Asserting Independence: Optimal Monetary Policy When the Central Bank and Political Authority Disagree*

Justin Svec[†] and Daniel L. Tortorice[‡]

January 14, 2022

Abstract

A central bank has preferences that differ from the political authority. While the central bank is independent, i.e. it maximizes its own preferences, households do not know this. Instead, households observe the interest rate choices of the central bank and update their beliefs regarding central bank independence using Bayesian learning. We solve for the optimal interest rate policy in a New-Keynesian model where the central bank considers the effect of its policy decision on the households' beliefs that it is independent. The model provides a theoretical measure of central bank independence and a mapping from this level of independence to expected future losses for the central bank. Because the central bank suffers large losses when it is not perceived as independent, the central bank may choose a policy that is quite distant from its rational expectations counterpart to bolster the perception of its independence. We show that productivity shocks provide greater scope for the central bank to demonstrate its independence than do demand shocks, leading the central bank to deviate more aggressively from the benchmark rational expectations policy choice for the former shock than for the latter. Finally, varying perceptions of independence over time generate time varying volatility in interest rate policy and macroeconomic outcomes.

JEL Codes: E52, E58, D83

Keywords: Monetary Policy, Central Bank Independence, Learning

*We thank participants of the Southern Economic Association Meeting, the Western Economic Association Meeting and the Holy Cross Economics and Accounting Department Summer Research seminar for helpful comments and questions. All mistakes are ours.

[†]Department of Economics and Accounting, College of the Holy Cross, 1 College St, Worcester MA, 01610, jsvec@holycross.edu, 1-508-793-3875

[‡]Department of Economics and Accounting, College of the Holy Cross, 1 College St. Worcester MA 01610, dtortori@holycross.edu, 1-508-793-3873

1 Introduction

Throughout the last two years of his administration, President Trump repeatedly and publicly criticized the Federal Reserve for its monetary policy choices, advocating for cuts to the Federal Funds rate. For example, he declared on August 19th, 2019, "The Fed Rate, over a fairly short period of time, should be reduced by at least 100 basis points, with perhaps some quantitative easing as well. If that happened, our Economy would be even better."[1] While Trump was arguably more explicit, sustained public pressure from the US President on the Federal Reserve to alter interest rates has historical antecedents. Examples can be seen from the administrations of Presidents Truman, Johnson, and Nixon. Moreover, political pressure on the Federal Reserve continues into the Biden administration. Recent examples from 2021 include Senator Joe Manchin's public letter to Chairman Powell, urging "the Federal Open Market Committee to immediately reassess our nation's stance of monetary policy" (public letter; 8/5/2021) and the reintroduction of the Federal Reserve Transparency Act (known as "Audit the Fed" bill) by Senator Rand Paul in March.[2]

The Federal Reserve is designed to be insulated from this political pressure. Among other design elements, Fed governors are appointed for 14-year terms, and the Federal Reserve's funding comes from its own operations and not from Congress. However, statutory oversight itself creates political pressure on the Fed. Congress can, for instance, directly modify the role and responsibility of the Federal Reserve (by amending the Federal Reserve Act). The President, via appointments to the Board of Governors, can alter the membership of the voting body of the FOMC, thus increasing the likelihood that the central bank accedes to the policy demands of the political authority. Noting how these appointments can influence public perception of the central bank, Blinder (2021) has argued for President Biden reappointing the current Federal Reserve Chair, Jerome Powell, to avoid politicizing the Fed.

Even if the central bank does, in fact, have complete autonomy from the fiscal authority, political pressure could influence Fed policy through its impact on household expectations. Assuming the public faces some uncertainty as to whether the central bank is truly independent, then a President's public demands regarding interest rates can influence household expectations about future monetary policy. In fact, there is recent evidence of this link in the literature. Bianchi et al. (2019) show that President Trump's tweets criticizing the chosen path of monetary policy decreases the expected Federal Funds rate. Binder (2020) shows in

[1] Subsequently he tweeted, "...My only question is, who is our bigger enemy, Jay Powel (sic) or Chairman Xi?". In another example, on October 10th, 2018, Trump announced to reporters, "I think the Fed is making a mistake. They're so tight. I think the Fed has gone crazy."

[2] Public pressure on a nation's central bank is not limited to the United States. Binder (2021), using a novel dataset on the political pressure faced by central banks across the world, documents that around 10% of central banks face political pressure each year.

a survey-based experiment that exposure to President Trump's tweets demanding that the Federal Reserve lower interest rates raises people's inflation expectations.

Given this link, the central bank may consider how its policy decisions, when viewed in relation to the demands of the political authority, influence the public's expectations regarding its degree of independence. Specifically, if the central bank chooses a policy that is sufficiently close to the desired policy of the political authority, then the public might worry that the central bank is no longer independent. This perception that the central bank might be captured by the political authority could, in turn, raise inflation expectations. If, though, the central bank chooses a policy that is further away from the political authority's desired choice, then the central bank might strengthen the public's perception of its independence, leading to lower inflation expectations. However, in doing so, the central bank might have to choose a policy that is sufficiently far from its otherwise optimal policy that the economy's performance in the short-run might suffer.

In light of this tradeoff, we examine how a central bank should set monetary policy in the face of political pressure. To do so, we assume there exists a political authority and an independent central bank, where the two institutions have different preferences. Specifically, the central bank puts more weight on inflation deviations and less weight on the output gap in its loss function than does the political authority. Households, for their part, do not know if the central bank has complete autonomy from the political authority and thus are unsure whether it maximizes its own preferences or the preferences of the political authority. The households start with a prior belief as to the likelihood that the central bank is independent and then update this belief, via Bayes rule, based on the interest rate choice of the central bank. The central bank then sets optimal interest rate policy, under discretion, taking into account the feedback between its policy decision and the households' beliefs.

We find that the central bank suffers significant losses when it is perceived to be captured, both unconditionally and conditional on the shocks affecting the economy. The central bank's concern over this perceived loss of independence leads it to look for conditions under which it can demonstrate its independence to the public. We show that the ability of the central bank to demonstrate its independence depends upon the type of shocks hitting the economy. Specifically, productivity shocks provide greater scope for the central bank to demonstrate its independence than do demand shocks. This is because productivity shocks create a tradeoff between stabilizing inflation and the output gap, exposing the rift in desired outcomes between the political authority and the independent central bank, while demand shocks do not. As a consequence, when the economy is hit by a productivity shock, the central bank chooses an interest rate that is distant from the policy it would have chosen absent political pressure. In choosing this policy deviation, the central bank is, in essence, investing in its reputation of independence. In doing so, it accepts suboptimal paths of inflation and the output gap in order to help convince the public that it is independent.

Further, we show that the degree to which the central bank deviates from an otherwise standard policy depends upon the ability of the public to distinguish between an independent and a captured central bank and the public's beliefs regarding how likely the central bank is to be independent. In particular, if the public is sufficiently worried that the central bank is not independent, then optimal policy flips and the central bank raises (cuts) the nominal interest rate in response to a positive (negative) productivity shock. Finally, there is feedback between perceived independence and volatility of interest rates that leads to time varying macroeconomic volatility as beliefs change over time.

Two critical assumptions in our analysis are: one, that the central bank cannot simply convince households that it is independent by a public statement, and two, that the central bank uses its policy tools to influence the households' beliefs. To support the first assumption, we note that any public statement by the Federal Reserve is likely to be viewed as cheap talk. This view is consistent with the previously noted rise in inflation expectations in response to Trump's tweets despite public statements from the Federal Reserve that it "never takes into account political considerations".[3] Moreover, we demonstrate in a modification to the model described in section 6.3 that a *dependent* central bank benefits from convincing households that it is independent, undermining the ability of the central bank to convince the public that it is independent through public statements. To support the second assumption, while we note that it is difficult to empirically demonstrate that political pressure influences a central bank's interest rate policy, we show in section 5.5 that ignoring the feedback between interest rate policy and household expectations of independence can lead to large losses for the central bank.

To the best of our knowledge, our paper is the first to model learning about whether the central bank is independent or not. As such, it makes several contributions to the literature on monetary policy. First, it provides a time-varying, theoretical measure of central bank independence, the household's perceived probability that the central bank is maximizing its preferences versus those of the political authority. Second, it describes how the degree of perceived independence alters optimal monetary policy. Third, it shows how the central bank can choose policy to demonstrate its independence, and under what circumstances it is optimal for the central bank to do so. Fourth, it maps central bank independence directly to a decrease in expected future losses from excess volatility in output and inflation, and

[3] In a 2019 news conference announcing a cut in the Federal Funds rate, Federal Reserve Chairman Jerome Powell stated that the Federal Reserve's monetary policy deliberations "never take into account political considerations. There's no place in our discussions for that."

therefore provides a novel measure of the benefits of central bank independence.

The rest of the paper proceeds as follows. In section 2 we review the literature. In section 3 we describe the model, and section 4 explains its calibration. Section 5 examines the main model results and provides intuition for these conclusions. In that section, we also analyze a thought experiment meant to capture the impact of the critical public statements by President Trump on optimal monetary policy, as well as the consequences of Powell's response that the Federal Reserve does not use monetary policy to "prove [the Fed's] independence" (7/31/2019). Section 6 considers three modifications to the model: a zero lower bound for the nominal interest rate, variation in the ability of the public to associate the chosen interest rate with a particular type of central bank, and assuming that the central bank has been captured and sets policy to maximize the preferences of the political authority. Section 7 contains our conclusion.

2 Literature review

There is a long literature, both theoretical and empirical, on central bank independence (CBI). While a full survey would be out of place here, we highlight some key contributions and relate them to our current paper. The theoretical arguments in favor of CBI include the ability of the central bank to withstand political pressure to finance government deficits (Sargent and Wallace, 1981) and to avoid political business cycles (Nordhaus, 1975). Rogoff (1985) and Walsh (1995) argue that a third benefit of CBI is that independence helps the central bank overcome the problem of time inconsistency, as described in Barro and Gordon (1983) and Kydland and Prescott (1977). In contrast to these papers which are set within the full information rational expectations framework, our paper considers how an independent central bank can convince households that it is truly independent.

In the literature, CBI measures fall into (at least) three categories depending upon the method used. One category measures the degree of CBI by examining the legal protections and regulations governing the central bank's operations. Put simply, the greater the government's influence over policy and employment decisions, the lower will be the measured level of the central bank's legal independence; see Crowe and Meade (2007) and Cukierman et al. (1992). A second category tries to measure the *de facto* independence of the central bank, a value sometimes proxied by the turnover rate of central bank governors following political transitions (Cukierman and Webb, 1995). A third category measures the degree of CBI by examining whether the central bank faces political pressure to take particular monetary actions. Developed by Binder (2021), this measure examines quarterly country reports from the Economist Intelligence Unit and Business Monitor International for mentions of governmental pressure on the central bank. Complementing this literature, our paper introduces a theoretical measure of central bank independence based on household beliefs in the likelihood that the central bank is independent.

Early empirical studies show that greater legal independence of the central bank reduces the level and volatility of a country's inflation rate (Alesina and Summers, 1993; Bade and Parkin, 1988; Grilli et al., 1991). The relationship between CBI and inflation, however, is less clear when developing nations are included in the dataset, when extending the dataset to include more recent periods, or when employing operational measures of CBI (Balls et al., 2016; Berger et al., 2001; Crowe and Meade, 2007; Dincer and Eichengreen, 2014; Eijffinger et al., 1996; Garriga and Rodriguez, 2020; Klomp and De Haan, 2010; Posso and Tawadros, 2013; Cukierman, 2008). Balls et al. (2016), Cukierman (2008), and Eijffinger et al. (1996) provide thorough reviews of the empirical CBI literature. There is also evidence that greater central bank independence reduces political business cycles (Maloney et al., 2003; Haga, 2015). Our paper draws on this literature to support the implication in our model that the central bank will be willing to suffer losses today to invest in its independence and measures the benefits of central bank independence as the reduction in expected future central bank losses given an increase in the probability that households view the central bank as independent.

The benefits of CBI and the desire to join the international financial community have arguably spurred countries to increase the autonomy of their central banks. Cukierman (2008) and Dincer and Eichengreen (2014) show that the degree of legal independence exhibited by central banks across both developed and developing countries has markedly increased in the 1990s and 2000s. At the same time, there is concern among academic economists in particular that the newly-increased independence of central banks might be reversed. In a survey given to both central bank governors and academic economists in 2016, Blinder et al. (2017) show that over one third of academic economists surveyed believe that the independence of their country's central bank was "threatened now or in the near-term future". Consistent with the motivation underlying our paper, the authors show that criticism of the central bank's actions and a public discussion of the central bank's mandate were both associated with increasing the likelihood of reporting that there was a threat to their country's CBI. Moreover, Kohn (2013) worries that the Federal Reserve's extraordinary response to the 2008 financial crisis, and in particular the choice to engage in unconventional policies, might erode public support for the independence of the Federal Reserve. Given this evidence, while CBI has surely increased over time, we view a situation where households are uncertain about the independence of the central bank to be worthy of exploration.

Finally, our paper also contributes to the literature on household learning about monetary policy. While the earliest literature focused on the ability of agents to learn rational expectations equilibira and the stability of the New-Keynesian model under learning (Bullard and Mitra (2002); Evans and Honkapohja (2003); **?**), subsequent papers examined the ability of households to learn about different aspects of monetary policy. For example, Schorfheide (2005) models learning about the central bank's inflation target, Bianchi (2013) examines a model where the household learns about the parameters in the Federal Reserve's Taylor rule, and Matthes (2015) studies learning about whether the central bank is operating under discretion or commitment. Our paper differs from these in calculating the optimal monetary policy and therefore how the presence of learning changes optimal monetary policy. Cogley et al. (2015) examines how a central bank should choose parameters of a Taylor rule when agents need to learn these parameters. Gaspar et al. (2006) and Molnár and Santoro (2014) consider optimal monetary policy when the central bank takes into account the impact of its policy on the beliefs of agents who use adaptive learning to forecast future inflation. Our paper is closest to these, we consider optimal policy when the central bank considers the impact of its policy on beliefs. However, it differs substantially from this literature by directly examining learning about central bank independence, a novel and timely monetary policy aspect to learn about and a variable that has received considerable interest in the macroeconomics literature.

3 Model

3.1 Dynamics of the economy

Assume an economy composed of households, firms, a central bank, and a political authority. The economy is characterized by the equations of the standard dynamic, New Keynesian model (see Galí, 2015):

$$\pi_t = \beta \hat{E}_t \pi_{t+1} + \kappa y_t - z_t \tag{1}$$

$$y_t = \hat{E}_t y_{t+1} - \frac{1}{\sigma}(i_t - \hat{E}_t \pi_{t+1}) + g_t \tag{2}$$

$$g_t = \rho^g g_{t-1} + \varepsilon_t^g \tag{3}$$

$$z_t = \rho^z z_{t-1} + \varepsilon_t^z \tag{4}$$

Here π_t is inflation (the first difference of the log price level), y_t is the output gap (the difference between log output and the log of its level absent price frictions), g_t is a demand shock such as government spending, z_t is a productivity/cost push shock such as a decrease in oil prices that tends to lower inflation. Steady state inflation is normalized to zero. The demand and productivity shocks follow AR(1) processes. The policy instrument is i_t, the one-period nominal interest rate. It is set optimally by the central bank to minimize a conventional loss function. We discuss the optimal central bank policy in section 3.3.

Two important parameters in the model are κ and σ. κ determines the slope of the New Keynesian Phillips curve. The magnitude of κ will depend on the degree of price stickiness in the model. The parameter σ is the inverse of the elasticity of intertemporal substitution and governs how responsive the output gap is to changes in the interest rate and expected inflation.

When the political authority does not publicly rebuke the policy stance of the central bank and advocate openly for an alternative policy choice, households take for granted the independence of the central bank from the political authority. In this case, households face no uncertainty about the preferences of the central bank and so the $\hat{E}$ operator in the equations above simplifies to the full information rational expectations operator.

In our version of the model, however, we assume that the political authority has publicly rebuked the central bank and its policy choice. The political authority has also openly called for a different policy to be implemented by the central bank. This public split between the political authority and the central bank exposes, in the minds of the households, the difference between the goals of the political authority and the goals of the central bank. In the realization that the two institutions have different preferences, households begin to question whether the central bank is sufficiently independent from the political authority to pursue its own objectives or whether the central bank must follow the direction of the political authority.

Given their uncertainty, households are endowed with an initial belief as to the probability that the central bank is independent. They then monitor the policy chosen by the central bank for signs indicating whether or not the central bank is independent. Since an independent and a dependent central bank would choose different interest rates, the households' posterior belief regarding the independence of the central bank depends upon their prior probability that the central bank is independent updated, via Bayes rule, after observing the interest rate chosen by the central bank. These beliefs regarding the degree of central bank independence implies beliefs about the future values of inflation and the output gap which in turn determines the current values of inflation and the output gap. Section 3.2 describes how households form these beliefs.

3.2 Household Beliefs

Households face uncertainty as to whether or not the central bank is independent[4]. They must form beliefs concerning the probability that the central bank is independent based on the observed policy choices of the central bank. Households believe that if the central bank is independent, then it would seek to minimize the loss function

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\pi_{t+j}^2 + \lambda^{CB} y_{t+j}^2\right]. \tag{5}$$

In this formulation, the central bank seeks to minimize squared deviations of inflation and the output gap from their target (set to zero), where λ^{CB} is the households' perception of the weight an independent central bank would place on the output gap. On the other hand, households believe that if the central bank loses its independence, it would maximize the preferences of the political authority by minimizing the following loss function:

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\pi_{t+j}^2 + \lambda^{PA} y_{t+j}^2\right]. \tag{6}$$

The perceived loss function of the political authority is identical to the perceived loss function of the independent central bank, except that the households believe that the political authority puts a greater relative weight on stabilizing the output gap, i.e. $\lambda^{PA} > \lambda^{CB}$.[5]

The methods of Söderlind (1999) allow us to calculate the optimal monetary policy under each of these possibilities, i.e. that the central bank is independent and maximizes its own preferences or that the central bank is dependent and maximizes the preferences of the political authority, subject to the rational expectations version of the New-Keynesian model, equations (1)-(4). These policy rules, in turn, allows us to determine the household's expectations of interest rates, inflation, and the output gap given their beliefs about the degree of central bank independence.

Specifically, under central bank discretion (i.e. no-commitment), the Söderlind (1999)

[4]In this model, we assume that central bank independence is dichotomous: in the minds of the households, either the central bank is independent of the political authority and chooses policy according to its own preferences, or the central bank is captured and chooses whatever policy the political authority prefers. Further, households in the model assume that both types of central bank are fully confident that the public knows their degree of independence; that is, the public does not consider that either type of central bank acknowledges that the public faces uncertainty about their beliefs and chooses policy to influence those beliefs.

[5]This formulation distinguishes our work from previous cited work that examines learning about the central bank inflation target.

optimal policy satisfies the following policy rule

$$i_t = F^j x_{1,t} \tag{7}$$

where $x_{1,t}$ is the state vector, $x_{1,t} = \{g_t, z_t\}$. And the endogenous variables, $x_{2,t} = \{y_t, \pi_t\}$, evolve according to

$$x_{2,t} = C^j x_{1,t} \tag{8}$$

Here the letter $j \in \{Independent, Dependent\}$ indexes the status of the central bank, dependent or independent. F and C are matrices that depend on the central bank type.

We presume the household is aware of these policy rules. Since the households know the policy rules of each type of central bank, the households, after observing the central bank's choice of interest rate, can use Bayes' rule to update their belief that the central bank is independent. The households begin the period with a prior p_t^I that the central bank is independent. The households then observe the interest rate, i_t, and the state variables $x_{1,t} = \{g_t, z_t\}$. We assume the households believe that the central bank's interest rate choice is normally distributed around the interest rate implied by the policy rule conditional on central bank type:

$$i_t | j \in \{Independent, Dependent\} \sim N(F^j x_{1,t}, \sigma^2). \tag{9}$$

We can interpret this assumption either as the households observing the interest rate with noise or that the households are unsure that they have the correct interest rate setting model for each type of central bank in mind and so allows for departures from the optimal interest rate with some probability.[6]

Given these beliefs, the household can then update their beliefs that the central bank is independent via Bayes' rule

$$p_{t+1}^I = \frac{p_t(i_t | Independent) p_t^I}{p_t(i_t | Independent) p_t^I + p_t(i_t | Dependent)(1 - p_t^I)}. \tag{10}$$

[6] In an earlier version of the model, we considered the alternative modeling assumption in which the political authority publicly announces a range of preferred policy values (or even a particular preferred policy target). The households, then, monitor whether or not the central bank chooses an interest rate within that policy range. If it does (does not), the households' beliefs would change, putting a greater (smaller) weight on the likelihood that the central bank is captured. We have moved away from that alternative modeling assumption for a number of reasons, but one in particular was that the independent central bank's optimal decision was both too stark and poorly defined.

3.3 Optimal Policy

In our main analysis, we consider the case where the central bank is, in fact, independent, though the households do not know this.[7] The independent central bank sets optimal interest rates by solving the following Bellman equation

$$V(S_t) = \min_{i_t} \left[\pi_t^2 + \lambda^{CB} y_t + \beta E_t V(S_{t+1})\right] \tag{11}$$

where S_t is the state vector, $S_t = \{g_t, z_t, p_t^I\}$, subject to the evolution of household beliefs (10) and the New Keynesian model equations (1-4). We solve for the value and policy function via value function iteration on a discrete grid. We discretize the AR process for the exogenous shocks using the method of Tauchen (1986). Note that the optimal policy here will depart from the Söderlind (1999) rational expectations solution described in section 3.2 because here the central bank accounts for the impact of its policy choice on household beliefs and the households are unaware that the central bank is independent.

Inherent in the setup of this problem is the idea that the central bank will use monetary policy to influence the households' beliefs as to its independence. To motivate this choice, we assume that the central bank cannot convince households of its independence merely through communication. Households would view this communication as cheap talk.[8] While we do not disregard the possibility of some types of communication could influence household expectations (the ex-ante announcement of a policy response function with ex-post transparency, for example), we assume that the central bank can only convince households with hard and costly choices. Consistent with this assumption is the fact that a captured central bank would also want to be perceived as independent, as we show in section 6.

Our assumption that communication alone cannot persuade households that the central bank is independent receives support in the literature. For example, Faust (2016) argues that increased transparency by the Federal Reserve -- a choice intended to add predictability to policy decisions -- has counter-intuitively increased the public's sense of confusion about the Fed's actions and should lead the Federal Reserve to modify its approach to communication. Additionally, Vissing-Jorgensen (2019) posits that the "quiet cacophony" of having numerous competing public statements made by different central bankers, with differing preferences, distorts market expectations rather than making them more accurate.

[7] We consider the case in which the central bank is dependent in section 6.

[8] In some sense our theory of beliefs is consistent with Carvalho et al. (2020) where agents do not simply believe the central bank's inflation target but must learn about it from data. It contrasts with the model of Eusepi and Preston (2010) where communication can directly influence the household's rule it uses to learn.

3.4 Timing and Equilibrium

The timing of each period is as follows: The households enter each period with a belief as to the likelihood that the central bank is independent from the political authority. Given these beliefs, the households' expectations of future endogenous variables are given by

$$\hat{E}_t\pi_{t+1} = p_t^I(E_t\pi_{t+1}|Independent) + (1 - p_t^I)(E_t\pi_{t+1}|Dependent) \tag{12}$$

where the conditional expectations, e.g. $[E_t\pi_{t+1}|Independent]$, are determined by equation (8) and the expectation of the evolution of the state variables using equations (3) and (4). Conditional on the household beliefs and the realizations of the productivity and demand shocks, the central bank chooses the optimal interest rate. This choice then determines the values of the endogenous variables. Finally, given the policy choice of the central bank, the households update their beliefs regarding central bank independence for the next period.

Therefore, an equilibrium in this model is a policy function $i(S_t)$ which solves the value function, equation (11), and equilibrium outcomes $\pi(S_t)$ and $y(S_t)$ which are given by equations (1) and (2) subject to the household expectation equation (12). Evolution of the state variables is determined by equations (3),(4) and (10).

4 Calibration

Some of the model calibration is standard. We take the quarterly discount factor β to equal 0.99. We assume that firms can change their prices on average every year which is equivalent to 25% of firms changing their price every quarter. The resulting fraction of firms with sticky prices in a given quarter, θ, equals 0.75 and the implied value for the slope of the New Keynesian Phillips curve is $\kappa = \frac{(1-\theta)(1-\theta\beta)}{\theta} = 0.086$. We allow for persistent demand and productivity shocks with $\rho^g = \rho^z = 0.975$ and set the standard deviation of the demand (ε_t^g) and productivity shocks (ε_t^z) equal to 1%.

We consider an independent central bank that is much more concerned about inflation than the political authority, consistent with the beliefs of the households. To this end, we set the independent central bank's output gap weight (λ^{CB}) to 0.1 and the political authority's output gap weight (λ^{PA}) equal to 2. Finally, we need to calibrate the parameters related to household beliefs. We assume that households begin with a prior of 50% that the central bank is independent ($p_0^I = 0.5$) and that the noise in their beliefs regarding the central banks interest rate choice given by equation (9) has a variance of $\sigma^2 = 1.5^2$. This parameter is important to our results because it determines the ability of the households to associate the monetary policy choice of the central bank with a particular type of central bank. As a result, it influences the households' speed of learning and the monetary policy choices of the central bank. We examine the impact of different values of this variance in section 6.

5 Results

In this model, the central bank has policy and objective independence. Households, though, are not convinced of this status. Rather, households believe that with some probability, the central bank takes its policy directives from the political authority. The households may come by this belief, for example, if the political authority publicly demands that the central bank choose an alternative interest rate. In this section, we show the consequences of this uncertainty, both in terms of the households' expectations and the policy response. We will start by showing that the households' uncertainty about the central bank's independence is costly to the central bank. The welfare losses stem from the households expecting a more volatile (smooth) path of inflation (output gap) than they would if they were confident that the central bank was independent.

Throughout the following exposition, we find it useful to compare the central bank in our model – the central bank about which households face uncertainty, labeled below as the "p^I central bank" – with two other types of central banks. The first type is an independent central bank that is known by the public to be independent; the second is a dependent central bank that is known to be dependent. The two alternatives represent rational expectations benchmarks as points of comparison to the central bank in our model. In drawing these comparisons, our goal is to elucidate the motivation and intuition underlying the choices made by the p^I central bank. A secondary benefit of introducing the other two types of central bank is that they play an important role in the minds of the households. Specifically, the households monitor the actions of the p^I central bank in order to judge whether those actions are more consistent with the actions of an independent central bank or those of a dependent central bank. Thus, by describing the behavior of the two rational expectations benchmarks, we can better describe how the p^I central bank attempts to influence the beliefs of the households.

5.1 Value of being perceived as independent

In figure 1 we plot the p^I central bank's value function as a function of p^I, the household's belief as to how likely it is that the central bank is independent. The value function is plotted for three different levels of the productivity shock $z_t = \{-0.081, 0, 0.081\}$, assuming that $g_t = 0$. These are the minimum, average, and maximum possible levels of the productivity shock in our model. The figure shows that, for any value of z_t, the present discounted value of the central bank's expected losses rises as p^I falls. This suggests that the central bank values being perceived by the households as independent of the political authority. Moreover, the central bank suffers relatively large losses when p^I approaches 0 because at that point, it can never reestablish the perception of independence.

Figure 1 also shows that the level of the productivity shock influences expected future losses as well. For any value of p^I, the central bank's loss function is minimized when $z_t = 0$; positive or negative productivity shocks result in greater losses for the central bank. This result occurs because productivity shocks in either direction cause volatility in the output gap and inflation, fluctuations that are painful to a central bank that seeks to minimize these deviations. We can show, though we have suppressed the figure, that the central bank's loss function is unrelated to the size of the demand shock. As we will discuss shortly, this is because the p^I central bank can offset any sized demand shock by setting an appropriate nominal interest rate.

5.2 Optimal policy in response to a demand shock

We next turn to describing how the central bank sets monetary policy in response to the households' uncertainty, focusing in particular on how that policy influences the households' beliefs. In figure 2, panel A, we plot the interest rate chosen by the p^I central bank, assuming that $p^I = 0.5$, for different values of the demand shock. For comparison purposes, we also plot the interest rates chosen by the two benchmark central banks: the known-to-be independent central bank (solid line) and the known-to-be dependent central bank (o) that follows the preferences of the political authority. z_t is assumed to equal 0 in this figure.

To understand the optimal policy of the p^I central bank in response to a demand shock, consider first how the two benchmark central banks react. In response to a positive (negative) demand shock, the upward (downward) pressure on both inflation and the output gap can be offset by raising (cutting) the nominal interest rate; the greater the size of the demand shock, the greater the interest rate change. Importantly, both of the benchmark central banks understand that there is an interest rate choice, $i_t = \sigma g_t$, that completely eliminates the impact of the demand shock on the endogenous variables. This choice ensures that there are no deviations in the paths of inflation and the output gap when the economy is hit by a demand shock. As a result, both the known-to-be dependent central bank choosing the preferred interest rate of the political authority and the known-to-be independent central bank would choose the same interest rate policy. Knowing this, the households expect that, regardless of whether the central bank is independent or dependent, the central bank will choose $i_t = \sigma g_t$.

In understanding these household expectations, we can now understand the interest rate choice of the p^I central bank. On the one hand, if the p^I central bank chooses $i_t = \sigma g_t$, the public cannot glean any information about the type of the central bank because both benchmark types would choose this value. As a result, p^I remains unchanged. On the other hand, if the p^I central bank chooses $i_t \neq \sigma g_t$, the households view this deviation from the optimal interest rate choice as being equally likely from either central bank and so again, they would be unable to update their beliefs. Taken together, the p^I central bank understands that, regardless of its interest rate choice, it cannot influence the beliefs of the households. This leads the p^I central bank to choose $i_t = \sigma g_t$ because at that value, even though the households' beliefs regarding the independence of the p^I central bank do not improve, the demand shock does not cause any deviations in the paths of inflation and the output gap. We can see this decision in figure 2, panel A, where the p^I central bank chooses the same interest rate as do the two benchmark central banks.

To underscore this intuition, in figure 2, panel B, we plot the impulse response of the economy to a one-standard deviation demand shock, assuming the interest rate policy is set optimally by a p^I central bank that has a perceived independence of $p^I = 0.5$. In response to the demand shock, the p^I central bank raises the interest rate to σg_t. This interest rate increase completely counteracts the increase in demand, and we see no change in inflation or the output gap. As noted previously, the households do not infer anything about the central bank type from the policy choice and therefore the public's perception as to the independence of the p^I central bank does not change. Finally, figure 3 plots the p^I central bank's loss function, the present discounted value of current and expected future losses, as a function of g for three values of p^I: $p^I = \{0.1, 0.5, 0.9\}$. z_t is still assumed to equal 0. The figure shows that the p^I central bank suffers no welfare loss in response to a demand shock as it is able to costlessly offset the demand shock.

5.3 Optimal policy in response to a supply shock

We now describe the behavior of the p^I central bank in response to a productivity shock. Unlike for a demand shock, there is no interest rate choice that can prevent a productivity shock from causing deviations in both inflation and the output gap. As a consequence, the p^I central bank must balance the costs of inflation deviations with the cost of deviations in the output gap. The key parameter mediating this tradeoff is λ^{CB}, the weight placed on the output gap in the p^I central bank's loss function. Households believe that an independent central bank prioritizes limiting inflation deviations at the expense of a more volatile output gap, while a dependent central bank prefers the opposite. The p^I central bank understands these household beliefs and knows that the households closely monitor the p^I central bank's choice of interest rate to glean whether or not the central bank is independent. As such, the p^I central bank can use its policy instrument to influence household beliefs. To do this, the p^I central bank balances the traditional tradeoff between inflation and output gap deviations with the additional incentive to choose a policy that helps persuade the public that it is independent. We will see the impact of this additional incentive in the next few figures.

Once again, in order to help describe the motivations of the p^I central bank, we start by describing how the two benchmark central banks react to a productivity shock. We plot those reactions, as well as the economic impact of those reactions in figure 4. Specifically, figure 4 plots the real interest rate and the resulting equilibrium outcomes in a model where the known-to-be dependent central bank sets monetary policy (dashed line) and a model where the known-to-be independent central bank sets monetary policy (solid line). As we can see, in response to a positive (negative) productivity shock, both types of benchmark central banks reduce (raise) the nominal interest rate and the real interest rate. But, critically, because a known-to-be independent central bank places a greater weight on inflation deviations than does a known-to-be dependent central bank, the former reduces (raises) the real interest rate by more than the latter. The result of this choice is that the known-to-be independent central bank pushes inflation deviations closer to zero (by offsetting the fall in inflation with a larger increase in output) and accepts a greater output gap than does the known-to-be dependent central bank.

Given this background on how the two benchmark central banks set policy, we now turn to how the p^I central bank responds to a productivity shock. We plot the nominal interest rate chosen by the p^I central bank – as well those chosen by the two benchmark central banks – in figure 5. To describe that behavior, suppose the economy was hit by the productivity shock, z_t. For that sized shock, there is an interval of interest rates defined by the choices made by the known-to-be independent central bank and the known-to-be dependent central bank. Given that same value of z_t, the p^I central bank chooses an interest rate that is both outside of this interval and beyond what the known-to-be independent central bank would choose. The resulting interest rate is always closer to the interest rate that would be chosen by the known-to-be independent central bank than to what the known-to-be dependent central bank would choose. Interpreting this solution, the p^I central bank demonstrates its independence by acting even more "independent" than a known-to-be independent central bank!

In choosing this policy, the p^I central bank accepts a sub-optimal combination of inflation and output over the short-run, as can be seen in figure 6. In that figure, we show that the p^I

central bank accepts more pronounced movements in both inflation and the output gap in response to a productivity shock than would a known-to-be independent central bank. The sizes of those movements grow as the value of p^I falls. But, the p^I central bank is willing to accept these inferior paths because, by choosing a nominal interest rate that is further away from the choice of the known-to-be dependent central bank, households interpret the observed interest rate as more likely coming from an independent central bank than from the dependent central bank. This prompts the household to update (via Bayes' rule) their subjective probability that thep^I central bank is truly independent of the political authority, increasing their belief in independence. These improved beliefs, in turn, provide a long-term benefit to the p^I central bank in the form of improved expectations.

The degree to which the p^I central bank chooses to diverge from the known-to-be independent central bank depends upon the central bank's reputation: the less the public believes that the p^I central bank is independent, the more the p^I central bank deviates from the optimal policy of the known-to-be independent central bank. In fact, when the public puts a sufficiently low probability on the p^I central bank being independent, then the p^I central bank's optimal policy is flipped relative to the known-to-be independent benchmark case, with the bank choosing to raise (cut) the nominal interest rate in response to a positive (negative) supply shock instead of the opposite. That is, when p^I is sufficiently low, the central bank values improving its reputation to such a degree that it is willing to completely flip how it responds to a productivity shock. This choice in turn has painful consequences for the economy in the short run. To take one example, if $z_t = 0.05$, the known-to-be independent central bank chooses to reduce the nominal interest rate, leading the real interest rate and inflation to fall and GDP to rise moderately. The $p^I = 0.5$ central bank, on the other hand, is worried about the public's belief that it could be captured by the political authority. So, to convince the public that it is independent, it chooses to dramatically raise the nominal interest rate. This choice leads to such a large increase in the real interest rate that the economy enters a recession. The benefit of this action, however, is that the public believes that it is highly unlikely that the choice would have been made by a central bank being told what to do by the political authority, thus improving household beliefs for the future.

Figure 7 underscores these results. Panel A plots the impulse response to a one-standard deviation productivity shock. The figure displays the interest rate policy of a p^I central bank with perceived independence $p^I = 0.5$ (solid) and $p^I = 1$ (dashed). The dashed line indicates that if the p^I central bank were known-to-be independent, it would slightly lower the nominal interest rate in response to the productivity shock, leading to a moderate fall in inflation and a moderate increase in output. If households were uncertain about the independence of the

p^I central bank ($p^I = 0.5$), though, the p^I central bank would raise the nominal interest rate to distance itself from the political authority. The result is clearly worse for the economy in the short-run: output falls sharply and inflation falls more than in the baseline case. However, this extreme action leads households to revise up their belief that the p^I central bank is independent and, after 20 quarters, their belief increases from $p^I = 0.5$ to $p^I = 0.6$. In panel B of the same figure, we plot the p^I central bank's loss function against the supply shock z. We can see that the p^I central bank experiences current and expected future losses when the economy experiences a supply shock. Moreover, these losses are larger the lower is the p^I central bank's perceived credibility.

Finally, in figure 8, we explore a thought experiment, one meant to capture the impact of President Trump's statements in 2018 and 2019 demanding a change in monetary policy. Specifically, we start by assuming that there exists a p^I central bank that the households are fairly confident is independent ($p^I = 0.9$). Figure 8 then plots the time paths of both the policy choice and the resulting economic outcomes of that p^I central bank in response to a one standard deviation productivity shock. This environment continues for 10 periods when a shock occurs: the political authority at $t = 10$ publicly rebukes the p^I central bank and calls for a lower nominal interest rate. This public statement by the political authority immediately undermines the public's confidence in the p^I central bank's independence, and we assume that p^I falls to $p^I = 0.5$. At this point, the p^I central bank must decide how to use its policy instrument to both manage the economy while restoring the public's confidence in its independence. For comparison purposes, we also plot using a dashed line the time paths of policy and economic outcomes of a p^I central bank that begins at $p^I = 0.5$ and does not face the shock in period 10.

Initially (before $t = 10$), the productivity shock prompts both p^I central banks to follow the policies described above: the central bank that begins with a greater reputation of independence feels less incentive to distance itself from the political authority's preferred interest rate than does the $p^I = 0.5$ central bank. As a result, the $p^I = 0.9$ central bank raises the nominal interest rate by less than does the $p^I = 0.5$ central bank. This choice implies that inflation and the output gap remain close to, though below, zero. The impact of this choice by the $p^I = 0.9$ central bank is that the economy's performance in the short-run remains relatively stable with inflation and the output gap not deviating much from zero, though the choice did not noticeably improve households' beliefs about CBI. The $p^I = 0.5$ central bank, on the other hand, raises the nominal interest rate by such a high degree in order to demonstrate its independence that the economy's output contracts significantly. This is painful in the short-run, but the benefit is that the households' beliefs improve steadily over time.

This intuition guides the behavior of both p^I central banks until the shock occurs in period 10. In that period, the political authority publicly complains that the $p^I = 0.9$ central bank is keeping interest rates too high. In response to the political authority's public rebuke, the $p^I = 0.9$ central bank immediately suffers a crisis of reputation: in the minds of households, it is no longer clear that the central bank chooses policy based on its own preferences, but they fear that the central bank might succumb to the pressure of the political authority and reduce rates. This perception prompts households to expect a more volatile path of inflation and a smoother path of the output gap. The $p^I = 0.9$ central bank, in turn, understands the uncertainty generated by the political authority and how that uncertainty represents a persistent worsening of the households' expectations about inflation and the output gap. At this point, the central bank realizes that its priority must be to convince the public that it truly is independent, even at the expense of choosing a nominal interest rate that harms the economy's short-run performance. Thus, the central bank immediately raises interest rates – the exact opposite action called for by the political authority – and in doing so, output and inflation plummet. The central bank will then maintain this high nominal interest rate as it slowly convinces the households that it is independent.

We should note here that, in the decision to demand publicly that the central bank choose an alternative path of policy, the political authority reduces the welfare of all agents in the model, including the political authority itself. A seemingly better choice for the political authority would have been to privately lobby the central bank to choose the alternative path of policy. If this is the case, why then would the political authority choose the public demand? To justify the decision, we assume that the political authority receives a political benefit from the public nature of the demand, a benefit which is outside of the model. The potential benefits we have in mind include the knowledge that the political authority's supporters value witnessing a public controversy or the political authority derives value from setting up the central bank for blame if the economy does not perform as well as supporters had hoped.

5.4 Simulation

To give some basic intuition for the model results, figure 9 plots a simulation of the model for one path of productivity and demand shocks. We can see that, early on, monetary policy (i_t) is quite volatile as the p^I central bank tries to establish credibility. It is eventually able to do so and by $t = 200$ (50 years) the households are highly confident that the p^I central bank is independent. One notable event is the period of tranquility of the interest rate around time 80 to 100. Recall from the previous results that credibility concerns cause a p^I central bank to raise interest rates in response to a positive supply shock when the known-to-be independent central bank would want to lower interest rates. As credibility increases, the incentive to raise interest rates falls. As a result there is a point, around $p^I = 0.9$, where these two effects largely cancel. During those periods in which p^I is approximately equal to 0.9, the interest rate is insensitive to the productivity shocks. Over time, as the public continues to gain confidence in the independence of the central bank, the central bank's priority switches away from improving its reputation to the traditional concern of managing the inflation/output gap tradeoff. At this point, the policy choices of the p^I central bank largely resemble those of a central bank with no concerns about its reputation. The outcome of these choices is that interest rates and productivity shocks are positively correlated before this period of tranquility and negatively correlated afterwards.

A critical implication of the simulation is that p^I – the household's belief as to how likely it is that the central bank is independent – influences economic volatility. To explore that relationship more closely, we simulate the economy 200 times, where for each simulation we allow the economy to evolve for 296 [(2020-1946)*4] quarters while being subjected to a random path of productivity and demand shocks. Across all of those simulations, we capture the economic properties of the macroeconomy, focusing on the volatility, correlations, and autocorrelations of inflation, the output gap, and the nominal interest rate. We describe the median values of those properties, as well as the 10th and 90th percentiles, in table 1.

First, we see that inflation is the most volatile variable, followed by output and the interest rate. Moreover, all these variables are highly correlated. The model also generates endogenous time varying volatility. To examine this fact, we report the autocorrelation of the squared differences of inflation, output, and interest rates in the last column of the top row. We can see that all of these correlations are positive and significant, indicating that large changes in these variables are positively correlated with large changes in the subsequent quarter.

In the columns of the middle row of that table, we show how those properties evolve over time, where we divide the 296 periods into three, roughly equal, periods. In the bottom rows of the table, we again show the volatility properties of the macro variables except this time we divide the periods into three, arguably more appropriate periods. The first period, ranging from $t = 1 - 40$, corresponds to the time period in which the central bank's main focus is improving its reputation. The second period, ranging from $t = 41 - 85$, corresponds to the time period in which the central bank weighs its reputational concerns to be roughly equally important to its traditional inflation/output gap concerns. And finally, the third period, ranging from $t = 86 - 296$, corresponds to the time period in which the central bank has already mostly convinced the public that it is independent and so the traditional concerns of a central bank are at the fore.

In the bottom rows of table 1, we see that the p^I central bank chooses a volatile path for the nominal interest rate during the first 40 periods especially, as the central bank attempts to use the nominal interest rate to convince the public that it is independent. Initially, when p^I is low, the central bank chooses a path of the nominal interest rate that positively co-moves with the productivity shock. But, as p^I grows and households become more convinced that the central bank is independent, the degree to which the central bank must tilt its policy to demonstrate its independence falls, leading the central bank to implement a smoother path of the nominal interest rate. This smoother path can be seen in the standard deviation of the nominal interest rate as well as the correlation between i_t and z_t. Finally, as p^I approaches 1, the central bank can focus on the traditional inflation/output gap tradeoff rather than trying to persuade the public that it is independent. The consequence of this focus is that the central bank chooses a path of interest rates that negatively co-moves with the productivity shock. This fact can be seen in the raised standard deviation of the nominal interest rate in the early part of the sample as well as the change in sign of the correlation between i_t and z_t. Finally, we examine how quickly households learn that the central bank is independent, i.e. how quickly p^I reaches 0.95 after beginning at 0.5. On average it takes about 85.5 quarters for households to learn the central bank is independent.

5.5 Federal Reserve Chair Powell's statement

The above analysis has at its center two key assumptions. The first is that public pressure from the political authority generates uncertainty in the minds of households about whether the central bank will succumb to the pressure and implement the political authority's preferred interest rate. The second assumption is that the central bank uses monetary policy to influence the households' beliefs as to its independence. Both were implicitly discussed in a 2019 news conference by Federal Reserve Chairman Jerome Powell. In that news conference, Powell stated that the Federal Reserve's monetary policy deliberations "never take into account political considerations. There's no place in our discussions for that. We also don't conduct monetary policy in order to prove our independence" (7/31/2019). On its face, the initial part of the statement represents an attempt to convince the public that the Federal Reserve has complete independence. If believed, then the public's uncertainty is eliminated, and there is no loss for the Federal Reserve to reject using monetary policy to influence the public's perception of its independence.

However, if the public is not convinced by Powell's assertion that the Fed is independent, then the claim that the Fed does not use its policy tools to demonstrate its independence is problematic. This difficulty arises because the Federal Reserve has in effect eliminated a possible policy path that would lead the public to have improved expectations, which in turn would generate a superior inflation/output gap tradeoff for the Fed.

To demonstrate this result, suppose we assume the same setup as above, where households again face uncertainty about the central bank's independence and update their beliefs using Bayes' rule. But, unlike before, we assume that the central bank does not consider how its policy choice impacts the households' beliefs about CBI. Rather, the central bank naively takes as given the evolution of p^I across time, i.e. the central bank's optimal policy is solved via the value function equation (11) but assuming that $p_t^I = p_{t+1}^I$. Then this chosen policy is fed back into the value function equation (11) assuming beliefs evolve according to equation (10). This setup is meant to capture the idea that the Federal Reserve does not "conduct monetary policy in order to prove [its] independence". After solving this model, we plot the resulting value function which captures the present discounted value of the welfare loss from the naive policy relative to the optimal policy in figure 10 for multiple different values of p^I. As can be seen, the welfare loss associated with the central bank not considering how its policy choice influences the households beliefs is substantial. The welfare loss is 300-400% as large in the case depending on the level of central bank credibility ($p^I = 0.1 - 0.7$). However, the welfare loss is small when the central bank has a high level of credibility, e.g. $p^I = 0.9$.

6 Model Extensions

This section considers robustness and extensions to the main model results.

6.1 Zero lower bound

In our first extension, we consider the case where the interest rate is constrained to not go below zero. We impose this constraint by imposing a zero constraint on the minimization problem when calculating the p^I central bank's loss function via equation (11). Figure 11 depicts the policy chosen by the p^I central bank in response to a productivity shock (the left side of the figure) and a demand shock (the right side of the figure) when there is a zero lower bound.

To understand the impact of the ZLB, let us first consider how the two benchmark central banks respond to a demand shock in the presence of the ZLB. As noted above, both the known-to-be independent and the known-to-be dependent central banks completely offset a positive demand shock by raising the nominal interest rate to $i_t = \sigma g_t$. This choice prevents inflation and the output gap from moving in response to a positive demand shock. When the demand shock is negative, however, the two benchmark central banks can no longer choose their desired negative nominal interest rate because they are constrained by the ZLB. This leads both to choose an interest rate as close as possible to their desired value, or $i_t = 0$.[9]

Turning to the p^I central bank, the p^I central bank understands that, because both benchmark central banks would choose the same policy in response to a (positive or negative) demand shock, it cannot demonstrate its independence to the public. With this incentive off the table, the p^I central bank only considers the inflation/output gap tradeoff of a standard central bank. This leads the p^I central bank to choose the same interest rate as the two benchmark central banks, raising rates in response to a positive demand shock and setting $i_t = 0$ in response to a negative demand shock. We see these choices on the right hand side of figure 11.

The more interesting and subtle consequences of the ZLB comes in response to a productivity shock, plotted on the left hand side of figure 11. Consider first a positive productivity shock. Figure 5 shows that, absent the ZLB, the two benchmark central banks would choose a negative interest rate in response to a positive productivity shock, with the known-to-be independent central bank choosing a less negative interest rate. In doing so, the known-to-be independent central bank accepts more volatility in the output gap in order so achieve a smoother path of inflation, relative to the known-to-be dependent central bank. Figure 5 also shows that in the absence of the ZLB, a p^I central bank chooses an interest rate that is less negative than a known-to-be independent central bank. This choice allows the p^I central bank to demonstrate its independence from the known-to-be dependent central bank. The size of that deviation rises – and interest rate choice becomes more positive – as p^I falls.

When the ZLB is a binding constraint, however, our results change. The ZLB prevents the two benchmark central banks from choosing a negative interest rate, leading them both to set $i_t = 0$. Similar to the demand shock case, because both benchmark central banks set the same interest rate, it is no longer possible for the p^I central bank to exploit the different choices of the banks to demonstrate its independence from the political authority. Thus, even though the p^I central bank would set a positive interest rate absent the ZLB, there is no benefit of doing so in the presence of the ZLB because the public is unable to interpret that deviation as more likely to come from the known-to-be independent central bank. The result is that the p^I central bank chooses $i_t = 0$ and accepts that it cannot influence people's expectations, even in response to a positive productivity shock. Thus, perhaps unexpectedly, the ZLB eliminates the ability of the p^I central bank to demonstrate its independence despite the fact that it ideally would want to set a positive interest rate!

The combination of the ZLB and a negative productivity shock flips the concern. In par-

[9]These rules are obtained by truncating equation (7) at zero.

ticular, in response to a negative productivity shock, the two benchmark central banks choose different nominal interest rates, with the known-to-be independent central bank choosing a less positive nominal interest rate than a known-to-be dependent central bank. Under our previous interpretation, this difference gives the p^I central bank the ability to distinguish itself from the political authority by choosing a policy that appears to come from an even more "independent" central bank than the known-to-be independent central bank. The trouble, though, is to exploit that space, the p^I central bank would choose an even less positive nominal interest rate, where "less positive" becomes "increasingly negative" as p^I falls. In the presence of the ZLB, though, the p^I central bank is unable to set a negative nominal interest rate. The consequence is that when the public is not very concerned that the central bank is dependent (p^I is close to 1), then the p^I central bank is able to enact the same interest rate policy as it would absent the ZLB. But, when the public is sufficiently concerned that the central bank has lost its independence (p^I is smaller), then the p^I central bank chooses $i_t = 0$ because that is the greatest deviation that is possible given the ZLB. That is, despite the p^I central bank wanting to set a negative nominal interest rate in order to demonstrate its independence, the constraint binds and it cannot. The p^I central bank, as a result, cannot achieve the same-sized improvement in the public's perception of the central bank's independence as it could when the zero lower bound did not bind.

Thinking more broadly about this extension, we see that absent the ZLB, the p^I central bank is limited in its ability to demonstrate its independence from the political authority because it can only exploit productivity shocks – and not demand shocks – for that demonstration. In the presence of the ZLB, the p^I central bank has, if anything, even fewer opportunities: positive productivity shocks no longer offer the ability for the p^I central bank to distinguish itself, while negative productivity shocks limit the scope of that demonstration with interest rates curtailed at zero. This suggests that when the ZLB is a factor – as it was in the US during President Trump's administration – the central bank will struggle to convince the public that it is independent.

6.2 Signal strength and monetary policy

A critical parameter in the model is σ^2, the noise in household beliefs regarding the central bank's interest rate choice. Recall that the household's belief distribution for the interest rate, conditional on central bank type, is normally distributed around the interest rate the bank would choose if its type were known with variance σ^2. This variance is important because it determines both how quickly the households can learn about the p^I central bank's type and also how substantially the p^I central bank must alter policy to change the household beliefs a specific amount. We examine the sensitivity of our results to different variance assumptions in figure 12.

On the left hand side of figure 12, we plot the p^I central bank's interest rate choice for different values of σ as a function of z, the supply shock, assuming a level of perceived independence of the central bank, p^I, equal to 0.5. For reference, we also plot the policy choice of a known-to-be independent central bank and a central bank known to maximize the preferences of the political authority. For $\sigma = 1.5$ we have our baseline result. In response to a positive productivity shock, the p^I central bank raises the interest rate substantially to distance itself from the political authority and build its reputation of independence. As we reduce σ, the noise in household expectations, the extent to which the p^I central bank chooses an interest rate away from the political authority falls. Put another way, when households are better able to associate a particular interest rate choice with a particular type of central bank, we see that the p^I central bank deviates less from the benchmark central bank's choice. There are two reasons for this. First, for the same sized interest rate deviation from the political authority's preferred policy, a smaller σ^2 implies that household beliefs will move more towards the p^I central bank being independent. This, in turn, suggests that the p^I central bank needs to distort policy less to establish credibility. Second, since households learn faster when σ is lower, it is easier for the p^I central bank to establish the perception of independence, and therefore it does not need to invest as much today in establishing that reputation.

One interesting note about the plot is that for a low level of noise, $\sigma = 0.3$, in response to extreme shocks, the optimal interest rate of the p^I central bank lies between the policies of the known-to-be dependent and known-to-be independent central banks. In this case, reputation is much less important because it is easy for the p^I central bank to establish the perception of independence. On the other hand, because households believe that there is a 50% chance that the p^I central bank is dependent, the expectations of households are different than in the known-to-be independent case, altering the optimal policy choice and pushing the independent central bank closer to the preferred policy of the political authority.

The above analysis examines how the p^I central bank's optimal interest rate moves if households are better at associating particular monetary policies with central bank type. One might be curious, though, about the converse: how should the p^I central bank set monetary policy when households are less and less able to decipher the signal in the noise? To that end, we plot on the right hand side of figure 12 the optimal interest rate of the p^I central bank for a wider range of σ, assuming that $p^I = 0.5$, $z = 0.0338$, and $g = 0$. In that graph, we see that if households have a moderate degree of ability to associate policy with CB type (roughly $\sigma = 2$), then the p^I central bank chooses a very positive nominal interest rate in response to a positive productivity shock. But, as σ moves away in either direction from this value, the p^I central bank chooses to distort its interest rate choice by less. Above, we discussed the logic of this movement when σ is small: if households are better able at attributing particular policy choices with an independent central bank, then the p^I central bank need not resort to such extreme policies to convince households that it is independent. The logic of the p^I central bank's choice for large values of σ is different. When σ is large and households struggle to associate policy decisions with a type of central bank, then the value of choosing an interest rate far away from the preferred choice of the political authority falls because the deviation is less effective at influencing p^I. In fact, for very large values of σ (when households are largely unable to attribute policy decisions with a type of central bank), then the p^I central bank accepts that its reputation as possibly dependent is immutable and so returns to an interest rate policy that would be optimal in the absence of household uncertainty about the type of central bank. Put differently, when σ is sufficiently large, the p^I central bank in effect gives up on influencing the households' beliefs and chooses standard optimal policy in response to a productivity shock.

6.3 Dependent central bank

Next we consider the intriguing scenario that a p^I central bank may in fact be captured by the political authority, though the public is unsure that this is true. In this case the p^I central bank maximizes the political authority's preferences, while the households attempt to learn the type of central bank from its interest rate choices. In this subsection we explore if the captured p^I central bank will set policy to maintain an illusion of independence or if it will reveal to the public that it is captured. That is, we seek to see if a dependent p^I central bank will benefit from having households believe that it is independent.

To explore the answer to this question, we again calculate the p^I central bank's loss function and policy function via the value function equation (11), but now we replace λ^{CB}, the independent p^I central bank's inflation weight, with λ^{PA}, the political authority's inflation weight. We find that indeed the dependent p^I central bank has the incentive to distort policy so that households believe it is independent. This effect is so strong that the p^I central bank will continue to choose policy to increase the households' belief that it is independent until the household believes that it is independent with probability one.

To see this result, examine the left hand side of figure 13. Here we plot the p^I central bank's welfare as a function of p^I, the household's belief that the central bank is independent. We can see that the p^I central bank's current and expected future losses are smaller the more the household believes it is independent. To see why this is the case, examine the right hand side of the same figure. Here, we plot the equilibrium outcomes for inflation and output under two scenarios. In the first row, the central bank maximizes the preferences of the political authority and households know this. In the bottom row, the p^I central bank again maximizes the preferences of the political authority but households believe the central bank is independent with probability one. One can see that the volatility of both inflation and the output gap are lower when households think the central bank is independent than when it knows the central bank is dependent. The reason for this result can be seen from figure 4: because an independent central bank chooses policy to mitigate fluctuations in inflation, households expect smaller fluctuations in inflation when they believe the central bank to be independent. A dependent central bank will benefit from these beliefs because inflation will fluctuate less in response to supply shocks. Moreover, as seen in figure 14, the dependent p^I central bank will need to adjust interest rates less to offset fluctuations in inflation and therefore can obtain lower output volatility as well. We have confirmed in simulations of the model (results omitted) that eventually a dependent p^I central bank will end up in the equilibrium where households believe it is independent.

7 Conclusion

In this paper we model optimal monetary policy when households are uncertain whether or not the central bank has policy and objective independence from the political authority. Households believe that if the central bank were independent, then it would set its monetary policy according to a loss function that places a greater weight on inflation deviations than on the output gap, but if the central bank were captured by the political authority and set policy according to the political authority's preferences, then the central bank would have the opposite priorities. The issue in this paper, though, is that the households are unsure of the central bank's true type. Given this uncertainty, households closely monitor the monetary policy choices of the central bank to glean information about the central bank's type. Specifically, households start with a subjective probability that the central bank is independent and update these beliefs via Bayes rule based on the observed policy choice of the central bank. The model generates a novel measure of central bank independence, the likelihood that the households believes the central bank is maximizing its own preferences, and links this measure of independence to expected future losses for the central bank.

Moreover, we show that the central bank has an incentive to choose policy to invest in the perception of its independence. The reason for this investment – and the driving force behind why there are conditions under which the central bank would be willing to tank the economy in the short run – is that future expected losses are significantly higher the more the central bank is perceived as dependent. Subsequently, the central bank may choose an optimal policy quite different than the full-information, rational expectations policy.

As it turns out, the ability of the central bank to demonstrate its independence to households depends upon the particular shocks hitting the economy. Demand shocks do not allow the central bank to demonstrate its independence because there is no trade-off between stabilizing inflation and output. Supply shocks are different, however, because there is a trade-off between stabilizing inflation and the output gap. As the independent central bank and the dependent central bank would choose different policies, prioritizing different deviations, the central bank can use this discrepancy to set a path of interest rates that is very different from what a dependent central bank would choose. In doing so, the central bank leads households to believe with greater weight that it is independent.

Further, we show that the willingness of the central bank to deviate from traditional optimal policy depends upon the ability of the households to distinguish between an independent and a captured central bank and the public's beliefs regarding how likely the central bank is to be independent. We characterize optimal policy of an unknown to be dependent central bank and demonstrate how the presence of the zero lower bound alters the central bank's optimal policy. Finally, the model endogenously delivers time-varying macroeconomic volatility, stemming from belief-dependent optimal monetary policy, that may be helpful for understanding an event like the Great Moderation and the evolution of monetary policy over time in the United States.

References

Alberto Alesina and Lawrence H Summers. Central bank independence and macroeconomic performance: some comparative evidence. *Journal of Money, Credit and Banking*, 25(2): 151–162, 1993.

Robin Bade and Michael Parkin. *Central bank laws and monetary policy.* Department of Economics, University of Western Ontario, Ontario, Canada, 1988.

Ed Balls, James Howat, and Anna Stansbury. Central bank independence revisited: After the financial crisis, what should. 2016.

Robert J Barro and David B Gordon. Rules, discretion and reputation in a model of monetary policy. *Journal of Monetary Economics*, 12(1):101–121, 1983.

Helge Berger, Jakob De Haan, and Sylvester CW Eijffinger. Central bank independence: an update of theory and evidence. *Journal of Economic Surveys*, 15(1):3–40, 2001.

Francesco Bianchi. Regime switches, agents' beliefs, and post-world war ii us macroeconomic dynamics. *Review of Economic Studies*, 80(2):463–490, 2013.

Francesco Bianchi, Thilo Kind, and Howard Kung. Threats to central bank independence: High-frequency identification with twitter. Technical report, National Bureau of Economic Research, 2019.

Carola Binder. Presidential antagonism and central bank credibility. *Economics & Politics*, 2020.

Carola Conces Binder. Political pressure on central banks. *Journal of Money, Credit and Banking*, 53(4):715–744, 2021.

Alan Blinder. Don't Politicize the Fed, Reappoint Chairman Jerome Powell. *Wall Street Journal*, October 2021.

Alan Blinder, Michael Ehrmann, Jakob De Haan, and David-Jan Jansen. Necessity as the mother of invention: Monetary policy after the crisis. *Economic Policy*, 32(92):707–755, 2017.

James Bullard and Kaushik Mitra. Learning about monetary policy rules. *Journal of Monetary Economics*, 49(6):1105–1129, 2002.

Carlos Carvalho, Stefano Eusepi, Emanuel Moench, and Bruce Preston. Anchored inflation expectations. CAMA Working Papers 2020-25, Centre for Applied Macroeconomic Analysis, Crawford School of Public Policy, The Australian National University, March 2020.

Timothy Cogley, Christian Matthes, and Argia M. Sbordone. Optimized taylor rules for disinflation when agents are learning. *Journal of Monetary Economics*, 72:131 – 147, 2015.

Christopher Crowe and Ellen E Meade. The evolution of central bank governance around the world. *Journal of Economic Perspectives*, 21(4):69–90, 2007.

Alex Cukierman. Central bank independence and monetary policymaking institutions-Past, present and future. *European Journal of Political Economy*, 24(4):722–736, 2008.

Alex Cukierman and Steven B Webb. Political influence on the central bank: international evidence. *The World Bank Economic Review*, 9(3):397–423, 1995.

Alex Cukierman, Steven B Webb, and Bilin Neyapti. Measuring the independence of central banks and its effect on policy outcomes. *The World Bank Economic Review*, 6(3):353–398, 1992.

Nazire Nergiz Dincer and Barry Eichengreen. Central bank transparency and independence: Updates and new measures. *International Journal of Central Banking*, 10(1):189–259, 2014.

Sylvester CW Eijffinger, Jakob De Haan, et al. The political economy of central-bank independence. *Special Papers in International Economics*, 19, 1996.

Stefano Eusepi and Bruce Preston. Central bank communication and expectations stabilization. *American Economic Journal: Macroeconomics*, 2(3):235–71, July 2010.

George W Evans and Seppo Honkapohja. Expectations and the stability problem for optimal monetary policies. *The Review of Economic Studies*, 70(4):807–824, 2003.

Jon Faust. Oh what a tangled web we weave: Monetary policy transparency in divisive times. *Hutchins Center on Fiscal and Monetary Policy, Working Paper*, (25), 2016.

Jordi Galí. *Monetary policy, inflation, and the business cycle: an introduction to the new Keynesian framework and its applications*. Princeton University Press, 2015.

Ana Carolina Garriga and Cesar M Rodriguez. More effective than we thought: Central bank independence and inflation in developing countries. *Economic Modelling*, 85:87–105, 2020.

Vitor Gaspar, Frank Smets, and David Vestin. Adaptive learning, persistence, and optimal monetary policy. *Journal of the European Economic Association*, 4(2-3):376–385, 2006.

Vittorio Grilli, Donato Masciandaro, and Guido Tabellini. Political and monetary institutions and public financial policies in the industrial countries. *Economic Policy*, 6(13): 341–392, 1991.

Mercedes Haga. On central bank independence and political cycles. *Journal of Applied Economics*, 18(2):267–295, 2015.

Jeroen Klomp and Jakob De Haan. Central bank independence and inflation revisited. *Public Choice*, 144(3):445–457, 2010.

Donald Kohn. Federal reserve independence in the aftermath of the financial crisis: should we be worried? *Business Economics*, 48(2):104–107, 2013.

Finn E Kydland and Edward C Prescott. Rules rather than discretion: The inconsistency of optimal plans. *Journal of Political Economy*, 85(3):473–491, 1977.

John Maloney, Andrew C Pickering, and Kaddour Hadri. Political business cycles and central bank independence. *The Economic Journal*, 113(486):C167–C181, 2003.

Christian Matthes. Figuring out the Fed-beliefs about policymakers and gains from transparency. *Journal of Money, Credit and Banking*, 47(1):1–29, 2015.

Krisztina Molnár and Sergio Santoro. Optimal monetary policy when agents are learning. *European Economic Review*, 66:39–62, 2014.

William D Nordhaus. The political business cycle. *The Review of Economic Studies*, 42(2): 169–190, 1975.

Alberto Posso and George B Tawadros. Does greater central bank independence really lead to lower inflation? evidence from panel data. *Economic Modelling*, 33:244–247, 2013.

Kenneth Rogoff. The optimal degree of commitment to an intermediate monetary target. *Quarterly Journal of Economics*, 100:1169–1189, 1985.

Thomas J Sargent and Neil Wallace. Rational expectations and the theory of economic policy. *Rational expectations and econometric practice*, 1:199–214, 1981.

Frank Schorfheide. Learning and monetary policy shifts. *Review of Economic Dynamics*, 8 (2):392–419, 2005.

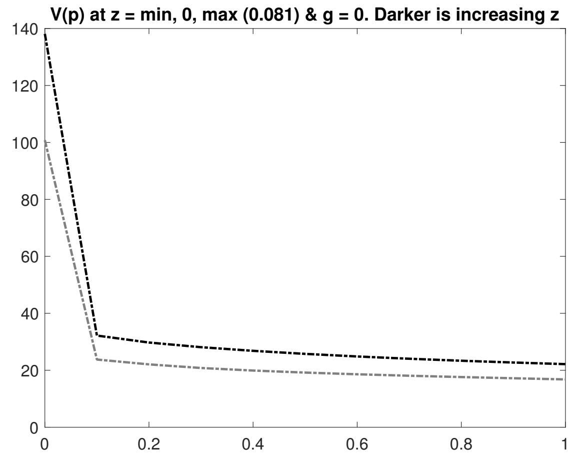
Paul Söderlind. Solution and estimation of re macromodels with optimal policy. *European Economic Review*, 43(4-6):813–823, 1999.

George Tauchen. Finite state markov-chain approximations to univariate and vector autoregressions. *Economics Letters*, 20(2):177–181, 1986.

Annette Vissing-Jorgensen. Central banking with many voices: The communications arms race. 2019.

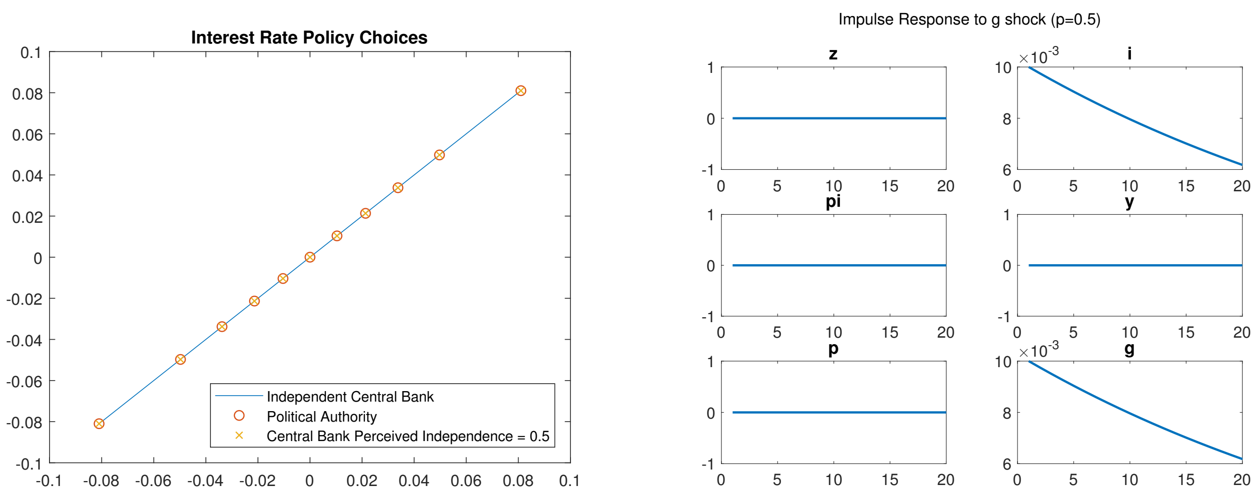
Carl E Walsh. Optimal contracts for central bankers. *The American Economic Review*, pages 150–167, 1995.

Figure 1: Central Bank Loss Function (Vary p^I)



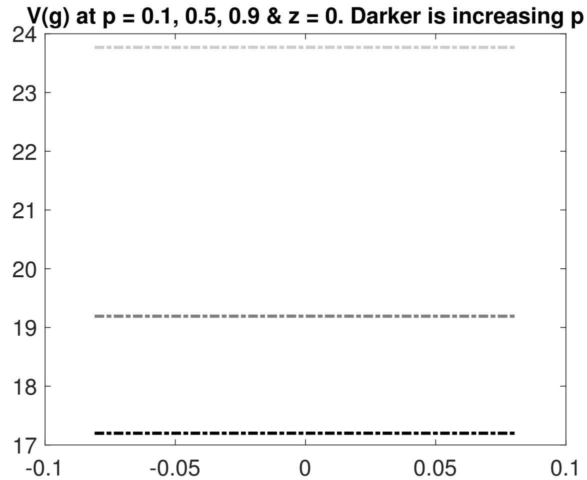
Note: This figure plots the central bank loss function, the present discounted value of current and future expected losses, as a function of p^I, the household's probability belief that the central bank is independent, for the minimum value of the supply shock, the maximum value and a value of zero. The demand shock is zero for all these plots. Given the symmetry of the loss function the lines for the min (0.081) and max (-0.081) overlap.

Figure 2: Policy Choices and Impulse Response with Demand Shock



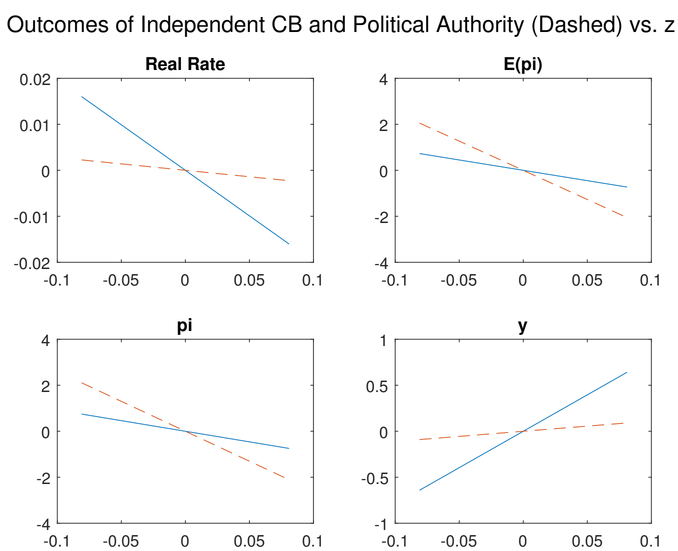
Note: The first panel plots the interest rate policy choice of the political authority, of the known to be independent central bank, and of a central bank that the household believes is independent with a 50% probability. The second panel plots the impulse response function to a one standard deviation shock to demand, given the policy chosen by an independent central bank with perceived independence (p) of 0.5.

Figure 3: Central Bank Loss Function (Vary g)



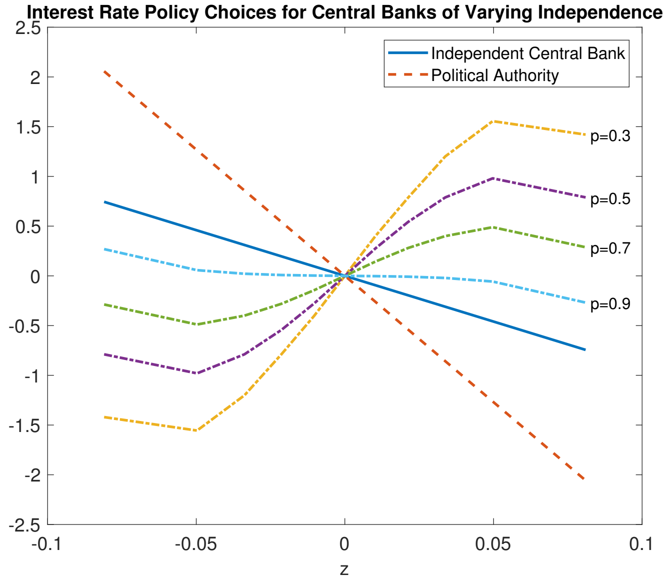
Note: This figure plots the central bank loss function, the present discounted value of current and future expected losses, as a function of g, the demand shock. The value function is plotted for perceived independence of 0.1, 0.5 and 0.9. The supply shock is zero for all these plots.

Figure 4: Outcomes Known to be Independent CB and Political Authority (Dashed)



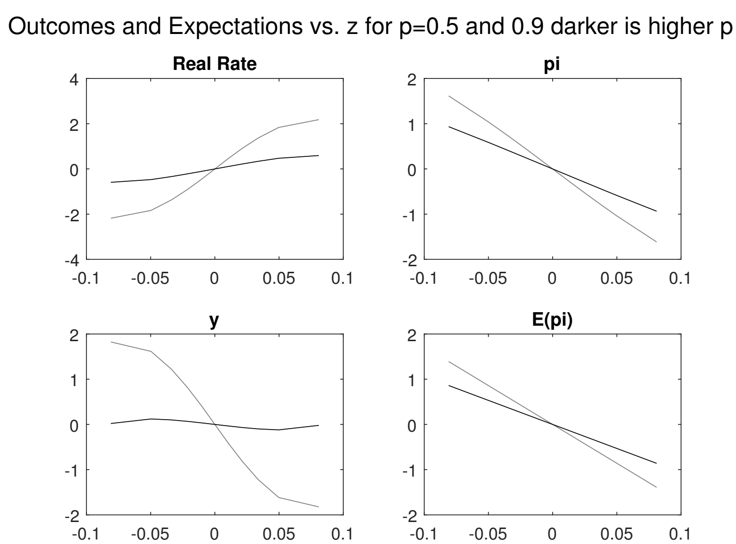
Note: This figure plots equilibrium outcomes as a function of the supply shock (z) for the independent central bank that is known to be independent and the political authority. For these plots the demand shocks is set equal to zero.

Figure 5: Interest Rate Choices for Central Banks of Differing Independence



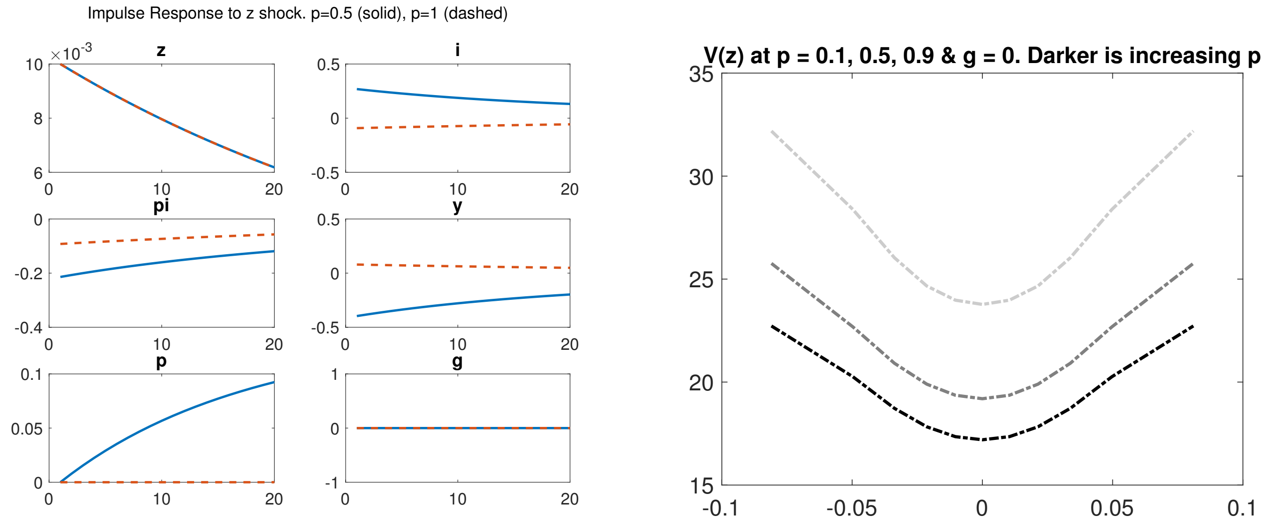
Note: This figure plots the nominal interest rate choice of the political authority, and known to be independent central bank, and independent central banks with varying degrees of perceived independence.

Figure 6: Outcomes p^I Central Bank ($p^I = \{0.5, 0.9\}$)



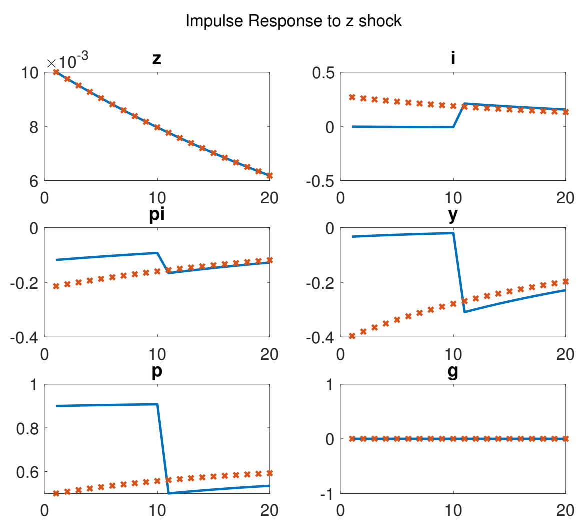
Note: This figure plots equilibrium outcomes as a function of the supply shock (z) for the for the p^I central bank where $p^I = 0.5$ or 0.9. The darker line corresponds to the higher probability $p = 0.9$. For these plots the demand shocks is set equal to zero.

Figure 7: Impulse Response to Supply Shock and Value Function (Vary z)



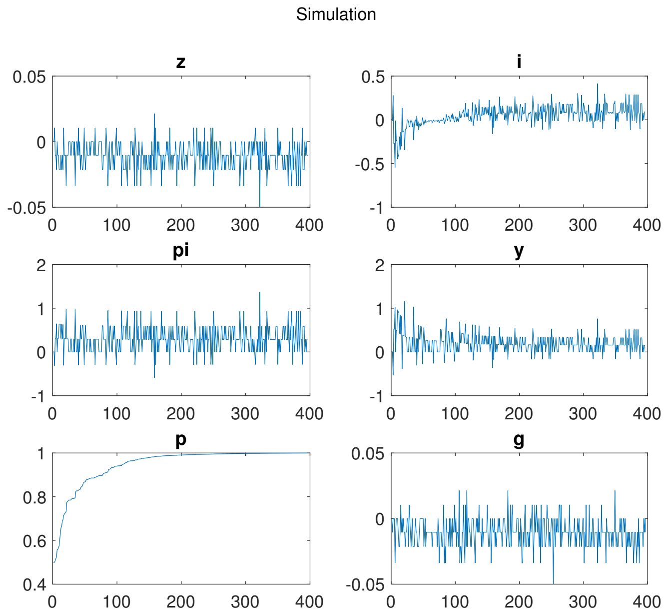
Note: The first panel of the figure plots the impulse response function for a one standard deviation supply shock z. The solid line gives the response for a central bank with credibility $p = 0.5$, the solid line gives the response for a central bank with credibility $p = 1$. The second panel plots the central bank loss function, the present discounted value of current and future expected losses, as a function of z, the supply shock. The value function is plotted for perceived independence of 0.1, 0.5 and 0.9. The demand shock is zero for all these plots.

Figure 8: Impulse Response to z shock for different beliefs



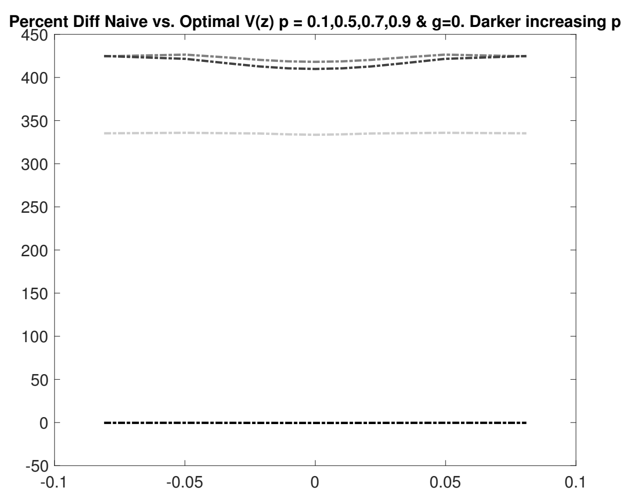
Note: This figure examines the response of the economy to a one standard deviation shock to productivity. The (x) line represents an economy that begins with the perceived independence of the central bank equal to $p^I = 0.5$. The solid line represent an economy that begins with $p^I = 0.9$ but suffers an unanticipated, exogenous shock at time 10 which reduces $p^I = 0.5$.

Figure 9: Simulation



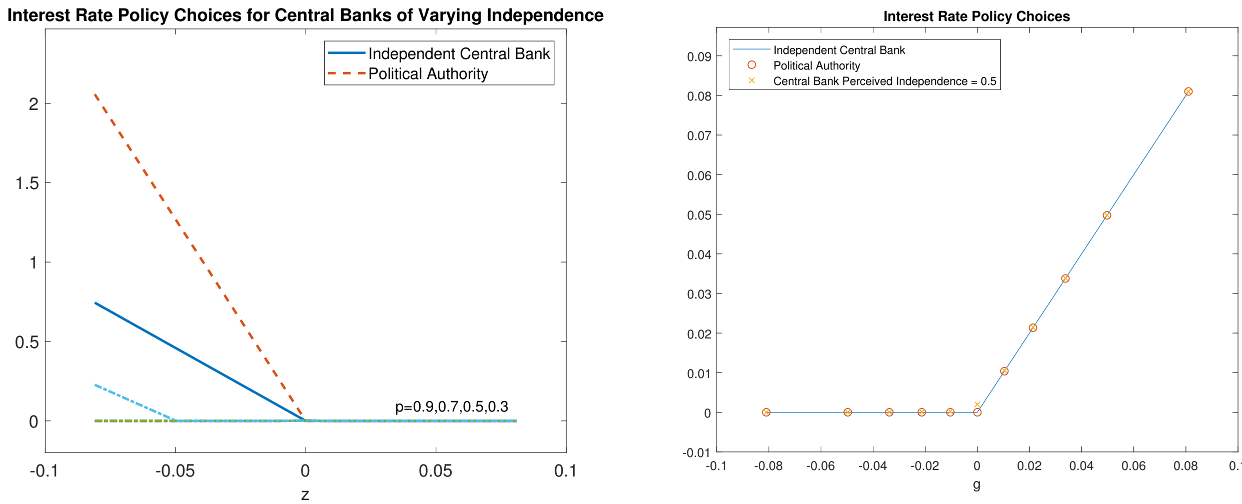
Note: This figure plots equilibrium outcomes for one random draw of supply and demand shocks. The simulation begins at perceived independence of $p = 0.5$.

Figure 10: Loss From Naive Policy



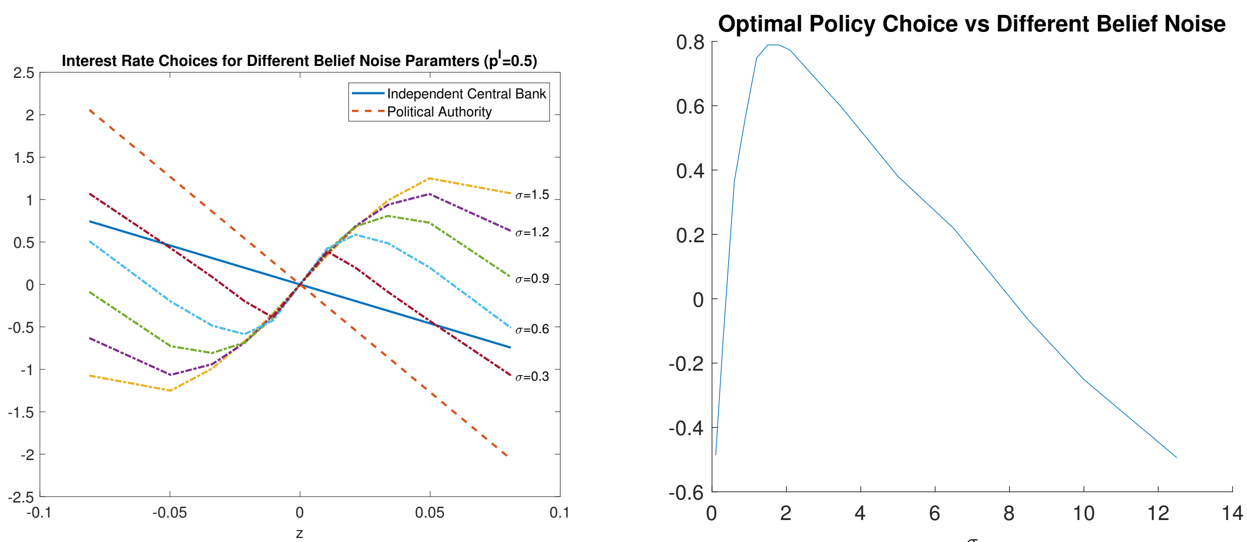
This figure plots the percent difference in the central bank loss function, the present discounted value of current and future expected losses, as a function of z, the supply shock for a bank that follows a naive policy that neglects the impact of its policy on household beliefs and for a bank that sets optimal policy considering the impact on household beliefs. The value function is plotted for perceived independence of 0.1, 0.5 and 0.9. The demand shock is zero for all these plots.

Figure 11: Policy Choices with a Zero Lower Bound



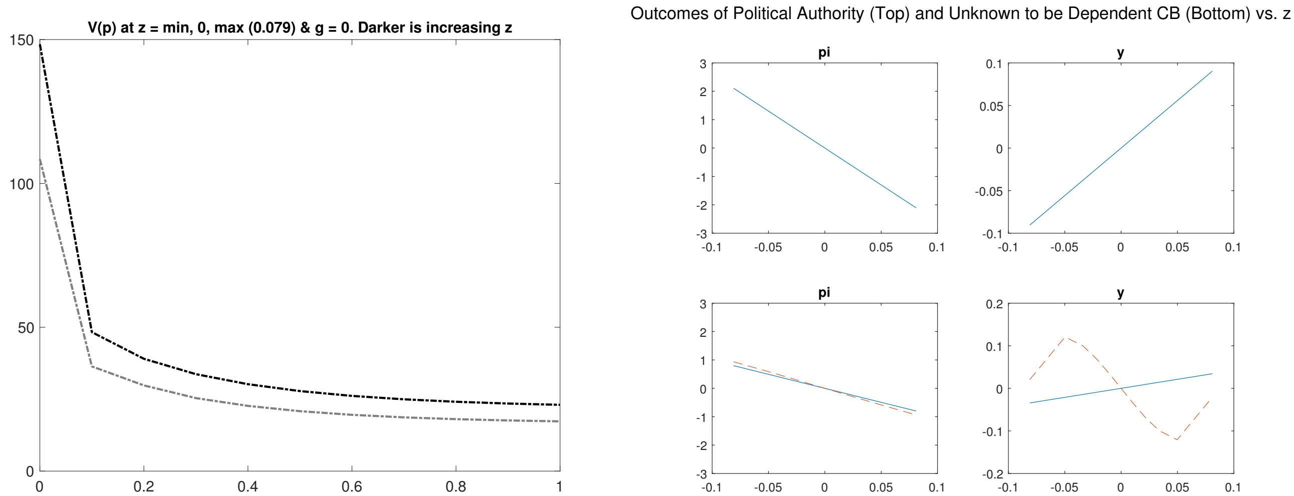
Note: The first panel of the figure plots the nominal interest rate choice of the political authority, and known to be independent central bank, and independent central banks with varying degrees of perceived independence, as in figure 5, when there is a zero lower bound constraint. The second panel plots the interest rate policy choice of the political authority, of the known to be independent central bank, and of a central bank that the household believes is independent with a 50% probability, as in figure 2, when there is a zero lower bound constraint. The optimal policy for the p^I central bank is zero for all but when $p^I = 0.9$.

Figure 12: Optimal Policy as a Function of Household Belief Noise



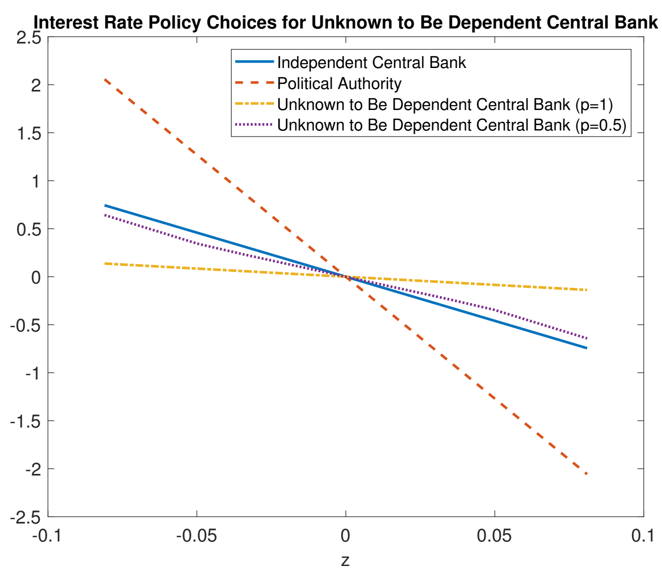
Note: The first figure plots the optimal interest rate policy for a central bank that the household believes is independent with probability, $p^I = 0.5$, for varying noise in the household beliefs (σ). Optimal policy is plotted as a function of z, the value of the supply shock. Also, plotted is the optimal policy of a known to be independent central bank and a known to be dependent central bank (political authority). The second figure plots the optimal interest rate policy when $p^I = 0.5$ and $z = 0.0338$ and $g = 0$ for a larger range of σ, the noise in household beliefs. For comparison, the optimal policy for this value of z and g when the central bank is known to be independent is -0.3105.

Figure 13: Outcomes for Unknown to be Dependent Central Bank



Note: This figure plots the central bank loss function, the present discounted value of current and future expected losses, as a function of p, the household's probability belief that the central bank is independent, for the minimum value of the supply shock, the maximum value and a value of zero. The demand shock is zero for all these plots. Here the central bank is dependent, it maximizes the political authority's preferences, but households do not know this. The second panel of the figure plots equilibrium inflation and output as a function of the supply shock. The top row is for a known to be dependent central bank; the bottom row is for a dependent central bank that households believe is independent with $p^I = 1$. The bottom panel also plots, using a dashed line, the outcomes for an independent central bank that is thought to be independent with probability $p^I = 0.9$.

Figure 14: Policy Choice of Unknown to be Dependent Central Bank



Note: This figure graphs the optimal policy choice of the political authority, a known to be independent central bank, and a dependent central bank that the public believes is independent with probability 1 and probability 0.5.

Table 1: Summary Statistics

	Std. Dev.	Corr. π	Corr. y	Corr. i	Autocorr. $[\Delta x_t]^2$
π	0.30	–	–	–	0.239
	[0.285 0.320]				[0.156 0.328]
y	0.174	0.997	–	–	0.246
	[0.165 0.185]				[0.158 0.33]
i	0.093	0.981	0.968	–	0.254
	[0.087 0.100]				[0.165 0.357]

	T = 1 to 100	T = 101 to 200	T = 201-296
$\sigma(\pi)$	0.312	0.300	0.300
	[0.283 0.341]	[0.277 0.325]	[0.267 0.331]
$\sigma(y)$	0.325	0.185	0.17
	[0.300 0.349]	[0.171 0.203]	[0.151 0.188]
$\sigma(i)$	0.13	0.082	0.095
	[0.124 0.139]	[0.073 0.090]	[0.086 0.11]
	T = 1 to 40	T = 41 to 85	T = 86 to 296
$\sigma(\pi)$	0.320	0.310	0.302
	[0.276 0.361]	[0.260 0.350]	[0.282 0.324]
$\sigma(y)$	0.406	0.251	0.181
	[0.363 0.450]	[0.215 0.286]	[0.170 0.195]
$\sigma(i)$	0.165	0.040	0.089
	[0.152 0.180]	[0.029 0.052]	[0.081 0.096]
$corr(i_t, z_t)$	0.791	-0.438	-0.867
	[0.670 0.890]	[-0.778 0.189]	[-0.916 -0.793]
Average Time to $p = 0.95$	85.5 quarters		

Note: This table lists median statistics across 200 simulations and 10th and 90th percentiles when applicable for the standard deviation, correlation, autocorrelation of squared differences, the standard deviations from three equal sample splits and the median number of quarters for p^I to increase from 0.5 to 0.95. Simulation are of length 296=(2020-1946)*4 quarters. For the standard deviation, correlations and squared autocorrelations, the model is run for a burn-in period of 100 quarters before obtaining the data used to calculate the statistics.