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Monetary Policy Credibility and the Comovement between Stock Returns and Inflation*

Eurilton Araújo**

Abstract

Empirical evidence suggests that the magnitude of the negative comovement between real stock returns and inflation declined during the Great Moderation in the U.S. To understand the role of monetary policy credibility in this change, I study optimal monetary policy under loose commitment in a macroeconomic model in which stock price movements have direct implications for business cycles. In line with the data, a calibration of the model featuring a significant degree of credibility can replicate the weakening of the negative relationship between real stock returns and inflation in the Great Moderation era.

Keywords: stock returns, inflation, loose commitment
JEL Classification: E31, E44, E52

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1 Introduction

Many empirical papers have documented a negative relationship between real stock returns and inflation in the U.S. post-war data. To understand this observed negative comovement, several hypotheses have been explored[1], including explanations in which monetary policy is an important element. Indeed, based on estimated vector autoregression (VAR) systems, Goto and Valkanov (2002) and Farka (2012) showed that, in samples including the Great Moderation, monetary policy shocks explained a smaller percentage of the covariance between the two variables compared with earlier periods.

Farka (2012) also documented the weakening of the observed negative comovement during the Great Moderation, an episode in economic history that coincides with the Volcker-Greenspan monetary regime, which represents a divide in post-war U.S. monetary policy[2]. These findings indicate that modifications in the conduct of monetary policy may affect the comovement between real stock returns and inflation[3].

Many studies on the Great Moderation era concentrate their analysis on the substantial reduction in the volatility of the growth rates of macroeconomic aggregates or of their business cycle components[4]. On the other hand, for this period, the behavior of financial variables and their relationship with macroeconomic factors have received insufficient attention in the literature.

In line with Pancrazi (2014) and Fuentes-Albero (2016), this paper complements the literature on the Great Moderation by focusing on the interac-

[1] Fama and Schwert (1977), Fama (1981), Geske and Roll (1983), Kaul (1987, 1990), Hess and Lee (1999) and Lee (2010) comprise a representative sample of this large body of literature.

[2] See Ilbas (2012) for a more extensive discussion.

[3] Laopodis (2013) also suggested that the relationship between monetary policy and the stock market depended on the monetary regime in place.

[4] Ahmed et al. (2004), Boivin and Giannoni (2006) and Benati and Surico (2009) are examples of these studies.

tion between financial and macroeconomic variables. In fact, it gauges the effects of monetary policy credibility on the comovement between real stock returns and inflation in the U.S. In a related paper, Wei (2010) studied a similar topic, which was the positive association between inflation and dividend yields. However, she did not consider the direct effect of stock prices on aggregate demand and did not emphasize monetary policy credibility.

First, based on quarterly data, I revisit the evidence indicating that, during the Great Moderation, the magnitude of the negative relationship between real stock returns and inflation had declined. I also reexamine the VAR analysis suggesting that the relevance of monetary policy shocks in explaining this comovement had decreased as well. This empirical investigation compares two different subsamples: the pre-Great Moderation period and the Great Moderation era.

Second, to understand how monetary policy credibility can account for the comovement between real stock returns and inflation and thus interpret the empirical evidence, I investigate optimal monetary policy design under imperfect credibility in a new Keynesian dynamic and stochastic general equilibrium model (DSGE) in which stock price movements have direct implications for macroeconomic fluctuations via financial wealth effects on consumption.

To model imperfect credibility, I choose the loose commitment approach introduced by Roberds (1987), Schaumburg and Tambalotti (2007), and Debortoli et al. (2014)[5]. According to this literature, a central bank's credibility refers to the probability that it will keep the promises it makes about future policy. Central banks with no credibility honor their promises with probability zero and implement a discretionary monetary policy. Central banks

[5]The following papers also adopted the loose commitment framework: Debortoli and Nunes (2010), Bodenstein et al. (2012) and Dennis (2014).

with imperfect credibility honor their promises with non-zero probabilities. Higher degrees of credibility thus relate to higher probabilities of keeping promises about future policy plans. In the limit, a probability equals one characterizes full commitment.

The DSGE model, based on Nisticò (2012) and Airaudo et al. (2015), is a discrete-time stochastic version of the Blanchard (1985) and Yaari (1965) perpetual-youth model with price rigidity[6]. Indeed, the Blanchard-Yaari overlapping generations structure leads to the turnover in financial markets between long-time traders (holding assets) and newcomers (entering the market with no assets). In this context, financial wealth becomes relevant for aggregate consumption, providing therefore a direct channel by which stock prices can influence macroeconomic dynamics.

I calibrate the model to match properties of quarterly U.S. data for each subsample, generating therefore two different parameterizations. I focus on the approximate replication of a set of empirical moments of interest. After specifying some parameters in consonance with the literature, I then search for the remaining parameter values in order to minimize a quadratic distance between the moments implied by the model and the moments taken from the data.

For the pre-Great Moderation period, the calibrated degree of credibility is extremely low, suggesting a discretionary monetary policy. During the Great Moderation, the calibration indicates a considerable increase in the probability of keeping announced promises, implying a shift to a more credible monetary policy. Moreover, for both subsamples, the relative importance of stabilizing the output gap is negligible. Summing up, the change in the

[6] Macroeconomists have been studying this class of models extensively. The following papers corroborate the dynamism of this literature: Castelnuovo et al. (2010), Milani (2011), Castelnuovo (2013) and Airaudo et al. (2013).

conduct of monetary policy leads to a substantial increment in credibility but also includes modified weights in the loss function summarizing the central bank's preferences. The parameterization of the Fed's loss function though does not point to a strong concern with the output gap stabilization in both periods.

The changing degree of credibility is an element absent in the literature connecting improvements in monetary policy with the Great Moderation, such as Benati and Surico (2009). In fact, this literature looked at changes in the magnitudes of the coefficients of Taylor rules concerning inflation and associated the Great Moderation with a strong Fed's response to this variable, while implicitly assuming that the central bank always had full credibility in implementing any policy rule.

The parameters describing private sector behavior and exogenous disturbances are also different across calibrations based on distinct subsamples. These adjustments suggest that changes in the conduct of monetary policy happen together with modifications in the monetary transmission mechanism. Though important, monetary policy is not the only factor influencing the relationship between real stock returns and inflation.

In both subsamples, simulation results show that, to some extent, the model is capable of replicating the empirical comovement between real stock returns and inflation. In fact, it is relatively more successful in the Great Moderation subsample. Hence, at least qualitatively, the model reproduces the declining magnitude of the negative relationship between real stock returns and inflation across subsamples.

In circumstances under which forward-looking behavior is significant, increasing credibility gives expectations a more prominent role as a transmission channel. In fact, expected stock prices, dividends and inflation are more relevant for the current behavior of economic variables and their initial reactions to disturbances. In this context, on impact, real stock returns and inflation are less responsive to technology shocks, which move them contemporaneously in opposite directions. Consequently, in the second subsample, this behavior weakens the negative comovement between them because these shocks engender the strongest initial responses. Indeed, credibility leads to more stable expectations that do not exacerbate the initial reactions of the two variables.

The paper proceeds as follows. Section 2 empirically investigates the comovement between real stock returns and inflation before and during the Great Moderation and uses a VAR system to gauge the importance of monetary policy shocks for this relationship. Section 3 sets out the model and discusses its calibration. Section 4 presents quantitative results. Finally, the last section concludes.

2 Empirical Analysis

Based on quarterly data, to reproduce the empirical results concerning the changes in comovement during the Great Moderation, I consider the following subsamples: pre-Great Moderation (from 1960:Q1 to 1979:Q3) and the Great Moderation period (from 1984:Q1 to 2007:Q4)[7].

For each subsample, following Den Haan (2000) and Den Haan and Sumner (2004)[8], I measure comovement by computing the correlations of VAR forecast errors of real stock returns and inflation at different forecast horizons.

[7]Following Dennis (2006), I exclude the beginning of the 1980s, period in which it is implausible to treat the federal funds rate as the policy instrument since non-borrowed reserves targeting characterized monetaty policy. The second subsample agrees with the definition of the Great Moderation era in Smets and Wouters (2007) and Pancrazi (2014).

[8]María-Dolores and Vázquez (2008) and Cassou and Vázquez (2014) adopted the same methodology to study the comovement between output and inflation.

Following Goto and Valkanov (2002) and Farka (2012), to evaluate the effect of monetary policy shocks on the relationship between the two variables, I use covariance decomposition based on a recursive VAR designed to identify these shocks.

2.1 Data

The quarterly sample ranges from 1960:Q1 to 2007:Q4 and I looked at the two subsamples previously defined to perform the empirical analysis.

I collected quarterly U.S. data from the FRED database, which is housed by the Federal Reserve Bank of St. Louis. The variables are real output, real money balances, inflation and the short-term interest rate. Real GDP is the measure of real output, real money balances equal nominal M2 money stock divided by the GDP deflator, inflation is the quarterly variation in GDP deflator and the Fed funds rate measures the nominal interest rate.

From the world bank, I retrieved a commodity price index, which I used in the VAR specification aimed at recovering monetary policy shocks. From Shiller's online database I built nominal stock returns based on S&P 500 data[9]. Real stock returns equal nominal stock returns divided by the GDP deflator.

Alternatively, I also considered a CPI-based measure of inflation and constructed real money balances and real stock returns using the CPI as deflator. Since the results conditional on these CPI-based observables are similar to the results from the benchmark data set using the GDP deflator, I only report the findings based on the benchmark time series.

[9] The S&P 500 data source is http://www.econ.yale.edu/ shiller/data.htm

2.2 Measuring comovement

In contrast to Farka (2012), which measured comovement by running a regression of real stock returns on a constant and on inflation, I choose an alternative approach that distinguishes between short-run and long-run comovement. This differentiation between short-run and long-run effects allows me to gauge which of these effects generate the strongest comovement between the variables.

I briefly describe the methodology in Den Haan (2000) and Den Haan and Sumner (2004). This procedure uses a VAR to study the correlation between two variables at several forecast horizons.

Consider a bivariate VAR that describes the dynamics of a random vector X_t containing inflation (π_t) and real stock returns (sr_t). The following equation summarizes the VAR specification:

$$X_t = a_0 + a_1 t + a_2 t^2 + \sum_{l=1}^{nl} A_l X_{t-l} + U_t$$

The variable nl is the total number of lags included. The term $g(t) = a_0 + a_1 t + a_2 t^2$ is a deterministic trend. Finally, U_t represents a vector of white noise processes, such that $E(U_t) = 0$, $E(U_t U_t^T) = \Omega$ and $E(U_t U_s^T) = 0$ for $t \neq s$.

The methodology proposed by Den Haan (2000) computes the correlation between the h-period ahead forecast errors related to the variables π_t and sr_t. Low values of h characterizes short-run correlations and high values of h corresponds to long-run correlations. The h-period ahead forecast for π_t and sr_t are: $E_t \pi_{t+h}$ and $E_t sr_{t+h}$. The variables $e^{\pi}_{t+h|t}$ and $e^{sr}_{t+h|t}$ denote the respective h-period ahead forecast errors. The expressions for them are

$$e^{\pi}_{t+h|t} = \pi_{t+h} - E_t \pi_{t+h} \text{ and } e^{sr}_{t+h|t} = sr_{t+h} - E_t sr_{t+h}$$

The correlation $corr(h)$ between the h-period ahead forecast errors is

$$corr(h) = \frac{cov(e^{\pi}_{t+h|t}, e^{sr}_{t+h|t})}{sd(e^{\pi}_{t+h|t})sd(e^{sr}_{t+h|t})}$$

In the expression above, $cov(.,.)$ and $sd(.)$ denote covariance and standard deviation operators.

Given the specified VAR, one can compute confidence bands for $corr(h)$ by bootstrap. By considering the correlation coefficients of the VAR forecast errors at different horizons, researchers can get a rich set of information about the comovement between two variables, compared with the inspection of the unconditional correlation between them.

2.3 Covariance and Variance decomposition in VAR systems

The covariance decomposition analysis is a way to decompose the covariance between two variables into components associated with exogenous shocks, extending the traditional variance decomposition analysis in VARs. By employing this concept, it is possible to measure the fraction of the negative covariance between sr_t and π_t that could be attributed to monetary policy shocks.

Next, following Farka (2012), I present the details on how to compute this decomposition based on estimated VARs.

Consider the following structural VAR model specified to identify monetary policy shocks:

$$A_o Z_t = A(L) Z_t + V_t$$

The matrix of contemporaneous effects of the shocks is A_o.

The variable $A(L) = A_1 L + A_2 L^2 + ... + A_p L^p$ is a matrix polynomial in the lag operator L with order p.

The shocks in V_t are orthogonal with identity covariance matrix I_n.

The vectors Z_t and V_t have dimensions $n \times 1$, where n is the number of economic variables in the VAR.

In this paper, the vector Z_t includes the following variables in this order: real GDP, inflation, commodity price index, real money balance, the fed funds rate and real stock returns.

To identify the system, I assume a recursive structure that imposes restrictions on A_o such that this matrix is lower triangular. The Choleski factorization of the residuals of the reduced form VAR allows the estimation of A_o^{-1}, which is a necessary step to recover the structural shocks V_t from the residuals of the reduced form VAR.

In this context, the following expression defines the vector of h-step ahead forecast errors:

$$Z_{t+h} - E_t Z_{t+h} = \sum_{s=0}^{h-1} B_s V_{t+h-s}$$

The definition of B_s involves an auxiliary matrix Ψ_s according to the following expressions:

$\Psi_0 = I_n$, $B_0 = A_o^{-1}$, $B_s = \Psi_s A_o^{-1}$ and $\Psi_s = \sum_{k=1}^{s} \Psi_{s-k} A_k$, $s = 1, 2, .., h-1$.

The h-step ahead forecast error covariance between two variables j_1 and j_2 due to the shock m is: $cov^m_{t+h|t}(j_1, j_2) = \sum_{s=0}^{h-1} b_s(j_1, m) b_s(j_2, m)$, where $b_s(j_1, m)$ and $b_s(j_2, m)$ are the elements of B_s in positions (j_1, m) and (j_2, m), respectively.

The h-step ahead forecast error covariance between two variables j_1 and j_2 due to all shocks is: $cov_{t+h|t}(j_1, j_2) = \sum_{m=1}^{n} cov^m_{t+h|t}(j_1, j_2)$.

For any given shock m, the proportion of $cov_{t+h|t}(j_1, j_2)$ accounted for by this particular shock is: $\frac{|cov^m_{t+h|t}(j_1,j_2)|}{|cov_{t+h|t}(j_1,j_2)|}$, where the symbol $|.|$ denotes the absolute value for the variable in question.

If $j_1 = j_2$, for each shock and forecast horizon, the ratio describes the standard variance decomposition exercise related to the variable j_1. Moreover, by bootstrapping the VAR, I compute standard errors for the ratio $\frac{|cov^m_{t+h|t}(j_1,j_2)|}{|cov_{t+h|t}(j_1,j_2)|}$ concerning the pair (j_1, j_2), given a particular shock and forecast horizon.

2.4 Results

I present results concerning VAR specifications in which I employ the variation of the GDP deflator as a measure of inflation. If I consider a definition based on CPI, the results are qualitatively very similar. For the sake of brevity, I stick to the measure of inflation based on GDP deflator for the rest of the paper.

2.4.1 Comovement Statistics

In the first column of Figure 1, I plot the comovement statistics proposed by Den Haan (2000) for each subsample with 90% confidence bands constructed by bootstrapping the VAR. To specify the VAR, I choose $nl = 4$ based on the AIC information criterion and do not include deterministic trends.

In the first column of Figure 1, the first row relates to the pre-Great Moderation and the second row shows the comovement pattern during the Great Moderation. In line with the findings reported by Goto and Valkanov (2002) and also discussed by Farka (2012), there is a change in the comovement between stock returns and inflation across the two subsamples. Indeed, the first column of Figure 1 documents that the magnitude of the negative relationship between real stock returns and inflation declines during the Great

Moderation.

According to the upper band associated with the Great Moderation period, the comovement may even have changed signs, becoming positive. In contrast, for the pre-Great Moderation sample, the upper band for the statistics $corr(h)$ supports only negative values. Concerning the lower bands, in the first column of Figure 1, the first row reveals that the magnitude of the negative correlation is bigger than 0.5. On the other hand, the second row shows a mild negative correlation, which is smaller than the estimated $corr(h)$ for the pre-Great Moderation era, represented by the solid line with circles in the first row of the first column.

Notwithstanding the differences in magnitude, the dynamic pattern of $corr(h)$ is similar across subsamples. For very short horizons, the magnitude of the negative correlation increases and, approximately after $h = 6$, reaches its long-run and stable value.

2.4.2 The importance of monetary policy shocks

Table 1 and 2 display the relative importance of monetary policy shocks in variance decompositions for inflation and stock returns and in a covariance decomposition exercise concerning the comovement between these two variables. Table 1 focuses on the pre-Great Moderation subsamble while Table 2 relates to the Great Moderation.

Comparing Table 1 and Table 2, during the Great Moderation, the variance of monetary policy shocks becomes less important in explaining the variance of the forecast error concerning inflation and real stock returns. In addition, the effect of these shocks on the comovement between the two series has drastically diminished.

These findings are again in line with the empirical results described in

Goto and Valkanov (2002) and also portrayed by Farka (2012). Indeed, Farka (2012)[10] presented additional evidence suggesting that a smaller role for monetary policy shocks also happened after the adoption of inflation targeting in a sample of developed countries. This pattern signals that the conduct of monetary policy may be an element contributing to explain the observed negative comovement.

In the context of the loose commitment framework for monetary policy design, it is legitimate to interpret monetary policy shocks as reoptimizations by the central bank, which are completely exogenous events that change the conduct of monetary policy. The relative importance of monetary policy shocks rises according to how frequent these reoptimizations occur. Therefore, the empirical evidence indirectly supports an increase in credibility during the Great Moderation since a smaller role for monetary policy shocks suggests a reduction in the number of reoptimizations, which is a consequence of higher levels of credibility.

3 The Model

I study monetary policy design in the context of the Blanchard-Yaari overlapping generations model with the consumption-wealth channel. This feature is a mechanism by which asset prices can have a direct effect on aggregate demand. Indeed, Castelnuovo and Nisticò (2010) estimated a closed-economy model for the U.S., showing that the consumption-wealth channel is empirically important for the monetary transmission mechanism. In addition, they perform a likelihood-based comparison with the representative agent model and obtain results that indicate the superiority of the Blanchard-Yaari model

[10] Farka (2012) used monthly data while I focused the analysis on the quarterly frequency.

as a more plausible specification.

In line with María-Dolores and Vázquez (2008) and Cassou and Vázquez (2014), I study a small-scale model in order to represent the transmission mechanism of monetary policy in a simple and transparent way, capturing the essential features of the new Keynesian framework. By keeping the structure of the model straightforward, I can highlight the role of monetary policy design for the interaction between macroeconomic variables and stock prices.

3.1 Private Sector Equations

I present the log-linear approximation of the DSGE model. Appendix A provides more details of the model.

The following equations define a linear rational expectations model, approximately describing the equilibrium conditions.

$$\begin{aligned} c_t - hc_{t-1} &= \frac{(1-h)\psi}{1-h+\psi} E_t(c_{t+1} - c_t) + \frac{(1-h)\psi}{1-h+\psi} q_t \\ &\quad - \frac{(1-h)^2}{1-h+\psi}[i_t - E_t(\pi_{t+1}) - i_t^n] \end{aligned} \tag{1}$$

$$q_t = \widetilde{\beta} E_t(q_{t+1}) + (1-\widetilde{\beta}) E_t(d_{t+1}) - [i_t - E_t(\pi_{t+1}) - i_t^n] + e_t \tag{2}$$

$$d_t = y_t - (\theta - 1) mc_t \tag{3}$$

$$\pi_t = \frac{\kappa}{1+\widetilde{\beta}\kappa}\pi_{t-1} + \frac{\widetilde{\beta}}{1+\widetilde{\beta}\kappa} E_t(\pi_{t+1}) + \frac{(1-\phi)(1-\phi\widetilde{\beta})}{(1+\widetilde{\beta}\kappa)\phi} mc_t + z_t \tag{4}$$

$$mc_t = \frac{1}{1-h}(c_t - hc_{t-1}) + \varphi y_t \tag{5}$$

$$y_t = c_t \tag{6}$$

$$sr_t = \widetilde{\beta}(q_t - d_t) - (q_{t-1} - d_{t-1}) + (d_t - d_{t-1}) \tag{7}$$

The endogenous variables are consumption (c_t), real stock prices (q_t), the nominal interest rate (i_t), inflation (π_t), dividends (d_t), the real marginal cost (mc_t), the real output (y_t) and real stock returns (sr_t). All variables are measured in log deviations from the flexible price equilibrium. They represent therefore the gap between the actual equilibrium and a hypothetical situation in which nominal rigidities and inefficient shocks are absent. In addition, i_t^n stands for the natural rate of interest. Finally, E_t denotes the expectation operator.

The first expression is the Euler equation with habit persistence in consumption, the second summarizes the dynamics of real stock prices, the third determines dividends, the fourth is a hybrid new Keynesian Phillips curve characterizing inflation dynamics, the fifth defines the real marginal cost, the sixth describes aggregate demand and the last one specifies real stock returns. Finally, the term $\frac{(1-h)\psi}{1-h+\psi}q_t$ in the first equation represents the consumption-wealth channel and the parameter ψ, defined below, controls the intensity of the direct effect that stock prices exert on consumption.

The flexible price equilibrium comprises the following equations:

$$y_t^n = c_t^n + g_t \tag{8}$$

$$c_t^n - hc_{t-1}^n + (1-h)\varphi y_t^n = (1+\varphi)(1-h)a_t \tag{9}$$

$$c_t^n - hc_{t-1}^n = \frac{(1-h)\psi}{1-h+\psi}E_t(c_{t+1}^n - c_t^n) + \frac{(1-h)\psi}{1-h+\psi}q_t^n - \frac{(1-h)^2}{1-h+\psi}i_t^n \tag{10}$$

$$q_t^n = \widetilde{\beta}E_t(q_{t+1}^n) + (1-\widetilde{\beta})E_t(y_{t+1}^n) - i_t^n \tag{11}$$

The variables y_t^n, c_t^n, q_t^n and i_t^n denote the natural rates for output, consumption, stock prices and the interest rate.

The exogenous shocks are the technology shock (a_t), the 'non-fundamental' component of stock prices (e_t), the demand shock (g_t) and the cost-push shock (z_t). These exogenous disturbances follow a first order autoregressive process, i.e., $s_t = \rho_s s_{t-1} + \eta_t^s$, with η_t^s normally distributed with variance σ_s^2 and s belonging to the set $\{a, e, g, z\}$.

The basic parameters are the subjective discount factor(β), the probability that households exit financial markets (γ), the degree of habit persistence in consumption (h), the Calvo parameter (ϕ) measuring the degree of price stickiness, the degree of indexation to past inflation (κ) and the price elasticity of demand for each intermediate good in the production of the final good (θ).

The auxiliary parameters are:

$$\psi = \gamma\frac{1-\beta(1-\gamma)}{1-\gamma}(\frac{Q+D}{C}),\ \widetilde{\beta} = \frac{\beta(1-h)}{(1-h+\psi)} \text{ and } \varphi = \frac{L}{1-L}.$$

The variables Q, D, C and L denote steady-state levels for real asset prices, dividends, consumption and labor, respectively.

3.2 Monetary Policy under Loose Commitment

Roberds (1987), Schaumburg and Tambalotti (2007) and Debortoli et al. (2014) developed the loose commitment approach to monetary policy design. In this framework, central banks have access to a commitment technology, but with some exogenous and publicly known probability they may revise their announced plans. Similar to the Calvo (1983) pricing scheme, the assumption of plans' revisions to be stochastic events, rather than endogenous choices, is a simplification to assure that the monetary policy design problem remains sufficiently tractable.

Alterations in the dominant view within the monetary policy committee, the appointment of a new member of the committee, the arrival of a new chairman, political pressures and the influence of public opinion may lead to a revision of announced policy plans since the commitment technology is limited and cannot guarantee that the central bank keeps the promises it previously made.

Under loose commitment, it is possible to study a continuum of intermediate cases between commitment and discretion and to evaluate the effects of imperfect commitment technologies on macroeconomic dynamics. In addition, agents may interpret the probability of keeping announced policy plans as a measure of the degree of credibility. This interpretation relates credibility to the concept of expected durability of policy commitments as discussed in Schaumburg and Tambalotti (2007), which compared this particular view with alternative perspectives put forth in the literature.

Next, I follow closely Debortoli et al. (2014) and describe the monetary policy design problem under loose commitment.

3.2.1 The loose commitment framework

Consider a linear approximation of a DSGE model given by

$$A_{-1}x_{t-1} + A_0 x_t + A_1 E_t x_{t+1} + B v_t = 0$$

The variable x_t represents a column vector of endogenous variables and v_t is a column vector of serially uncorrelated exogenous disturbances with zero mean and covariance matrix V.

The central bank chooses the best policy by minimizing the intertemporal quadratic loss function $E_{-1}\sum_{t=0}^{\infty}\beta^t x_t^T \overline{W} x_t$ subject to the constraints imposed by private agents' behavior. The symbol x_t^T denotes a row vector obtained by transposing x_t. The matrix $\overline{W}$ of policy weights summarizes the central bank's policy preference concerning the goals of monetary policy.

The central bank honors past commitments with probability ϑ and reneges on previous pledges with probability $1-\vartheta$. Indeed, a two-state Markov stochastic process η_t describes this behavior. This process is such that $\eta_t = 1$ with probability ϑ and $\eta_t = 0$ with probability $1-\vartheta$. In any given period, $\eta_t = 1$ indicates that the central bank keeps its previous promises. On the other hand, $\eta_t = 0$ reveals that it reneges on past announced policy plans and reoptimizes starting at date t. Finally, in this context, it is natural to see the probability ϑ as an index of credibility, with $\vartheta = 1$ corresponding to full commitment and $\vartheta = 0$ representing discretion.

The optimization problem for the central bank is:

$$x_{t-1}^T \overline{P} x_{t-1} + f = \min_{\{x_t\}_{t=0}^{\infty}} E_{-1}\sum_{t=0}^{\infty}(\beta\vartheta)^t \left[x_t^T \overline{W} x_t + \beta(1-\vartheta)\left(x_t^T \overline{P} x_t + f\right)\right]$$

subject to:

$$A_{-1}x_{t-1} + A_0 x_t + \vartheta A_1 E_t x_{t+1} + (1-\vartheta) A_1 E_t x_{t+1}^{reop} + B v_t = 0$$

The value function at time t is $x_{t-1}^T \overline{P} x_{t-1} + f$, which is a quadratic expression in the state vector x_{t-1}. The quadratic format for the value function is a feature of the linear-quadratic optimization problem above.

In the objective function, the infinite sum discounted at the rate $\beta\vartheta$ represents the history in which reoptimizations never occur. Each term in the summation has two components, the first component is the period loss function and the second indicates the value the central bank gains if a reoptimization occurs in the next period.

The sequence of constraints hinges on the equations describing the linear approximation of the DSGE model. However, the expectation of the vector comprising future variables is now a weighted average between x_{t+1} and x_{t+1}^{reop}, with weights ϑ and $1-\vartheta$. The vector x_{t+1} reflects the case in which the central bank will honor current plans and x_{t+1}^{reop} represents the choices in period $t+1$ that will result from the reoptimization, after the central bank reneges on its promises.

Debortoli et al. (2014) developed and described a numerical algorithm to solve the central bank's problem, which I use in this paper. The solution involves the characterization of the matrices H and G in order to write the policy function in the following form:

$$\begin{bmatrix} x_t \\ \lambda_t \end{bmatrix} = H \begin{bmatrix} x_{t-1} \\ \eta_t \lambda_{t-1} \end{bmatrix} + G v_t$$

where λ_t stands for the vector of Lagrange multipliers.

After the solution procedure finds the policy function representation above, it is straightforward to simulate the model for different realizations of the shocks as long as one specifies a history for η_t.

Next, I discuss the specification of the one-period loss function $x_t^T \overline{W} x_t$.

3.2.2 The loss function

The formulation of a Ramsey policy problem, in which a benevolent planner maximizes the utility of the representative household, is theoretically the best approach from a public finance perspective. In the context of the model presented in appendix A, the analytical derivation of the loss function as an approximation of households' utility is a challenging task beyond the scope of this paper.

The challenge lies on the aggregation of preferences across agents belonging to different cohorts. Nevertheless, Nisticò (2016) pioneered a welfare-based analysis in the context of the Blanchard-Yaari new Keynesian framework, considering a model without habit formation and inflation indexation. For this simpler situation, he provided a quadratic approximation of households' utility, which highlighted the role of wealth or the stock price as an argument of the loss function.

From an empirical perspective, a disadvantage of his formulation hinges however on the fact that households' preferences constrain the welfare-based objective function by imposing highly nonlinear structural restrictions, which are most likely misspecified. To avoid this drawback, the empirical papers on optimal policies in dynamic stochastic general equilibrium models, such as Söderström et al. (2005) and Ilbas (2012), employed ad hoc loss functions.

In contrast to the welfare-based approach, I assume that the central bank follows a mandate and I postulate an ad hoc loss function summarizing the objectives of monetary policy according to this mandate. The specification of an ad hoc loss function leads to free parameters concerning the weights on specific goals, which are defined in the central bank's mandate. This modelling avenue is a sensible strategy since the calibration seeks to pin down these weights in order to infer the relative importance of targets that the central bank may care about in each subsample.

The one-period ad hoc loss function includes inflation, the output gap, a smoothing component for the interest rate and the stock price gap. The central bank targets these variables, which are the goals of monetary policy, according to the following objective function.

$$Loss_t = x_t^T \overline{W} x_t = \pi_t^2 + \omega_y y_t^2 + \omega_i (i_t - i_{t-1})^2 + \omega_q q_t^2$$

The weights ω_y, ω_i and ω_q summarize the central bank's preferences concerning these goals. When calibrating the model, I allow the matching moments procedure to freely pin down these parameters, subject only to non-negativity constraints.

The first term establishes inflation stabilization as a monetary policy goal and the term $\omega_y y_t^2$ concerns the output gap stabilization.

The term $\omega_i(i_t - i_{t-1})^2$ describes a preference for interest rate smoothing. Central banks typically set policy by changing incrementally the policy rate and many papers, including Söderström et al. (2005) and Ilbas (2012), have included the change in the interest rate in the loss function. These papers have also argued that adding this term in the loss function is relevant for capturing movements in interest rates observed in U.S. data.

According to its assigned mandate, the central bank also pursues the stabilization of the stock price gap, which corresponds to the term $\omega_q q_t^2$. I include this term to take into account the results in Nisticò (2016), showing that financial stability may arise as an additional and independent monetary policy goal, besides the usual concern with inflation and the output gap stabilization.

4 Quantitative Analysis

The empirical evidence documents weak effects of monetary policy shocks on stock returns and inflation during the Great Moderation. From the vantage point of the loose commitment framework, this minor role for monetary policy shocks indicates an improvement in credibility as a potential contributing factor explaining the change in the correlation between these two variables.[11].

In this section, I calibrate a simple model, including the parameters describing the central bank's behavior, to evaluate the relevance of credibility as an element that helps the understanding of the decline in magnitude of the negative comovement between stock returns and inflation.

4.1 Calibration

To calibrate the model, I first set the values of some parameters according to the literature. Next, for the remaining ones, I choose their magnitudes aiming at maximizing the model's ability to reproduce key moments concerning inflation, the nominal interest rate, the output growth rate and real stock returns. I do not use correlations based on Den Haan (2000) methodology as targeted moments since one of the goals of this paper is to gauge the model's ability to replicate these features in each subsample.

From the literature, I choose the values of the following parameters: β, θ, ϕ and φ. Irrespective of the subsample considered, the benchmark calibration sets $\beta = 0.9925$, $\theta = 10$, $\phi = 0.75$ and $\varphi = \frac{1}{3}$. I group the remaining

[11] The loose commitment framework interprets the importance of monetary policy shocks as more frequent reoptimizations and thus less credibility.

parameters in three categories: monetary policy parameters (mp), private sector parameters (ps) and parameters governing the AR(1) processes for the disturbance specifications (ds). I define the following vectors according to each category:

$$mp = [\omega_y \ \omega_i \ \omega_q \ \vartheta], \ ps = [h \ \kappa \ \psi] \text{ and } ds = [\rho_a \ \rho_z \ \rho_e \ \rho_g \ \sigma_a \ \sigma_z \ \sigma_e \ \sigma_g]$$

The vector of calibrated parameters is:

$$\chi = [\omega_y \ \omega_i \ \omega_q \ \vartheta \ h \ \kappa \ \psi \ \rho_a \ \rho_z \ \rho_e \ \rho_g \ \sigma_a \ \sigma_z \ \sigma_e \ \sigma_g]$$

Following Jermann (1998), Palomino (2012), Cassou and Vázquez (2014) and Pancrazi (2014), I calibrate the parameters in the vector χ to enable the model to match some moments from the data as close as possible[12].

If M_T denotes the set of moments from the data and $M(\chi)$ stands for the moments computed by simulating the model, the choice of χ minimizes the following quadratic expression:

$$[M_T - M(\chi)]' \, [M_T - M(\chi)]$$

The vectors M_T and $M(\chi)$ comprise the following moments:

- standard deviation: inflation $\sigma(\pi)$, the nominal interest rate $\sigma(i)$, the output growth rate $\sigma(\Delta y)$ and real stock returns $\sigma(sr)$.
- first order autocorrelation: inflation $\rho_1(\pi)$, the nominal interest rate $\rho_1(i)$ and the output growth rate $\rho_1(\Delta y)$.
- second order autocorrelation: inflation $\rho_2(\pi)$, the nominal interest rate $\rho_2(i)$ and the output growth rate $\rho_2(\Delta y)$.

[12] An alternative strategy is to perform a simulated method of moments (SMM) estimation. Instead, I choose to calibrate the model because the focus of the paper is not on statistical inferences about specific parameters.

- correlation coefficient between the following pair of variables: inflation and the nominal interest rate $\rho(\pi, i)$, inflation and the output growth rate $\rho(\pi, \Delta y)$, inflation and real stock returns $\rho(\pi, sr)$, the nominal interest rate and real stock returns $\rho(i, sr)$, the output growth rate and real stock returns $\rho(\Delta y, sr)$.

For each subsample, Table 3 shows the targeted empirical moments as well as the simulated moments based on the benchmark calibration of the model. For each period of analysis, Table 4 presents the calibrated vector χ under the benchmark calibration.

As reported in Table 3, the model replicates relatively well standard deviations and first order autocorrelations. It shows difficulties in reproducing the correlations between macroeconomic variables and stock returns. In the pre-Great Moderation subsample, the signs of these statistics though are always correct. In contrast, the model misses the sign of $\rho(\Delta y, sr)$ during the Great Moderation.

According to Table 4, in both periods, the calibration of the Fed's loss function points to small figures for ω_y and ω_q. During the pre-Great Moderation period ω_i is high and the calibrated degree of credibility ϑ is extremely low, suggesting a discretionary monetary policy. During the Great Moderation, the calibration indicates a decrease in ω_i and a considerable increase in the probability of keeping announced promises, implying a shift to a more credible monetary policy.

In short, the change in the conduct of monetary policy involves modified weights in the loss function and a substantial increment in credibility. In the first subsample, a high value for ω_i reflects the importance of stabilizing interest rate movements, which tend to be more violent if monetary policy is close to discretion. The role of the Fed's relative concern for price stability against fluctuations in the output gap is not relevant in accounting for the changes in monetary policy during the Great Moderation. The improvement in credibility stands as the major development in shifting the central bank's behavior.

The inspection of Table 4 reveals changes in the private sector parameters across subsamples. For instance, during the Great Moderation, there is a substantial reduction in κ and a significant increase in ψ, indicating less indexation to past inflation and a strong wealth effect on consumption. In addition, parameters governing the AR(1) processes for the disturbances are very different across periods, though technology shocks are always very persistent and volatile.

4.2 Results

The second column of Figure1 and Figure 2 display the comovement statistics $corr(h)$ implied by the model under alternative calibrations. I exhibit the mean across 1500 replications and also provide 90% confidence intervals based on the estimated bivariate VAR discussed in subsection 2.2. In each replication, I generate artificial series of length 500 for real stock returns and inflation. Then, I compute the comovement statistics proposed by Den Haan (2000) by applying the procedure described in subsection 2.2 to these artificial time series.

4.2.1 The Benchmark Calibration

The second column of Figure1 exhibits the comovement statistics $corr(h)$ associated with the benchmark calibration. Qualitatively, the model reproduces the decline in the magnitude of the negative relationship between real stock returns and inflation across subsamples, though it is not able to replicate the dynamic pattern of $corr(h)$ in the first column of Figure 1. For $h = 1$, in the first period, the model delivers a correlation outside the upper band and, during the Great moderation, the initial movements in $corr(h)$ are very smooth compared with the second row of the first column of Figure 1.

The model is relatively more successful in the Great Moderation subsample since the mean of the simulated values for $corr(h)$ is always within the 90% bands. On the other hand, in the pre-Great Moderation subsample, for $h = 1$, the model generates a negative comovement that is much less stronger than the observed comovement in the first column of Figure 1. Indeed, this finding suggests that the assumption of optimal monetary policy seems to be an adequate description of the monetary policy stance during the Great Moderation but less justifiable in the pre-Great Moderation period.

4.2.2 Alternative Calibrations

Figure 2 presents the comovement statistics $corr(h)$ associated with alternative calibrations concerning the fixed parameters θ and ϕ. The first column of Figure 2 displays $corr(h)$ for cases in which θ equals 6 and 21, respectively. The second column of Figure 2 shows $corr(h)$ in simulations fixing the Calvo probability ϕ in 0.6 or 0.9. The first row of Figure 2 concerns the first subsample while the second row regards the Great Moderation era. In all simulations, I recalibrate the remaining parameters according to the matching moments procedure. For the sake of brevity , I do not report the recalibrated parameters.

The inspection of the first column of Figure 2 indicates that a very high elasticity of substitution, which corresponds to a smaller price mark-up in the steady-state, allows the model to generate stronger negative comovement between stock returns and inflation. For $\theta = 6$, the initial positive correlation becomes stronger in the first subsample and it is still positive in the second subsample, but the magnitude is small.

Concerning the Calvo probability ϕ, small degrees of price rigidity lead to stronger negative comovement between stock returns and inflation in the first subsample. The initial positive correlation remains under the alternative calibrations. During the Great Moderation, the results are very similar and do not depend on the calibrated value for ϕ.

Overall, for alternative values of θ and ϕ, which I fix *a priori*, the model shows a satisfactory performance in replicating approximately the comovement statistics, especially in the long run.

4.2.3 Understanding the role of monetary policy credibility during the Great Moderation

For the Great Moderation era, Figure 3 shows the comovement statistics $corr(h)$ for the following counterfactual situations: a) $\vartheta = 0.2$; b) $\kappa = 0.7$; c) $\psi = 0.05$ and d) $\omega_i = 5$. I set the remaining parameters according to the benchmark calibration associated with the second subsample.

The first row of Figure 3 depicts cases (a) and (b), while the second row contemplates cases (c) and (d). Inspecting Figure 3 and comparing it with the benchmark case, one can see that low ϑ, high κ, low ψ and high ω_i lead to more negative comovement statistics, which is an outcome qualitatively similar to the first subsample.

As described in Figure 3, the strongest negative comovement regards small ϑ and large κ. Indeed, $\vartheta = 0.2$ corresponds to a low degree of credibility and $\kappa = 0.7$ represents a situation in which forward-looking behavior in price-setting plays a secondary role. In this last case, even a central bank with credibility is unable to use expectations as a transmission channel in its full extent. Therefore, the outcomes of full commitment and discretion are very similar.

To understand the role of monetary policy credibility, I plot impulse responses concerning technology shocks since they induce the strongest initial reactions of inflation and stock returns. As Table 4 shows, this particularity happens because the size of one standard deviation impulse in technology is relatively large compared with alternative shocks. As shown in Den Haan (2000) and discussed in María-Dolores and Vázquez (2008), the covariance between the forecast errors related to two variables is the sum of the products of the two variable impulses across different economic shocks. This result connects the initial patterns of impulse responses with the comovement statistics $corr(h)$.

Figure 4 and 5 show impulse responses to technology shocks for the benchmark calibration and for the situation in which $\vartheta = 0.2$ and the specification of all the remaining parameters agrees with the third column of Table 4. In both parameterizations, κ is small and the more credible central bank uses expectations to achieve a more favorable current output-inflation tradeoff, avoiding an excessive stabilization of the output gap. In addition, the consumption-wealth effect is strong.

According to Figure 4, the impulse to the shock a_t moves inflation and stock returns in opposite directions on impact. More credibility leads, initially, to a less negative inflation response and a less positive stock return response. This behavior engenders a weak negative comovement between the two variables in the benchmark case with high credibility.

This pattern of response is due to gradual movements in monetary policy introduced by credibility, leading to an initial moderate drop in interest rates. Indeed, the central bank promotes this mild interest rate cut right after the favorable technology shock because it credibly promises a specific future path for inflation and the output gap. This promise affects expectations and is compatible with a smaller deflation today, as well as a small cost in terms of the output gap, because expectations are more stable and influence these variables contemporaneously with more intensity.

Figure 5 shows the repercussions of monetary policy on financial variables. Stock prices rise with the technology shock but dividends increase mildly in the benchmark case with high credibility. Hence, the dividend-price ratio drops more leading to a small increase in stock returns in the benchmark situation. The initial rise in the stock price gap refrains the initial drop in the output gap through the consumption-wealth effect. The modest movement in dividends, on impact, reflects the stability of expectations brought about by a more credible central bank under the benchmark calibration.

5 Conclusion

Empirical studies have documented a negative relationship between real stock returns and inflation in the U.S. post-war data, which experienced a decline in its magnitude during the Great Moderation. This paper revisited this empirical evidence on the comovement between stock returns and inflation for the following subsamples: pre-Great Moderation (from 1960:Q1 to 1979:Q3) and the Great Moderation period (from 1984:Q1 to 2007:Q4). I then numerically characterized optimal monetary policy under loose commitment in a calibrated DSGE model in which stock prices directly influenced macroeconomic dynamics. The goal was to gauge the role of an increase in credibility as a factor explaining the documented decline in the magnitude of the comovement statistics.

In fact, I considered the role of monetary policy credibility as a complementary element to the well studied effects of changes in parameters describing macroeconomic shocks and to the role of the Fed's relative concern for price stability against fluctuations in the output gap, which was not relevant according to the benchmark calibration based on a matching moments procedure. On the other hand, this same parameterization featured a significant degree of credibility, allowing the model to qualitatively replicate the weakening of the negative relationship between real stock returns and inflation during the Great Moderation.

Though I looked at a particular episode in US economic history, i.e. the Great Moderation era, the influence of credibility on the comovement between stock returns and inflation is not limited to this case, suggesting that improvements in the conduct of monetary policy have an effect on this comovement not only by changing the relative importance of macroeconomic variables as monetary policy objectives, but also by increasing the degree of credibility of a central bank.

APPENDIX A : The model

This appendix presents details of the model presented in subsection 3.1. The economy consists of overlapping generations of households and a continuum of firms indexed by $j \in [0, 1]$. The model abstracts from capital accumulation and features price stickiness.

- **Households**

At a given time t, a new generation of consumers with uncertain lifetimes is born. Let γ be the probability of dying before the next period begins. One can think of γ as the probability that households exit markets and therefore their decision-making process does not affect the economy.

The size of cohort s at time t is given by $n_{s,t} = n\ (1-\gamma)^{t-s}$. Thus, the aggregate population can be computed as $n_t = \sum_{s=-\infty}^{t} n(1-\gamma)^{t-s} = \frac{n}{\gamma}$.

Assuming zero population growth, n_t can be normalized to 1. Therefore, $n = \gamma$ is the size of a new generation born at time t. Since population is constant, a fraction of equal size is dying.

I consider a cashless economy in which a representative consumer belonging to a generation born at s faces the following optimization problem:

$$Max\ E_0 \sum_{t=0}^{\infty} \beta^t (1-\gamma)^t [\log(\widetilde{C}_t(s)) + \varkappa \log(1 - L_t(s))]$$

The variable $\widetilde{C}_t(s) = C_t(s) - hC_{t-1}$ represents preferences with external habits, in which the parameter h governs habit persistence and C_t denotes aggregate consumption.

The budget constraint is:

$$P_t C_t(s) + E_t\left[\mathcal{F}_{t,t+1} B_{t+1}\right] + P_t \int_0^1 Q_t(j) Z_{t+1}(s,j) dj \leq W_t L_t(s) + \omega_t(s)$$

The variables are consumption $C_t(s)$, labor $L_t(s)$, a portfolio of shares $Z_t(s,j)$, whose real price is $Q_t(j)$, which are issued by a continuum of firms indexed by j. In addition, $E_t\left[\mathcal{F}_{t,t+1} B_{t+1}\right]$ is the portfolio of state-contingent claims, paying B_{t+1} the next period and $\mathcal{F}_{t,t+1}$ is the stochastic discount factor. W_t is nominal wage and $\omega_t(s)$ is the amount of financial wealth belonging to the representative consumer from the generation born at s. Finally, β is the subjective discount factor and $\varkappa$ is a preference parameter.

- **Firms and Price-Setting Behavior**

The production function $Y_t(j) = A_t L_t(j)$ describes the technology for firm j. The variables $Y_t(j)$ and $L_t(j)$ represent output and work-hours hired from households; and the technology shock is A_t . The aggregate output is given by $Y_t = \left(\int_0^1 Y_t^{\frac{\theta-1}{\theta}}(j)dj \right)^{\frac{\theta}{\theta-1}}$, where θ is the elasticity of substitution. The price charged by firm j is $P_t(j)$ and the aggregate price level is P_t. The aggregate real marginal costs are $MC_t = \frac{1}{A_t}\frac{W_t}{P_t}$.

Firms operate in a monopolistic competitive market and set prices in a staggered fashion using the scheme proposed by Calvo (1983). According to Calvo (1983), only a fraction of firms, given by $(1-\phi)$, is able to adjust prices. Therefore, each period, these firms reset their prices to maximize expected profits.

Following, Christiano, Eichenbaum & Evans (2005), I introduce an indexation mechanism in which firms that do not set prices optimally at time t will adjust their prices to lagged inflation, according to the equation $P_{t+\tau}(j) = P_{t+\tau-1}(j)(\Pi_{t+\tau-1})^{\kappa}$, where the parameter κ indicates the degree of price indexation and π_t denotes inflation. This framework for price-setting behavior leads to a hybrid specification for inflation dynamics. Thus, inflation is a forward-looking variable, but some backward-looking component is necessary to describe inflation dynamics.

When the Calvo mechanism allows a firm to adjust its price, it chooses the new price P_t^* to maximize expected future profits. Hence, the price-setting problem is the following:

$$\underset{P_t^*}{Max}\ E_t \sum_{\tau=0}^{\infty} \phi^{\tau} \mathcal{F}_{t,t+\tau} \left\{ \begin{array}{c} \left[\frac{P_t^*}{P_{t+\tau}} \Pi_{t-1,t+\tau-1}^{\kappa} - MC_{t+\tau} \right] \\ \left(\frac{P_t^*}{P_{t+\tau}} \Pi_{t-1,t+\tau-1}^{\kappa} \right)^{-\theta} Y_{t+\tau} \end{array} \right\}$$

The variable $\mathcal{F}_{t,t+\tau}$ is the stochastic discount factor and $\Pi_{t-1,t+\tau-1}$ is the accumulated inflation rate between $t-1$ and $t+\tau-1$.

- **Main Equilibrium Conditions**

Following Nisticò (2012), after solving the optimization problems for households and firms, I aggregate across generations to write the set of non-linear conditions that characterizes the equilibrium. Next, I present these expressions.

$$\frac{\beta(1-\gamma)}{1-\beta(1-\gamma)}\left(C_t - hC_{t-1}\right) = \gamma Q_t + \frac{(1-\gamma)}{1-\beta(1-\gamma)} E_t[\mathcal{F}_{t,t+1}\frac{P_{t+1}}{P_t}\left(C_{t+1} - hC_t\right)]$$
$$Q_t = E_t[\mathcal{F}_{t,t+1}\frac{P_{t+1}}{P_t}(Q_{t+1} + D_{t+1})]$$
$$SR_t = \frac{Q_t + D_t}{Q_{t-1}}$$
$$D_t = Y_t(1 - MC_t)$$
$$\frac{P_t^*}{P_t} = \frac{\theta}{\theta - 1}\frac{X_{1t}}{X_{2t}}$$
$$X_{1t} = MC_t Y_t + \phi \Pi_t^{-\kappa\theta} E_t\left[\mathcal{F}_{t,t+1}\Pi_{t+1}^{\theta} X_{1t+1}\right]$$
$$X_{2t} = Y_t + \phi \Pi_t^{\kappa(1-\theta)} E_t\left[\mathcal{F}_{t,t+1}\Pi_{t+1}^{\theta-1} X_{2t+1}\right]$$
$$1 = \left[\phi\left(\frac{(\Pi_{t-1})^{\kappa}}{\Pi_t}\right)^{1-\theta} + (1-\phi)(\frac{P_t^*}{P_t})^{1-\theta}\right]^{\frac{1}{1-\theta}}$$
$$MC_t = \frac{\varkappa(C_t - hC_{t-1})}{A_t - PD_t Y_t}$$
$$PD_t = (1-\phi)\left(\frac{P_t^*}{P_t}\right)^{-\theta} + \phi\left(\Pi_{t-1}^{-\kappa\theta}\Pi_t^{\theta}\right) PD_{t-1}$$
$$Y_t = C_t + G_t$$
$$\frac{\varrho_t^g}{1+\varrho_t^g} = \frac{G_t}{Y_t}$$

The new auxiliary variables are X_{1t}, X_{2t} and ϱ_t^g. I need the first two to write the new Keynesian Phillips curve recursively and, after the log-linearization, the variable $1+\varrho_t^g$ corresponds to g_t. In addition, PD_t denotes the price dispersion due to the presence of nominal price rigidity. Regarding the remaining variables, I have already defined them in the body of the paper. In this appendix, I use the same notation of subsection 3.1, but now I employ capital letters to emphasize that I am considering the variables in level rather than a log-linear approximation.

Finally, in the log-linear new Keynesian Phillips curve, I introduce the cost push shock z_t. Researchers often model this type of disturbance as a shock to the elasticity θ, capturing a time-varying degree of market power for the firm producing good $Y_t(j)$. This approach leads to the same log-linear approximation presented in subsection 3.1. Thus, I choose a more direct route and incorporate z_t in an *ad hoc* way.

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TABLES

Table 1. Percentage due to monetary policy shocks : pre − Great Moderation

Horizon	*Variance Decomposition*	*Variance Decomposition*	*Covariance Decomposition*
h quarters	π_t	sr_t	π_t *and* sr_t
3	17.8105 (6.7757)	8.4299 (6.5643)	36.0994 (12.5030)
6	22.3303 (6.9130)	9.6226 (6.0365)	31.2502 (8.9905)
12	23.7047 (6.8913)	10.9396 (5.6946)	30.2863 (8.0460)
18	25.0531 (7.8027)	11.2275 (5.6830)	30.7967 (8.1998)
24	24.8392 (7.8175)	11.1892 (5.7022)	30.3958 (8.1698)
32	24.9211 (8.0432)	11.4066 (5.7902)	30.6023 (8.3198)

Note: Bootstrapped standard errors in parenthesis

Table 2. Percentage due to monetary policy shocks : Great Moderation

Horizon	*Variance Decomposition*	*Variance Decomposition*	*Covariance Decomposition*
h quarters	π_t	sr_t	π_t *and* sr_t
3	0.5320 (2.1325)	2.7744 (3.3215)	2.0681 (3.3851)
6	0.3831 (2.9399)	1.6952 (3.2656)	0.4794 (3.4452)
12	0.2902 (2.8910)	0.7830 (2.4848)	0.3718 (2.8115)
18	0.1505 (2.7522)	0.7472 (2.1074)	0.2146 (2.5825)
24	0.1385 (2.7085)	0.6027 (2.3022)	0.1692 (2.4273)
32	0.1703 (2.5617)	0.8073 (2.9134)	0.2920 (2.5138)

Note: Bootstrapped standard errors in parenthesis

Table 3. Moments for the Benchmark Calibration

Targeted	Pre − Great Moderation		Great Moderation	
Moments	Data	Benchmark	Data	Benchmark
$\sigma(\pi)$ in %	0.6819	0.5431	0.2403	0.2709
$\sigma(i)$ in %	0.6177	0.7061	0.5903	0.5992
$\sigma(\Delta y)$ in %	0.9922	1.0122	0.5093	0.5434
$\sigma(sr)$ in %	5.8512	5.8501	5.5897	5.5873
$\rho_1(\pi)$	0.8473	0.8243	0.5357	0.5904
$\rho_1(i)$	0.9039	0.9242	0.9568	0.9906
$\rho_1(\Delta y)$	0.2092	0.2149	0.2311	0.2428
$\rho_2(\pi)$	0.7707	0.6062	0.4607	0.4102
$\rho_2(i)$	0.7738	0.7676	0.8899	0.9685
$\rho_2(\Delta y)$	0.1894	0.2426	0.3237	0.2807
$\rho(\pi, i)$	0.8322	0.9091	0.3739	0.4001
$\rho(\pi, \Delta y)$	−0.3110	−0.1996	−0.1773	−0.2144
$\rho(\pi, sr)$	−0.2894	−0.3797	−0.0041	−0.0241
$\rho(i, sr)$	−0.4227	−0.3041	0.2077	0.1493
$\rho(\Delta y, sr)$	0.2748	0.3002	0.0840	−0.0987

$Table\ 4.\ Calibrated\ Parameters : Benchmark$

$Parameters\ (\chi)$	$Pre - Great\ Moderation$	$Great\ Moderation$
ω_y	1.16×10^{-9}	0.0092
ω_i	5	0.5131
ω_q	0.0705	0.0015
ϑ	≈ 0	0.8669
h	0.7377	0.8998
κ	0.95	0.0019
ψ	0.082	0.4957
ρ_a	0.99	0.9899
ρ_z	0.1194	0.6601
ρ_e	0.0805	9.16×10^{-4}
ρ_g	0	0.4094
σ_a	0.0173	0.0144
σ_z	9×10^{-4}	0.0021
σ_e	0.0512	0.0033
σ_g	0.004	0.0011