Raising the Inflation Target: What Are the Effective Gains in Policy Room?

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Abstract

A macroeconomic setting characterized by higher inflation represents an opportunity to increase a central bank's inflation target, which can mitigate the risk of future liquidity traps. We show that the gains generated by this strategy are not one-to-one: Because a higher inflation target leads to a steeper Phillips curve, to effectively get, for instance, 2 percentage points of extra room, policymakers need to raise their inflation target from 2% to 5%. Taking this mechanism into consideration changes the optimal inflation target. When the natural rate is near zero, the optimal inflation target is 1 percentage point higher than the optimal target obtained by conventional, earlier, calculations.

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1 Introduction

The global rise in inflation represents an opportunity for central banks to revise their views on their inflation targets. On the one hand, it is far from clear whether lowering inflation back to 2 percent will be straightforward in the new post-covid world. On the other hand, a lurking medium-term macroeconomic risk is the return of the zero lower bound on interest rates. The threat of repeated liquidity traps is a serious macroeconomic challenge for developed economies. Even though the post-pandemic recovery has been strong, structural factors, such as demographic change and excess global demand for safe assets, suggest that future liquidity traps may remain a systematic threat in the medium to longer term. Liquidity traps are a major problem because the ZLB leaves central banks without their key instrument to fight recessions. A prominent proposal to remedy such a situation has been to increase the inflation target, thereby raising the level of the nominal interest rate and creating more room to lower interest rates again when needed.[1] In short, the proposal is to move the economy away from the ZLB.[2]

As we argue in this paper, this strategy comes attached with a particular constraint for the policymaker. This constraint severely hampers the usefulness of this strategy, or has even the potential to undo it completely. The constraint is rooted in the response of the private sector – an increase in the inflation target constitutes a significant policy change, and firms will respond to it. In particular, firms will adjust prices more frequently with higher trend inflation. This plausible channel was first considered in a classic paper by Ball, Mankiw, and Romer (1988).[3] Empirically, there is indeed a clear relationship between the frequency of price changes and trend inflation over the 1970–2015 period, as we show in this paper.

This theoretical mechanism, which arises as a result of increased price flexibility under a higher inflation target, is straightforward: The slope of the Phillips Curve steepens and the potency of monetary policy, defined by the ability of policy to affect output, decreases. Therefore, a central bank is forced to lower the policy rate by more in recessions to counteract a given demand shock. Hence, a central bank will push the rate closer to the ZLB than it would do under constant price flexibility. Part of the extra room gained by raising the target is lost due to the way the private sector adapts to the new environment: the *effective* extra room is smaller that the *intended* extra room.[4]

[1] Throughout the paper, "policy room" refers to the percentage point difference between the steady-state nominal interest rate and zero.

[2] See, for instance, the discussions in Blanchard, Dell'Ariccia, and Mauro (2010), Mishkin (2018), and Cechetti and Schoenholtz (2017). These authors differ with respect to their preferred solution. For small open economies, Svensson has suggested an alternative way to escape liquidity traps through the exchange rate, which in the later stage also includes inflation targeting as in Svensson (2003) or Jeanne and Svensson (2007).

[3] See also Romer (1990).

[4] To be clear, our point is about the behavior of the nominal interest rate *away* from the ZLB. A different implication of increased price flexibility is that, *at the ZLB*, the real interest rate is more affected by deflationary spirals as in Eggertsson and Woodford (2003) or Werning (2012). Whereas this latter point has important implications for our calculations of the optimal inflation target, it is not our focus of attention in this paper.

By the nature of this mechanism, our paper mainly focuses on the *positive* aspects of the constraint faced by a central bank attempting to gain more policy room away from the ZLB. Given the immediate policy implications of our focus, we start off by analyzing the increased price flexibility channel in a 3-equation New Keynesian (NK) model. This allows us to derive a set of simple theoretical results that highlight how increased price flexibility interacts with a higher target to deliver a gap between intended and effective policy rooms. For example, our analysis allows us to derive a formal result showing how a monetary authority can raise the inflation target without losing policy room. It also allows us to understand the role of optimal monetary policy in our context. We then calibrate a set of benchmark quantitative models, matching the observed relation in the data between the inflation target and the frequency of price adjustment. There, we use both a NK model and a model with state-dependent price stickiness. A methodological contribution of our work in this context is to discipline the extent of increased price flexibility using the micro data put together by Nakamura, Steinsson, Sun, and Villar (2018). The relevant question answered with these calibrated models is about the strength of these theoretical effects in practice.

We find that the variation of the degree of price stickiness observed in the U.S. micro data since the 1970s has quantitatively relevant, powerful implications for the assessed potency of monetary policy and the implied loss of monetary policy room with higher targets. Using a modern medium-scale DSGE model (Coibion, Gorodnichenko, and Wieland (2012)), our first illustrative exercise is the following: Suppose that, *ceteris paribus*, the inflation target in the U.S. were to be raised, from the average rate of inflation prevailing in the last few decades (2.25%) to the observed average inflation rate during the late 1970s (6.73%). Given the available micro price data produced by Nakamura, Steinsson, Sun, and Villar (2018), we can compute the average frequency of price changes during this period and calibrate our model to match these data to gauge the corresponding potency of monetary policy, and resulting extra room. We find that raising the target to 6.73% would only generate 3.32 percentage points (pp.) of effective extra room, whereas the intended room would be 4.48 pp. Hence, the monetary authority would only gain 74% of room in effective terms. The conclusion is that the higher price flexibility observed in the 1970s has quantitatively relevant implications for the potency of monetary policy, and for the gap between effective and intended extra room.

We extend our key result in two ways. First, we look across a range of models, calibrated to match the observed statistical relation between the target and price flexibility. Second, in an effort to better capture this relation, we assume a functional form linking the Calvo parameter to the inflation target and estimate it. We use several sources to measure the inflation target, including Cogley and Sbordone (2008) and Fuhrer and Olivei (2017). We find a strong, positive relationship between the probability of price adjustment and trend inflation during the 1970-2015 period. The economic magnitude is large: Our most conservative estimate indicates that a 1%

increase in the inflation target is associated with an increase in the average monthly frequency of price changes in a given year by 0.98%. According to our estimates, when trend inflation is 2%, the quarterly Calvo parameter is 0.74; when 4%, the parameter falls to 0.70 and when 6%, it falls to 0.65 (price flexibility increases). As in our illustrative exercise, we use the model by Coibion, Gorodnichenko, and Wieland (2012) and match this observed relation. We find that an hypothetical increase in the target from 2% to 4%, as proposed by Blanchard, Dell'Ariccia, and Mauro (2010), generates an effective extra room of 1.54 pp. Only 76.5% of the intended extra room is achieved. Furthermore, in order to get 2 pp. of effective extra room, the target needs to be raised by significantly more than 4%. We also consider a menu cost model a la Dotsey, King, and Wolman (1999) in which the degree to which price stickiness varies with trend inflation is now disciplined by the model, and the model is calibrated to match the data. We confirm in all exercises that our mechanism is strong and quantitatively relevant. The magnitude of the effect is similar to that in the illustrative exercises above.

What is the intuition behind the large quantitative effect of increased price flexibility for the effective extra room we have obtained? Our theoretical analysis provides intuition. We derive an explicit formula for the effective extra room. This formula provides the quantitative insight that, unless the observed increase in the frequency of price changes is exactly zero, one should expect the fall in potency effect to be quantitatively relevant for the computation of the extra room. This is because the combination of shocks that drive the economy to the ZLB has a large total effect, generating large effects even for small changes in the frequency of price adjustment. Thus, a large elasticity of the frequency to the inflation target is not needed to generate our results (unlike for example in Levin and Yun (2007) or Kurozumi (2016)).

The results of the analysis are robust in several important dimensions. First, they are robust to parameter uncertainty which we explore for the Coibion et al. (2012) model. How large the loss in potency effect is, is somewhat sensitive—not surprisingly—to model parameters. However, as we consider an empirically relevant joint distribution of the main model parameters, our channel remains always highly relevant quantitatively. We assess the empirical relevance by generating 10000 draws from the joint parameter distribution estimated in the Smets-Wouters model. Then, we compute the effective extra room in our main model for each draw, going from 2% to 4% steady state inflation. Our median estimate for effective extra room is 1.416 pp., with a mean of 1.418 pp. The 25th and 75th percentile of the distribution are 1.371 pp. and 1.430 pp. Clearly, for a wide set of empirically relevant model parameters, the policy-maker is not able to achieve his or her intended extra room of 2 pp.

Second, we establish that the slope coefficient of the linear relation between trend inflation and the frequency of price adjustment is 1, a robust and stable relation across data sets. In our regressions for the U.S., we find that, roughly, the frequency increases by approximately 1 pp. when the target increases by 1 pp. Using the important Argentine data set collected by Alvarez et al. (2019), we estimate a slope coefficient comparable to the one obtained for the U.S. The associated semi-elasticity of the frequency of price adjustment to inflation at 0% inflation, is also non-zero, equal to 4%.

Third, the specification of the monetary policy reaction function is of independent theoretical and policy interest. We investigate variations of the monetary policy rule and find that its specification is crucial. A rule in which inflation deviations from target are strongly penalized by the monetary authority alleviates the concerns raised by the loss of monetary policy potency. Also, if the rule puts a high weight on the output gap, for instance, then monetary policy potency is not a major concern, either. The scope of these observations, however, appears limited in practice: Our Bayesian exercise explicitly allows for an empirically relevant variation in the systematic response parameters of the monetary policy reaction function, but finds our main conclusion is unaffected by such variation.

Our analysis does not only provide positive insights about monetary policy room, but also normative insights. This holds specifically for the *optimal* inflation target in the presence of the ZLB. Seminal contributions on this topic are by Billi (2011) and Coibion, Gorodnichenko, and Wieland (2012). Complementary to their work, we analyze what happens if the ZLB is a chronic threat due to a low level of the natural rate of interest. Specifically, we combine a low natural rate with our empirically motivated relation between trend inflation and the frequency of price adjustment. Our main finding is that the optimal target is approximately 1 pp. higher in a low natural rate environment, such as the one prevalent in the last decade, due to the loss in potency. The intuition is the following: With more flexible prices and a lower potency, the nominal interest rate is more volatile. As a result, it falls by more in the presence of negative demand shocks. This provides a motivation for raising the inflation target by more, even though this may increase the welfare costs of inflation.[5] Our exercise quantifies this tradeoff. The key to this result is the *interaction* between a low natural rate and the loss of monetary policy potency.

An important closely related paper by Hazell et al. (2022) estimates the slope of the Phillips curve using U.S. state-level data. Because their data set goes back to 1978, this allows the authors to evaluate the extent of the flattening of the curve. Importantly, these authors take into consideration that average inflation expectations have declined over time. The finding of the paper is that the Phillips curve is not only flat in recent years, but it appears to have been quite flat *also* in the early 1980s. This finding suggests that the flattening of the Phillips curve (if any) has been moderate (the main estimate by Hazell et al. (2022) suggests that the slope has decreased roughly by half.) As we discuss in detail in the body of our paper,[6] a modest

[5]The literature has recently considered a different approach to generating a positive and sizable optimal inflation target in NK models. Indeed, Adam and Weber (2019) generate an optimal inflation target between 1 and 3 percent in an environment that is free of welfare costs related to the ZLB. Their argument relies on differences in firm trend productivities. More recently, see also Adam and Weber (2022) and Adam, Gautier, Santoro, and Weber (2022). As a result of these different modeling mechanisms, our analysis is complementary to this approach focused on productivity trends.

[6]See page 23, and page 30.

flattening of the Phillips curve does not render our insights invalid. The simple reason for this is that we address a combination of negative shocks that have sizable effects on the economy (or a single, large, shock), which end up *magnifying* even small differences in the slope of the Phillips curve. Also, the moderate flattening pointed out by Hazell et al. (2022) is consistent with the micro data evidence on the frequency of price adjustment that we use in our calibrations.

In related work, Bhattarai, Eggertsson, and Schoenle (2018) study the effects of increased price flexibility on output, inflation and welfare within the New Keynesian model. While their analysis explores the intricate implications of increased price flexibility on those variables, our focus lies on exploring the implications for the interest rate and monetary policy room when the inflation target changes and flexibility as a derivative result. Our relative contribution also lies in considering the optimal inflation target. Budianto (2023) shows how firms' forward looking behavior can increase the risk of hitting the ZLB at high inflation, providing a complementary channel to ours. Related work with endogenous contract duration includes Kiley (2000) and Levin and Yun (2007). There, firms choose the duration of contracts as a function of the environment. In our paper, we discipline the contract duration empirically using the newly available data by Nakamura and Steinsson (2008), and also consider a menu cost framework (where the degree of price stickiness is also endogenous).

The paper is organized as follows. Section 2 presents the empirical evidence given support to the conclusion that a higher target increases price flexibility. Section 3 presents the simple analytical model to transparently show the mechanisms at play in our analysis. Section 4 quantifies these mechanisms in several ways, with the goal of measuring the effective gains in monetary policy room achieved by raising the target. Section 5 looks at the implications of our mechanism for the optimal inflation target. We then present a few conclusions in Section 6. The Appendix presents all tables and figures, and the Online Appendix presents extra tables and figures, complementary exercises and robustness checks.

2 Empirical Evidence: Inflation Target and the Degree of Price Stickiness

This section presents new empirical evidence establishing a relation between the inflation target and the degree of price stickiness. Our analysis is comprehensive by presenting four different, complementary exercises. Taken jointly, these constitute evidence of a strong, positive relationship between these two variables.

Specifically, we build up towards our result by first looking at the relation between the frequency of price adjustment in the micro data and inflation, rather than the inflation target. Second, we establish the empirical relation between the frequency of price adjustment and the inflation *target*. This main exercise consists of exploring the role of inflation targets by relying on four different measures produced by other researchers. This set includes the highly cited measure by Cogley and Sbordone (2008). This is the evidence that our calibration in Section 4 will target. Third, we also consider the relationship between the frequency and inflation in other data sets. Fourth, we consider structural estimation of a medium-scale DSGE model over subsamples. Finally, as summarized in the online appendix, we complement this analysis by looking at other high-frequency estimates of the inflation target and the probability of price adjustment (the Calvo parameter) in the literature.

2.1 Data Description

Our data set encompasses a variety of microeconomic and aggregate data. We focus on U.S. data covering the 1970s, a period in U.S. history with significantly higher inflation.

First, we include into the analysis a new micro-data set on U.S. consumer prices from the Bureau of Labor Statistics (BLS). These data have recently become available through the work of Nakamura, Steinsson, Sun, and Villar (2018) and extend back to 1978, including the peak of inflation at approximately 12% per year. Previous to the work of Nakamura, Steinsson, Sun, and Villar (2018), the BLS CPI Research Database contained data starting in 1988. The existence and availability of data going back to 1978 is a remarkable achievement through the digitization of old microfilm scanners that cannot be read with modern scanners. For more details of the process, please refer to their paper. Nakamura, Steinsson, Sun, and Villar (2018) have generously shared with us a series of the annual average of the frequency of price changes (Figure 14 in their paper). The series is annual, spanning 1978–2014.

Second, we rely on four measures of the inflation target developed by other researchers. These are obtained using several approaches based either on VARs, structural estimation, or Kalman filtering. Specifically, we include the estimates that Cogley and Sbordone (2008) obtain from a two-step VAR procedure and present in their Figure 1. We also use two model-based estimates: the inflation target series underlying Figure 4 in Ireland (2007), and the inflation target series underlying Figure 1 in Milani (2019). Finally, we borrow the inflation target series underlying Figure 3 in Fuhrer and Olivei (2017). This series is obtained using a rich state-space representation of the target. It includes variables such as estimates of potential growth and the natural rate of unemployment from the Federal Reserve's Greenbook and Tealbook, along with survey and market inflation expectations, among others. In terms of data availability, all of our inflation target series stop right before the Great Recession (this includes the series by Milani (2019) and Fuhrer and Olivei (2017).)[7]

Third, we also include several aggregate time series. We use the implicit GDP deflator from

[7]Another piece of work providing data-rich measures of the Federal Reserve's inflation goals is by Amstad, Potter, and Rich (2017). Unfortunately, we could not use it since it starts in 1994, and therefore it is too short to assess longer term changes in the target.

the Bureau of Economic Analysis as our measure of inflation (Series ID GDPDEF). We also include the other series typically used in DSGE estimation: GDP, consumption, investment, employment (measured in hours), wage inflation, and the Fed Funds rate (same series IDs as Smets and Wouters (2007)).

2.2 A First Pass: Evidence Based on Micro Data

The first exercise we present is very simple. It exploits the regime change in monetary policy after the high inflation of the 1970s and the subsequent appointment of Paul Volcker at the Federal Reserve. We interpret this change of regime as the shift from a 'high' to a 'low' inflation target.[8] To this end, and following this distinction, we divide the aggregate inflation series and the frequency of price changes series into two plausible sub-samples: a high trend inflation sub-sample (1978-1984) and a low trend inflation sub-sample (1985-2014).[9]

We use the inflation series to measure the (implicit) target in each subsample by simply computing average inflation.[10] We then use the frequency of price changes and compute its average over each subsample. The question is whether we observe any sizable change in the frequency of price changes over these subsamples, which were chosen according to average inflation. Subsequent to this first computation, we want to see whether any difference is consistent with a lower target being associated with a lower frequency of price changes (more sticky prices).

The answer to both questions is yes, which Figure 1 illustrates. In both panels, the solid line captures movements of inflation (left axes); the dashed line captures movements of the frequency of price changes (right axes). In the right panel inflation is measured by the GDP deflator; in the left panel, it is measured by the CPI. We focus the following description on the right panel since the left panel presents a very similar picture. An initial observation is that the frequency of price changes series shows large volatility, peaking at 17.31% in 1980, and with the lowest observation in 2002 at 7.78%. These numbers imply a change in the duration of price spells of approximately 6 months to 13 months.[11]

The flat horizontal lines show the average of each series over the subsamples. Clearly, both series are lower in the second subsample. The difference, for both, is economically significant: average inflation drops from 6.73% to 2.25%; the frequency of price changes drops from 13.32%

[8] Actually, early on, the Federal Reserve did not have an explicit inflation target, so we interpret these as "implicit" targets. A similar interpretation is the shift from a regime in which long-term inflation was not explicitly targeted and was allowed to move freely at high levels (anything between, say, 2% and 10%), to a regime in which inflation was pinned down by a low target (around 2%).

[9] Later we will also exploit the full variation in our data set to look at the link between the target and the frequency of price changes.

[10] For brevity, we shall use the term "target" instead of "implicit target" throughout the paper. See Svensson (2010) for a comprehensive history of inflation targeting.

[11] Wulfsberg (2016) documents a similar decline in the mean (median) frequency of price changes from 17.9 (12.8) percent during high inflation in Norway to 12.1 (8.3) percent during low inflation with a concurrent decline in observed inflation rates.

to 10.08%. Thus, prices change on average approximately every 7 months and a half in the first sample, and every 10 months in the second subsample. Interpreting average inflation as a measure of the target, this figure provides support to the view that a lower target is associated with a lower frequency of price changes. Moreover, under the assumption that the relation is linear—an assumption not crucial for our analysis but useful for illustrative purposes—the observed change implies a slope coefficient of the relation between the frequency and the target of 0.72.[12]

2.3 Evidence on the Relation Between the Frequency and the Target

In order to exploit all the time-variation in the micro data, we next regress the frequency of price changes on measures of the inflation target. We find an economically and statistically significant, as well as robust relation between the two variables.

As explained above in the data section, we have constructed a data set that joins 4 different measures of the target produced by other researchers. Our analysis shows that our 4 series for the inflation target share key dynamics. They are highly correlated with one another with a cross-correlation coefficient of 0.70-0.90, with the exception of the series of Fuhrer and Olivei (2017) which shows a positive but more moderate cross-correlation with the other series of 0.17-0.43. Aside from such commonality, a few noticeable differences emerge from the different measures of the target. For instance, it is clear that the two most volatile measures are the model-based ones (by Ireland (2007) and Milani (2019)). The two reduced-form measures (by Cogley and Sbordone (2008) and Fuhrer and Olivei (2017)) show less volatility. According to these measures, the target or inflation goal rose to between 5% to 7% in the 1970s. The Cogley and Sbordone (2008) measure is the least volatile and slightly anticipates the Volcker disinflation, whereas the Fuhrer and Olivei (2017) measure turns around precisely in 1979. Figure 2 illustrates these findings while Figure 8 in the online appendix scatter plots the remarkable positive relationship between the frequency of price changes and the different measures of the inflation target. This scatter plot suggests that this relationship is well approximated by a linear regression model, motivating our main specification below.

As our main step, we estimate the following specification:

$$f_t = \beta_0 + \beta_1 \overline{\pi}_t + \epsilon_t \tag{1}$$

where f_t is the average monthly frequency of price changes in a given year in percentages, and $\overline{\pi}_t$ the annualized inflation target, also in percentages. We estimate this specification separately for each of the four inflation target series. Table 1 summarizes the results.

We find that the frequency of price changes is statistically highly significantly, positively

[12] $0.72 = \frac{13.32-10.08}{6.73-2.25}$

associated with the target. In all four specifications, the coefficient on the target is statistically significant at the 1% level. The magnitudes of the slope coefficient β_1 are economically large, and range from 0.98 in specification (II) to 2.26 in specification (IV).[13] Among the model-based and Kalman filtering estimates, the median estimate is 1.04, which means that a 1% increase in the inflation target is associated with an increase in the annual monthly average frequency of price changes by 1.04%.

One may be concerned that all these regressions are capturing is the drop in the frequency after the Volcker disinflation. This is not the case. Our results are robust to omitting the 1970s (by estimating the above specification only for the post-1984 period.) Table 3 in the online appendix shows the results. Now, the mean and the median estimated coefficients on the target are both 1.10 for the model-based estimates (Specifications II and III). Including the VAR-based specification (IV) raises the mean estimated coefficient to 1.32 (the median remains the same at 1.10.) In all four specifications, the coefficient on the target is again statistically significant at the 1% level. This finding gives us confidence that the arguably somewhat special period of the 1970s does not much affect our main relationship: When the inflation target is higher, the frequency of price changes is higher.

2.4 Related Estimates

A number of papers in the literature have considered a related relation: the relationship between the frequency of price changes and inflation. The seminal contribution in this context is by Cecchetti (1986), who was the first to study the frequency of price adjustment, using data on newsstand American magazines. One of the findings of that earlier paper clearly corroborates our hypothesis: "[...] it appears that a magazine is more likely to change its price when general price inflation is high." (Cecchetti (1986), pp. 257) More recent papers have confirmed this conclusion using more comprehensive data sets, such as Nakamura and Steinsson (2008), Barros, Carvalho, Bonomo, and Matos (2009), or Wulfsberg (2016). They all find a positive relationship between the frequency of price changes and inflation. Important related work by Vavra (2013) and Berger and Vavra (2018) documents variation of price flexibility over the business cycle.

While these findings are supportive and complementary to our empirical results, we still view them as quite distinct. The main reason lies in the distinction of one of the objects we analyze: the inflation target rather than the inflation rate. These two objects embody a major conceptual difference. For example, this difference leads us to have no negative inflation targets in our data while the inflation rate can be negative. Furthermore, our interest lies in quantitatively answering a specific policy question for the U.S. This interest means that related elasticity estimates, for example from Argentina (Alvarez et al. 2019) or Mexico (Gagnon 2009), become quantitatively

[13] Estimation of a non-linear specification that includes a quadratic term leads to a positive but small coefficient on the quadratic term.

less relevant for our focus.

Nonetheless, when we consider data from Argentina, our main result also finds support also in this context. We show this by re-estimating our exact empirical specification (1) using the data for the frequency of price changes and the (expected) inflation rate[14] from Alvarez et al. (2019). As in their paper, we use an inflation rate cutoff of 14% and run the regression for observations below this cutoff (which also this turns out to be the relevant range for the U.S. economy). As Table 7 shows, we find a coefficient estimate that aligns closely with our main estimate: The slope coefficient is estimated to be 1.03 and highly statistically significantly different from 0 (first row). Since this relation is linear, this parameter measures the absolute change in the frequency for an absolute, percentage point change, in inflation. When instead we estimate the semi-log relation as in their paper, we back out a semi-elasticity of the frequency at 0% inflation of 3.68%.[15]

To understand the numerical relation between the two estimates from the linear and semi-elastic specifications, consider Figure 11, which illustrates the raw data from Argentina in the relevant inflation range. One can immediately notice the key similarity and the key difference to our Figure 8: On the one hand, the frequency of price changes increases from 0.25 to 0.27 as one goes from 2% to 4% inflation, in line with a slope estimate of 1 in our linear specification. On the other hand, the frequency of price changes starts off at a much high intercept in Argentina with around 23% compared to the US with around 7%. This higher intercept means that an estimated semi-elasticity will be lower simply because one starts off at a higher value. It can be interpreted as evidence of larger idiosyncratic shocks in Argentina. However, the absolute change in the frequency is comparable to what we observe in the U.S.: approximately 1 pp. (1.03 pp. to be exact) for 1 pp.[16]

When one includes observations with negative inflation rates into the regression, the semi-elasticity is even higher. Table 7 also presents this finding. Furthermore, the table presents a regression that, as in the original codes by these authors for Argentina, uses monthly inflation. The table shows that in all of these cases one obtains a semi-elasticity of around 4%.

Ultimately, what alternative estimates mean for the answer to our specific policy question of interest has to be determined in a model. As we show in Appendix Section C, our results remain quantitatively robust when we use the estimate based on data from Argentina (albeit

[14] They construct an expected inflation series based on the assumption that current inflation approximates expected future inflation.

[15] This figure is different from the one reported by Alvarez et al. (2019). Due to a typographic error, that paper reports a semi-elasticity a hundred times smaller (0.04% instead of 4%). (See code `Figure_5.m` in their replication package, output variable named '`lambda_change`'.) This point does not affect their main conclusion that the relation of the frequency to inflation is much stronger at higher rates of inflation.

[16] The semi-elasticity at 0% inflation is equal to $(frequency(1) - frequency(0))/(frequency(0)) = (0.2379 - 0.2295)/0.2295 = 0.0084/.2295 = 0.0368 \approx 4\%$. This number is consistent with an (absolute) slope estimate of around 1 as in our main specification: As one increases inflation by 1 pp. from 0% to 1%, the frequency goes up by .84 pp. (The semi-elasticity corresponds to the slope of 1.03 divided by a factor of 23, approximately.)

being somewhat diminished). While this might come as a surprise, we present further discussion on the reasons for this in the modeling section.

2.5 Structural Estimates

To complement our evidence that the inflation target bears a significant relation with the degree of price stickiness, we turn to structural estimation. We use structural estimation to reestablish the earlier empirical conclusions using a different data set (because for structural estimation we will not use the micro data, but an array of aggregate time series.) To do so, we estimate a benchmark DSGE model. Two key parameters in the estimation are the (implicit) target, denoted by $\overline{\pi}$, and the probability of price adjustment in a time period or the Calvo parameter, denoted by θ. Our empirical strategy consists of estimating these parameters (among all others in the model) over the full sample, and the same low-target subsample as above (post-1984).

In order to make our results transparent, we use the benchmark DSGE model developed by Smets and Wouters (2007) (henceforth SW). We proceed using Bayesian estimation. The appendix presents the details of the procedure. We estimate a lower inflation target in the post-1984 subsample compared to the full sample (3.33% versus 2.59%), and a higher Calvo parameter (0.61 versus 0.71). This is a large increase in the Calvo parameter, indicating stickier prices in the post-1984 subsample.

Our results are consistent with the results in SW for the pre-1979 versus post-1984 samples. They also find a higher target and lower value of both Calvo parameters (prices and wages) in the pre-1979 sample (see Table 5, p. 603).

3 Analytics Based on a 3-Equation New Keynesian Model

Using a simple and transparent setup, we now study theoretically the implications of a higher inflation target for the policy room. Our goal is to focus on how a higher inflation target can affect the *effective room* available to the policy maker through the slope of the Phillips curve. Since we are interested how much the nominal interest rate will fall in a recession, we analyze the effect of a contractionary shock resulting in a demand shortfall. For instance, the aggregate demand effects of the loss of confidence following the 2008 crisis, or the impact of COVID-19 starting March 2020, embody such a shortfall.

A notion that will emerge in our analysis is the “potency” of monetary policy. We call potency of monetary policy the ability of the monetary authority to affect output for a given change in the interest rate. We use this notion to give the intuition behind our results. In fact, in the results below we will express the effective room for monetary policy in terms of the change in the potency of monetary policy after an hypothetical increase in the target.[17]

Due to the widespread familiarity with the three-equation NK model, we only briefly reproduce the key log-linearized equations.[18] The model has an output gap shock which, in this model, can be thought as resulting from preference or TFP shocks, and a nominal interest rate shock.

The consumption Euler equation (with log utility) is

$$c_t = E[c_{t+1}] - (i_t - E[\pi_{t+1}]) + \zeta_t \tag{2}$$

where c_t is the log-deviation of consumption from steady state at time t, i_t is the deviation of the nominal interest rate from the its steady-state value $\bar{i}$, π_{t+1} is the log-deviation of inflation at $t+1$ from the inflation target $\overline{\pi}$, $E[\,\cdot\,]$ is the expectation operator, and ζ_t is an i.i.d. preference shock. This shock generates deviations of desired consumption away from its steady state $\bar{c}$. Thus, we name it a 'demand' shock. This analytical section restricts attention to i.i.d. shocks for simplicity. It is easy to generalize our results to AR(1) shocks.

In our setup, output y_t is equal to consumption:

$$y_t = c_t$$

which allows us to express (2) as an IS equation in terms of the output gap at time t, $x_t \equiv y_t - a_t$, where a_t is an i.i.d. shock to log TFP (normalized to zero in steady state). This equation is

$$x_t = E[x_{t+1}] - (i_t - E[\pi_{t+1}]) + \eta_t$$

where η_t is an output-gap shock which is a linear function of ζ_t and a_t: $\eta_t = \zeta_t - a_t$.

The Phillips curve is

$$\pi_t = \beta E[\pi_{t+1}] + \kappa x_t$$

where β is the discount factor, and $\kappa \in [0, \infty)$ is the slope of the Phillips curve. Note that κ depends on the Calvo parameter θ because

$$\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta} \cdot \frac{1+(\varphi+\alpha)}{1-\alpha+\alpha\varepsilon}$$

where $1-\alpha$ is the elasticity of output to the labor input, φ denotes the Frisch elasticity of labor supply, and ε is the elasticity of substitution between goods.[19] At each period t, a fraction $1-\theta$

[17] Potency can, alternatively, be defined as the ability of the monetary authority to affect inflation. This alternative definition would lead to an analogous analysis.

[18] See Woodford (2003) for a detailed exposition.

[19] A recent important paper by Auclert, Rigato, Rognlie, and Straub (2023) establishes equivalence results between Calvo and menu cost models after an adjustment to the slope of the Phillips curve.

of firms is allowed to adjust prices. We use the assumption that firms perfectly index sticky prices to either past inflation or the inflation target in order to get an expression of the Phillips curve similar to the baseline case of a zero inflation target (see Ascari (2004)), Appendix A, for a proof). This assumption serves only purposes of analytical tractability, and we relax it below, in the quantitative section 4.1.

The following relation holds for the nominal interest rate in the above equation:

$$i_t = \phi \pi_t + \nu_t \tag{3}$$

with $\phi > 1$ denoting the systematic reaction of policy to inflation, and ν_t denoting an i.i.d. monetary shock.[20]

Note that in steady state, the Fischer equation holds:

$$\bar{i} = \bar{r} + \bar{\pi} \tag{4}$$

where $\bar{r}$ is the steady-state real interest rate, and $\bar{\pi}$ is steady-state inflation, equal in this model to the inflation target of the monetary authority. Thus, increasing the inflation target $\bar{\pi}$ amounts to increasing $\bar{i}$.

Throughout the paper, our baseline model will not impose the zero lower bound on interest rates. In fact, our main exercise will consider general, "normal times" and unrestricted interest rate dynamics where the interest rate is above the lower bound. In this context, we will consider a negative shock that brings the rate exactly to 0 (but with the lower bound only weakly binding).[21] This setup buys us analytical and computational simplicity. It is however important to check that our quantitative measures of the effective room away from the zero lower bound are not meaningfully affected by the explicit presence of the bound in the model, a verification we explicitly undertake in the quantitative section below. Also, there, in the context of a welfare computation of the optimal inflation target, the zero lower bound is imposed since it represents the standard ingredient to obtain a non-zero optimal target.

We define the room away from zero as the nominal interest rate in steady state $\bar{i}$. Below, we will define a shock that completely and exactly erodes this room, and consider different scenarios for the target and for the degree of price flexibility.

[20]For a thorough discussion of monetary policy rules and its relation to inflation targeting, see the classic contribution by Svensson (1999).

[21]Conceptually, it would be similar to consider an *effective* lower bound, or any other chosen bound of interest. Our exercise consists mainly in asking how sensitive is the nominal interest rate to negative output gap shocks, and what is the space (if any) remaining before reaching any lower bound.

Lemma 1 *The unique solution of the model is given by*

$$
\begin{aligned}
x_t &= \frac{1}{1+\phi\kappa}\eta_t - \frac{1}{1+\phi\kappa}\nu_t \\
\pi_t &= \frac{\kappa}{1+\phi\kappa}\eta_t - \frac{\kappa}{1+\phi\kappa}\nu_t \\
i_t &= \frac{\phi\kappa}{1+\phi\kappa}\eta_t + \frac{1}{1+\phi\kappa}\nu_t
\end{aligned}
$$

The proof is standard via the method of undetermined coefficients.

The key departure from the canonical NK approach lies in the assumption that prices are more flexible for a higher inflation target:

Assumption 1 *The Calvo parameter θ is a decreasing function of the inflation target $\overline{\pi}$:*

$$\frac{\partial \theta}{\partial \overline{\pi}} < 0$$

We justify this assumption mainly on an empirical basis, given the evidence presented earlier. We also emphasize how easy it is to implement this assumption on the NK model—the economics of the NK model are unaffected; the same approach goes through with a θ parameter that is different depending on $\overline{\pi}$.[22]

Since the slope of the Phillips curve κ is a decreasing function of θ, by Assumption 1 it is straightforward to establish that κ is an increasing function of the target $\overline{\pi}$:

$$\frac{\partial \kappa}{\partial \overline{\pi}} > 0$$

Thus, the higher the target, the steeper the Phillips curve, and the more inflation moves with both shocks η and ν. On the contrary, if the target is low, the Phillips curve flattens, with muted responses of inflation to the shocks. Of special interest for our purposes is the coefficient of reaction of the interest rate to demand shocks η_t, which we will write as a function of κ:

$$g(\kappa) = \frac{\phi\kappa}{1+\phi\kappa}$$

Notice two properties of this function. First, g is an increasing function of κ, and thus an increasing function of $\overline{\pi}$. The higher the target, the *more* the interest rate reacts to a given shock η_t. Second, the function g is convex in κ, which suggests that, when the Phillips curve is

[22]Notice that we maintain (consistent with our notation) that the monetary authority chooses policy parameters once and for all. In order to deliver a clear and transparent analysis of our mechanism, we make use of a *ceteris paribus* assumption. Corollary 2, and the discussion that follows, explore the implications of simultaneously changing interest rule parameters. Furthermore, Section 4.1.2 empirically explores the sensitivity of our conclusions using Bayesian posteriors for both the systematic responses of the monetary policy function to inflation and the output gap, as well as to other parameters of a medium-scale model.

fairly flat (small κ), a small change in κ can induce big differences in how much the rate reacts to demand shocks.

It is interesting to consider what happens when prices become very flexible ($\theta \longrightarrow 0$). Since

$$\lim_{\theta \to 0} \kappa(\theta) = \infty$$

then, when prices become very flexible, the coefficient of nominal rates tends to 1 from below:

$$\lim_{\theta \to 0} g(\kappa) = 1$$

The nominal interest rate moves one-to-one with demand shocks, that is, it moves *a lot*. Intuitively, what is driving this result is that an increase in price flexibility increases the response of inflation, and monetary policy takes into account inflationary movements.

We formalize this point by the concept of *potency* of monetary policy. When potency is high and an output gap shock hits, systematic monetary policy needs to move by small amounts to stabilize the output gap. Instead, when potency is low and an output gap shock hits, systematic monetary policy needs to move by large amounts to stabilize the output gap. Below, we will analyze how potency depends on the degree of price flexibility.

To make this notion precise, the following definition is useful. The notion of potency can be cast in terms of a measure of the impact of *exogenous* monetary policy shocks. When potency is high, an unexpected monetary shock moves the output gap by a lot. When potency is low, the output gap moves very little.

Definition 1 *Consider the effect of a one-time shock $\nu > 0$ to the nominal interest rate i_t. The maximum effect possible on the output gap is $-\nu$. Thus, the potency of monetary policy $\mathfrak{P} \in [0, 1]$ is given by*

$$\mathfrak{P} = -\frac{x_t}{\nu}$$

Following on the reasoning above, when the potency is high, it is relatively easy for the systematic arm of monetary policy to stabilize the output gap. The main question we are after in this paper is: how are the potency $\mathfrak{P}$ and the monetary policy room related?

A few straightforward facts about the potency $\mathfrak{P}$ are worth noticing. First, $\mathfrak{P}$ is decreasing in the inflation target $\overline{\pi}$. Thus, monetary shocks have less of an effect on the output gap. This is an implication of money 'becoming neutral' for more flexible prices, and it is trivial to prove by using the solution of the model above.[23] By similar logic, output gap shocks have less of an effect on the output gap.

Besides these two points, a less obvious and critical question for us concerns the impact of output gap shocks *on the nominal rate*. This is characterized as follows.

[23]Focusing on the stable solution above avoids the subtlety that more generally, the nominal interest rate is not determined.

Lemma 2 (Effects of Flexibility) *Consider the effect of a one-time shock $\eta > 0$ to the output gap x_t. Then, the response of i_t is increasing in $\overline{\pi}$. At the limit when $\theta \longrightarrow 0$:*

$$x_t = 0; \quad \pi_t = \frac{1}{\phi}\eta; \quad i_t = \eta$$

$$\mathfrak{P} = 0$$

The proof immediately follows from the solution above.

Let us go back to our original question regarding the link between the inflation target and the policy room. We analyze this by considering the following thought experiment. Consider 2 economies: $\{\overline{\pi}_1, \kappa_1, \bar{i}_1\}$, $\{\overline{\pi}_2, \kappa_2, \bar{i}_2\}$ with $\overline{\pi}_2 > \overline{\pi}_1$. Thus, $\kappa_2 > \kappa_1$.

Now, consider a shock $\hat{\eta}$ that lowers the economy 1 interest rate by $-\bar{i}_1$ from steady state:

$$\hat{\eta} = -\bar{i}_1 \frac{1 + \phi\kappa_1}{\phi\kappa_1}$$

By considering this given shock, we heuristically focus on the ZLB, but notice that our point is more general and a similar analysis can be applied to *any* lower bound on the interest rate.

Suppose then that $\hat{\eta}$ hits economy 2. The question at hand is: By how much does i_2 move? And what is the remaining room away from $-\bar{i}_2$? To answer this question, consider first the following definition.

Definition 2 *The **effective extra room** is given by*

$$\mathfrak{R}^{eff}(\hat{\eta}) = \Delta\overline{\pi} + (i_2(\hat{\eta}) - i_1(\hat{\eta}))$$

where $\Delta\overline{\pi} = \overline{\pi}_2 - \overline{\pi}_1$, and $i_1(\hat{\eta})$ and $i_2(\hat{\eta})$ are the responses to the shock $\hat{\eta}$ in economies 1 and 2 respectively.

The idea here is that, in order to compute the effective extra room, one needs to take into consideration the change in the response of the policy rate. The key insight is that this is given by the change in the potency $\mathfrak{P}$, formally expressed as follows.

Proposition 1 (Formula for Extra Room) *Consider the shock $\hat{\eta} < 0$. Then,*

1. *The effective extra policy room is given by*

$$\mathfrak{R}^{eff}(\hat{\eta}) = \Delta\overline{\pi} + \Delta\mathfrak{P} \cdot |\hat{\eta}|$$

2. *The effective extra room is strictly smaller than the intended extra room $\Delta\overline{\pi}$:*

$$\mathfrak{R}^{eff}(\hat{\eta}) < \Delta\overline{\pi}$$

Proof The first part follows from simple algebra using the closed-form solution. To prove the second part, notice

$$\kappa_2 > \kappa_1 \Longleftrightarrow i_2(\hat{\eta}) < i_1(\hat{\eta}) \Longleftrightarrow \Delta\mathfrak{P} < 0$$

and so

$$\mathfrak{R}^{eff}(\hat{\eta}) = \Delta\overline{\pi} + \Delta\mathfrak{P} \cdot |\hat{\eta}| < \Delta\overline{\pi}$$

■

By the formula above, the effective extra room then is equal to the intended extra room $\Delta\overline{\pi}$, plus the change in monetary policy potency times the shock. Since potency is reduced after an increase in the target, the effective room is lower than the intended room.

To complement Proposition 1, it is actually possible to show the following stronger result regarding the effects of price flexibility when raising the target.

Corollary 1 (Room Neutrality) *Consider economy $\{\overline{\pi}_1, \kappa_1, \bar{i}_1\}$. For any moderate change in the target $\Delta\overline{\pi}$, there exists a slope of the Phillips curve κ_2 such that the change is room-neutral:*

$$\mathfrak{R}^{eff}(\hat{\eta}) = 0$$

Proof Using the expressions above, we want κ_2 such that

$$0 = \overline{\pi}_2 - \overline{\pi}_1 + (g(\kappa_2) - g(\kappa_1))\hat{\eta}$$

Equivalently,

$$g(\kappa_2) = \frac{\overline{\pi}_2 - \overline{\pi}_1}{|\hat{\eta}|} + g(\kappa_1)$$

Since $g(x)$ is strictly increasing, $g(0) = 0$, and $\lim_{x\to\infty} g(x) = 1$, for $\overline{\pi}_2$ close to $\overline{\pi}_1$, one can compute a unique κ_2 such that $\mathfrak{R}^{eff}(\hat{\eta}) = 0$. ■

This result can be extended to trace out the degree of flexibility needed, as a function of all admissible targets, that delivers room-neutrality. In that case, the inflation target becomes irrelevant for the question asked in this paper. Indeed, any given raise in the target can be neutralized by a suitable increase in price flexibility, leaving the room available for monetary policy unchanged.

Another question raised by these results is whether the monetary authority could engineer a way to increase the inflation target and avoid the loss in effective policy room. Lowering the reaction to inflation fluctuations ϕ constitutes a simple way to do so. However, this approach will lead to higher inflation volatility, which entails welfare costs. An alternative way that does not lead to welfare losses coming from extra inflation volatility is described in the following corollary.

Corollary 2 (Avoiding the Loss of Potency) *The loss in potency of monetary policy is given by:*

$$\Delta\mathfrak{P} = -\frac{\phi(\kappa_2 - \kappa_1)}{(1+\phi\kappa_1)(1+\phi\kappa_2)} < 0$$

Thus, the potency loss vanishes when the effect of the systematic response of monetary policy to inflation ϕ is infinitely strong.

The proof is immediate. In other words, in order to minimize the potency loss, the monetary authority should raise the inflation target, but keep inflation very close to this target. The intuition for this result is that this dampens the effect of the loss of potency. Even is there is such loss, if the interest rate responds very aggressively to inflation, the effective extra room will tend to approach the intended extra room.

This corollary is a feature of a policy that perfectly stabilizes inflation and output. This result becomes clear when we are systematic about optimal policy and its relation to the effective extra room: What happens to the effective extra room when the monetary authority behaves optimally instead of following a simple rule as the one postulated above?

As the next result states, under output gap shocks solely, the optimal policy under discretion can be shown to amount to setting the nominal interest rate such that the real rate is equal to the natural rate. Thanks to the divine coincidence, this can be obtained as the interest rate rule (3) penalizes inflation deviations from target infinitely ($\phi \longrightarrow \infty$).[24]

Lemma 3 *Assume $\nu_t = 0$, $\forall t$. At the limit when $\phi \longrightarrow \infty$:*

$$\pi_t = 0; \quad x_t = 0; \quad i_t = \eta_t$$

Moreover, in this case, $\mathfrak{R}^{eff}(\hat{\eta}) = \Delta\overline{\pi}$, $\forall \hat{\eta}$.

The proof is immediate. The effective extra room is equal to the intended extra room, because the behavior of inflation does not change the nominal rate set by the authority. Therefore, the inflation target can be raised without losing monetary room through the loss of potency channel. A finite loss of potency is irrelevant when the monetary authority is infinitely hawkish.

Although quite interesting as a theoretical benchmark, this is a result of limited interest in practice. There are two reasons for this conclusion. First, a policy rate that moves one-to-one with nominal demand shocks would be unrealistically volatile. To give a sense of the magnitudes, consider a large shock (or a series of shocks) capable of bringing an economy to the ZLB (a 2008 financial crisis or COVID lockdown scenario). This shock (or combination of shocks) is likely to total -10%.[25] So, facing such a shock, the nominal rate would need to fall by 10 pp., an

[24] How to obtain this rule is well known, see for example Svensson (2010).

[25] This is used purely for illustration. The idea is that a year after the 2008 financial crisis, the output gap in the U.S. was, say -5%. If, for purposes of this illustration, about half of the shock was absorbed by automatic stabilizers, then the size of

unrealistically large amount.[26]

The second reason is simply that in realistic settings central banks do use inflation as a guide for policy, but have a bounded reaction to its fluctuations due to uncertainty regarding measurement or external shocks. Thus, the effects of price flexibility are likely to remain. Said differently, as it is well known, interest rate rules as the one considered here fit the data better.[27]

4 Quantitative Importance

An important open question is whether the theoretical insights of the previous section are quantitatively relevant in a realistic and commonly-used medium-scale DSGE model. In order to answer this question, we consider two alternative medium-scale models. First, we consider a medium-scale DSGE model based on Coibion, Gorodnichenko, and Wieland (2012). There, we calibrate the Calvo parameter of price stickiness to target moments of the frequency of price changes and trend inflation. Second, we consider a medium-scale menu cost model. In this case, the model endogenously pins down the degree of price stickiness as function of the inflation target.

Our quantitative exploration will also move away from the purely positive focus the paper has taken this far, by looking at the normative implications of our mechanism. We compute the optimal inflation target as a function of the natural rate of interest, both in the case where the degree of price flexibility is constant, and where it varies with the target. As in previous work (Coibion, Gorodnichenko, and Wieland (2012)), these calculations take into consideration the tradeoff between higher welfare costs due to higher inflation, and the benefits of more space away from the zero lower bound. Our goal is to deliberately use off-the-shelf setups. The only novelty in our calculation is to consider that the degree of flexibility may vary with the target, and hence have implications for the effective room away from the zero bound.

4.1 Using a Medium-Scale New Keynesian Model

We consider a medium-scale DSGE model à la Coibion et al. (2012). Our model thus shares the common features of modern NK DSGE models. These features include habit formation and a richer specification of the interest rate rule. A key deviation from the bare-bones NK

shock was about -10%.

[26] Notice, therefore, within the spirit of the paper, the difficulties of avoiding the ZLB under optimal policy. If the steady-state real rate r is 2% (and the nominal rate 4%), not even raising the inflation target by 5 percentage points (from $\overline{\pi} = 2\%$ to 7%) can ensure not hitting the ZLB in the presence of a large shock.

[27] The reader might wonder what would happen in the presence of markup shocks, which are typically used to justify the tradeoff between inflation and output gap volatility perceived by actual central banks. Even though this is not the focus of our paper, this tradeoff should crucially depend on the degree of price stickiness when markup shocks are microfounded. Therefore, raising the inflation target appears to have the virtue of easing this tradeoff via the increased price flexibility generated by raising the target (that is, a form of divine coincidence is again valid for $\theta \longrightarrow 0$.)

model lies in incorporating trend inflation under imperfect indexation. This leads to a different expression of the Phillips curve, and to richer inflation dynamics (see Ascari (2004) and Ascari and Sbordone (2014)).

Our model takes an extreme version of imperfect indexation by assuming no price indexation at all. There are two reasons for this decision. First, we want to keep close comparability to the benchmark model by Coibion et al. (2012), who do not include price indexation either. Second, as shown in their paper, the presence of indexation does not impact their results in important ways. Nevertheless, we add indexation to the model and examine the robustness of our conclusions in the online appendix.[28]

Consumers. The infinitely-lived, representative consumer maximizes their expected discounted stream of utility from consumption and labor:

$$\max E_t \left[\sum_{j=0}^{\infty} \beta^j \left\{ \log\left(C_{t+j} - hC_{t+j-1}\right) - \frac{\varphi}{1+\varphi} \int_0^1 N_{i,t+j}^{\frac{1+\varphi}{\varphi}} di \right\} \right] \tag{5}$$

where final goods consumption is denoted by C_t, labor supplied to sector i at time $t+j$ by $N_{i,t+j}$, the Frisch elasticity of labor supply by φ, internal habit by h, and the rate of time preference by β.

The consumer solves (5) subject to the following period budget constraint:

$$P_t C_t + S_t \leq \int_0^1 N_{it} W_{it} \; di + e^{\zeta_{t-1}} R_{t-1} S_{t-1} - P_t T_t + P_t D_t$$

where P_t denotes the aggregate price level, S_t the holdings of one-period bonds, W_{it} the nominal wage rate in sector i, R_t the gross nominal rate of return, T_t lump-sum taxes and D_t dividends paid to the consumer by firms. The risk-premium shock ζ_{t-1} follows the auto-regressive process

$$\zeta_t = \rho_\zeta \zeta_{t-1} + \epsilon_t^\zeta$$

where ϵ_t^ζ is i.i.d. with $E[\epsilon_t^\zeta] = 0$ and $var[\epsilon_t^\zeta] = \sigma_\zeta^2$.

Firms and Price-Setting. A perfectly competitive sector produces the final consumption good. The final goods producer combines the continuum of intermediate goods using the following Dixit-Stiglitz production function:

$$Y_t = \left(Y_{it}^{(\varepsilon-1)/\varepsilon} di \right)^{\varepsilon/(\varepsilon-1)}$$

[28] Coibion, Gorodnichenko, and Wieland (2012) (p. 1383) provide a discussion of the advantanges and disadvantanges of

where Y_t denotes the amount of the final good produced each period, Y_{it} the amount of intermediate good i used from sector i and ε the elasticity of substitution between any two intermediate goods. The aggregator implies the following aggregate price level and demand for sector i intermediate good demand:

$$P_t = \left[\int_0^1 P_{it}^{1-\varepsilon} \right]^{1/(1-\varepsilon)}$$

and

$$Y_{it} = Y_t (P_{it}/P_t)^{-\varepsilon}$$

Monopolistically competitive firms produce each intermediate i using a production technology that is linear in labor, given by

$$Y_{it} = A_t N_{it}$$

where A_t denotes productivity. (In our simulations, we will actually not use technology shocks and thus A_t grows at a constant rate $A_t/A_{t-1} - 1 = \mu$.)

In terms of price setting, we assume that intermediate goods' prices will adjust exogenously following Calvo (1983) (unlike in the next subsection where we outline a model with endogenous price adjustment.) Each period, a firm will be able to adjust prices with probability $1-\theta$. Firms that get to adjust prices maximize the following expression for choosing the new price P_{it}^*:

$$E_t \left[\sum_{j=0}^{\infty} (\beta\theta)^j Q_{t,t+j} \left(Y_{t+j} P_{it}^* - W_{i,t+j} N_{i,t+j} \right) \right]$$

where $Q_{t,t+s}$ denotes the stochastic discount factor. These assumptions about price setting imply that the aggregate price level evolves as

$$P_t^{1-\varepsilon} = (1-\theta) \left(P_{it}^*\right)^{1-\varepsilon} + \theta \left(P_{t-1}\right)^{1-\varepsilon}$$

Monetary Policy and Market Clearing. We assume that monetary policy follows an interest rate rule that also features interest-rate smoothing:

$$I_t = I_{t-1}^{\rho_1} I_{t-2}^{\rho_2} (\pi_t^{\phi_\pi} X_t^{\phi_x} (Y_t/Y_{t-1})^{\phi_{\Delta y}})^{1-\rho_1-\rho_2}$$

where I_t is the gross nominal interest rate, ρ_1 and ρ_2 denote the interest rate smoothing parameters with respect to the first and second lags of the nominal rate, ϕ_π, ϕ_x, and $\phi_{\Delta y}$ parametrize the systematic response of the policy-maker to inflation, output gap (log-deviations from the flexible price equilibrium) and output growth.

including indexation, and provide a number of arguments in favor of removing indexation in their baseline exercise for clarity and empirical reasons in the context of trend inflation.

As explained in the previous section, for simplicity, our benchmark models used for the computation of the effective room do not impose the ZLB on interest rates. This is because our IRF simulations are away from the ZLB (the ZLB will only be weakly binding when the interest rate reaches 0). Nevertheless, we extend our analysis to the presence of the ZLB as well, and find that are results are not meaningfully affected.

Goods market clearing requires

$$Y_t = C_t + G_t$$

where we allow for government consumption of the final consumption good, evolving with a persistence parameter ρ_g as follows:

$$G_t = \bar{G}^{1-\rho_g} G_{t-1}^{\rho_g} e^{\epsilon_t^g}$$

Government spending will be constant in our main simulation ($\epsilon_t^g = 0$).

4.1.1 Baseline Quantitative Exercises

Our calibration strategy is as follows. We calibrate the inflation target and Calvo parameter to match the time-varying relation between trend inflation rates and the frequency of price changes, embodied by the empirical evidence in Section 2. Specifically, we present two alternative calibrations of the Calvo parameter θ. The first is based on the observed values for the frequency of price adjustment before and after the drop of average inflation in the early 80s (pre- and post-1984). The second calibration brings in more information from the data by matching the results from our regression of the frequency of price adjustment on the inflation target (equation (1)).[29]

Turning to the first calibration strategy, we set $\overline{\pi}$ equal to average values of inflation before and after 1984. Similarly, we set θ as a function of the observed average values of the monthly frequency of price adjustment before and after 1984. Since the model is quarterly, we use the relation

$$\theta = (1 - frequency)^3$$

This strategy results in target values for $\overline{\pi}$ equal to 6.73% before 1984, and equal to 2.25% after 1984; and values for θ equal to 0.65 and 0.73 respectively. In this model, the slope of the Phillips curve is determined by the Calvo parameter θ and other preference and technology parameters. Importantly for us, higher values of θ correspond to a flattening of the Phillips curve. Related to to Hazell et al. (2022), these values of θ correspond to a modest flattening of the Phillips curve.[30]

[29]The rest of the parameters are calibrated using the same values as in Coibion, Gorodnichenko, and Wieland (2012). Table 4 (online appendix) presents the full set of parameters values (except for θ and $\overline{\pi}$) used to calibrate the model.

[30]In Tables 3 and 4 of their paper, they observe that the slope of the Phillips curve has only declined by about half post-1990 when controlling for time-fixed effects or using IV. Such a decline is in line with our calibration.

The thought experiment in our first calibration is the following. Suppose that the monetary authority increases the inflation target to the trend inflation rate observed before 1984. By the Fisher equation, this would raise the steady state nominal rate by the same percentage amount, that is, by 4.48 pp. This is therefore the intended gain in policy room. The question we are interested is: What is the corresponding quantitative effective gain in policy room?[31]

We answer this question as follows. Economy 1 is the economy with $\{\overline{\pi} = 2.25, \theta = 0.73\}$. Economy 2 is the economy with $\{\overline{\pi} = 6.73, \theta = 0.65\}$. We consider a shock that makes the nominal interest rate drop to zero in economy 1. We fix the size of this shock, and we ask by how much does the interest rate drop in economy 2. Consistent with Definition 2, the percentage point distance remaining before hitting zero in economy 2 is the effective extra room. With the aim of being comprehensive in our answer, we consider three cases: one in which the shock makes the interest rate hit zero on impact (but then revert back to positive territory), another case in which the shock makes the interest hit zero at the lowest point of the response (the IRF is hump-shaped), and one where the shock makes the interest rate hit zero on impact and the ZLB is, later on, binding.[32]

Table 2 presents the results. In the first case, the effective extra room is equal to 3.32 pp. Because the increase in the target is 4.48 pp, the monetary authority achieves 74% of this intended extra room. The table shows that whether we define the room through the IRF at its lowest level, or with the ZLB constrained imposed, does not affect our result that the central bank is only able to achieve significantly less than the intended room (3.62 pp. and 3.25 pp., delivering 81% and 72% of the intended room, respectively). An interesting case is the one of less interest rate smoothing by the monetary authority[33], because it underlines, together with the last two rows of the table, the crucial role played by the interest rate rule in determining the effective extra room. When the interest rate rule exhibits less inertia, it drops by more when prices are more flexible. This lowers the effective room to 2.95 pp. This result is similar to what is obtained in a bare-bones NK model that features a Taylor rule (NK-1, delivering 2.94 pp.) When the rule depends only on inflation (NK-2), the increased flexibility channel is operating in isolation and the effective extra room is significantly reduced to 2.16 pp., or 48% of the intended room.[34] Overall, the average percentage of extra room achieved across these simulations is 68%. Thus, we find that approximately two thirds of room are gained in effective terms in this type of model.

The second calibration strategy used to pin down the Calvo parameter is based on the re-

[31] To be clear, this is the same experiment considered in Section 3.

[32] In the first case the shock on impact is negative and followed by an *unexpected* positive shock; in the second and third cases there is a negative shock only.

[33] We use $\rho_1 = 0.85,\ \rho_2 = 0$.

[34] In both cases, there is no habit formation. We calibrate the model taking the values in Gali (2015): We use a value of β equal to 0.99, a value of ϕ equal to 1.5, a value of ϕ_y equal to 0.5/4, a Frisch elasticity of labor supply equal to 0.2, a the capital share equal to 0.25, an elasticity of substitution equal to 9 (see Gali 2015 p. 67).

gression of the frequency of price adjustment and available inflation target measures, equation (1). We implement directly into the model this estimated relationship above for the monthly frequency of price changes. As a result, the model mechanically matches the relationship observed in the data. We have produced four different estimates of this relationship (Table 1). We take a conservative position and choose the estimate with the *lowest* sensitivity of the frequency of price changes and the inflation target (Specification II based on Ireland 2007). This implies the following equation for the Calvo parameter at quarterly frequency:

$$\theta = (1 - (0.0742 + 0.98\overline{\pi}))^3 \tag{6}$$

This function implies a range of values for θ depending on $\overline{\pi}$. For $\overline{\pi} = 2\%$, this gives $\theta = 0.74$; for $\overline{\pi} = 4\%$, $\theta = 0.70$.

The advantage of relying on the estimated relationship (1) is that now we can use the model to predict the effective extra room away from the ZLB for a range of values of the inflation target. We take the baseline value of the target to be 2%. We focus on the first case in Table 2 of an unexpected shock that drives the nominal interest to the ZLB upon impact. We then increase the inflation target, and pin down θ using (1). Fixing the size of the shock computed for the 2% economy, we compute the remaining room away from the ZLB as the percentage points distance between the interest rate after the shock, and zero.

The green curve in Figure 3 (tagged by 'CGW') summarizes our findings for the Coibion, Gorodnichenko, and Wieland (2012) specification. We plot the effective room relative to the benchmark of intended, one-to-one increases in policy room which are indicated by the dashed 45-degree line. This green line is substantially below the 45-degree line, suggesting an important effect of the increased price flexibility, as measured by our regression. For example, when moving from a 2% to a 4% inflation target, there is an increase of the steady state nominal rate of 2 pp. by the Fisher equation, which is the intended extra room of 2 pp. Instead, we see that the effective extra room is only 1.54 pp. Thus, the policy-maker is only able to achieve 76.5% of her or his intended extra room.

We also compute the effective extra room predicted by simpler models as the 3-equation NK model of Section 3 (NK-2) and the same model with a Taylor rule (NK-1). Similar to the previous results, in both versions of the simpler, 3-equation, model, the predicted effective extra room is substantially lower. Indeed, if the monetary authority raises $\overline{\pi}$ to 4%, we find a predicted effective extra room of 1.06 pp. by the NK-1 model, and of 0.51 pp. by the NK-2 model.

As a further exercise, we can use this regression-based approach to compute the required increase in the target to gain a given amount of *effective* policy space. Let us suppose that the policymaker wishes to gain 2 pp. of effective extra room. According to the exact Coibion, Gorodnichenko, and Wieland (2012) calibration, one would need to raise the target to 4.65% (indicated in the figure). However, the simpler NK model with a Taylor rule (which we know from above delivers approximately similar calculations for the effective room as the Coibion, Gorodnichenko, and Wieland (2012) specification with less smoothing) predicts a required increase to 5.79%, a significantly higher number. Moreover, it can be seen that the NK-2 specification predicts a much higher target to achieve this goal.

Overall, in both exercises, we note that the specification in which the interest rate depends only on inflation is the one that delivers the lowest predicted effective extra room. This underlines the importance of interest rate rule parameters for accurately predicting the amount of effective extra room that can be gained by an increase in the inflation target. Moreover, this suggests that central banks that have a strong focus on price stability are those for which the gap between the intended and the effective policy room might be the greatest in practice.

4.1.2 Model Uncertainty: Bayesian Assessment of the Effective Extra Room

Given our previous conclusion regarding the importance of the exact specification and calibration of NK models for the predicted values of the effective extra room, the next exercise we perform with the medium-scale DSGE is the following. We consider the joint distribution of several key parameters that may affect the effective room in this quantitative model. Specifically, we consider the joint distribution of the following parameters: the Frisch elasticity of labor supply φ, the discount factor β, the habit parameter h, the steady-state growth rate μ, the interest rate smoothing coefficients ρ_1 and ρ_2, and all systematic response-parameters in the Taylor rule (ϕ_π, ϕ_y, and $\phi_{\Delta y}$). To approximate the joint distribution, we generate 10,000 joint draws from the Bayesian estimate of their joint distribution in the Smets-Wouters model. Then, we compute the effective extra room for each draw when going from 2% to 4% steady state inflation.

Figure 5 illustrates the resulting, empirical distribution of the effective extra policy room. Our median estimate is 1.416 pp., the mean is 1.418 pp. The 25th and 75th percentile of the distribution are 1.371 pp. and 1.430 pp. Clearly, for a wide set of empirically relevant model parameters that include empirically relevant variations in the systematic responses to inflation and the output gap, the policy-maker is not able to achieve his or her intended extra room of 2 pp. In effect, his or her median effective extra room is only 70.8% of the intended extra room. Thus, we conclude that our results are robust to parameter uncertainty.

4.2 Using a Medium-Scale Menu Cost Model

While it does not bring with it analytical tractability and portability to conventionally used policy models, explicitly modeling endogenous price adjustment, for example through menu cost models, may affect the importance of the price flexibility channel for a change in the target in important ways. In particular, shocks that bring the interest rate to zero might be large, and will now be endogenously associated with a higher probability of price adjustment. This may interact with our higher-target mechanism and associated flexibility in non-trivial ways. Therefore, it is important to check how our results might be affected in this type of setup. Overall, this alternative modeling approach of price setting provides an important evaluation of the effective extra policy room achieved by raising the target. We find that modeling price setting endogenously with a menu cost model leads to approximately the same quantitative conclusions.

To implement endogenous price setting, we follow the menu cost approach in Dotsey, King, and Wolman (1999). In this approach, firms compare the costs and benefits of price adjustment when deciding whether to change prices or not, and take into account past prices, the distribution of vintages of prices and a random cost of adjustment. Our quantitative exercise calibrates the menu cost to match our empirically observed relationship between the frequency of price changes and the inflation target, and then varies the inflation target while holding menu costs constant.

We use exactly the same model as in the previous subsection, with only minimal modifications and the main modification imposed on the price-setting mechanism. We outline all changes below.

4.2.1 Firms and Price-Setting

Now, firms adjust their prices endogenously. The adjustment decision of firms depends on weighing the value of adjusting its price, the value of not adjusting price, and the random, period realization of adjustment costs. Adjustment costs k_t are randomly drawn each period, independently across firms and over time, and represent a fraction of labor costs. We denote their c.d.f. by $\mathcal{G}$, which is specified as a uniform distribution.

Following Dotsey et al. (1999), we denote by J the (endogenous) maximum number of periods after which all firms adjust. That means the maximum duration of a price spell can be J periods. At the beginning of each period t, denote by ζ_{jt} the fraction of firms with price spells equal to j periods. Among these firms (i.e. those that have not changed its price for j periods) we write by θ_{jt} the (now endogenous) fraction that change it at t.

We now describe the firm's problem. To decide whether to adjust or not, a firm considers the value of adjusting and not adjusting. Denote by π_{jt} period profits of a firm at period t given it has set price P^*_{t-j} optimally j periods ago. Denote by V_{0t} the value at time t of an adjusting firm, gross of the adjustment cost, that chooses an optimal reset price P^*_t. Denote by V_{jt} the value of a firm at time t that last adjusted its price $j = 0, 1, ..., J-1$ periods ago. The value of an adjusting firm is the following:

$$V_{0t} = \max_{P_t} \left(\pi_{0,t} + E_t \left[\beta Q_{t,t+1} \left[(1-\theta_{1,t+1}) V_{1,t+1} + \theta_{1,t+1} V_{0,t+1} - \Xi_{1,t+1} \right] \right] \right)$$

where

$$\Xi_{jt} = \int_0^{\mathcal{G}^{-1}(\theta_{jt})} k_t \, d\mathcal{G}(k_t)$$

is the expected adjustment cost of firms with price spells of j periods. The value of a firm at time t with prior optimally chosen price P^*_{t-j} is the following:

$$V_{jt} = \left(\pi_{j,t} + E_t\left[\beta Q_{t,t+1}\left[(1-\theta_{j+1,t+1})V_{j+1,t+1} + \theta_{j+1,t+1}V_{0,t+1} - \Xi_{j+1,t+1}\right]\right]\right)$$

Because $\theta_{Jt} = 1$, the value of firms with price spell of $J-1$ periods is given as follows:

$$V_{J-1,t} = \left(\pi_{J-1,t} + E_t\left[\beta Q_{t,t+1}\left[V_{0,t+1} - \Xi_{J,t+1}\right]\right]\right)$$

Firms of each vintage decide to adjust price if the gain in value from doing so is at least as big as the cost of adjustment. That is, if

$$V_{0t} - V_{jt} = k_t W_t$$

Given the distribution of fixed costs, this implies that the fraction of firms θ_{jt} that adjust to the new optimal price P^*_t given that they have not adjusted for j periods is equal to

$$\theta_{jt} = \mathcal{G}(V_{0t} - V_{jt}/W_t)$$

Notice that the adjustment technology uses labor, which impacts the aggregate resource constraint compared to the previous variant of the NK model. The resource constraint now equals

$$Y_t = C_t + G_t + \sum_{j=1}^{J} \zeta_{jt}\Xi_{jt}$$

The aggregate price level is now pinned down by the vintage structure of prices. That is,

$$P_t = \left(\sum_{j=0}^{J-1} \zeta_{jt}\left(P^*_{t-j}\right)^{1-\varepsilon}\right)^{1/(1-\varepsilon)}$$

This completes the presentation of the new elements introduced in this model.

4.2.2 Quantitative Exercise

We calibrate the model to match our data, that is, we target the empirically observed relationship between frequency and inflation target: We calibrate the menu cost to match a price spell duration of 2.77 quarters at 4% steady-state inflation, and price spell duration of 3.38 at 2% steady-state inflation. This calibration implies a menu cost of approximately 5.1% of steady-state output. Table 5 in the appendix presents parameter details. We refer the reader for details of the model and implementation to Dotsey et al. (1999) and Coibion et al. (2012).

With our calibrated menu cost model in hand, we repeat exactly the same experiment as in the previous subsections. That is, at a steady-state rate of 2% inflation, we consider a demand shock that drives the nominal interest to the ZLB upon impact (and then the rate is unexpectedly lifted away from the ZLB). We then fix the size of the shock and increase the inflation target. However, as we increase the inflation target, the probability of price adjustment now endogenously increases. Again, we ask how much effective extra room we get as we move to higher targets. To avoid redundancy, we only present the results for the most telling case, which is the figure of the effective extra room for alternative increases of the target, with degrees of price flexibility predicted by the menu cost model.

Figure 4 shows our main finding. We find that increasing the inflation target from 2% to 4% only provides 1.58 pp. of effective extra room, not the full intended extra room of 2 pp. The policy-maker's action, similar in magnitude as before, only achieves 79% of the intended extra policy room. This represents a sizable gap between effective and intended extra room.

The most important lesson from this analysis based on a model of endogenous price adjustment is that the quantitative effects are approximately the same as in the baseline Calvo model calibrated to match the evidence in terms of target and frequency. This result addresses the concern that large shocks may lead to a different result because they increase the degree of price flexibility endogenously. In the empirically relevant calibration we consider, this is not the case.

4.3 Why Do Our Empirical Estimates Generate Large Policy Effects?

As we have shown through a range of exercises, the effective extra room and the intended extra room never coincide. In fact, we find quantitatively large differences in all our exercises. The main reason for this finding is intuitive and is related to our formula for the effective extra room presented in Proposition 1.

The formula provides intuition on why we get large policy effects: According to the formula, the difference between the effective and intended extra room, $\mathfrak{R}^{eff}(\hat{\eta}) - \Delta\bar{\pi}$, is given by the product of the change in potency $\Delta\mathfrak{P}$, and the absolute value of the shock $\hat{\eta}$. In our exercise we are considering a large shock, or a sequence of shocks with large total effect — that bring the nominal rate to the ZLB. Thus, the change in potency would need to be zero for $\mathfrak{R}^{eff}(\hat{\eta}) - \Delta\bar{\pi}$ to be zero in our exercise. In other words, even if the sensitivity of the frequency of price changes to changes in the inflation target is "small" (which implies a correspondingly small change in potency), a large shock can still generate a quantitatively relevant policy effect. Thus, in all likelihood, one should expect that even "modest" changes in the probability of price adjustment, or modest changes in the slope of the Phillips curve (as found by Hazell, Herreno, Nakamura, and Steinsson 2022), generate sizable differences between the effective and the intended extra room.

We show that indeed different parameter estimates for the sensitivity of the frequency of price changes to changes in the inflation target mean a very stable and sizable quantitative effect on the effective extra room. We show this result in Figure 6, briefly discussed in Appendix Section C: The figure shows the effective room gained on the vertical axis and the sensitivity of the frequency of price changes to changes in the inflation target, $\hat{\beta}_1$ as in the main empirical specification while holding the intercept constant. The effective extra room is computed using the Coibion, Gorodnichenko, and Wieland (2012) benchmark model. The different blue markers along the line denote our empirical estimates. The red marker denotes the sensitivity we estimate based on the Argentine data from Alvarez et al. (2019). We see very clearly that for all estimates, the effective extra room gained is much below the intended extra room of 2 pp. We still get large effects even for estimates only half the size of our conservative choice (0.98/2 instead of 0.98).[35]

5 The Optimal Inflation Target

We complement our positive analysis by showing that our main mechanism also matters for normative analysis. We find that the optimal inflation target is approximately 1 percentage point higher near a 0 natural rate of interest if one allows the frequency of price changes to vary with the inflation target.

Given the results of the previous section, in particular the finding that a NK model that matches the data in terms of targets and frequency of price adjustment delivers similar results to a menu cost model, we focus on the Coibion, Gorodnichenko, and Wieland (2012) specification. We calibrate the frequency of price changes to match our estimated empirical relationship (equation (6)). Then, we vary the steady-state real interest rate, denoted r^*, between 0% and 9% and solve for the corresponding optimal inflation target $\bar{\pi}$.[36] We do so under 2 specifications: First, holding the frequency of price changes fixed, and second, allowing for the frequency to adjust according to our estimated relationship with the inflation target (equation (6)).[37] Com-

[35]In the context of the New-Keynesian models we explore, there is yet a second reason why we find large quantitative effects. In these models, the loss of potency is pinned down by the slope of the Phillips curve κ. This slope is an hyperbolic function of the Calvo parameter θ, and its slope is quite steep around the relevant range we consider, say, for values around 0.60 and 0.80. When $\theta = 0.80$, $\kappa = 0.1040$ in NK-1; when prices at more flexible at $\theta = 0.60$, the slope of the Phillips curve increases approximately by a factor of 5 at $\kappa = 0.5413$. Thus, over this range, even moderate changes in the probability of price adjustment are actually able to produce a significant change in the slope κ. This change in turn translates into a relatively large change in potency.

[36]In our description, we use the terms 'steady-state real interest rate' and 'natural rate' interchangeably.

[37]Moreover, we choose the exogenous Calvo parameter such that it matches the frequency of price changes implied by our estimated relationship at the Coibion et al. (2012) baseline ratio of the steady state nominal rate to optimal inflation, which

pared to Coibion et al. (2012), we raise the volatility of government and preference shocks to $\sigma_g = 0.0078$ (from $\sigma_g = 0.0052$) and $\sigma_q = 0.0036$ (from $\sigma_q = 0.0024$) such that we quantitatively match the relevant ranges of r^* and $\bar{\pi}$ in more recent studies as Andrade et al. (2019).

Our findings show a very clear effect of allowing the frequency of price changes to react to the inflation target, especially when the natural rate of interest is low. Figure 7 summarizes our key findings graphically. We see the varying-frequency specification has a steeper, more negative slope than the fixed-frequency specification. A lower natural rate of interest is associated with a higher optimal inflation target if we allow for the endogenous relationship. The intuition is the same as in Andrade et al. (2019): First a fall in r^* means a higher risk of hitting the ZLB so the inflation target increases to mitigate that risk. Second, the cost of hitting the ZLB increases if we allow for more price flexibility because it amplifies the destabilizing real-interest rate effect at the ZLB.[38] Quantitatively, our main finding is that for a natural rate near 0, the optimal target that is approximately 1 percentage point higher if we allow the frequency of price changes to vary.[39]

6 Conclusion

There are two ways of interpreting our results.

A conservative interpretation is that our channel provides a further reason not to attempt raising the inflation target in order to achieve higher inflation, because the monetary authority needs to *also* fight against the loss of potency in order to gain extra room for monetary policy. This may not justify the extra welfare costs of higher inflation.[40]

Another interpretation, potentially of a more radical nature, is that—on the contrary—this channel provides a justification to raise the inflation target by *more* than intended or initially discussed (to say to 5% instead of 4%), in order to ensure getting enough room for monetary policy. Which of these two interpretations ought to be adopted seems to depend on the exact macroeconomic context, and on the relative importance of minimizing the impact and length of liquidity traps in the future.

occurs at a natural rate of 3%. In other words, the two lines intersect at a natural rate of 3%.

[38] A related paper is by Blanco (2021), who exploits this channel in a menu cost setting.

[39] Given the steady-state relation of the real rate, the discount factor, and growth, the natural (or steady state) real rate can be varied by varying either the discount factor the the steady-state growth of productivity. This result is obtained by varying the discount factor. Figure 9 in the online appendix instead repeats the exercise by varying the steady-state growth rate of productivity. The results are similar.

[40] On a related vein, see Bernanke (2020). As commented therein, our argument suggests that such moderate increases could turn out to be of questionable use, after all.

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A Main Tables and Figures

Table 1: Frequency of Price Changes and Inflation Target

	(I)	(II)	(III)	(IV)
Target $\overline{\pi}_t$	1.61***	0.98***	1.04***	2.26***
	(0.24)	(0.08)	(0.11)	(0.41)
constant	4.61***	7.42***	7.26***	5.25***
	(0.86)	(0.37)	(0.40)	(0.91)
N	28	27	28	26
R^2	68%	83%	78%	66%
Data means:				
Target $\overline{\pi}_t$	3.42	4.04	3.90	2.85
Freq f_t	10.69	10.75	10.69	10.8

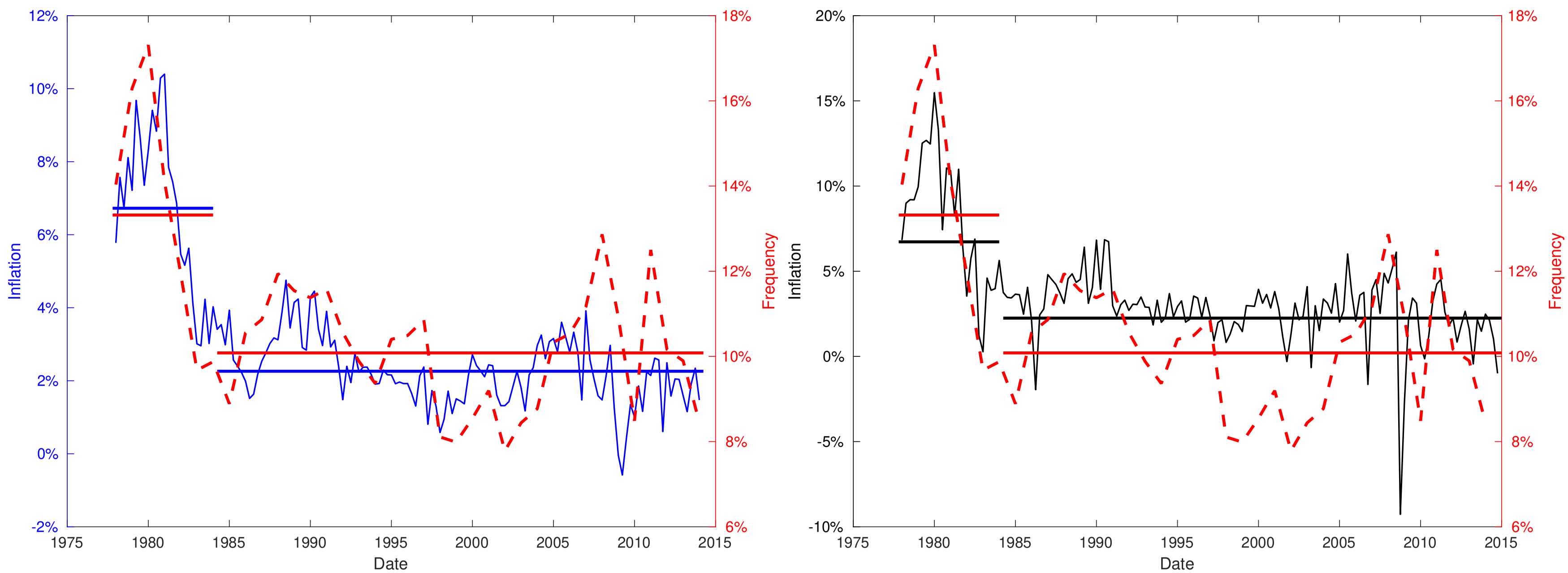
The table shows estimates of the following specification: $f_t = \beta_0 + \beta_1 \overline{\pi}_t + \epsilon_t$, where f_t is the annual average monthly frequency of price changes in %, and $\overline{\pi}_t$ the annual inflation target, also in %. We estimate this specification separately for our three inflation target series: Specification (I) is based on the estimates by Fuhrer and Olivei (2017); Specification (II) is based on Ireland (2007); Specification (III) is based on Milani (2019); and Specification (IV) is based on Cogley and Sbordone (2008). We use robust Newey-West standard errors (1 lag). The rows "data means" show, respectively: the means of the independent variable (inflation target), and of the dependent variable (frequency of price changes).
*** denotes statistical significance at the 1% level.
** denotes statistical significance at the 5% level.

Table 2: Effective Extra Room When Raising the Target to the Pre-1984 Inflation Rates (Intended Extra Room of 4.48 pp.)

Case	Effective Extra Room (in pp.)	Fraction of Room Achieved
On Impact	3.32	74%
Min. of IRF	3.62	81%
ZLB Imposed	3.25	72%
Less Smoothing	2.95	66%
NK-1	2.94	66%
NK-2	2.16	48%

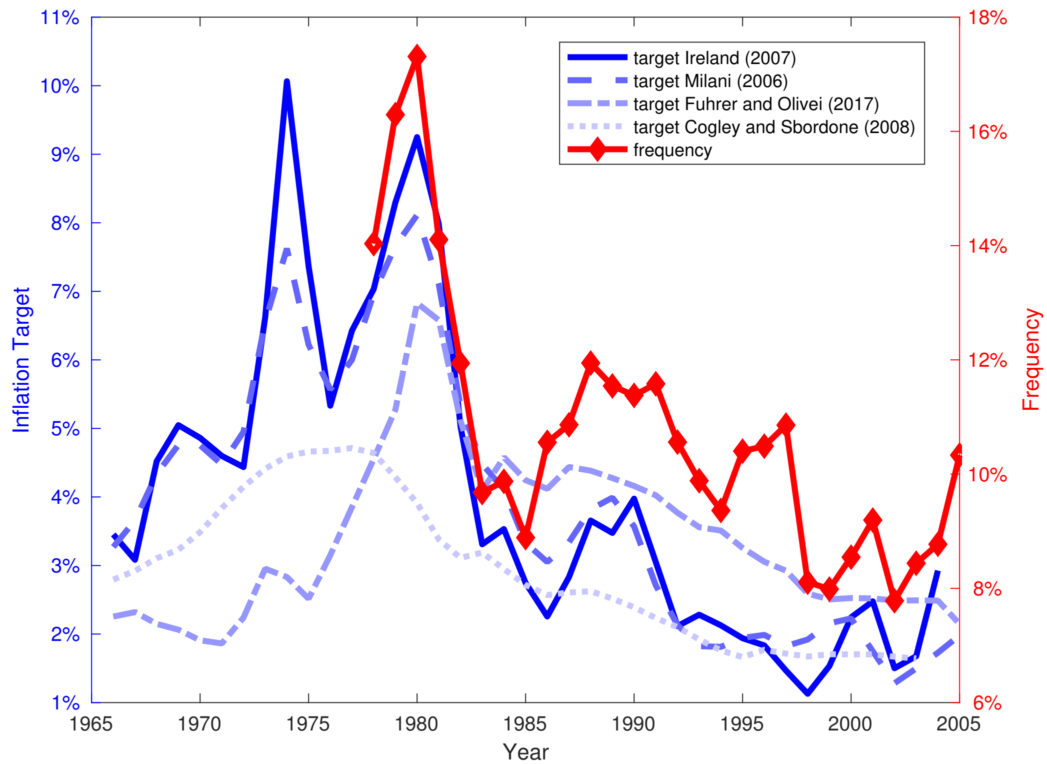
This table presents our quantitative results using the baseline Coibion, Gorodnichenko, and Wieland (2012) model, a bare-bones NK model with a Taylor rule (NK-1), and a bare-bones NK model with a simple interest rule that depends only on inflation (NK-2). The target is raised from its post-1984 level of 2.25% to the pre-1984 average inflation rate of 6.73%. The Calvo parameter is calibrated using the observed frequencies of price adjustment for the two sub-samples. For the Coibion et al. (2012) model, the table presents the computed effective extra room in percentage points for several cases: a shock that brings the rate to zero on impact, and then the rate is lifted away from the ZLB; a shock that brings the rate to zero at the lowest value of the IRF; a shock that brings the rate to zero on impact, and then ZLB is imposed; less interest rate smoothing ($\rho_1 = 0.85,\ \rho_2 = 0$). For the bare-bones NK models, the shock brings the rate to zero on impact. The last column computes the ratio of the effective extra room and the intended extra room.

Figure 1: Inflation and the Frequency of Price Changes Over Subsamples



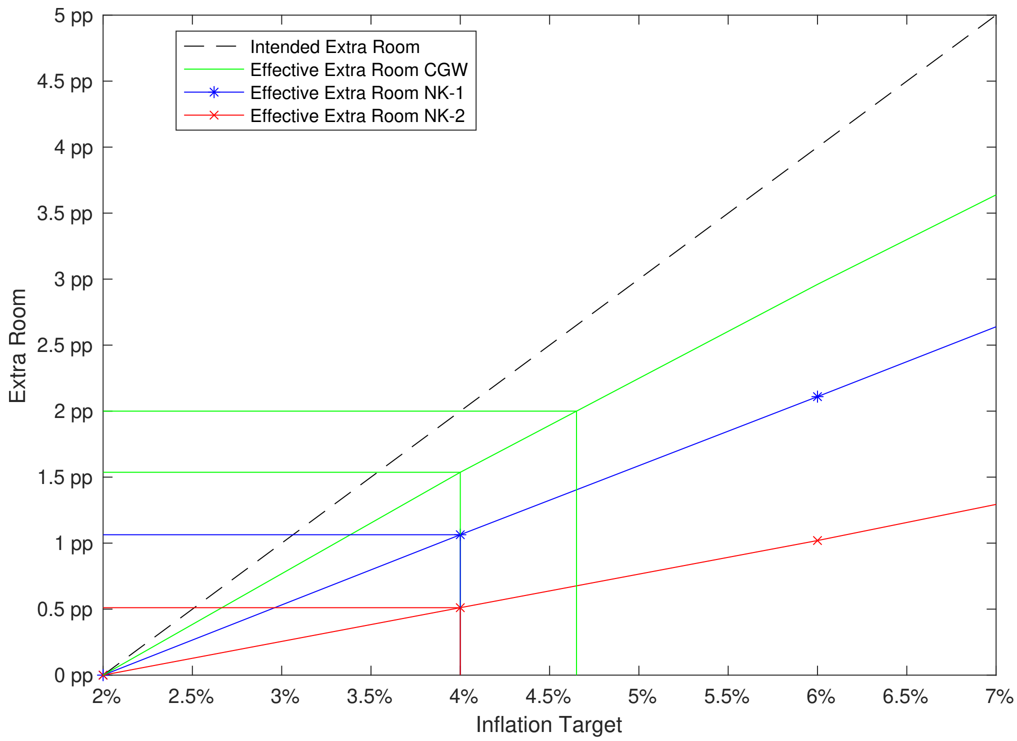
This figure shows the average monthly frequency of U.S. consumer price changes from Nakamura, Steinsson, Sun, and Villar (2018) (right axis, red dashed line) and U.S. inflation measured in the left panel by the GDP deflator (left axis, blue solid line) and in the right panel by the CPI (left axis, black solid line). The subsamples are pre-1984 and post-1984.

Figure 2: Inflation Target and Frequency of Price Changes



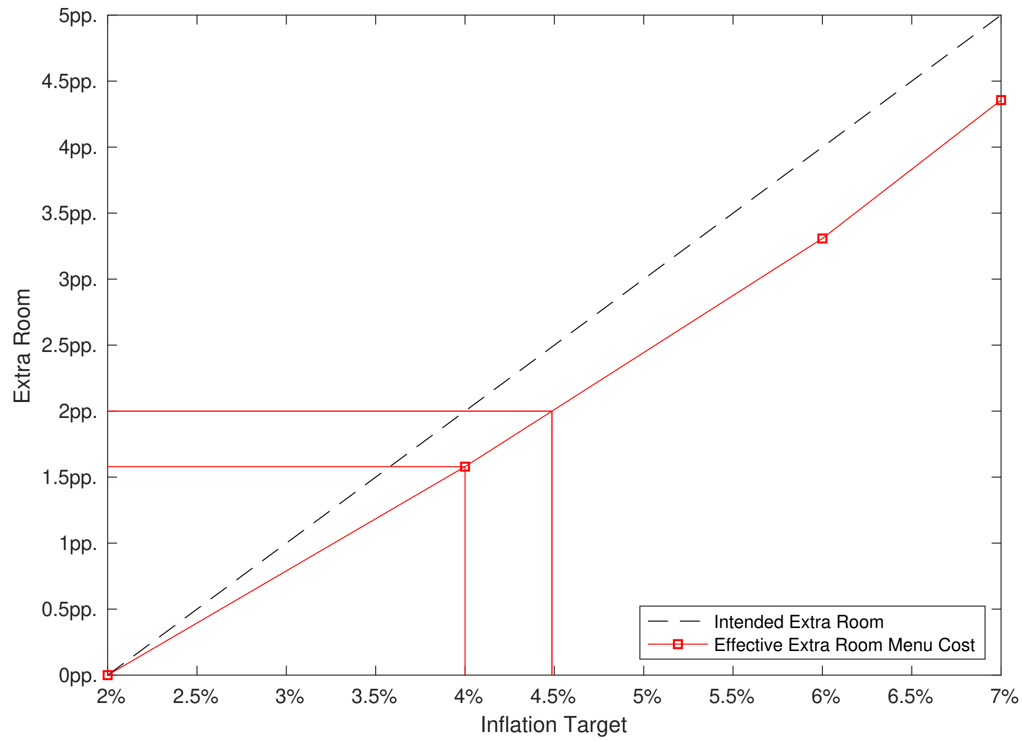
This figure plots the times series, by year, of the average monthly frequency of price changes (red dashed line, right axis) against estimated inflation targets for the U.S. The frequency of price changes is based on micro price data from the Bureau of Labor Statistics (BLS), generously shared by Emi Nakamura (Figure XIV in Nakamura et al. (2018)). Second, data on the time-varying inflation target comes from four different sources: the inflation target series underlying Figure 4 in Ireland (2007), the series underlying Figure 1 in Milani (2019), the series underlying Figure 3 in Fuhrer and Olivei (2017), and the series underlying Figure 1 in Cogley and Sbordone (2008).

Figure 3: Effective Extra Policy Room Obtained by Raising the Target



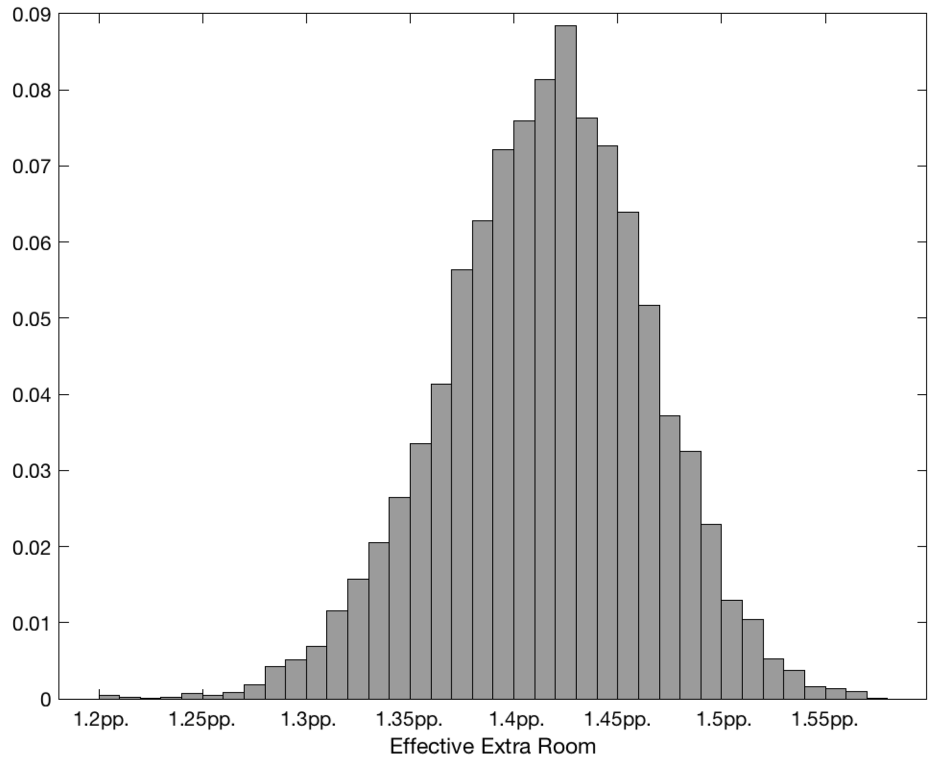
This figure plots the effective extra policy room gained in percentage points (pp.) against the inflation target, when moving away from a 2% baseline up to 7%. To compute the effective extra room, we consider an unexpected shock that makes the nominal interest rate drop to zero upon impact, for a 2% target. We fix the size of this shock, and we ask, for different values of $\overline{\pi}$, by how much the interest rate will fall. The remaining space is the effective extra policy room. We compute it for two versions of the bare-bones New Keynesian model (see main text for details) and the New Keynesian model by Coibion, Gorodnichenko, and Wieland (2012).

Figure 4: Effective Extra Policy Room Obtained by Raising the Target, Using a Menu Cost Model



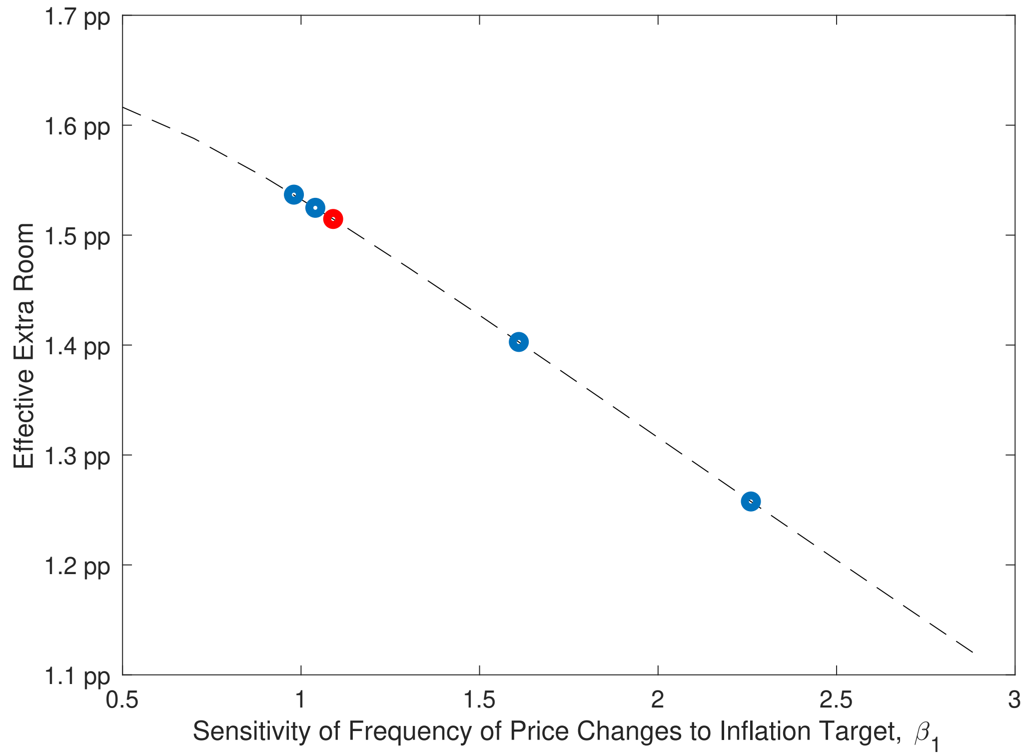
This figure plots the effective extra policy room gained in percentage points (pp.) against the inflation target, when moving away from a 2% baseline up to 7%. To compute the effective extra room, we consider an unexpected shock that makes the nominal interest rate drop to zero upon impact, for a 2% target. We fix the size of this shock, and we ask, for different values of $\overline{\pi}$, by how much the interest rate will fall. The remaining space is the effective extra room. We assume a menu cost pricing mechanism following Dotsey, King, and Wolman (1999).

Figure 5: Distribution of Effective Extra Room Obtained by Raising the Target from 2% to 4%



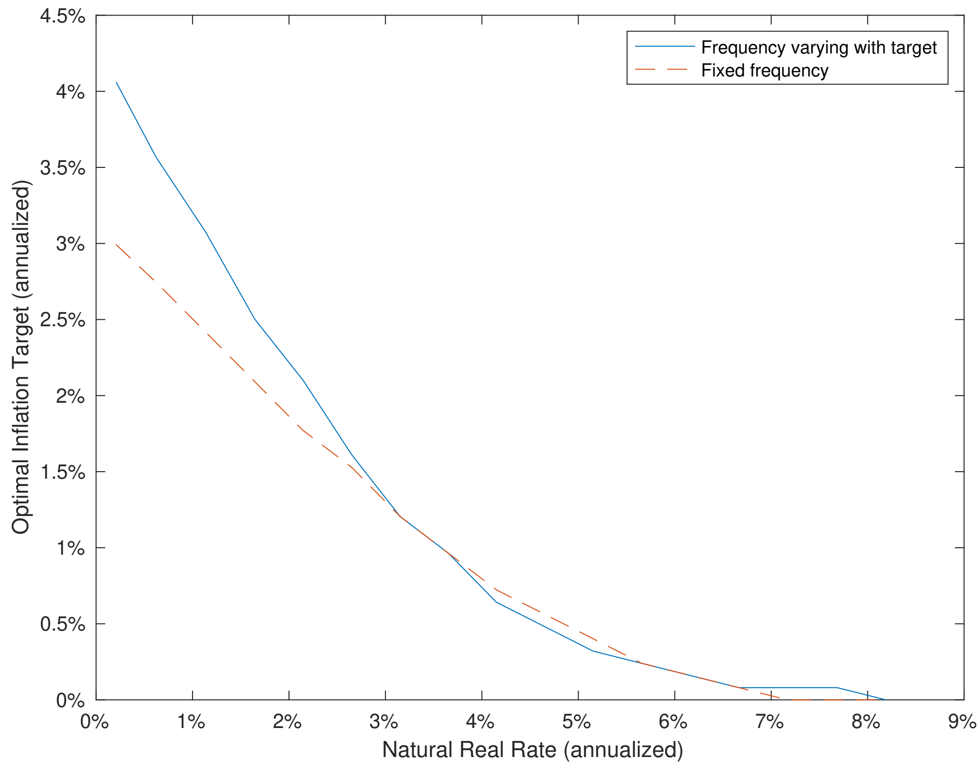
This figure plots the empirically relevant distribution of effective extra room when going from a target of 2% to 4%. We draw 10000 joint draws from the joint parameter distribution estimated in the Smets-Wouters model for the following parameters: the Frisch elasticity of labor supply, the discount factor, the habit parameter, the steady-state growth rate, the interest rate smoothing coefficients, all systematic response-parameters in the Taylor rule. Then, we compute the effective extra room in our main model for each draw, going from 2% to 4% steady state inflation. The effective extra room is computed as described in Figure 3 (also explained in the main text.)

Figure 6: Sensitivity β_1 and Effective Extra Room



This figure plots the effective extra room when we simulate our baseline model for different sensitivites of the frequency of price changes to the inflation target, either according to our empirical estimates (blue) or the estimate based on Argentine data (red) holding the intercept constant.

Figure 7: Optimal Inflation Target



This figure plots the optimal inflation target against the (steady-state) natural rate of interest. We generate this relationship for two scenarios: 1) fixed frequency of price adjustment (blue, solid) and 2) frequency of price adjustment that varies with the inflation target (red, dashed). The natural rate of interest is changed by changing the discount factor (the online appendix shows the alternative case of changing the steady-state growth rate. See the main text for a full explanation.).

[FOR ONLINE PUBLICATION]

Online Appendix For: "Raising the Inflation Target: How Much Extra Room Does It Really Give?"

Jean-Paul L'Huillier and Raphael Schoenle

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B Complementary Regressions

An alternative way of checking the validity of our main assumption is, instead of producing our own estimates of a SW model over different subsamples as shown above, to instead go back to a previous paper by Fernandez-Villaverde and Rubio-Ramirez (2007) (henceforth FVRR) that estimated a time-varying parameter DSGE similar to SW. By doing this, they obtained time series of estimates for several parameters of interest. We use their series of estimates for the (time-varying) probability of price adjustment, and for the (time-varying) inflation target. We regress the former on the latter in order to see if these are significantly associated statistically.

This exercise complements our previous estimation of a SW model in two ways. First, it allows for a richer time-variation between the probability of price adjustment and the target (while at the same time allowing for rational expectations on the part of agents about these changes.) Second, it confirms our previous aggregate-data claims using data produced by other researchers.

For convenience, we reproduce Figure 2.20 from Fernandez-Villaverde and Rubio-Ramirez (2007) (Figure 10), which plots, from 1956 to 2000, their estimate of quarterly (non-annualized) target and the duration of price spells. The Figure shows that the target increases steadily from the beginning of the sample to roughly 1979, reaching a level at less than 2% (quarterly). Then, the target steadily declines to roughly 0.5%. The duration of price spells is negatively correlated, decreasing and then increasing. To check this correlation more precisely, we consider the specification

$$f_t^{FVRR} = \beta_0 + \beta_1 \overline{\pi}_t^{FVRR} + \epsilon_t$$

where the superscript $FVRR$ indicates these are measures from Fernandez-Villaverde and Rubio-Ramirez (2007): f_t^{FVRR} is the quarterly probability of price adjustment, and $\overline{\pi}_t^{FVRR}$ is the target (converted, for convenience, to annual).

Table 6 presents the results. The first column presents the baseline regression over the whole sample considered by FVRR. The estimated elasticity β_1 is significant at the 1% level, and positive. The second and third column consider the robustness over the post-1970 and post-1984 subsamples. In both cases the estimated elasticity is also significant at the 1% level and positive. Thus, the conclusion from looking at the estimates generated by FVRR is that a higher inflation target robustly implies more flexible prices.

C More on Robustness

Here we repeat our main quantitative exercise based on other data sets on the relation between the frequency of price changes and inflation. We use the inflation data from Alvarez et al. (2019) and re-estimate our main specification (1) for "low" inflation rates as defined in Alvarez et al. (2019) as less than 14%. We then feed the estimated relationship into our model as before. Figure 12 shows our findings. As we increase the inflation target, we see once again that the effective extra room is less than the intended extra room. The gap between the two is smaller than what is obtained by looking at the U.S. data, but it is quantitatively meaningful nonetheless.

D Estimation

For the estimation exercise, our analysis directly follows Smets and Wouters (2007) and the treatment in Bhattarai and Schoenle (2014). We refer the reader to the Smets and Wouters (2007) paper for a detailed description of their well-known model and data sources. Since our main goal is to obtain a joint distribution of key parameters from an empirically widely used and estimated model, we only focus on a description of key elements of the estimation and computation.

The data we use are the same as in Smets and Wouters (2007): The quarterly data range from 1966:QI through 2004:QIV and include the log difference of real GDP, real consumption, real investment, real wage, the GDP deflator, log hours worked, and the federal funds rate. Each observable serves to pin down one of seven shocks. Our exercise in Table 3 additionally restricts the estimation to the post-1984 sub-period only.

Our Bayesian estimation and model comparison procedure for linearized models follows the established conventions. As such, we evaluate the likelihood function using the Kalman filter, and compute the mode of the posterior. We use a Metropolis-Hastings algorithm to sample from the posterior distribution, with a scaled inverse Hessian as a proposal density for the Metropolis-Hastings algorithm.

We calibrate a few parameters as in Smets and Wouters (2007), and choose the same prior densities (see Table 8). The only exception concerns the price and wage markup shocks: Smets and Wouters (2007) combine the true markup shocks and various structural parameters (in particular, the price and wage Calvo parameters) when estimating markup shocks while we estimate the "true" markup shocks with appropriately rescaled priors. This difference is not essential, however, for the identification of parameters. Overall, our parameters estimates come out to be extremely close to those of Smets and Wouters (2007).

Last, in order to compute an empirically relevant distribution of effective extra policy room, we do the following: First, we load our MCMC draws and disregard the first 10% as burn-in. Second, we draw 10,000 random sets of key parameters in common with our main model from the estimated joint distribution of parameters, including the Frisch elasticity of labor supply, the discount factor, the habit parameter, the steady-state growth rate, the interest rate smoothing coefficients, and all systematic response-parameters in the Taylor rule. Finally, for each set of draws, we compute the effective, extra policy room we get when we move from 2% to 4% steady state inflation. The results are summarized in the histogram in Figure 5 in the main body of the paper. Table 9 shows our posterior estimates.

E Incorporating Indexation

Here, we deviate from the off-the-shelf benchmark Coibion, Gorodnichenko, and Wieland (2012) and incorporate indexation into the model. The goal is to check how our results are affected by it. In summary, we find that the effective extra policy room raises a bit, but it is still meaningfully different that the intended extra policy room.

Now, if firms do not get to re-optimize, they will automatically re-scale their prices by the steady state rate of inflation, $\overline{\pi}$, with a degree of indexation $\omega \in [0, 1)$. Thus, $\omega = 1$ denotes full indexation, $\omega = 0$ no indexation.

Firms that get to adjust prices maximize the following expression for choosing the new price P_{it}^{*}:

$$E_t \left[\sum_{j=0}^{\infty} (\beta\theta)^j Q_{t,t+j} \left(Y_{t+j} P_{it}^{*} \overline{\pi}^{\omega j} - W_{i,t+j} N_{i,t+j} \right) \right]$$

where $Q_{t,t+s}$ denotes the stochastic discount factor. These assumptions about price setting imply that the aggregate price level evolves as

$$P_t^{1-\varepsilon} = (1-\theta) \left(P_{it}^{*}\right)^{1-\varepsilon} + \theta \left(P_{t-1} \overline{\pi}^{\omega}\right)^{1-\varepsilon}$$

Figure 13 presents the results, including a comparison with the baseline without indexation. The difference between the two effective extra room lines is small.

We also check the empirical distribution of the effective room, presented in Figure 14. The distribution left tail is now slightly pushed to higher values of the room over the horizontal axis, but is it largely quite similar to the one without indexation (Figure 5).

F Extra Tables and Figures

Table 3: Frequency of Price Changes and Inflation Target, Post 1984

	(I)	(II)	(III)	(IV)
Target $\overline{\pi}_t$	1.16***	1.10***	1.04***	1.99**
	(0.27)	(0.31)	(0.27)	(0.75)
constant	6.06***	7.26***	7.42***	5.86***
	(0.92)	(0.76)	(0.74)	(1.51)
N	21	20	21	19
R^2	47%	41%	42%	37%
Data means:				
Target $\overline{\pi}_t$	3.31	2.36	2.38	2.04
freq f_t	9.88	9.88	9.88	9.91

The table shows estimates of the following specification: $f_t = \beta_0 + \beta_1 \overline{\pi}_t + \epsilon_t$, where f_t is the annual average monthly frequency of price changes in %, and $\overline{\pi}_t$ the annual inflation target, also in %. We estimate this specification separately for our three inflation target series: Specification (I) is based on the estimates by Fuhrer and Olivei (2017); Specification (II) is based on Ireland (2007); Specification (III) is based on Milani (2019); and Specification (IV) in based on Cogley and Sbordone (2008). We use robust Newey-West standard errors (1 lag). The rows "data means" show, respectively: the means of the independent variable (inflation target), and of the dependent variable (frequency of price changes).
*** denotes significant at the 1% level.
** denotes significant at the 5% level.

Table 4: Model Parameters

Parameters of Utility Function		**Steady-State Values**	
φ: Frisch Labor Elasticity	1.00	μ: Growth Rate	1.5% p.a.
β: Discount factor	0.998	$\overline{c_y}$: Consumption Share of GDP	0.80
h: Internal habit	0.7	$\overline{g_y}$: Government Share of GDP	0.20
Pricing Parameters		**Shock Persistence**	
ϵ: Elasticity of substitution	7	ρ_g: Government Spending Shocks	0.97
		ρ_ξ: Risk Premium Shocks	0.947
Taylor Rule Parameters		**Shock Volatility**	
ϕ_π: Response to inflation	2.50	σ_g: Government Spending Shocks	0.0052
ϕ_x: Response to output gap	1.50	σ_ξ: Risk Premium Shocks	0.0024
$\phi_{\Delta y}$: Response to output growth	0.11		
ρ_1: Interest smoothing	1.05		
ρ_2: Interest smoothing	-0.13		

The table summarizes the parameter values in our medium-scale model. They are identical to the parameter values in Coibion et al. (2012), with the exception of the Calvo parameter which is set to match the frequency of price adjustment in the data.

Table 5: Model Parameters: Menu Cost Model

Parameters of Utility Function		**Steady-State Values**	
φ: Frisch Labor Elasticity	1.00	μ: Growth Rate	1.5% p.a.
β: Discount factor	0.998	$\overline{c_y}$: Consumption Share of GDP	0.80
h: Internal habit	0.7	$\overline{g_y}$: Government Share of GDP	0.20
Pricing Parameters		**Shock Persistence**	
ϵ: Elasticity of substitution	2	ρ_g: Government Spending Shocks	0.97
		ρ_ξ: Risk Premium Shocks	0.947
Taylor Rule Parameters		**Shock Volatility**	
ϕ_π: Response to inflation	2.50	σ_g: Government Spending Shocks	0.0052
ϕ_x: Response to output gap	1.50	σ_ξ: Risk Premium Shocks	0.0024
$\phi_{\Delta y}$: Response to output growth	0.11		
ρ_1: Interest smoothing	1.05	**Expected Menu Cost**	
ρ_2: Interest smoothing	-0.13	0.19531	

The table summarizes the parameter choices in our medium-scale menu cost model. They are chosen to match a duration 2.77 quarters at a 4% steady-state inflation and a duration of 3.38 quarters at 2% steady-state inflation, as in the data. The menu cost follows a uniform distribution with a minimum cost of 0.

Table 6: Frequency of Price Changes and Inflation Target, based on Fernandez-Villaverde et al. (2007)

	(I) 1956-2000	(II) > 1978	(III) > 1984
Target $\overline{\pi}^{FVRR}$	2.95***	3.34***	8.57***
	(0.73)	(0.38)	(1.12)
constant	17.38***	11.99***	7.41***
	(0.97)	(0.51)	(0.79)
N	180	88	64
R^2	6%	31%	30%

The table shows estimates of the following specification: $f_t^{FVRR} = \beta_0 + \beta_1 \overline{\pi}_t^{FVRR} + \epsilon_t$, where f_t^{FVRR} is the quarterly frequency quarterly average of price changes estimated by Fernandez-Villaverde and Rubio-Ramirez (2007) in %, and π_t^{FVRR} the annual inflation target estimated by Fernandez-Villaverde and Rubio-Ramirez (2007), also in %. We use robust Newey-West standard errors (1 lag). We estimate this specification separately for different subsamples.
*** denotes significant at the 1% level.

Table 7: Regressions of the Frequency on Inflation Rates Using Alvarez et al. (2018) Data for Argentina, and Semi-Elasticity at Zero Inflation

Specification	$\hat{a}$	$\hat{b}$	$\lambda(\pi = 0\%)$	$\lambda(\pi = 1\%)$	Implied Semi-Elasticity
(Annual, positive π)					
(1) $\lambda = a + b * \pi$	0.23***	1.03***	0.2314	0.2417	4.45%
	(0.01)	(0.21)			
(2) $log(\lambda) = a + b * \pi$	-1.47***	3.62***	0.2295	0.2379	3.68%
	(0.04)	(0.76)			
(Annual, all π)					
(3) $\lambda = a + b * \pi$	0.23***	1.09***	0.2255	0.2364	4.85%
	(0.01)	(0.13)			
(4) $log(\lambda) = a + b * \pi$	-1.51***	4.03***	0.2218	0.2310	4.11%
	(0.02)	(0.47)			
(Monthly, all π)					
(5) $log(\lambda) = a + b * \pi$	-1.51***	50.37***	0.2219	0.2314	4.27%
	(0.02)	(5.81)			

The table presents several specifications for the regression of the frequency of price adjustment on inflation, for inflation rates below 14% (the cutoff used by Alvarez et al. 2019). (1)–(4) use annualized inflation rates (the frequency of the data is monthly). (1) and (2) present the regressions including only observations with positive inflation rates, which corresponds most closely to our trend inflation regressions on Table 1. (3) and (4) include the observations with negative realizations of inflation. (5) uses monthly inflation rates, as in the Alvarez et al. (2019) replication codes, and includes the observations with negative rates. The semi-elasticity is computed by taking the percentage change in the frequency when going from 0% to 1% inflation. We manage to replicate the 4.27% (or 0.0427) semi-elasticity produced by their `Figure_5.m` code (output variable named '`lambda_change`'), despite using a simple log-linear model for rates below 14% (Alvarez et al. 2019 include a quadratic term, and estimate the model via non-linear least squares using a log-log specification for inflation rates above 14%). Due to a typographic mistake, this is reported as 0.04% in the paper. In all regressions, similar to Alvarez et al. (2019), we express inflation and the frequency in decimals (1% inflation as $\pi = 0.01$, and a frequency of 1% as $\lambda = 0.01$).
*** denotes significance at the 1% level.

Table 8: Prior Distribution of Structural Parameters

Parameters	Domain	Density	Prior Mean	Prior Stdev
φ	$\mathbb{R}$	Normal	4.00	1.50
σ_c	$\mathbb{R}$	Normal	1.50	0.37
h	[0,1)	Beta	0.70	0.10
ξ_w	[0,1)	Beta	0.50	0.10
σ_l	$\mathbb{R}$	Normal	2.00	0.75
ξ_p	[0,1)	Beta	0.50	0.10
ι_w	[0,1)	Beta	0.50	0.15
ψ	[0,1)	Beta	0.50	0.15
Φ	$\mathbb{R}$	Normal	1.25	0.12
r_π	$\mathbb{R}$	Normal	1.50	0.25
ρ	[0,1)	Beta	0.75	0.10
r_y	$\mathbb{R}$	Normal	0.12	0.05
$r_{\Delta y}$	$\mathbb{R}$	Normal	0.12	0.05
$\overline{\pi}$	$\mathbb{R}^+$	Gamma	0.62	0.10
$100(\beta^{-1}-1)$	$\mathbb{R}^+$	Gamma	0.25	0.10
$\bar{l}$	$\mathbb{R}$	Normal	0.00	2.00
$\overline{\gamma}$	$\mathbb{R}$	Normal	0.40	0.10
α	$\mathbb{R}$	Normal	0.30	0.05
ρ_a	[0,1)	Beta	0.5	0.2
ρ_b	[0,1)	Beta	0.5	0.2
ρ_g	[0,1)	Beta	0.5	0.2
ρ_I	[0,1)	Beta	0.5	0.2
ρ_r	[0,1)	Beta	0.5	0.2
ρ_p	[0,1)	Beta	0.5	0.2
ρ_w	[0,1)	Beta	0.5	0.2
ρ_{ga}	[0,1)	Beta	0.5	0.2
μ_p	[0,1)	Beta	0.5	0.2
μ_w	[0,1)	Beta	0.5	0.2
σ_a	$\mathbb{R}^+$	InvG	0.10	0.5
σ_b	$\mathbb{R}^+$	InvG	0.10	2
σ_g	$\mathbb{R}^+$	InvG	0.10	2
σ_I	$\mathbb{R}^+$	InvG	0.10	2
σ_r	$\mathbb{R}^+$	InvG	0.10	2
σ_p	$\mathbb{R}^+$	InvG	4.00	4
σ_w	$\mathbb{R}^+$	InvG	5.00	5

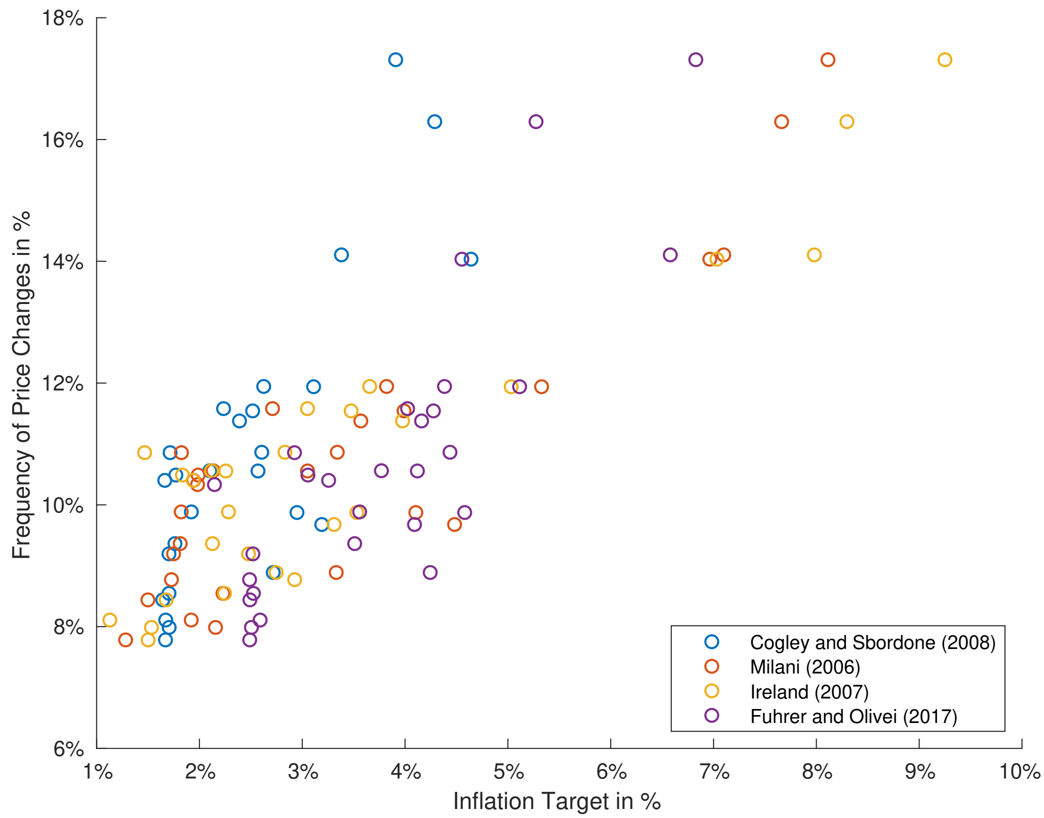
The table summarizes the prior distributions for the shock processes in the Bayesian estimation.

Table 9: Posterior Estimates of Structural Parameters

Parameters	Prior Mean	Posterior Mean	Credible Interval 90%	
φ	4.00	5.4692	[3.7853	7.0934]
σ_c	1.50	1.3393	[1.1331	1.5514]
h	0.70	0.7177	[0.648	0.79]
ξ_w	0.50	0.6124	[0.5204	0.7097]
σ_l	2.00	1.4597	[0.6744	2.233]
ξ_p	0.50	0.6104	[0.5413	0.6794]
ι_w	0.50	0.6189	[0.4231	0.8196]
ψ	0.50	0.5708	[0.392	0.7475]
Φ	1.25	1.6157	[1.4891	1.7453]
r_π	1.50	2.071	[1.7849	2.3573]
ρ	0.75	0.7924	[0.751	0.8365]
r_y	.125	0.0841	[0.0474	0.1205]
$r_{\Delta y}$	.125	0.2167	[0.1696	0.2632]
$\overline{\pi}$	.625	0.8315	[0.6559	1.0032]
$100(\beta^{-1}-1)$	0.25	0.1693	[0.0743	0.2605]
$\bar{l}$	0.00	-0.0859	[-1.9125	1.7332]
$\overline{\gamma}$	0.40	0.4273	[0.4031	0.4518]
α	0.30	0.1918	[0.1623	0.2212]
ρ_a	0.5	0.956	[0.9372	0.9755]
ρ_b	0.5	0.2055	[0.066	0.3377]
ρ_g	0.5	0.9748	[0.9612	0.9892]
ρ_I	0.5	0.7148	[0.6181	0.8115]
ρ_r	0.5	0.1741	[0.061	0.2832]
ρ_p	0.5	0.9058	[0.8435	0.9698]
ρ_w	0.5	0.9737	[0.9578	0.9905]
ρ_{ga}	0.5	0.5708	[0.392	0.7475]
μ_p	0.5	0.5595	[0.3786	0.7506]
μ_w	0.5	0.7981	[0.7005	0.9026]
σ_a	0.10	0.4565	[0.4103	0.5021]
σ_b	0.10	0.243	[0.2045	0.2822]
σ_g	0.10	0.5284	[0.4786	0.5785]
σ_I	0.10	0.4521	[0.3704	0.5325]
σ_r	0.10	0.2499	[0.2236	0.2753]
σ_p	4.00	3.7318	[2.0877	5.3171]
σ_w	5.00	13.7272	[5.9349	22.0592]

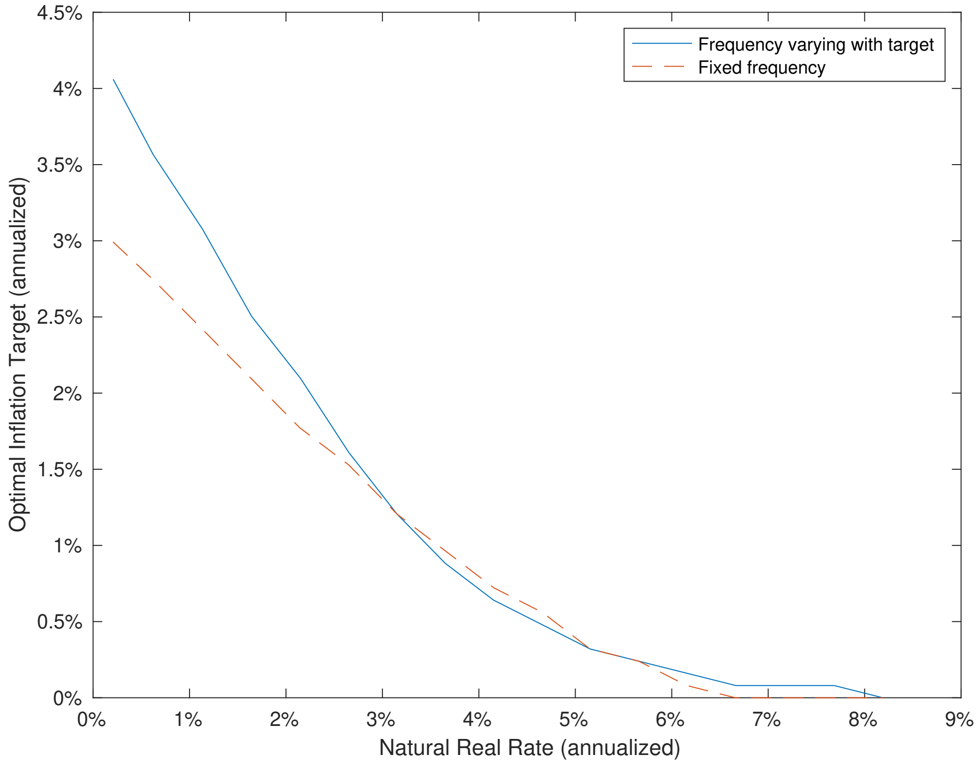
The table summarizes the posterior parameter estimates for the shock processes from the Bayesian estimation.

Figure 8: Scatter Plot: Frequency of Price Changes and Inflation Target Measures



This figure shows a scatter plot, by year, of the average monthly frequency of price changes against estimated inflation targets for the U.S. The frequency of price changes is based on micro price data from the Bureau of Labor Statistics (BLS), generously shared by Emi Nakamura (Figure XIV in Nakamura et al. 2018). Second, data on the time-varying inflation target comes from four different sources: the inflation target series underlying Figure 4 in Ireland (2007), Figure 1 in (Milani 2019), Figure 3 in Fuhrer and Olivei (2017) and Figure 1 in Cogley and Sbordone (2008).

Figure 9: Optimal Inflation Target: Alternative Experiment



This figure plots the optimal inflation target against the (steady-state) natural rate of interest. We generate this relationship for two scenarios: 1) fixed frequency of price adjustment (blue, solid) and 2) frequency of price adjustment that varies with the inflation target (red, dashed). The natural rate of interest is changed by changing the steady-state growth rate. (See the body for a full explanation.)

Figure 10: Trend Inflation and Duration of Price Spells

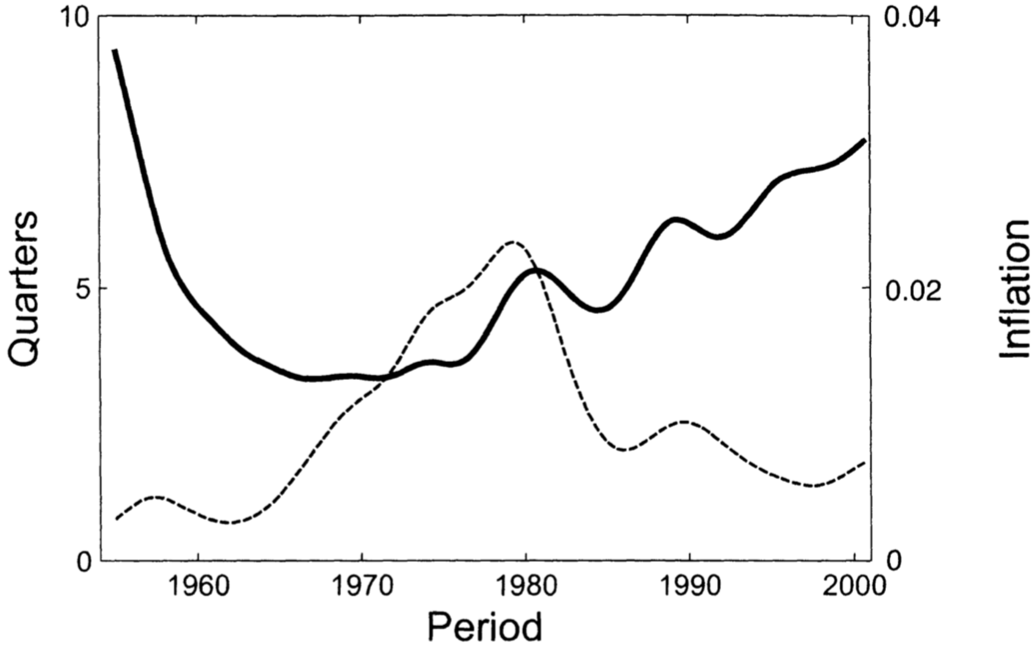
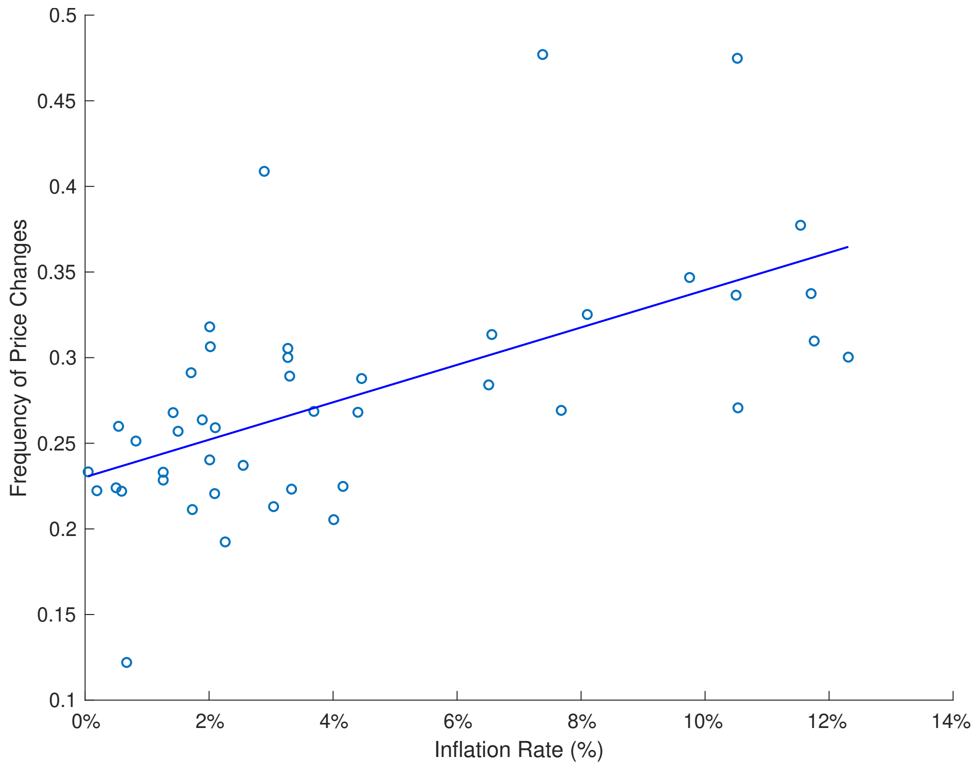


Figure 2.20
HP-Trend Price Rigidity vs. HP-Trend Inflation

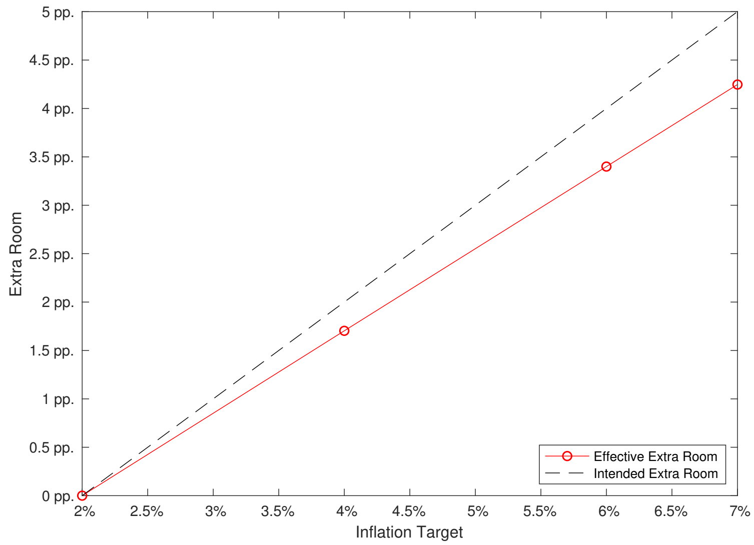
Source: Fernandez-Villaverde and Rubio-Ramirez (2007).

Figure 11: Frequency of Price Changes and Inflation Rate for Argentina



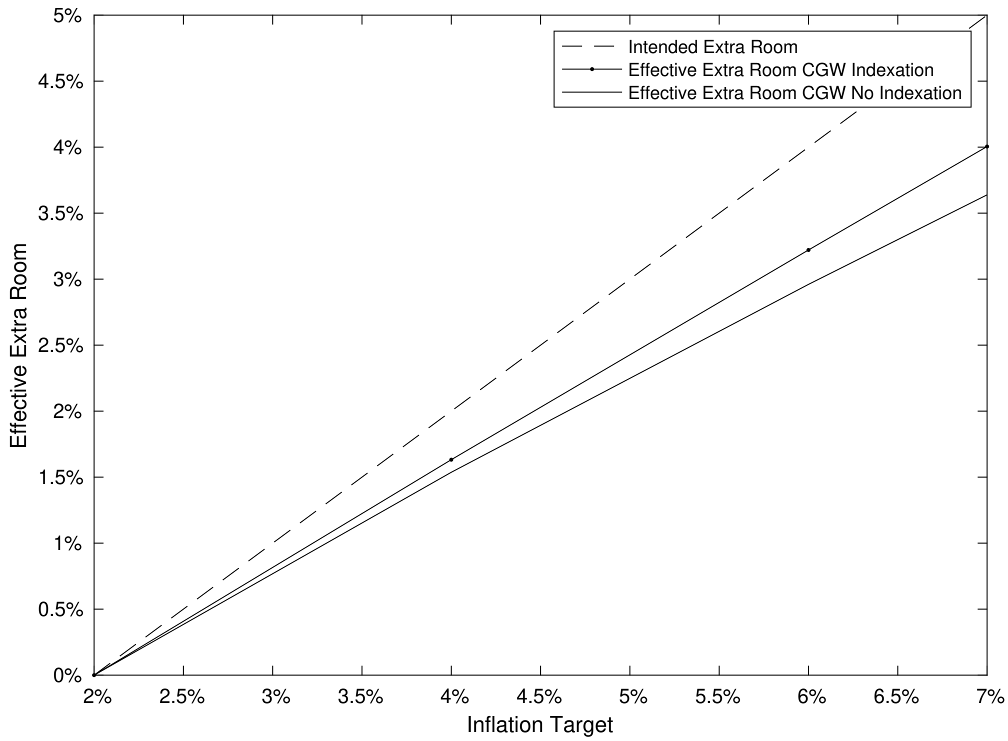
This figure plots frequency of price changes against the observed positive inflation rates below 14% from Alvarez et al. (2019).

Figure 12: Robustness to Calibration Based on Argentine Data



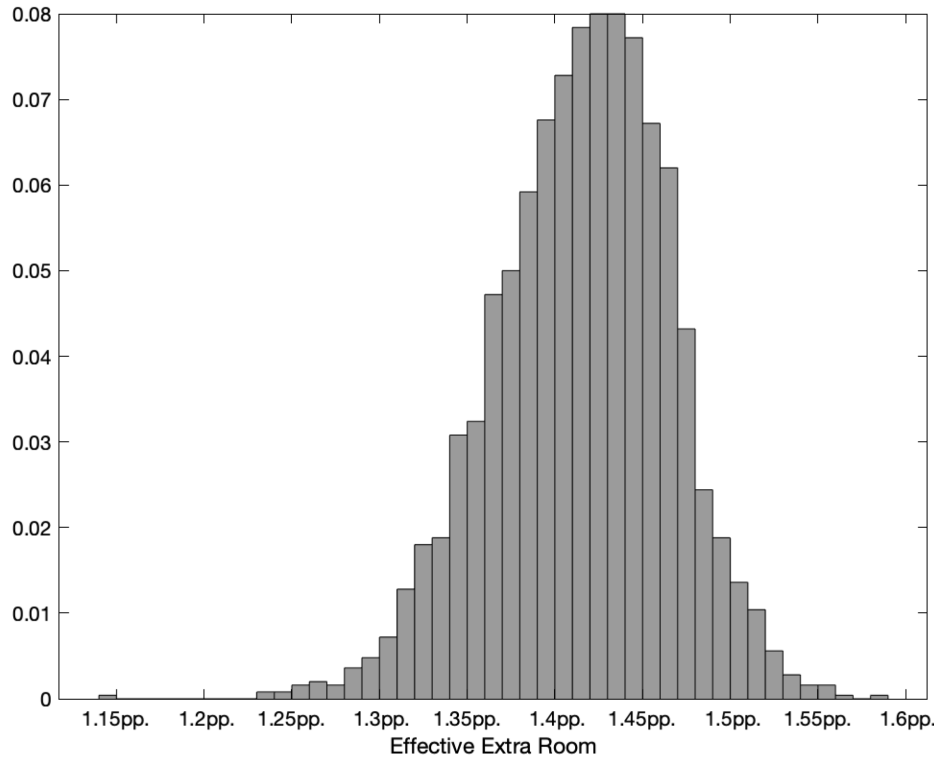
This figure plots the effective extra room, computed as in Figure 3 above for the Coibion, Gorodnichenko, and Wieland (2012) model, when matching the degree of increased price flexibility using data for Argentina (the results in Table 7).

Figure 13: Effective Extra Policy Room Obtained by Raising the Target, Under Indexation



This figure plots the effective extra policy room gained in percentage points (pp.) against the inflation target, when moving away from a 2% baseline up to 7%. To compute the effective extra room, we consider an unexpected shock that makes the nominal interest rate drop to zero upon impact, for a 2% target. We fix the size of this shock, and we ask, for different values of $\overline{\pi}$, by how much the interest rate will fall. The remaining space is the effective extra policy room. We compute it for the model by Coibion, Gorodnichenko, and Wieland (2012), with and without indexation.

Figure 14: Distribution of Effective Extra Room Raising the Target from 2% to 4%, Under Indexation



This figure plots the empirically relevant distribution of effective extra room when going from a target of 2% to 4%. We draw 2500 joint draws from the joint parameter distribution estimated in the Smets-Wouters model for the following parameters: the Frisch elasticity of labor supply, the discount factor, the habit parameter, the steady-state growth rate, the interest rate smoothing coefficients, all systematic response-parameters in the Taylor rule and the degree of price indexation. Then, we compute the effective extra room in our main model for each draw, going from 2% to 4% steady state inflation. The effective extra room is computed as described in Figure 3 (also explained in the main text.)