banks do not exhibit perfectly symmetric preferences.

3.3.2 Results

Before considering each of the specific theoretical expectations in turn, some initial patterns emerge when examining the raw data. In Figure 3.6, the observed inflation outcomes are plotted against the normalized measure of uncertainty for each central

bank. While some countries perform reasonably well in terms of meeting their respective inflation targets, there is unsurprisingly meaningful variation across all levels of uncertainty. Further, with the exception of the observed inflation outcomes in Hungary, there appears to be a bias towards undershooting inflation targets in the face of heightened monetary uncertainty. While the United Kingdom has several above target outcomes in the presence of higher uncertainty, all of them can be attributed to the years of the financial crisis and banking bailouts. I do not drop these observations, but it is worth noting the inflation performance bears a closer resemblance to Sweden's when these years are removed from the sample. In the remainder of this section, I draw on permutations of this raw data and specific country comparisons to examine whether the theoretical predictions from the simulations are borne out in the data.

Inflation Target Performance with Low Uncertainty. The first empirical implication from the theoretical exercise suggests under low levels of uncertainty, inflation outcomes should be close to the inflation target regardless of how the target is defined. There is some evidence of this prediction even in the raw data presented in Figure 3.6, where mean inflation outcomes under low-levels of uncertainty adhere reasonably closely to the target levels of inflation. This appears particularly true in the case of the United Kingdom, for example, where under low levels of uncertainty nearly all of the mean outcomes are within a percentage point of the target rate.

To examine this relationship in the data more systematically, I explore how uncertainty is related to the root mean squared error (RMSE) of inflation outcomes with respect to the inflation targets. In Table 3.3, I provide the results for six bivariate regressions to examine whether uncertainty explains variation in central banks' success in hitting their inflation targets. While the estimated effect of uncertainty only reaches statistical significance for Sweden and the UK, the coefficient is signed as predicted in every case except the Czech Republic, for which it is negative but effectively

Table 3.3: Results: Uncertainty and Inflation Target Performance

Country	Czech Republic	Hungary	Poland	S. Korea	Sweden	U.K.
Uncertainty	-0.04	1.30	1.32	0.81	1.12*	0.98*
	(0.64)	(1.26)	(0.90)	(0.56)	(0.33)	(0.42)
Intercept	0.82	1.86	1.47	0.48	0.88	0.74
	(0.42)	(0.53)	(0.58)	(0.29)	(0.16)	(0.21)
N	6	19	15	10	20	18

Results of bivariate regressions of uncertainty on the RMSE of inflation outcomes and inflation targets. Standard errors are given in parenthesis. *p < 0.05.

zero and statistically insignificant. For Sweden and the United Kingdom, a standard deviation increase in uncertainty corresponds to an increase in the RMSE of 0.43 and 0.35, respectively. Given average RMSE of just over 1 point in these countries, this amounts to a roughly 30% increase in error with a single standard deviation increase in uncertainty. Though the empirical evidence supporting the prediction that inflation will be at target on average under low levels of uncertainty is mixed, the results indicate central banks are most likely to hit their target when uncertainty is low.

Further, as expected from the simulation results, there is no discernible pattern relating the definition of the inflation target or degree of preference asymmetry with targeting performance at low levels of uncertainty. From Figure 3.6, it appears the United Kingdom and Sweden, who exhibit asymmetric and nearly perfect symmetric preferences, respectively, perform similarly with one another as well as with the Czech Republic and South Korea, who both target inflation zones. As uncertainty increases, however, we should expect to see both policy and inflation outcomes which discriminate across the types of inflation targeting regimes.

Inflation Outcomes and Preference Asymmetries with High Uncertainty. Following from Observation 3, inflation outcomes under heightened uncertainty should differ depending on the symmetry of central bank preferences. Specifically, a central bank with asymmetric preferences should lead to inflation outcomes de-

viating further from their target than they would under symmetric preferences due to the hedging behavior induced by increased uncertainty. To examine whether this relationship appears in the data, I compare the inflation performance of South Korea with that of the Czech Republic, who both target inflation zones, and then similarly the performance of Poland and the United Kingdom with Sweden, all of which have point inflation targets. These pairwise comparisons allow me to hold constant the structure of the target (i.e., point or zone) and better isolate the effect of preference symmetries on the inflation outcomes.

First, consider the success of each inflation zone targeting central bank in achieving outcomes in their target range when faced with heightened uncertainty. In Figure 3.7, I compare the relative frequency each central bank achieved inflation outcomes at each level of high uncertainty. Similar to the patterns observed in the raw data in Figure 3.6, South Korea performs relatively poorly compared to the Czech Republic when it comes to achieving outcomes in their target zone under high levels of uncertainty. In the 32 months in which uncertainty was its highest, observed inflation outcomes in South Korea were in the target zone only six times. By contrast, in the Czech Republic inflation outcomes are in the target zone 50% of those months they faced high levels of uncertainty. These results are consistent with the theoretical claim that asymmetric preferences about a target zone in South Korea leads policymakers to engage in hedging under high levels of uncertainty that can result in inflation outcomes consistently deviating from the target in expectation. The absence of this hedging behavior due to symmetric preferences about the target inflation zone in the Czech Republic is on possible explanation for their comparatively strong performance in achieving inflation within the target zone under high uncertainty.

A similar pattern should also emerge among those countries who target an inflation rate rather than zone. Under heightened uncertainty, those central banks with asymmetric preferences (Poland and the United Kingdom) should lead to inflation

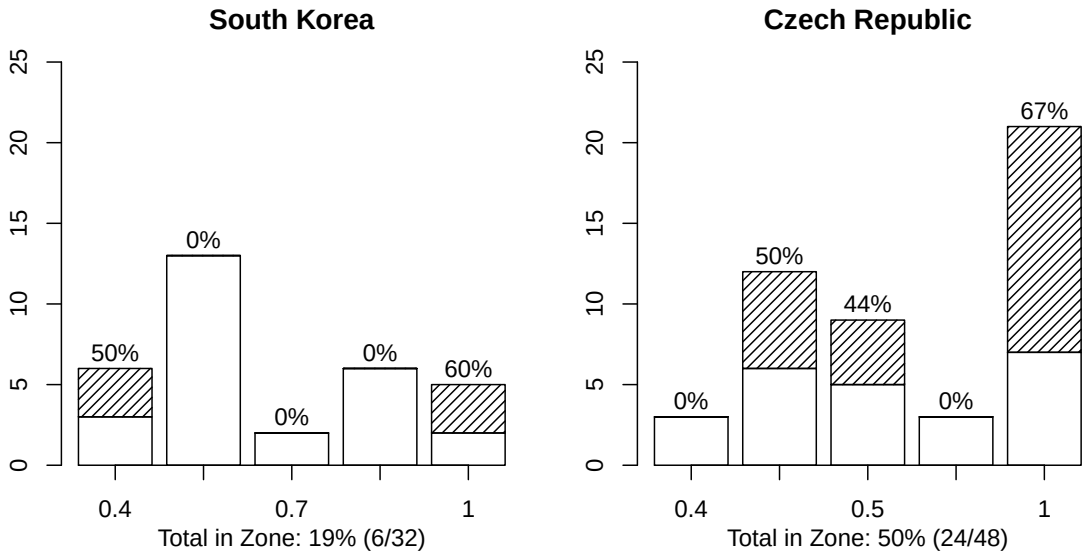

Figure 3.7: Inflation Performance with High Uncertainty and Zone Targets
This plot shows the percentage of inflation outcomes occurring in the target zone at each level of high uncertainty for the two inflation zone targeting central banks in the sample, South Korea and the Czech Republic.

outcomes deviating further from target than they do when the central bank has symmetric preferences (Sweden). It does not make sense here as it did before to talk about the percentage of outcomes precisely at the target because that rarely (if ever, in some cases) happens. Instead, we can compare across varying levels of asymmetry the magnitude of deviations from target when uncertainty is high. The evidence for this prediction is mixed. While Poland clearly performs the worst with respect to meeting its target under high levels of uncertainty, the United Kingdom slightly outperforms Sweden, who according to the theory should have the smallest deviations from target due to the central bank's near perfectly symmetric preferences.

Policy Choices under Inflation Point and Zone Targets. In addition to expectations over how the symmetry of central bank preferences interacts with uncertainty and affects inflation outcomes, the theoretical model yields discriminating predictions about the policymaking strategies and inflation outcomes of central banks targeting inflation rates and inflation zones. Following from Observation 4, the policy choices

of central banks targeting inflation zones ought to be less influenced by uncertainty than those with point inflation targets. This prediction arises due to the claim that the presence of an inflation zone curbs the incentive for policymakers to hedge by decreasing the relative costs of deviating within a target zone. The results from the model estimated in Equation 1 and presented in Figure 3.5 provide some evidence in line with this expectation. Each of the central banks with asymmetric preferences and a point target (Poland, Hungary, and the United Kingdom) have larger coefficients on uncertainty than South Korea, who has asymmetric preferences about a target zone. Therefore, in terms of policy outcomes, the presence of a target zone does appear to mitigate some of the incentives at the policymaking stage that lead to large deviations in outcomes under heightened uncertainty.

Does this same relationship hold when we think about constraining the discretion and policy choices of individual central bankers? Up until this point, the unit of analysis for preferences has been the central bank and focus has therefore been on the policy outputs of the multi-member monetary policy committees. While looking at policy outcomes and aggregating preferences in this way makes sense when we want to speak directly to their influence on realized inflation outcomes, there is nothing inherent in the theory to suggest the relationship between the structure of the target and effect of uncertainty shouldn't also hold at the individual level. To assess whether a target inflation zone leads individual central bankers to hedge less in the presence of uncertainty than they might with a single target inflation rate, I modify the preference estimation strategy given by Equation 3.12 to estimate individual central bank reaction functions. Drawing on voting records from the monetary policy committees in the United Kingdom, Poland, and South Korea, I estimate the following Bayesian Random Coefficient Model (RCM) which allows the effect of uncertainty

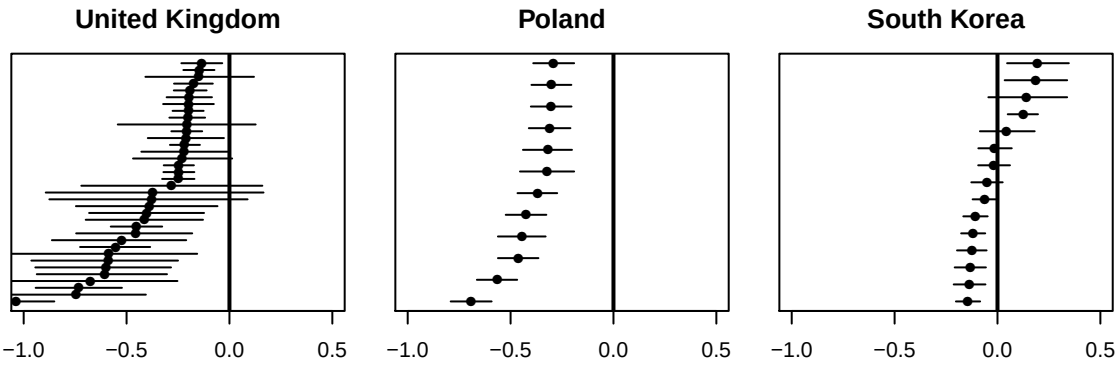

Figure 3.8: Individual Preference Estimates: the UK, Poland, and South Korea
For each central banker, I have plotted the estimated coefficient on uncertainty given by Equation 3.13 (β_i). The solid horizontal bands around the points correspond to 95% credible intervals.

on the preferred interest rate to vary by individual central banker, i:

$$R_{i,t} \sim N(r^* + \beta_i * \text{Uncertainty}_t + \gamma * R_{t-1}, \sigma_R^2), \tag{3.13}$$

where the dependent variable $R_{i,t,}$ is the stated preferred interest rate of central banker i at meeting t.[36] As before, I include the lagged interest rate to control for interest rate smoothing. The individual-level estimated coefficients for uncertainty are depicted graphically in Figure 3.8.

Consistent with the theoretical expectations and evidence from aggregated central bank preferences, the effect of uncertainty on individual policy choices is larger in magnitude when inflation targets are defined by a point rather than zone target. Central bankers at both the Bank of England and National Bank of Poland are significantly more sensitive to uncertainty when voting on interest rates than their counterparts at the Bank of Korea. This is consistent with the expectations from the simulations on how the definition of inflation targets affects policymaking under

[36]This voting data from these MPC meetings is particularly rich for two reasons. First, unlike the majority of central banks, dissenting votes are attributed to individual central bankers by name. Further, in the event of a dissenting vote, the record includes the central banker's alternative preferred rate rather than only recording disagreement.

uncertainty. Because members of the Monetary Policy Board at the Bank of Korea choose policies with the goal of achieving inflation outcomes in a target zone, their incentive to hedge against inflationary shocks is lessened and thus policy choices are less sensitive to changes in the uncertainty environment.

Inflation Outcomes under Point and Zone Targets with High Uncertainty. Finally, while this supports the claim that the effect of uncertainty on *policy choices* is conditional on the design of the inflation target, is there evidence to suggest this systematically translates into an effect on inflation outcomes and targeting performance? That is, does targeting an inflation zone actually curb the policy drift and result in inflation outcomes more in line with the target? In Figure 3.9 I return to an analysis of the relationship between the RMSE of inflation outcomes with respect to the targets and uncertainty. First consider the left panel, which plots inflation outcomes and uncertainty for Sweden, the United Kingdom, Poland (all in black), and South Korea (in blue) as well as the line of best fit (given by the results in Table 3.3). While South Korea does appear to outperform all three of the central banks with point inflation targets, we should expect this in the absence of any theory because we are comparing errors from a single point to errors outside of a (wider) range.

To correct for this in a way that allows for a comparison of target performance without inherently biasing success in inflation zones, I provide a hypothetical estimation of South Korea's targeting performance *if* it were assessed according to a point target. I recode South Korea's inflation target to a point rate of 3% and re-estimate the RMSE and bivariate relationship between it and uncertainty. While South Korea explicitly defines their target by an inflation zone without emphasizing the midpoint or another target rate, this seems like a reasonable proxy given the evolution of their inflation zone during the sample period. Unlike the Czech Republic whose inflation zone shifted during the period from 2-4% to 1-3%, in South Korea their zone adjustment was only to effectively narrow the band around 3%, moving from a target zone

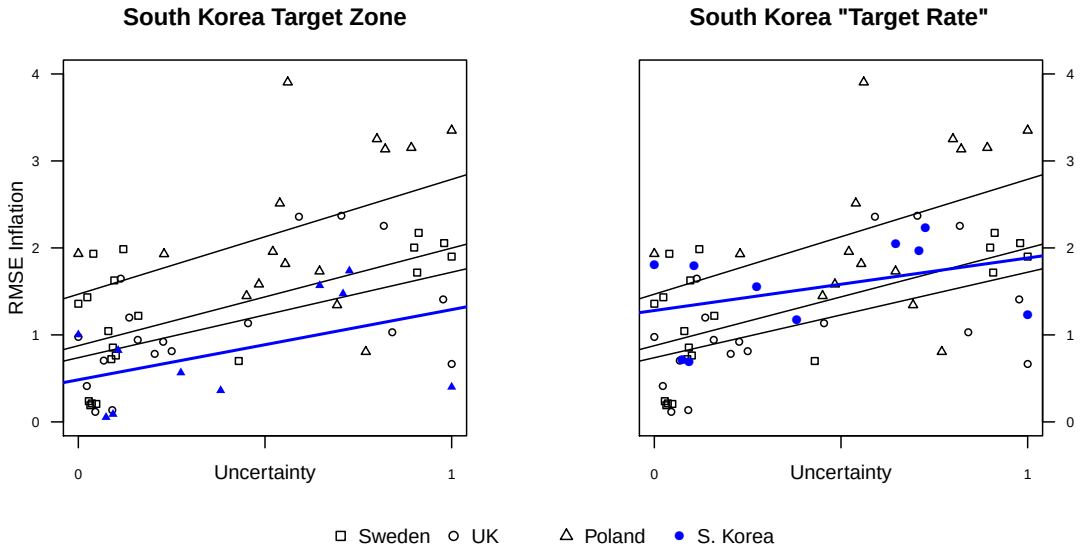

Figure 3.9: Asymmetric Targets, Monetary Uncertainty, and Inflation Outcomes
Both figures plot uncertainty against the RMSE of inflation at the central banks. The three black lines represent the lines of best fit for those banks with point inflation targets (Poland, Sweden, and the UK, from top to bottom) and the blue line is the line of best fit for South Korea. In the left figure, the RMSE is calculated according to South Korea's zone target, which was 2-4% and then 2.5-3.5%. In the right figure, the RMSE for South Korea is calculated assuming a point target of 3%.

of 2-4% to 2.5-3.5%. Without suggesting such target zones are not distinct from a point target of 3%, this seems like the most appropriate reference point to calculate a measure comparable to the point targeting banks.

The results from recalculating South Korea's RMSE are shown in the right panel of Figure 3.9. Two results are worth highlighting. First, the expected RMSE for low levels of uncertainty increases. This is perhaps unsurprising given the target for which this measure is calculated may not be what they are actually targeting in this low-uncertainty environment. Second, and more importantly, the estimated effect of uncertainty on the RMSE with respect to the hypothetical 3% point target is significantly smaller than it is in the remaining three cases who actually possess point inflation targets. The diminished effect of uncertainty is such that despite the higher margin of error under low uncertainty (i.e. the higher intercept), outcomes appear closer to target under heightened uncertainty than they are in Sweden and effectively

converge on the estimate for the United Kingdom. This reflects precisely the dynamic which emerged from this comparison in the simulations presented in Figure 3.3. While under low levels of uncertainty the performance of central banks with target points is generally the same (or in this case, better) than it is with target zones, as uncertainty increases target zones curb the policy drift associated with preference asymmetries and produce outcomes closer to their target rates.

3.4 Conclusion

The independence of central banks and their insulation from political influence is a defining feature of contemporary monetary policymaking. While the advantages of monetary delegation are plentiful and well-documented, such independence creates substantial opportunity for policy drift and capture common in such principal-agent dynamics. How can governments reap the benefits of an independent central bank without giving up so much discretion they risk unbounded monetary policy drift?

This article focuses on one particular institutional mechanism governments may be able to use to constrain central bank decision-making and curb the amount of monetary policy drift: the definition of inflation targets. When central bank objectives are defined according to a target inflation zone rather than single target inflation rate, both policy and in turn observed inflation rates exhibit smaller deviations from preferred outcomes. By reducing the disutility of inflation outcomes within a specified range, target inflation zones curb the degree of hedging we observe in central banks making monetary policy decisions with an eye towards achieving a target rate. The empirical investigation of this claim draws on policymaking and inflation performance data in six inflation targeting countries and provides evidence largely consistent with theoretical expectations. First, I extend to new cases evidence of asymmetric central bank preferences. In addition to demonstrating its existence at both the individual

and committee level, I show empirically the relationship between preference asymmetries and inflation performance with respect to a target. Consistent with theoretical expectations, central banks with asymmetric preferences will when faced with heightened uncertainty choose policies that deviate from their targets in expectation. Second, I consider how the presence of an inflation target and its design affects this policy hedging and drift from the target. The evidence indicates that central banks whose targets are defined by an inflation zone will engage in policy hedging to a lesser degree and thus produce inflation outcomes closer to their target.

These findings are significant because they highlight an aspect of the institutional design of monetary policy regimes which has been overlooked by much of the literature. While this distinction between target inflation rates and zones is widely acknowledged, less consideration has been given to how the structure of targets might affect policymaking and inflation performance. This finding ought to be of considerable interest for the literature on the adoption of inflation targets, which often focuses on whether a given central ought to move to an explicit inflation target. In addition to considering whether the adoption of an inflation target is appropriate, this line of work can speak to the form the target should take. Further, as central banks have recently chosen to change the structure of their target from a point to zone (Hungary) and vice versa (Czech Republic), this theoretical framework provides a lens for understanding and evaluating these decisions.

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Appendix to *Central Bank Appointments and Decision-Making Under Uncertainty*

A.1 Theoretical Appendix

Proof of Lemma 1. Recall that when choosing monetary policy themselves, the government solves the following maximization problem:

$$\max_{\pi} \left[-(\pi - \pi_g)^2 - \phi(y - (y^* + y_g))^2 \right],$$

where $y = y^* + (\pi - \pi_e) + u$, $u \sim N(0, \sigma_u^2)$, and without loss of generalization $y^* = 0$. Therefore, the first order condition for a maximum is:

$$-2\pi + 2\pi_g - 2\phi\pi + 2\phi\pi_e + 2\phi u + 2\phi y_g = 0,$$

and solving for the π^* we get the government's choice is given by the following:

$$\pi^* = \frac{\pi_g + \phi\pi_e + \phi u + \phi y_g}{1 + \phi}.$$

However, the government's optimal choice is conditional on the inflation expectations set by the private sector, π_e, where

$$\pi_e(\pi_g, y_g) = \arg\max_{\pi_e} \left[\mathbb{E}\left[-(\pi_e - \pi^*)^2\right]\right].$$

Therefore, in equilibrium inflation expectations are given by $\pi_e = \pi_g + \phi y_g$. Plugging this in to the government's choice above gives us an equilibrium level of inflation when the government maintains policy discretion given by Equation 3.

Proof of Lemma 2. Recall when a central banker with linex preferences defined by a pair of parameters $(U_c(\pi_c, \alpha_c))$ is delegated monetary policy discretion, they manipulate inflation outcomes by choosing an interest rate i such that $\pi = i + \varepsilon$ where $\varepsilon \sim N(0, \sigma_\varepsilon)$. The central bank solves the following maximization problem:

$$\max_{\pi} \left[-\mathbb{E}\left[\frac{e^{\alpha_c(\pi-\pi_c)-\alpha_c(\pi-\pi_c)-1}}{\alpha_c^2}\right]\right].$$

The first order condition for a maximum is:

$$\mathbb{E}\left[\left(\frac{\partial U_c}{\partial \pi}\right)\left(\frac{\partial \pi}{\partial i}\right)\right] = \mathbb{E}\left[\frac{1}{\alpha_c}\left(e^{\alpha_c(\pi-\pi_c)} - 1\right)\right] = 0.$$

Because of the assumption that $\varepsilon \sim N(0, \sigma_\varepsilon)$, and therefore $\pi \sim N(0, \sigma_\varepsilon)$:

$$\mathbb{E}\left[\frac{1}{\alpha_c} e^{\alpha_c(\pi-\pi_c)}\right] = e^{\frac{\alpha_c(\pi-\pi_c)}{\alpha_c}} + \frac{\frac{1}{2}\sigma_\varepsilon \alpha_c^2}{\alpha_c},$$

and therefore plugging this back into the first order condition above yields:

$$e^{\pi-\pi_c} + e^{\frac{\alpha_c}{2}\sigma_\varepsilon} - 1 = 0.$$

Solving for π^* gives us the equilibrium level of inflation under monetary delegation given by Equation 5.

Proof of Proposition 1. By Equation 5, the equilibrium inflation under monetary delegation is $\pi^* = \pi_c - \frac{\alpha_c}{2}\sigma_\varepsilon$. Therefore, the deviation of expected inflation outcomes from the central banker's ideal point is given by,

$$\pi^* - \pi_c = -\frac{\alpha_c}{2}\sigma_\varepsilon$$

Therefore, it is trivial to show the magnitude of this deviation ($|\pi^* - \pi_c|$) is non-zero when $\alpha_c \neq 0$ and $\sigma_\varepsilon \neq 0$; and increasing in $|\alpha_c|$ and σ_ε.

Proof of Lemma 3. Recall the government's choice of central banker is reduced to a single parameter ω_c which maps on to a pair of central bank preferences (π_c, α_c) through the functions $f(\omega_c) = \omega_c$ and $g(\omega_c) = b - \omega_c$, respectively. The government solves the following maximization problem:

$$\max_{\omega_c} \left[-\left(\omega_c - \frac{(b-\omega_c)}{2}\hat{\sigma}_\varepsilon - \pi_g \right)^2 - \phi\left(\pi^* - \pi_e - y_g\right)^2 \right].$$

The government's optimal choice is conditional on the inflation expectations set by the private sector, π_e, where

$$\pi_e(\pi_c, \alpha_c, \sigma_\varepsilon) = \arg\max_{\pi_e} \left[\mathbb{E}\left[-(\pi_e - \pi^*)^2 \right] \right].$$

Therefore, $\pi_e = \pi^* = \pi_c - \frac{\alpha_c}{2}\sigma_\varepsilon$. Plugging this in to the government's maximization problem gives the first order condition:

$$-2\omega_c + b\hat{\sigma}\varepsilon - 2\hat{\sigma}_\varepsilon\omega_c + 2\pi_g + \frac{\hat{\sigma}_\varepsilon}{2}b - \frac{\hat{\sigma}_\varepsilon}{2}\omega_c + \hat{\sigma}_\varepsilon\pi_g = 0.$$

Solving for ω_c^* gives us the government's equilibrium appointment given by Equation 6.

Proof of Lemma 4. Given the government's equilibrium strategy $\omega_c^* = \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2+\hat{\sigma}_\varepsilon}$, the

appointed central banker has preferences:

$$\pi_c = f(\omega_c^*) = \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2 + \hat{\sigma}_\varepsilon} \qquad \text{and} \qquad \alpha_c = g(\omega_c^*) = b - \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2 + \hat{\sigma}_\varepsilon}.$$

Thus, $\alpha_c \geq 0$ when:

$$\begin{aligned} \alpha_c = b - \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2 + \hat{\sigma}_\varepsilon} &\geq 0 \\ b(2 + \hat{\sigma}_\varepsilon) - b\hat{\sigma}_\varepsilon &\geq 2\pi_g \end{aligned}$$

Therefore, $b \geq \pi_g \iff \alpha_c^* \geq 0$. Conversely, $b < \pi_g \iff \alpha_c^* < 0$.

Proof of Proposition 2. The government's equilibrium appointment ω_c is increasing in expected monetary uncertainty $\hat{\sigma}_\varepsilon$ when:

$$\frac{\partial}{\partial \hat{\sigma}_\varepsilon} \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2 + \hat{\sigma}_\varepsilon} = \frac{2b - 2\pi_g}{(2 + \hat{\sigma}_\varepsilon)^2} > 0.$$

Therefore, when $b > \pi_g$, ω_c is strictly increasing in $\hat{\sigma}_\varepsilon$. Additionally, when $\pi_g < 0$, ω_c is also strictly increasing in $\hat{\sigma}_\varepsilon$. Only when $0 < \pi_g < b$ is it true that ω_c is decreasing in $\hat{\sigma}_\varepsilon$.

Proof of Lemma 5. By Lemma 1, the expected inflation outcome when the government maintains policy discretion is,

$$\mathbb{E}[\pi^*_{\neg delegate}] = \pi_g + \phi y_g.$$

By Lemmas 2 and 3, the expected inflation outcome when the government delegates to an independent central bank is,

$$\mathbb{E}\left[\pi^*_{delegate}\right] = \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2 + \hat{\sigma}_\varepsilon} - \frac{\sigma_\varepsilon}{2}\left(b - \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2 + \hat{\sigma}_\varepsilon}\right)$$

Therefore, inflation outcomes under delegation to an independent central bank exceed those

in the absence of delegation when $\mathbb{E}[\pi^*_{delegate}] > \mathbb{E}[\pi^*_{\neg delegate}]$:

$$\frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2+\hat{\sigma}_\varepsilon} - \frac{1}{2}b\sigma_\varepsilon + \sigma_\varepsilon\left(\frac{2\pi_g + b\hat{\sigma}_\varepsilon}{4+2\hat{\sigma}_\varepsilon}\right) > \pi_g + \phi y_g,$$

which reduces to the condition $\frac{(b-\pi_g)(\hat{\sigma}_\varepsilon - \sigma_\varepsilon)}{2+\hat{\sigma}_\varepsilon} > \phi y_g$ given by Lemma 5.

Proof of Proposition 3. Focusing on the case in which $b \geq \pi_g$, this result follows trivially from Lemma 5. When the government overestimates uncertainty ($\hat{\sigma}_\varepsilon > \sigma_\varepsilon$), it must be true that inflation in expectation exceeds the government's target rate (π_g):

$$\begin{aligned} \frac{2\pi_g + b\hat{\sigma}_\varepsilon}{2+\hat{\sigma}_\varepsilon} - \frac{1}{2}b\sigma_\varepsilon + \sigma_\varepsilon\left(\frac{2\pi_g + b\hat{\sigma}_\varepsilon}{4+2\hat{\sigma}_\varepsilon}\right) &> \pi_g \\ b(\hat{\sigma}_\varepsilon - \sigma_\varepsilon) &> \pi_g(\hat{\sigma}_\varepsilon - \sigma_\varepsilon). \end{aligned}$$

The conditions in which $\mathbb{E}[\pi^*_{delegate}] > \mathbb{E}[\pi^*_{\neg delegate}]$ are given by Lemma 5.

When the government underestimates uncertainty ($\hat{\sigma}_\varepsilon < \sigma_\varepsilon$), it must be true that inflation in expectation is below the government's target rate (π_g) when $b \geq \pi_g$.

When $b < \pi_g$, the opposite results hold.

A.2 Empirical Appendix

Alternative Specifications of Individual Reaction Function

Table A.1 provides the results from a series of alternative specifications for the estimation of individual-level monetary reaction functions. Column 1 includes the results presented in the paper for the fully saturated specification that includes all controls: monetary uncertainty, lag of interest rate, output gap, inflation gap, and exchange rate. In the four columns that follow, I introduce sequentially controls for the output gap and inflation gap. In addition to the model given by Equation 1.6 being the most theoretically grounded specification (Taylor

	(1)	(2)	(3)	(4)	(5)
$Intercept_i$	-2.37	0.01	-2.25	-1.19	-2.60
	(0.17)	(0.08)	(0.15)	(0.17)	(0.16)
$Uncertainty_i$	-0.06	-0.004	-0.08	-0.02	-0.06
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
$Current\ Interest\ Rate_i$	0.99	0.99	0.96	1.00	0.98
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$Output\ Gap$	0.057		0.044		0.03
	(0.004)		(0.01)		(0.003)
$Inflation\ Gap$	0.077			0.19	0.093
	(0.016)			(.004)	(.01)
$Exchange\ Rate$	0.007				
	(0.001)				
DIC	-485.4	-36.6	-261.8	-208.2	-290.1

Table A.1: Alternative Specifications for Estimates of Central Bank Reaction Functions
Results from Bayesian random coefficient model defined in Equation 1.6. Posterior standard deviations in parentheses. Dependent variable is preferred interest rate ($R_{i,t}$).

1993, 2001) and common practice in the extant literature on monetary reaction functions, the deviance information criterion (DIC) statistics presented in the bottom row suggest it is in fact the preferred specification for the data. Thus, while there is not significant variation across preference estimates, I move forward testing the second hypothesis with the estimates given in column 1.

Robustness Check: Appointments Pre-2010

Since 2010 when the Fidesz Party lead by Viktor Orbán reclaimed control of the Hungarian government, there have been concerns raised about the degree of central bank independence in practice. To ensure this perceived decline in independence is not driving the results, I re-run the models for the nine appointments made by the previous two governments lead by Prime Ministers Medgyessy (2002-04) and Gyurcsány (2004-09). The results, presented in Table A.2, are even stronger on this subset of the data.

Variable	(1)	(2)
Uncertainty	-0.10	-0.13
	(0.03)	(0.05)
Medgyessy		-1.55
		(0.27)
Gyurcsány		-1.60
		(0.23)
N	9	9
Adjusted-R^2	0.5024	0.9994

Table A.2: Estimation of Appointments and Uncertainty Model, Orbán Subsample
Results from linear regression model defined in Equation 1.7, with a reduced sample of appointments from 2002-2009, excluding Prime Minister Orbán's second term. Standard errors in parentheses. Dependent variable is individual intercept estimated from Equation 1.6.

Appendix to *Central Bank Transparency and the Performance of Market Expectations*

B.1 Empirical Appendix

Robustness Check: Industrial Production Expectations

A central result of the intervention analyses — that there is less updating of market expectations following meetings — could alternatively be explained by any simultaneous change in behavior induced by the implementation of AIA that has no relation to the theoretical mechanism of primary interest here. For example, those responding to the MES could have cut back on the frequency of updating their forecasts, which has nothing to do with a perception that monetary policy minutes are less informative. To address this plausible concern, I draw on market expectations over industrial production. The MES collects this information from the same sample of survey participants in the same manner as they do inflation and Selic rate expectations. Drawing on this data, however, provides a discriminating prediction for the theory presented in this article: the implementation of the AIA and changes in procedural transparency should not affect expectations over industrial production. I repeat the intervention analysis on the series of market expectations for industrial production in an effort to examine whether changes in the updating of market expectations are unique

Variable	Parameter	(1) IndProd1	(2) IndProd2	(3) IndProd3
Intervention	ω_0	-0.027	0.0690	0.075
(step)		(0.035)	(0.040)	(0.046)
Mean (constant)	μ	0.113	0.146	0.204
		(0.017)	(0.020)	(0.023)
Autoregressive Terms				
First Order	ϕ_1	-	-0.824	-0.217
		-	(0.103)	(2.708)
Moving Average Terms				
First Order	θ_1	-	0.913	0.234
		-	(0.140)	(2.709)
Second Order	θ_2	-	-0.024	0.019
		-	(0.114)	(0.103)
AIC		-	-61.16	-31.01
N		101	101	101

Table B.1: Time Series Intervention Analyses — Market Expectations Industrial Production Updating
These estimates are for the time series intervention analyses on the series for industrial expectations updating the days following Copom announcements: IndProd1, IndProd2, and IndProd3. Standard errors are provided in parentheses.

to monetary policy expectations. The results, presented in Table B.1, indicate there is no effect of central bank transparency on the updating of industrial production expectations.

Power Computations for Time Series Intervention Analysis

Variable	ω_0	12/2015	12/2016	12/2017
InflationError	σ_y	60%	69%	75%
	$1.25\sigma_y$	79%	87%	92%
	$1.5\sigma_y$	93%	96%	98%
InflationVar	σ_y	62%	73%	79%
	$1.25\sigma_y$	81%	91%	94%
	$1.5\sigma_y$	94%	97%	99%

Table B.2: Power Computations for Intervention Analyses
Following the derivation provided in McLeod and Vingilis (2005), these estimates provide the likelihood of recovering a statistically significant estimate (with 95% confidence) for a true σ standard deviation change in the data generating process for each series given the number of observations at each date.

The demands on sample size present in estimating the effect of interventions in quasi-

experimental models are well-established in the existing methodological and applied research (Box-Steffensmeier et al. 2014, Monogan 2015). This concern is particularly prevalent in medical and policy analyses which not only face extremely costly data collection efforts, but also need to understand the effect of a treatment and intervention as quickly as possible. In response to this issue, McLeod and Vingilis (2005) propose a pre-analysis measure of statistical power which estimates the likelihood of recovering a statistically significant estimate for a true σ standard deviation change in the data generating process. In addition to pre- and post-intervention sample sizes, their estimates incorporate the degree of autocorrelation to be filtered out in a Box-Tiao analysis. Unsurprisingly, with the current sample size the likelihood of the proposed analyses identifying as statistically significant a true single standard deviation change is relatively low: 60% for the InflationError, and 62% for the InflationVar. For a true effect equal to the current point predictions, the likelihood of "accurately" identifying the effects as statistically significant is even lower at 7% and 8%, respectively. In Table B.2, I show how the likelihood of uncovering a statistically significant effect increases over time in each series. By the final Copom meeting of 2017 there will be an additional 32 post-intervention observations in the sample and the probability of misidentifying a true change in the data generating process as insignificant falls to less than 25% in both series. Further, even this improvement with the increased sample size could be a lower bound if we suspect there is a gradual intervention effect in one or both series and the magnitude of the impact on the data generating process (i.e. ω_0) is not yet fully realized.