

# “Monetary Rules, Financial Stability and Welfare in a non-Ricardian Framework”

Francisco Adame-Espinosa\*

Banco de México

July 28, 2023

## Abstract

This paper studies the implications for optimal monetary policy associated to the wealth effects induced by stock-price dynamics within a non-Ricardian framework. We use a new Keynesian model incorporating households with perpetual youth to study whether a monetary rule responding to asset price fluctuations could find sizeable welfare improvements with respect to pursuing a policy tracking flexible price allocations. First, we find that, for different types of shocks (i.e. productivity, demand, and financial), pursuing optimal policies can provide sizeable reductions in the social welfare loss with respect to flexible price allocations. Second, we study whether a monetary policy rule tracking the natural rate and responding to asset price fluctuations can attain reductions in the welfare losses close to the magnitude found by pursuing optimal policies. We find that such a rule is effective to attain optimal outcomes when the economy faces productivity shocks and financial shocks. However, we find that such rule can attain marginal reduction in the welfare losses when the economy faces demand shocks.

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\*I am grateful to Salvatore Nisticò, Julio Carrillo, Rocío Elizondo-Camejo and Ángel Gutiérrez-Daza.



# 1 Introduction

The monetary policy literature has documented contrasting points of view about how the central bank should react to shocks affecting financial markets. On the one hand, there is the view of Bernanke and Gertler (2001) that an inflation-targeting (IT) framework should not respond to stock price fluctuations. They advocate that that stabilizing stock prices may lead to a negative effect by disturbing output dynamics. On the other hand, Cecchetti et al. (2000) suggest that a central bank should “lean against the wind” and achieve a greater macroeconomic stabilization by including asset prices in its loss function. Both approaches have focused on the effects that asset price fluctuations could have in the supply-side of the real economy mainly to channels of financial intermediation. However, less attention is drawn to the effects that asset prices could have in the demand-side of the economy.

A channel through which asset price fluctuations could have influence on aggregate demand is by affecting household’s financial wealth. Therefore, a drop in stock prices decreases the wealth of households owning stocks. Empirical literature has shown that this channel is particularly sizeable in developed economies.<sup>1</sup> Based on textual analysis of the FOMC minutes and transcripts, recent literature finds that this channel is of particular interest for the Federal Open Market Committee (FOMC) participants.<sup>2</sup> In this paper, we study theoretically how this channel can be incorporated in the design of optimal monetary policy for an economy that faces different types of uncertainty (i.e. productivity, demand and financial shocks). Also, we study whether, in the presence of this channel, monetary rules can be implemented to reproduce optimal policy allocations.

By using a non-Ricardian framework, we study whether a monetary authority is able to implement a policy that allows them to attain optimal social welfare outcomes in an economy where the demand-side is sensitive to fluctuations in financial wealth. To this aim, first, we quantify the reduction of the social welfare loss that results from conducting optimal policy, under commitment and discretion, instead of an IT regime that pursues allocations consistent with flexible prices. We conduct this analysis by considering the existence of different types of shocks which affect financial wealth fluctuations.

Second, we quantify the welfare loss that arises when the central bank conducts its policy through a monetary rule that tracks the natural rate and incorporates a response to asset prices. We use a rule with these features to characterize the case of a monetary authority transiting from an IT regime to a regime that incorporates the importance of financial wealth stabilization. We illustrate the effectiveness of these rule to reproduce optimal policies under discretion and commitment. In the case of productivity and financial shocks, we find that this rule

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<sup>1</sup>While Review (2021) estimates the importance of the wealth effect for the US, of Finance (2020) estimates size of this channel for Sweden.

<sup>2</sup>Cieslak and Vissing-Jorgensen (2021) show that policy makers has a tendency to pursue analysis on asset prices as they see them as an important driver of household’s financial wealth.



is able to reproduce the outcomes from an optimal policy under commitment. However, in the case of demand shocks, the reduction in the welfare loss is limited.

Drawing in Nisticò (2016), we use a model which introduces a perpetual-youth assumption into the standard new-Keynesian model of the business cycle. This model features segmentation of the asset market participants. Every period, agents are ex-ante identical and face an idiosyncratic probability in their ability to participate in financial markets for the rest of their lives. Whereas not active participants use only their labor income to finance consumption, active participants use a financial asset to smooth consumption considering the uncertainty in their future access to financial markets. Crucially, agents not able to participate in financial markets are replaced by new agents with zero financial assets.

While incumbent market participants with accumulated wealth can use it to satisfy their consumption, new participants are constrained in their consumption as they do not have financial wealth. The turnover of market participants leads to a condition where financial wealth becomes relevant to determine aggregate consumption. As a result, the interaction of agents with accumulated wealth and those with zero wealth drives a wedge in the aggregate Euler equation. Notably, this feature allows to represent a channel where fluctuations in assets prices are transmitted to the real economy through the aggregate demand in a small-scale new Keynesian model.

In this setup, Nisticò (2016) analytically derives a second-order approximation of the social welfare loss function which incorporates the heterogeneity within and across cohorts that results from differences in accumulated wealth. The result, is a loss function that increases with quadratic deviations of inflation, output, and financial wealth from its steady state. The rationale for the undesirability of fluctuations in financial wealth is that it increases consumption dispersion across cohorts. By modelling the response to productivity shocks, this author showed quantitatively that there is an important reduction in the welfare loss when a central bank pursues optimal policies that reduces the volatility in financial wealth.

We extend the results from Nisticò (2016) and incorporate the shocks affecting household's marginal utility and shocks affecting fundamental asset prices, i.e. demand and financial shocks, respectively. We compare the optimal policy with respect to an economy that pursues IT by following flexible prices allocations, i.e. zero-inflation and output at its natural level. In the case of a demand shock, under discretion the welfare loss is reduced to about 45% of the loss under an IT regime and about to 41% under commitment. In the case of a financial shock, under discretion the welfare loss is reduced to about 62% and to 59% under commitment. While pursuing optimal policies can bring sizeable reductions in the welfare loss for a central bank pursuing strict IT, it is not clear whether these outcomes can be implemented through traditional monetary rules.



Accordingly, we quantify the reduction of the welfare loss when monetary policy is implemented through monetary rules. We consider a simple monetary rule, responding to inflation and output gap, and an augmented rule that also incorporates a response to asset prices. A rationale for introducing asset prices in the rule is that these are an intermediate target to stabilize fluctuations in financial wealth. In the model, financial wealth depends on the dividends paid by the corporate sector and future asset prices. For instance, a sudden increase in financial wealth can be dampened by a tightening in the policy rate which reduces assets market valuation through the discount rate. Also this rule tracks the fluctuations of the natural rate. This feature is introduced to illustrate the potential welfare improvements that an economy which pursues an IT regime can attain by including considerations in financial wealth.

While we find that an augmented rule to include fluctuations in asset prices can reproduce the outcomes of the optimal policy under discretion for financial and productivity shocks, this rule is less effective when the economy faces demand shocks. Under financial and productivity shocks, this augmented rule allows to reduce the welfare loss to 65% of the level quantified under an IT regime, for both shocks. However, under demand shocks, the welfare loss is reduced to 86% of the loss observed under an IT regime. Also, the augmented monetary rule provides even worse welfare benefits as demand shocks become more persistent. A sensitivity analysis, also shows that the welfare benefits of implementing such a rule can even be worse than pursuing an optimal policy which ignores the importance of the wealth dynamics as in a flexible inflation targeting regime. Moreover, simple monetary rule stabilizing only output and inflation fluctuations provide null improvements in terms of welfare benefits.

These results suggest that, in a New Keynesian non-Ricardian framework, simple deviations from the IT regime through an augmented monetary rule can reproduce optimal outcomes in the face of productivity and financial shocks. Notwithstanding, this rule can provide marginally, or even negative, welfare benefits when the economy faces demand shocks.

**Related literature.** Our paper is related to two strands of the literature which use the new Keynesian non-Ricardian framework to analyse the response of the monetary policy in the presence of the financial wealth-channel that drives aggregate demand. The first strand characterizes monetary rules that allow to find stability in the rational expectations solution of the model. Airaud et al. (2015) show that in this framework with simple monetary rules, the rational expectations equilibrium can be undetermined under standard values of the rule. Furthermore, they show that a mild response to stock prices in the simple monetary rule may restore equilibrium determinacy. Similar to our paper, Nisticò (2012) also uses a monetary rule tracking the natural rate outcomes which is augmented to introduce a response to deviations of the stock-price from its level in the flexible-price allocation. This author finds that an important condition to preserve the rational expectations



equilibrium is that such rule has respond aggressively to inflation. We refrain from evaluating the sensitivity of the equilibrium to several structural parameters. Actually, the combination of parameters used in our model does not introduce rational expectations instability. In contrast, we focus on the potential of monetary rules responding to asset prices to attain optimal outcomes.

Within this framework, a second strand from the literature studies the consequences for the conduction of monetary policy for macroeconomic stability and welfare considerations. Nisticò (2012) study the effectiveness of different monetary rules augmented to respond to asset prices in order to compute an ad-hoc loss function that may represent central bank preferences. This loss function is a weighted average of the variances of inflation, output gap, and interest rates.<sup>3</sup> This author uses this loss function to quantify the optimal response to asset prices and show how structural parameters, affecting determinacy, can affect the magnitude of this response. Unlike this paper, we use a micro-founded social welfare loss that arises from the non-trivial aggregation across cohorts. While we also find optimal values for the response to asset prices, we use this parameter to calibrate a monetary rule that tries to mimic optimal policies. We use this rules to quantify the potential of monetary rule to attain optimal outcomes.

Also in this strand we identify the influential contribution of Nisticò (2016). As explained before we extend this work in two directions. First, we introduce demand and financial shocks in order to quantify the welfare improvement that an economy can attain if it transits from an strict IT to a regime that attain socially optimal outcomes. A second extension, is to evaluate the potential of monetary rules to reproduce optimal policies. We provide a novel finding showing that, within this framework, monetary rules are effective to reproduce socially outcomes when the economy faces productivity and financial shocks. However, the effectiveness of such rules is reduced when the economy faces demand shocks.

The paper is also related to a literature which study the empirical tendency of negative stock market returns to be followed by monetary policy easing in the US, also called the FED put.<sup>4</sup> Cieslak and Vissing-Jorgensen (2021) show evidence that negative stock market returns are associated with negative updates of the real GDP growth forecasts presented in the FED's monetary policy meetings.

They estimate monetary rules to show that negative stock market returns predict changes in the target rate mainly to its effects on GDP growth forecasts. Using textual analysis, they show evidence where FOMC partici-

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<sup>3</sup>The weights for each volatility is chosen arbitrarily.

<sup>4</sup>The term FED put arises from the analogy to a financial put option. An asset holder with a put option has the right to sell such asset at an strike price which can be higher to market price at the moment of contract's expiration. In that sense, Cieslak and Vissing-Jorgensen (2021) identifies that after mid-1990s the FED decreases their target rate when stock markets prices drop abruptly. In that sense, FED's actions are analogous to a put option as asset holders will be benefited with better prices of those that arise if the target rate would have been not adjusted.



pants update their GDP growth forecasts as they view stock markets returns as an important driver of household's financial wealth and, consequently, on consumption. We contribute to this literature by showing how effective are monetary rules augmented to respond to asset prices to attain the efficient outcomes derived from optimal policy.

The paper is organized as follows. Section 2 shows the model and section 3 shows the optimal problem of the monetary authority. Section 4 presents the quantitative results. First, we explain the parametrization of the model. Second, we quantify the welfare losses under alternative policies. Third, we present an impulse response analysis to explain the mechanisms through which monetary rules can reproduce welfare losses under optimal policies. Finally, we provide a robustness exercise to observe whether the properties of the model holds under different persistence of the shocks. Finally, Section 5 concludes.

## 2 Model

### 2.1 Supply side.

There exists two type of firms: final goods producers and intermediate goods producers. Intermediate good producers supply differentiated goods to final goods producers which transforms these inputs in a final product. While intermediate good producers sell their products as imperfect monopolists, final good producers operate as perfectly competitive firms. Importantly, instead of assuming that intermediate good firms' are evenly distributed across households, as in Nisticò (2012), we consider that these firms issue financial assets which are claims associated to their dividends. This assumption allows to introduce asset prices fluctuation which coupled by the perpetual youth assumption introduce a channel where financial fluctuations affect the real sector of the economy.

#### Final goods producers

Final goods producers are competitive firms and sell a final good,  $Y_t$ , at the aggregate price,  $P_t$ , to households. They have access to a CES technology,  $Y_t = \left[ \int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$ , that is used to combine intermediate goods,  $Y_t(i)$ , that are imperfectable substitutable with elasticity of substitution  $\epsilon$  where we define a markup over marginal costs as  $\mu \equiv \frac{\epsilon}{\epsilon-1}$ . The standard solution of the firm's cost minimizing problems yields that the optimal demand for intermediate goods is  $Y_t(i) = \left[ \frac{P_t(i)}{P_t} \right]^{-\epsilon} Y_t$  where the aggregate final good price index is defined as  $P_t \equiv \left[ \int_0^1 P_t(i)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$ .



### Intermediate goods producers.

There is a continuum of intermediate good producers  $i$  which sell its differentiated good,  $Y_t(i)$ , to final producers. An intermediate good producer  $i$  has access to a constant returns to scale technology,  $Y_t(i) = \exp(a_t)N_t(i)$ . The firm hires labor,  $N_t(i)$ , at the aggregate wage rate,  $W_t$ , and face the productivity shock,  $a_t$ , which follows an autoregressive process  $a_t = \rho_a a_{t-1} + \varepsilon_t^a$  where  $\varepsilon_t^a \sim N(0, \sigma_a^2)$ . Each firm receives a subsidy  $1 - \tau$  over its marginal costs.

The linear technology for production allows to represent a marginal cost which is the same for all intermediate goods producers  $MC_t = \frac{W_t}{\exp(a_t)P_t}$ . Notice that the linearised marginal cost is

$$mc_t = w_t - p_t - a_t. \quad (1)$$

Intermediate goods producers face nominal rigidities as in Calvo (1983). Every period an intermediate good producer is able to either update their prices  $P_t(i)$  with probability  $(1 - \theta)$  or maintain their price fixed,  $P_{t-1}^*(i)$ , as in the previous period with probability  $\theta$ . Hence, the problem of a firm able to update its price at time  $t$  consists of setting an optimal price  $P_t^*(i)$  that maximizes its future stream of profits by taking into account its future marginal costs  $MC_{t+k}$ , the demand for their product  $Y_{t+k}(i)$ , and the probability  $\theta^k$  that it would not be able to reset its prices  $\forall k \geq 0$ . This problem can be characterized as follows

$$\begin{aligned} \max_{P_t^*(i)} \quad & \mathbb{E} \sum_{t=0}^{\infty} \theta^k \mathcal{F}_{t,t+k} Y_{t+k}(i) [P_t^*(i) - (1 - \tau)P_{t+k} MC_{t+k}] \\ \text{s.t} \quad & \\ & MC_{t+k} = \frac{W_{t+k}}{\exp(a_{t+k})P_{t+k}} \\ & Y_{t+k}(i) = \left[ \frac{P_t^*(i)}{P_{t+k}} \right]^{-\epsilon} Y_{t+k} \end{aligned} \quad (2)$$

where  $\mathcal{F}_{t,t+k}$  is the discount factor of the households. The optimal price is a weighted sum of future discounted markups over marginal cost:

$$P_t^*(i) = \mathbb{E}_{t,k=0}^{\infty} \omega_{t,t+k} (1 + \mu) P_{t+k} MC_{t+k} \quad (3)$$

where  $\omega_{t,t+k}$  is the income discount factor for the firm  $k$  periods ahead knowing that  $\omega_{t,t+k} = \frac{\theta^k \mathcal{F}_{t,t+k} P_{t+k}^\epsilon}{\sum_{k=0}^{\infty} \theta^k \mathcal{F}_{t,t+k} P_{t+k}^\epsilon}$ .

In fact, in the limiting case without nominal rigidities, where  $\theta = 0$ , the optimal price for all the firms is equal  $P_t^*(i) = (1 + \mu)(1 - \tau)P_t MC_t$  and implies that the natural level for the marginal costs is constant  $MC_t^n = \frac{1}{1+\mu}$ . Imposing this definition in the linear marginal cost expression (1) we obtain that the natural level



of output in the flexible economy is the productivity shock, i.e.  $y_t^n = a_t$ . Using this notation, we define the linearised output gap as  $x_t \equiv y_t - y_t^n$ .

### Corporate assets.

Following Nisticò (2012) we explicitly model a corporative sector that issues assets that are bought by household's.<sup>5</sup> In this economy, intermediate good firms have outstanding assets  $Z_t(i)$  held by households and valued at price  $Q_t(i)$ . The total amount of corporative assets issued by intermediate firms  $i$  is normalized to one, therefore  $Z_{t+1}(i) = 1 \forall i \in [0, 1]$ . Each period, the holder of this financial asset obtains a share of total dividends  $D_t(i)$  from the intermediate goods firm  $i$ . The dividends are defined as the profits from the firm profits of firm, i.e.

$$D_t(i) = Y_t(i)(1 - (1 - \tau)MC_t) \quad (4)$$

and the linearised equation for dividends is expressed by

$$d_t = \frac{1 + \mu}{\mu} y_t - \frac{1}{\mu} (n_t + w_t - p_t). \quad (5)$$

Define the total dividends  $D_t \equiv \int_0^1 D_t(i) di$  and the stock price index by  $Q_t \equiv \int_0^1 Q_t(i) di$ .

## 2.2 Demand side

The demand side of the economy features a discrete-time stochastic version of the perpetual youth model with overlapping generations as in Castelnovo and Nisticò (2010) and Nisticò (2012). Every period a share of the population  $\vartheta$  participates in financial markets and a measure  $1 - \vartheta$  does not have access to saving decisions. Agents not participating in financial markets behaves as a non-Ricardian consumer as its only source of income comes from their labor supply, i.e. they are hand-to-mouth consumers. There is rotation between active and inactive participants. Every period, the active share of cohorts can be replaced with constant probability  $\gamma$ . The old cohort is replaced by a newcomer cohort of equal size but owning zero financial assets.<sup>6</sup> Also with probability  $\varrho$  a non-Ricardian agent becomes active in financial markets. To maintain both shares of agents constant, we assume  $\varrho(1 - \vartheta) = \vartheta\gamma$ . New market participants (non-participants) at time  $t = j$  ( $t = k$ ) become a new cohort and its measure  $m_t(j)$  ( $m_t(k)$ ) decays with time as there is rotation in participation, i.e  $m(j) = \vartheta\gamma(1 - \gamma)^{t-j}$  ( $m(k) = (1 - \vartheta)\varrho(1 - \varrho)^{t-j}$ ).

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<sup>5</sup>Notice that standard new Keynesian models assume that dividends are evenly distributed across households. Whereas in the current model we assume that firms issued claims on such dividends at time  $t = 0$ . Each period households can trade such claims and, therefore, these assets are valued given households' optimality conditions.

<sup>6</sup>On the one hand, as you will notice later as  $\gamma \rightarrow 0$  the the household problem represents the standard infinite horizon consumer problem.



**Non-market participants.** The problem of a cohort of non-participants ( $k$ ) is reduced to take consumption  $C_{k,t}^{NP}$  decisions given its labor supply  $N_{k,t}^{NP}$

$$\begin{aligned} & \max_{\{C_{k,t}^{NP}, N_{k,t}^{NP}\}} \mathbb{E}_t [\delta \log C_{k,t}^{NP} + (1 - \delta)(1 - N_{k,t}^{NP})] \\ & \text{s.t.} \\ & P_t C_{k,t}^{NP} = W_t N_{k,t}^{NP} - T_{k,t}. \end{aligned}$$

where  $P_t$  is the price of the final good,  $W_t$  is wage rate, and  $T_{k,t}$  is a lump sum tax. The optimality condition of this problem and the budget constraint impose that labor supply is constant  $N_{k,t}^{NP} = \frac{1}{1+\delta}$  and consumption is determined by the wage rate, i.e.  $C_{k,t}^{NP} = \frac{W_t}{1+\delta}$ .

**Market participants.** A financial participant that is within a  $j$ -period-old cohort has Cobb-Douglas preferences on consumption  $C_{j,t}^P$  and leisure  $N_{j,t}^P$ . With respect to financial assets, households has access to one-period state contingent bonds  $B_{j,t+1}^*$  which are discounted by the factor  $\mathcal{F}_{t,t+1}$ . Also they have access to financial assets  $Z_{j,t}(i)$  sold at price  $Q_t(i)$  by the intermediate good firm  $i$ . Each cohort pays lump-sum taxes  $T_{j,t}$ .

Lastly, each period, household's face an exogenous stochastic shock shifting their period utility  $\nu_t$  which follows an autoregressive process  $\nu_t = \rho_\nu \nu_{t-1} + \varepsilon_t^\nu$  where  $\varepsilon_t^\nu \sim N(0, \sigma_\nu^2)$ . We assume stocks markets face a shock ex-post of being liquidated, i.e. once dividends are paid. This shock  $e_t$  follows an autoregressive process  $e_t = \rho_e e_{t-1} + \varepsilon_t^e$  where  $\varepsilon_t^e \sim N(0, \sigma_e^2)$ . A positive shock  $e_t$  is introduced to represent a excess of value above the fundamental price.

The infinite horizon problem at time 0 faced by a  $j$ -period-old representative agent is characterized by

$$\begin{aligned} & \max_{\{C_{j,t}^P, B_{j,t+1}^*, Z_{j,t}(i), N_{j,t}^P\}_{t=0}^\infty} \mathbb{E}_t \sum_{i=t}^\infty \beta^i (1 - \gamma)^t \exp(\nu_t) [\delta \log C_{j,t}^P + (1 - \delta)(1 - N_{j,t}^P)] \\ & \text{s.t.} \\ & P_t C_{j,t}^P + \mathbb{E} \{ \mathcal{F}_{t,t+1} B_{j,t+1}^* \} + P_t \int_0^1 Q_t(i) Z_{j,t+1}(i) = W_t N_{j,t}^P - T_{j,t} + \Omega_{j,t}^* \\ & \Omega_{j,t}^* \equiv \frac{1}{1 - \gamma} \left[ B_{j,t}^* + P_t \int_0^1 \exp(e_t) (Q_t(i) + D_t(i)) Z_{j,t}(i) \right] \end{aligned}$$

where  $\beta \in (0, 1)$  and  $\delta \in (0, 1)$  represents the discount factor and the weight of consumption in the utility function, respectively. Moreover, the term  $\Omega_{j,t}^*$  represents previous period financial accumulated wealth.

The first order conditions of the  $j$ -period-old representative agent can be characterized by the following



optimality conditions:

$$N_t : \quad C_{j,t}^P = \frac{\delta}{1-\delta} \frac{W_t}{P_t} (1 - N_{j,t}^P) \quad (6)$$

$$B_{j,t}^* : \quad \mathcal{F}_{t,t+1} = \beta \mathbb{E}_t \left\{ \frac{P_t}{P_{t+1}} \frac{C_{j,t}^P}{C_{j,t+1}^P} \exp(\varepsilon_t^\nu) \right\} \quad (7)$$

$$Z_{j,t}^*(i) : \quad Q_t(i) = \mathbb{E}_t \left\{ \mathcal{F}_{t,t+1} \frac{P_{t+1}}{P_t} \exp(e_t) [Q_{t+1}(i) + D_{t+1}(i)] \right\}. \quad (8)$$

We define the nominal one-period expected return of a bond as  $1 + r_t \equiv \frac{1}{\mathbb{E}_t \{\mathcal{F}_{t,t+1}\}}$ . This definition is important as the central bank implements its monetary policy by setting the nominal interest rate  $r_t$ .

In this setup, the accumulated wealth is important to determine the consumption profile for each  $j$ -period-old cohort. In fact, new cohorts start with zero accumulated wealth, i.e.  $\Omega_{t,t}^* = 0$ . There is an structure of lump sum taxes that affect differently to old and new participants. On the one hand, old participants pay a lump sum transfer  $T_{j,t} = T_t + \Upsilon_j \left[ \frac{1}{1-\gamma} - \mathbb{E} \left\{ \mathcal{F}_{t,t+1} \frac{P_{t+1}}{P_t} \right\} \right]$ . The first term  $T_t$  is a lump sum tax and the second term is a tax over each cohort  $\Upsilon_j$ . A new financial participant pays a similar tax but instead receives a transfer to start operations  $\Upsilon_t$ .<sup>7</sup>

As we will argue, the interaction between surviving and new cohorts has aggregate consequences for the channel of intertemporal substitution for consumption. Actually, as explained by Castelnuovo and Nisticò (2010), unlike the standard new Keynesian IS equation, the heterogeneity across the consumption profiles drives a wedge between the discount factor pricing all assets and the rate of intertemporal substitution.<sup>8</sup>

In order to express the distortion of the aggregate intertemporal substitution channel, we proceed in two steps. First, we argue how the dynamics of the consumption profile of each cohort is determined by its financial wealth. Second, we show how the uncertainty about being able to participate in financial markets introduces a motive to consider the future value of wealth when determining current consumption.

**Consumption dynamics.** Let define a measure of the discounted flow of after tax labor income as  $h_t = \mathbb{E}_t \sum_{k=0}^{\infty} \mathcal{F}_{t,t+k} (1-\gamma)^k \left( \frac{W_{t+k}}{P_{t+k}} - T_{t+k} \right)$ . This measure characterizes the expected lifetime labor income that a  $j$ -old-cohort has access in case of surviving during  $k$  periods with probability  $(1-\gamma)^k$ . After substituting the optimality condition for labor supply and iterating forward the financial assets decision, we can express budget

<sup>7</sup>In this case  $j$  corresponds to old generations born before  $t$  and the subscript  $t$  is the generation born at  $t$ .

<sup>8</sup>Recall that consumption profiles across new and old cohorts is different because the former starts with zero wealth. Therefore new cohorts consume less than  $j$ -period-old cohorts for  $j < t$ .



constraint of a  $j$ -period-old-cohort as:

$$\frac{1}{1+\delta}C_{j,t}^P = h_t + \mathbb{E}_t \sum_{k=0}^{\infty} \left\{ \mathcal{F}_{t,t+1}(1-\gamma)^k \frac{1}{\delta} P_{t+k} C_{t+k}^P \right\} + \mathbb{E}_t \{ \mathcal{F}_{t,t+1} \Omega_{j,t+1} \}. \quad (9)$$

By using the optimality condition for bonds' pricing and a non-ponzi scheme condition, we can derive the following expression for consumption profile of the  $j$  period-old cohort

$$C_{j,t}^P = \begin{cases} \frac{\delta}{\Sigma_t} (h_t + \Omega_{j,t} - \Upsilon_{j,t}) & \text{existing cohorts } j < t \\ \frac{\delta}{\Sigma_t} (h_t + \Upsilon_j) & \text{new cohorts } j = t \end{cases} \quad (10)$$

where we let  $\Sigma_t \equiv \mathbb{E}_t \{ \beta^k (1-\gamma)^k \exp(\varepsilon'_{t+k} - \varepsilon'_t) \}$  to represent the discounted lifetime sum of shocks affecting the marginal propensity to consume.<sup>9</sup> As you can observe from the consumption profile  $C_{j,t}$ , while existing cohorts ( $j < t$ ) use their financial wealth to smooth consumption, the new cohort consume less because it has no financial wealth.<sup>10</sup>

**Aggregation across cohorts.** The aggregation of the optimality conditions across cohorts allow us to show how a financial financial wealth channel introduces a wedge that distorts the traditional intertemporal substitution channel. Consider the aggregate version of the cohort's optimality conditions

$$\frac{1}{1+\delta}C_t^P + \mathbb{E}_t \left\{ \mathcal{F}_{t,t+1} \frac{P_{t+1}}{P_t} \Omega_{t+1} \right\} = \frac{W_t}{P_t} - T_t + \Omega_t \quad (11)$$

$$C_t^P = \frac{\delta}{\Sigma_t} (\Omega_t + h_t) \quad (12)$$

where the first equation combines that aggregation of the budget constraints and the labor supply condition and the second equation is the optimal consumption dynamics.<sup>11</sup> The solution of this set of aggregate equations provides an expression for the dynamics of the aggregate consumption

$$C_t^P = \frac{\gamma \Sigma_t}{\beta(1-\gamma)} \underbrace{\mathbb{E}_t \left\{ \mathcal{F}_{t,t+1} \frac{P_{t+1}}{P_t} \Omega_{t+1} - \Upsilon_t \right\}}_{\text{Financial wealth channel}} + \frac{1}{\beta} \mathbb{E}_t \left\{ \mathcal{F}_{t,t+1} \Sigma_{t+1} \frac{P_{t+1}}{P_t} C_{t+1}^P \right\}. \quad (13)$$

The first term in the right hand side is the financial wedge channel where fluctuations in financial wealth  $\Omega_{t+1}$  drives today's aggregate consumption. Notice that as  $\gamma \rightarrow 0$  this equation resembles the standard Euler equation in the new Keynesian framework. The linearised version of the equation describing the aggregate consumption

<sup>9</sup>The non-ponzi scheme condition implies that  $\mathbb{E}_t \{ \mathcal{F}_{t,t+1} \Omega_{j,t+1} \} \rightarrow 0$  as  $t \rightarrow \infty$

<sup>10</sup>Notice that at period  $t$  the discounted lifetime sum of shocks  $\Sigma_t$  and the discounted lifetime non-financial income  $h_t$  does not depend on the cohort profile. Therefore, it is straightforward to argue that the consumption is lower for new cohorts.

<sup>11</sup>In this equation the term associated with the taxes and transfers disappears as they are redistributed across cohorts.



dynamics can be expressed as

$$c_t^P = \mathbb{E}_t c_{t+1}^P + \psi \mathbb{E}_t \omega_{t+1} - (r_t - \mathbb{E}_t \pi_{t+1} - \rho) - \frac{\psi}{1 - \beta(1 - \gamma)\rho_\nu} \mathbb{E}_t \nu_{t+1} \quad (14)$$

where we define  $\psi \equiv \gamma \frac{1 - \beta(1 - \gamma)}{(1 + \delta)(1 - \gamma)} \frac{1}{1 - \beta} \frac{\mu}{1 + \mu}$ . The remaining set of aggregate important aggregate optimal conditions determine the labor supply and the asset price dynamics. First, the aggregation across cohorts of the labor supply condition can be represented by the following equation

$$\frac{\delta}{1 - \delta} \frac{W_t}{P_t} (1 - N_t^P) \quad (15)$$

and its corresponding linearised equation is

$$w_t - p_t = c_t^P + \varphi n_t^P \quad (16)$$

where  $\varphi \equiv \frac{N_{ss}}{1 - N_{ss}}$  and  $N_{ss}$  corresponds to the value of the labor supply in steady state.

Second, given the optimality conditions for the asset price of corporative stocks and the aggregate definitions for dividends and stock prices, we can get an equation representing the dynamics of the stock-price index:

$$\begin{aligned} Q_t &= \mathbb{E}_t \left\{ \mathcal{F}_{t,t+1} \exp(e_t) \frac{P_{t+1}}{P_t} (Q_{t+1} + D_{t+1}) \right\} \\ &= \mathbb{E}_t \left\{ \mathcal{F}_{t,t+1} \exp(e_t) \frac{P_{t+1}}{P_t} (\Omega_{t+1}) \right\} \end{aligned} \quad (17)$$

The linearised equation representing the dynamics of the stock-price index is represented by

$$q_t = \beta \mathbb{E}_t q_{t+1} + (1 - \beta) \mathbb{E}_t d_{t+1} + (r_t - \mathbb{E}_t \pi_{t+1} - \rho) + e_t. \quad (18)$$

In turn, dividends can be linearised as

$$d_t = \frac{\mu - (1 + \varphi)}{\mu} x_t - a_t \quad (19)$$

Simultaneously, from the definition of financial wealth we can derive its dynamics from (20):

$$\omega_t = \beta \mathbb{E}_t \omega_{t+1} + (1 - \beta) \frac{\mu - (1 + \varphi)}{\mu} x_t - (1 - \beta) a_t + (r_t - \mathbb{E}_t \pi_{t+1} - \rho) + e_t. \quad (20)$$



### 2.3 Market clearing and optimality conditions.

The set of equilibrium conditions can be summarized in three linearised (i.e. IS equation, Phillips curve, and asset price) equations that, for a given monetary policy ( $r_t$ ) and exogenous shocks ( $\varepsilon_t^a, \varepsilon_t^q, \varepsilon_t^\nu$ ), can describe the dynamics of the output ( $x_t$ ), inflation ( $\pi_t$ ), and asset price ( $q_t$ ).

Notice that in equilibrium, the net supply of state-contingent bonds is zero, i.e.  $B_t = 0$ . This economy is closed, therefore

$$Y_t = C_t. \quad (21)$$

Aggregate consumption  $C_t$  is determined by active participants  $C_t^P$  and non-participants  $C_t^{NP}$

$$C_t = \vartheta C_t^P + (1 - \vartheta) C_t^{NP}. \quad (22)$$

Aggregate consumption  $C_t$  is determined by active participants  $C_t^P$  and non-participants  $C_t^{NP}$

$$N_t = \vartheta N_t^P + (1 - \vartheta) N_t^{NP}. \quad (23)$$

Let define the aggregate labor demand by  $N_t \equiv \int_0^1 N_t(i) di$  and notice that we can represent the aggregate supply by

$$Y_t \Xi_t = \exp(a_t) N_t \quad (24)$$

where  $\Xi_t \equiv \int_0^1 \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon}$  and its corresponding linearised equation as

$$y_t = a_t + n_t. \quad (25)$$

From the aggregate price definition and the optimal price (3), the labor supply condition (16), and the aggregate supply (25), we obtain the following version of the new Keynesian Phillips curve which is represented by

$$\pi_t = \kappa x_t + \beta \mathbb{E}_t \pi_{t+1} \quad (26)$$

where the Phillips curve slope  $\kappa = \frac{(1-\theta)(1-\theta\tilde{\beta})}{\theta}$ .

By considering the closed economy, the IS curve (14) can be derived as

$$y_t = \mathbb{E}_t y_{t+1} + \frac{\psi}{\Theta} \mathbb{E}_t \omega_{t+1} - \frac{1}{\Theta} (r_t - \mathbb{E}_t \pi_{t+1} - \rho) - \frac{\psi}{1 - \beta(1 - \gamma)\rho_\nu} \mathbb{E}_t \nu_{t+1} \quad (27)$$

where  $\Theta \equiv 1 - \varphi \frac{1-\vartheta}{\vartheta}$ . Finally, the asset price dynamics can be represented by combining the dividend dynamics



(5), the labor supply condition (16), and asset price (20)

$$q_t = \beta \mathbb{E}_t q_{t+1} - (1 - \beta) \frac{1 + \phi - \mu}{\mu} \mathbb{E}_t(x_t) - (r_t - \mathbb{E}_t \pi_{t+1} + \rho) + (1 - \beta) \mathbb{E}_t y_{t+1}^n + \varepsilon_t^e. \quad (28)$$

### 3 Optimal monetary policy and monetary rules

The monetary policy problem is to set allocations that minimize the social welfare loss subject to the structural equations of the model. The second-order approximation of the social welfare function is derived in Nisticò (2016) and considers the non trivial aggregation across heterogeneous cohorts. As shown in Nisticò (2016) the social welfare can be expressed as follows:

$$\mathcal{L}_{\pi, x, \omega} = \frac{(1 + \varphi)\nu}{2\vartheta} \mathbb{E}_t \left\{ \sum_{t=0}^{\infty} \beta^t (x_t^2 + \alpha_{\pi} \pi_t^2 + \alpha_{\omega} \omega_t^2) \right\}, \quad (29)$$

where while  $\alpha_{\pi} = \vartheta \frac{\varepsilon}{\nu \kappa}$  corresponds to the relative weight for inflation,  $\alpha_{\omega} = \vartheta^2 \psi \mu / \nu [(1 + \phi)(1 - \beta)(1 + \mu)]$  is the relative weight for financial stability, where  $\nu = [\vartheta + \varphi(1 - \vartheta)]$ . It is important to mention that the functional form of the social welfare is not affected by the introduction of exogenous demand and financial shocks. As a benchmark, as in Nisticò (2016), the central bank has three alternative regimes to follow as an optimal monetary policy: inflation targeting (IT), optimal policy under discretion, optimal policy under commitment.<sup>12</sup>

Notice that in a non-flexible economy, the aggregate the relevant aggregate equations are output gap ( $x_t$ ) that summarizes the aggregate euler condition augmented to consider a financial wealth channel

$$x_t = \mathbb{E} x_{t+1} + \psi \Theta \mathbb{E} w_{t+1} - \frac{1}{\Theta} (r_t + \mathbb{E} \pi_{t+1} - r_t^n) \quad (30)$$

where  $r_t^n$  is the natural rate consistent with a flexible price equilibrium

$$r_t^n = \rho + \mathbb{E}_t \Delta a_{t+1} + \frac{(1 - \beta \rho^a) \psi \rho_a}{1 - (1 - \psi) \beta \rho_a} a_t + \frac{\psi \rho_e}{1 - (1 - \psi) \beta \rho_e} e_t - \frac{\beta \Theta \psi_{\nu} (\rho_{\nu} - 1)}{1 - (1 - \psi) \beta \rho_{\nu}} \nu_t. \quad (31)$$

In turn, the inflation ( $\pi_t$ ) the traditional new Keynesian Phillips curve

$$\pi_t = \beta \mathbb{E} \pi_{t+1} + \kappa x_t \quad (32)$$

and, finally, an equation that describes the dynamics of the financial wealth ( $\omega_t$ ) equation which shows the

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<sup>12</sup>To implement a central planner solution, the tax subsidy has to be the inverse to the markup  $1 - \tau = \frac{\varepsilon - 1}{\varepsilon}$  and  $\Upsilon_j = \omega j - (1 - \gamma)\Omega$ .



evolution of future asset prices and dividends

$$\omega_t = \beta \mathbb{E} \omega_{t+1} - (1 - \beta) \frac{1 + \varphi - \mu}{\mu} x_t - \beta(r_t - r_t^n) - (\beta \rho_a - 1) a_t + e_t + \frac{\beta \psi}{1 - \beta \rho_\nu (1 + \psi)} \mathbb{E} \Delta \nu_{t+1}. \quad (33)$$

The monetary authority sets the nominal interest rate  $r_t$  to find allocations consistent with its objective of minimizing the welfare function under different criteria.

### 3.1 Inflation targeting regime

The IT regime considers to maintain allocations at the flexible price-equilibrium. Under the current framework, fluctuations in inflation ( $\pi_t = 0$ ) and output gap ( $x_t = 0$ ) completely disappear in equilibrium. However, financial wealth ( $\omega_t$ ) is subject to fluctuations which are responsible for consumption heterogeneity across active agents in the financial market. In our current setup, the financial wealth dynamics is affected by the three sources of shocks in the economy, i.e. productivity shocks ( $\epsilon_t^a$ ), demand shocks ( $\epsilon_t^\nu$ ), and financial shocks ( $\epsilon_t^e$ ):

$$\omega_t = \frac{1 - \beta \rho^a}{1 - (1 - \psi) \beta \rho_a} a_t + \frac{1}{1 - (1 - \psi) \beta \rho_e} e_t - \frac{\beta \Theta \psi_\nu (\rho_\nu - 1)}{1 - (1 - \psi) \beta \rho_\nu} \nu_t. \quad (34)$$

### 3.2 Optimal monetary policy: discretion and commitment

The problem of a monetary authority under discretion is to find allocations for output gap ( $x_t$ ), inflation ( $\pi_t$ ) and financial wealth ( $\omega_t$ ), such that given the dynamics of these variables the welfare loss  $\mathcal{L}_{\pi, x, \omega}$  (29) is minimized period by period. As discussed in Nisticò (2016), the intra-temporal trade-off is summarized by the following condition

$$x_t = -\alpha_\pi \kappa \pi_t - \alpha_\omega \eta \omega_t. \quad (35)$$

In the case of allocations under commitment the central bank considers the intertemporal trade-off assign a path of allocation which maintain optimal relationships across periods, i.e.  $\{x_t, \omega_t, \pi_t\}_{t \geq 0}$ . As a consequence, the inter-temporal trade-off is summarised by the following set of equations

$$\begin{aligned} x_t &= \eta \lambda_{2,t} - \Theta \lambda_{2,t-1} + \kappa \lambda_{t,1} \\ \alpha_\pi \pi_t &= \lambda_{1,t-1} - \lambda_{1,t} \\ \alpha_\omega \omega_t &= (1 - \frac{\psi}{\Theta}) \mathbb{E} \omega_{t+1} - \frac{1}{\Theta} (r_t - \mathbb{E}_{t+1} - r_t^n) \end{aligned} \quad (36)$$

where  $\lambda_{1,t}$  and  $\lambda_{2,t}$  are Lagrange multipliers associated with the constraints associated with constraints imposed by inflation dynamics  $\pi_t$  in equation (32) and financial wealth  $\omega_t$  in equation (33).



### 3.3 Monetary rules

We study the potential of a simple monetary rule to provide an approximation to the optimal policy presented in the previous section. We consider that such monetary rule follows a central bank reaction function of the form

$$r_t = r_t^n + \phi_\pi \pi_t + \phi_x x_t + \phi_q q_t. \quad (37)$$

where we will fix parameters  $\phi_\pi$  and  $\phi_x$  to the standard to the literature and set the value for  $\phi_q$  to minimize the loss function (29). This monetary rule is represented as a deviation from the natural rate ( $r_t^n$ ) as we explore rules that allows for welfare improvements from a central bank focused in an strict IT regime.<sup>13</sup> This monetary rule has the property that, in absence of fluctuations deviating the economy from flexible-price allocations, it will be consistent with an equilibrium where inflation and output gap are completely stabilized. In the current model, the monetary policy operates to stabilize the financial wealth ( $\omega_t$ ) through the asset price valuation. Therefore, the inclusion of a response to asset prices ( $\phi_q$ ) intends to dampen the fluctuations in future financial wealth as expressed by optimality condition (17). In the monetary rule, we consider introducing a response to asset prices as they deviate from its steady state.

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<sup>13</sup>For instance, Cúrdia et al. (2015) provide empirical evidence for the U.S. showing that a monetary rule tracking the natural rate of return fits the data better than standard monetary rules. Cúrdia and Woodford (2010) uses a similar rule and introduces financial stability considerations, in the form of credit spreads, to quantify the welfare gains of pursuing such a rule compared to traditional Taylor-type rules.



Table 1: Benchmark calibration

Definition	Parameter	Source
	Literature	
Discount factor	$\beta = 0.99$	Annual interest rate of 4%
Calvo parameter for nominal rigidity	$\theta = 0.75$	Price adjustment for quarters
Weight for consumption in utility function	$\delta = 3.33$	Elasticity of labor supply equal to $\frac{1}{\delta} = 0.3$
Share of participants in financial markets	$\vartheta = 0.8$	
Turnover rate of financial markets participants	$\xi = 0.17$	Financial wealth effect $\frac{\psi}{\Theta} = 0.15$

## 4 Quantitative results

In this section, we calibrate the theoretical model and evaluate the optimal monetary response under the existence of fluctuations due to productivity shocks, demand shocks, and financial shocks. In this line, we extend the results of Nisticò (2016) to compare the relative importance of demand and financial shocks in the conduction of the optimal welfare policy. To this aim, we compute the social-welfare loss function under a regime pursuing inflation targeting, an optimal policy under discretion, and an optimal policy under commitment. Indeed, Nisticò (2016) shows that there exists a quantitatively sizeable reduction in welfare loss from transiting from IT to conduct optimal policy when considering only productivity shocks. In this section we assess whether this quantitative result holds under the existence of demand and financial shocks.

### 4.1 Parametrization.

Table 1 presents the benchmark parameter values used to reproduce the results. To understand the importance of demand and financial shocks for the welfare-maximizing optimal policy, we use Nisticò (2016) to calibrate the model. This strategy will allow us to compare whether the suboptimality of an inflation targeting regime holds under the existence of demand and financial shocks. Each period is a quarter, and the coefficient for the discount factor  $\beta = 0.99$ , consistent with a real interest rate in steady state  $r_{ss} = 0.1$ , and the nominal price rigidity  $\theta = 0.75$  take standard values in the literature. Therefore, share of agents participating in financial markets is set to  $\vartheta = 0.8$ . The consumption weight,  $\delta$ , is set to maintain a real wage elasticity of  $\varphi \equiv \frac{1}{\delta} = 0.3$ . The elasticity of demand for an intermediate input  $\epsilon$  is set to maintain a markup of 20%, i.e.  $\frac{\mu}{1-\mu} = 1.2$ . The standard deviations for the shocks are consistent with the values in Castelnuovo and Nisticò (2010). Therefore, we set  $\sigma_a = 0.01$ ,  $\sigma_\nu = 0.0314$ , and  $\sigma_e = 0.0059$ . As a benchmark case, we set no persistence for each shock.

As mentioned before, we consider a monetary rule consistent with equation (37) where the central bank responds to deviations from inflation, output gap, and asset prices fluctuations around its steady state. The response to macroeconomic variables is set at standard values, i.e.  $\phi_\pi = 1.5$  and  $\phi_x = 0.125$ . In table Table 2



we compute the optimal response to an asset price fluctuations ( $\phi_q$ ) which minimizes the welfare loss function ( $\mathcal{L}_{\pi,x,\omega}$ ), i.e.  $\phi_q \in \arg \min \mathcal{L}_{\pi,x,\omega}$ . Each column shows the optimal  $\phi_q$  in the monetary rule for each type of shock of persistence  $\rho_x$ .<sup>14</sup> As it can be seen, for given parameters  $\phi_x$  and  $\phi_\pi$ , the optimal is close across shocks. Also as the persistence of the shock increases the response to asset prices decreases. In our benchmark results we will let a zero persistence assumption, but later we explain how our results can be sensitive or robust for different assumptions about the persistence.

Table 2: Parameter  $\phi_q$  that minimizes welfare function.

Persistence of the shock	$\epsilon^A$	$\epsilon^\nu$	$\epsilon^e$	Simultaneous
$\rho_x = 0$	0.92573	0.92570	0.92573	0.92570
$\rho_x = 0.20$	0.59380	0.59375	0.59380	0.59375
$\rho_x = 0.40$	0.31298	0.31290	0.31298	0.31289
$\rho_x = 0.60$	0.11160	0.11149	0.11160	0.11149
$\rho_x = 0.8$	0.00900	0.00961	0.00900	0.00961
$\rho_x = 0.99$	-0.00399	-0.00374	-0.00390	-0.00372

Source: Author's calculations. Each column considers the optimal  $\phi_q$  that minimizes the social welfare function for fixed parameters  $\phi_x = 0.125$  and  $\phi_\pi = 1.5$ .

## 4.2 Quantitative welfare losses under different policies

Table 3 shows the quantitative calculation of the social welfare loss considering each type of shock under alternative policy regimes. Each panel shows the welfare loss for each type of shock, i.e. productivity, demand, and financial shocks. Additionally, the panel at the bottom shows a measure of the welfare loss considering a case where all shocks in this economy interact simultaneously. Given a panel representing the welfare loss under a particular shock, each column shows the welfare loss considering each type of policy reaction function: inflation targeting, discretion, commitment, a simple monetary rule and an augmented monetary rule.<sup>15</sup> Ultimately, the first three rows in each panel shows the standard deviation of the targeted variable (i.e. inflation, output gap and financial wealth) and the last row shows the welfare loss.

Panel A in table 3 shows the welfare loss of the economy when the economy is only subject to productivity shocks. Columns one to three shows the there is an important reduction from implementing an optimal monetary policy, either under discretion or commitment, instead of pursuing IT.<sup>16</sup> While conducting a monetary policy

<sup>14</sup>Last column shows the optimal  $\phi_q$  when all shocks are turned on simultaneously.

<sup>15</sup>While a simple rule considers an specifications as in equation (37) but considering only the response to inflation and output gap (i.e.  $\phi_q = 0$ ), an augmented rule considers a functional form as equation (37).

<sup>16</sup>The same quantitative results as in table shown in Table 1 from Nisticò (2016). Notice that the magnitudes differ to those shown in



under discretion reduces the welfare loss up to 65% of what can be implemented under IT, under commitment the reduction is up to 59.1% of what is implemented under IT. The results from Nisticò (2016) are extended to observe whether the use of a monetary policy rule that deviates from the natural rate can reduce the welfare loss. Column four shows that a simple rule barely increases the welfare loss compared to the IT case. Interestingly, column 5, shows that an augmented monetary which reacts to asset prices reduces the welfare loss to a point close to an optimal policy under discretion. Notice that that these rule attains this welfare loss in the same way as optimal policies, that is, decreasing significantly the volatility of financial wealth associated with consumption dispersion but allowing for a marginal increase in the volatility of inflation and output gap.

Panel B in table 3, we extend the analysis of Nisticò (2016) and study the welfare loss when we observe only preference shocks, i.e. a demand shock. Consistently, the flexible price allocation shows sizeable higher losses with respect to optimal policy under commitment and discretion. It turns out, the relative welfare loss of conducting monetary policy under discretion (commitment) is 45% (41%) of the level observed under IT. Notwithstanding, the reduction in the relative welfare loss is lower when with monetary rules. A simple (augmented) rule results in a welfare loss up to 71% (86%) of the loss under IT.

Monetary rules are not only far from the welfare reduction obtained under optimal policy, these rules also introduces a trade-off as they are effective moderating the volatility of financial wealth but they exacerbate the volatility of macroeconomic variables, i.e. inflation and output gap. To illustrate this, consider the ratio of the volatility of inflation under an augmented rule with respect to commitment, this ratio is almost 2.5. In turn the relative volatility of output gap under the augmented rule vis-a-vis commitment is 1.86. Simultaneously, under the augmented rule there is a reduction in the volatility of financial wealth with respect to commitment, i.e. the ratio is 0.35. Interestingly, even a simple monetary rule introduces better outcomes in term of welfare than an augmented rule.

Panel C in table 3, also extends the analysis of Nisticò (2016) and shows the previous welfare analysis considering an exogenous financial shock that disturbs the asset price fundamentals. As in previous cases, there are important welfare improvements of pursuing optimal policy that stabilizes the financial welfare channel. On the one hand, column 1 and 2 shows that the relative loss under discretion is 62% to the loss under flexible price allocations. On the other hand, the loss under commitment is 59% of the loss under discretion. Also notice that while a simple rule reproduces almost the same loss than a simple rule, an augmented monetary rule provides a welfare loss close to the optimal policy under discretion.

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the published paper for two reasons. First, we use a different magnitude for the shock and, second, we consider a social welfare function derived in the corrigendum associated to the published version.



Lastly, panel D in table 3 shows the welfare losses that arises when all the shocks interact simultaneously. This panel shows that conducting a monetary policy through an augmented monetary rule can bring welfare benefits with respect to a framework that pursues the flexible price allocations. In relative terms, an augmented rule introduces lower losses of around 74% to the level under IT. In terms, the policy under commit and discretion produces loss up 64% and 58% of the level under IT. Notice that the augmented rule is limited in its scope to bring lowers losses with respect to optimal policies. From the analysis shown above, given the relative size of the shocks, this imperfect outcome is a result of the exacerbation that a demand shocks produces on inflation and output gap when the policy is conducted by the augmented rule.

In this section we showed quantitatively that a monetary rule that tracks the natural rate and responds to asset price has the ability to reduce welfare losses with respect to an extreme case of an inflation targeting regime. The reduction of the welfare loss throughout a monetary rule is particularly sizeable when the economy faces productivity and financial shocks but it is moderate in the face of demand shocks. This result arises because introducing a response to asset prices reduces volatility of financial wealth and in turn the undesirable consumption dispersion.

In the next section, we explain through an impulse response analysis how the augmented rule allows to reduce the disruption that each shock introduce to wealth channel inherent in the non-Ricardian framework.

### 4.3 Impulse response analysis

In the previous section, we showed the potential of an augmented monetary rule to attain welfare losses close to the optimal welfare outcomes when the economy face productivity and financial shocks. Also, we found that in the case of demand shocks the welfare improvement is moderate. In this section, we study the impulse response functions (IRF) for each type shock and explain how a monetary rule augmented to respond to asset prices can provide these results. As we will see in the following analysis, the effectiveness of the monetary rule to mimic the response of optimal policy depends on its ability to adjust the response of asset price as an intermediate target to reduce the effect of financial wealth.

Figure 1 shows the IRF of several variables under alternative approaches to conduct the monetary policy: inflation targeting, discretion, commitment, and an augmented monetary rule. The solid line shows the response of the economy under commitment allocations, the dotted line allocations under discretion, the circled line the outcomes under inflation targeting, and the red line the response when the monetary policy follows an augmented monetary rule.



Table 3: Welfare loss for different shocks.

<b>Panel A: Productivity Shock</b>					
	IT	Discretion	Commitment	Simple Rule	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.00000	0.04991	0.04114	0.00001	0.04757
$(\sigma_x)$ Std. Output gap	0.00000	0.44746	0.49647	0.00012	0.42647
$(\sigma_\omega)$ Std. Financial Wealth	1.00230	0.61687	0.55882	1.00230	0.63494
Welfare Loss	<b>0.00959</b>	<b>0.00627</b>	<b>0.00567</b>	<b>0.00959</b>	<b>0.00625</b>
<b>Panel B: Demand Shock</b>					
	IT	Discretion	Commitment	Simple Rule	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.00000	0.02200	0.01816	0.04078	0.04591
$(\sigma_x)$ Std. Output gap	0.00000	0.19726	0.21906	0.36554	0.41157
$(\sigma_\omega)$ Std. Financial Wealth	0.52973	0.27194	0.24617	0.12699	0.08734
Welfare Loss	<b>0.00268</b>	<b>0.00122</b>	<b>0.00110</b>	<b>0.00192</b>	<b>0.00231</b>
<b>Panel C: Financial Shock</b>					
	IT	Discretion	Commitment	Simple Rule	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.00000	0.02936	0.02421	0.00001	0.02827
$(\sigma_x)$ Std. Output gap	0.00000	0.26323	0.29211	0.00012	0.25339
$(\sigma_\omega)$ Std. Financial Wealth	0.58963	0.36289	0.32870	0.58964	0.37136
Welfare Loss	<b>0.00332</b>	<b>0.00217</b>	<b>0.00196</b>	<b>0.00332</b>	<b>0.00216</b>
<b>Panel D: Simultaneous shocks</b>					
	IT	Discretion	Commitment	Simple Rule	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.00000	0.06196	0.05105	0.05728	0.05989
$(\sigma_x)$ Std. Output gap	0.00000	0.55542	0.61609	0.51349	0.53688
$(\sigma_\omega)$ Std. Financial Wealth	1.27777	0.76570	0.69380	1.46001	0.90207
Welfare Loss	<b>0.01559</b>	<b>0.00966</b>	<b>0.00874</b>	<b>0.02383</b>	<b>0.01157</b>

Source: Author's calculations. This table shows the welfare loss for different regimes: flexible price allocations, optimal policy under discretion, and optimal policy under commitment. The values presented in the table were scaled by the factor  $10^3$ .



Panel A in figure 1 shows the IRFs to a productivity shock of one standard deviation. At the response, we observe that under IT regime the nominal interest rate decreases more than in either any optimal policy or the augmented rule. Under IT, increase in productivity requires to decrease the natural rate to set inflation and output gap at its zero-steady state. However, also under IT, financial wealth increases as dividends and asset prices rise. While the former rises mainly because of the productivity shock, the latter rises by the decrease in the nominal interest rate. As consequence, financial wealth is translated in consumption dispersion across cohorts.<sup>17</sup>

Unlike the IT regime, at the response, we observe that alternative optimal policies and the monetary rule allow for a negative inflation and output gap which interact with a moderate increase in financial wealth. Under these policies, the adjustment of the interest rate is moderate. Optimal policies prescribe an smaller decrease in the policy rate to dampen the increase in financial wealth. As consequence, the restrictive policy, will affect the output gap negatively which is consistent with a negative inflation level.

Interestingly, the augmented monetary rule recommends an adjustment to the interest rate close to the optimal policy under discretion. Particularly, the close adjustment in the policy rate in both type of policies, introduces an smaller increase in asset prices which in the end is the main source driving down financial wealth. As a result, both policies allows for almost the same response in all the endogenous variables. Not surprisingly, this explain the findings in panel A from table 3.

Simultaneously, the marginal cost for producing an intermediate good creates downward pressures for inflation. In the case of an economy under inflation targeting, the monetary policy prescribes a downward adjustment in the natural rate of interest in order to stabilize output at its natural level consistent with the zero-inflation target. However, under discretion and commitment, the adjustment in the interest rate is lower because it tries to counteract the effect of the rise in dividends on financial wealth. The policy rate adjustment under optimal policy is consistent with a response of inflation and output gap that deviates from the steady state.

Panel B in figure 1 shows the IRFs to a positive shock of one standard deviation to the household's marginal utility, i.e. a demand shock. All the alternative policies prescribe a tightening of the monetary policy to this shock. As under flexible-prices consumption dispersion is not important, the monetary policy under IT is less restrictive than under optimal policies. Interestingly, even with a less restrictive policy under IT, asset prices decreases more than under optimal policies. This result is due to the dynamics of dividends which fall with a positive output gap, i.e.  $d_t = \left[ \frac{\mu - (1+\varphi)}{\mu} \right] x_t + a_t$ .

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<sup>17</sup>Notice that under zero persistence, the active cohorts have more wealth than agents not participating in financial markets. When the persistence parameter increases, the wealth across financially active cohorts also rises as the shocks is persistent and some households will not be active in the period.



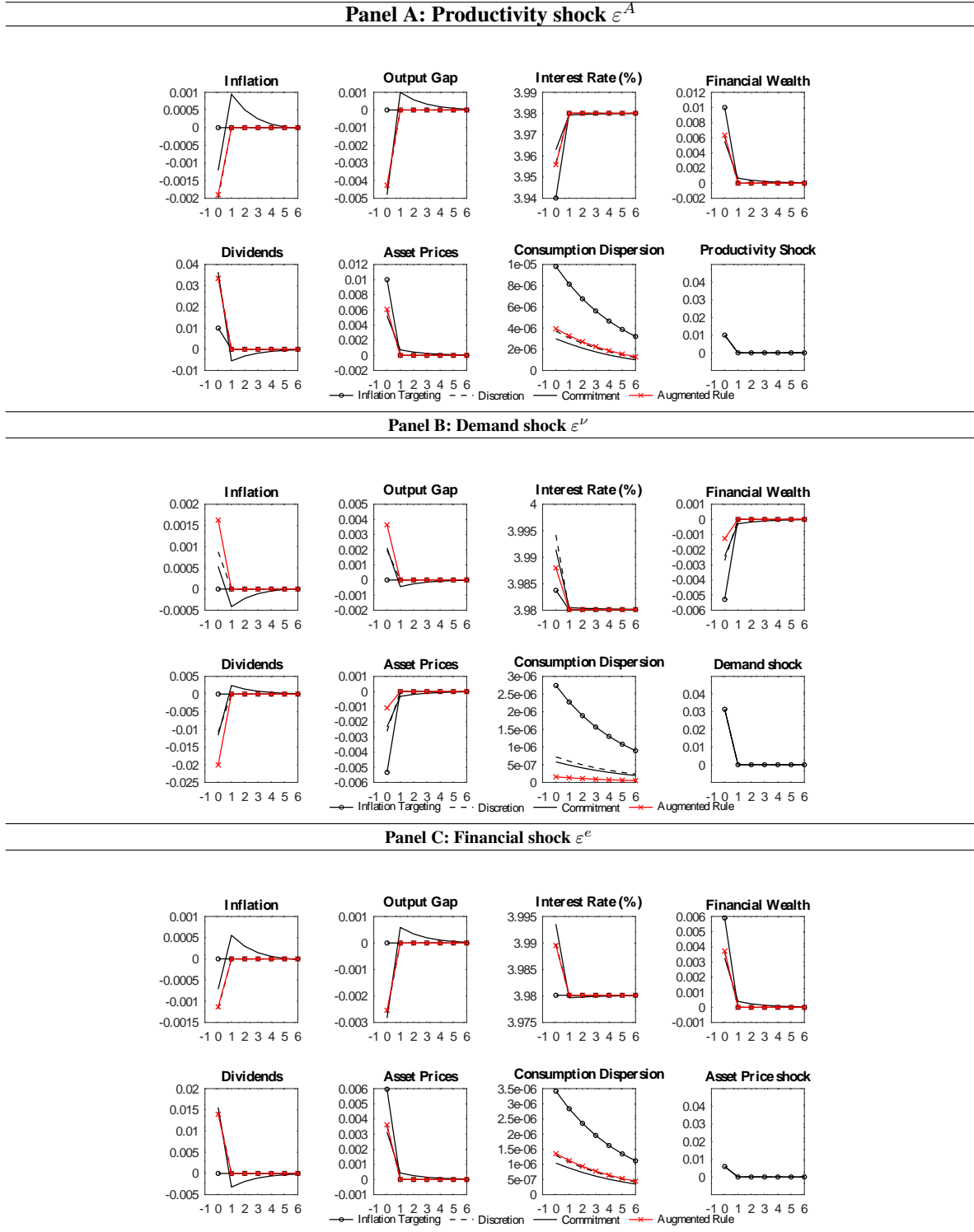
In this context, the monetary rule is less responsive than optimal rules. In fact, the relatively lower increase allows asset price to barely adjust with direct lower effects in the financial wealth. However, the lower increase does not allow to adjust to pressures in the demand side and, therefore, in inflation. The monetary rule is missing to attain macroeconomic stabilization while it seeks lower consumption dispersion through the wealth channel.

Panel C shows the IRF after a positive shock to the valuation of financial assets, i.e. a financial shock. In this case, the exogenous shock increases directly the asset price which affects directly the financial wealth valuation. In the IT regime, a shock affects the natural rate when it is persistent therefore in our benchmark calibration the effect is null. While monetary policy is neutral under IT, optimal policies prescribe to tight the interest rate. In this frameworks optimal policies intend to reduce asset prices valuation in order to offset the rise in financial wealth. The side effect is to reduce current output as households find optimal to postpone the consumption which is consistent with a fall in inflation.

As in the case of a productivity shock, an augmented monetary rule reproduce the outcomes under a optimal policy with discretion. In this case, the monetary authority can offset directly the shock to asset price through the policy tightening. However, this policy increases the volatility of inflation and output gap. Actually, the last column of table 3 shows this result.



Figure 1: Impulse response functions for a productivity, demand, and asset price shock.



Source: Author's calculations. The figure shows the impulse response for inflation, output gap, interest rate, financial wealth, and consumption dispersion. Each plots shows the response of such variables for different policy regimes: inflation targeting, optimal policy under discretion, and optimal policy under commitment. The size of the shock corresponds to one standard-deviation estimated in Castelnuovo and Nisticò (2010).



## 4.4 Sensitivity analysis

In this section we provide inspect the robustness of the previous results in two dimensions. First, as in Cúrdia and Woodford (2010), we explore whether the persistence of the shocks affects the relative welfare loss reduction that a monetary rule can introduce to the economy. Second, instead of using the IT regime to compare the welfare reduction, we consider the case where the reference is a flexible inflation targeting regime (FIT). This regime introduces minimizing a welfare loss considering only the discounted sum of the quadratic deviations of inflation and the output gap from its steady state of zero, i.e. in the welfare loss (29)  $\alpha_q = 0$ .

### Sensitivity to shock's persistence

In previous section, we parametrize a benchmark version of the model where we considered that shock persistence is null. In table 2 we observe a reduction in the optimal response to asset price dynamics when the persistence of the shock increases, i.e.  $\rho_x \rightarrow 1$  then  $\phi_q \rightarrow \bar{z}$  where  $\bar{z} < 0$ . In this section we explore whether the lower responsiveness of the monetary rule to asset prices affects its effectiveness to attain better welfare outcomes. In particular, for productivity and financial shocks, we study whether the quantitative decrease in losses are robust even when shocks are persistent. Also, in the face of demand shocks, we study whether the marginal benefits of using an augmented monetary rule are still positive.

Table 4 shows a measure of the welfare loss of conducting the monetary through an augmented rule relative to the welfare loss of pursuing flexible price allocations. Therefore, as this relative value is above (below) 1 it implies that an augmented rule loss is higher (lower) than the flexible price allocation. The first column in table 4, shows the relative welfare when the economy faces only productivity shocks  $a_t$ . It shows that even for high values ( $\rho_a = 0.60$ ), introducing an augmented rule provides positive welfare benefits.

The second column in table 4, shows the relative welfare when the economy is subject only to demand shocks  $\nu_t$ . Not surprisingly, at very low levels of persistence ( $\rho_\nu$ ), an augmented monetary rule provides higher welfare losses than in the flexible price case. This result suggests that in the face of demand shocks, using an augmented monetary rule responding to asset prices, can be inefficient. Finally, the third column in table 4, shows that for highly persistent financial shock  $e_t$  the augmented rule still provides positive welfare benefits.



Table 4: Welfare under augmented monetary rule relative to welfare under flexible prices.

Persistence of the shock	$\epsilon^A$	$\epsilon^\nu$	$\epsilon^e$
$\rho_x = 0$	0.65398	0.86863	0.65479
$\rho_x = 0.20$	0.72821	1.07298	0.72898
$\rho_x = 0.40$	0.83445	1.41865	0.83509
$\rho_x = 0.60$	0.97475	2.08788	0.97511
$\rho_x = 0.8$	1.13080	11.61748	1.13084
$\rho_x = 0.99$	1.37840	10.59969	1.37842

Source: Author's calculations. For a given shock persistence  $\rho_x$ , each row considers the ratio of the welfare following an augmented rule with respect to the welfare when the economy follows flexible prices. Each column consider the only shock that is turned on in the simulation.

### Sensitivity to IT as benchmark regime

In this part we compute a similar analysis as in Table 3. But instead of comparing the results with respect to a strict inflation targeting regime, we consider a flexible inflation targeting regime as in Svensson (1999). A FIT regime considers minimizing a loss function as in equation (29) but where  $\alpha_\omega = 0$ . The aim is to quantify the welfare reduction that an augmented monetary rule can bring if we consider a less restrictive policy regime than IT.

Table 5 shows the quantitative welfare losses for: i) optimal policy with commitment under FIT, ii) optimal policies (i.e. discretion and commitment) for the optimal social welfare problem, and iii) the augmented rule. Panel A and C, corresponding to welfare losses for productivity and financial shocks respectively, shows that a policy under commitment under FIT is similar to the one observed under a strict IT. Therefore, for the shocks where the monetary rule finds a sizeable reduction in welfare loss, introducing a less restrictive regime does not reduce the quantitative gains of pursuing an augmented monetary rule.

In the case of panel B in table 5, corresponding to demand shocks, we observe a result that strengthens the finding under FIT. Column 1 shows that pursuing a FIT regime reduces the welfare loss considerably with respect to an IT regime (column 1 in Panel B from table 3). As a consequence, we observe that in the face of demand shocks pursuing an augmented rule is suboptimal with respect to a commitment under FIT. In this case a simple rule can be a better option to approximate a reduction in the social welfare loss. As a consequence, this exercise supports our results shown previously, in the face of demand shocks, a rule responding to asset prices can provide very limited, or even null, reduction in welfare loss.



Table 5: Welfare loss for different shocks.

<b>Panel A: Productivity Shock</b>				
	Commitment FIT	Discretion	Commitment	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.00000	0.04991	0.04114	0.04757
$(\sigma_x)$ Std. Output gap	0.00000	0.44746	0.49647	0.42647
$(\sigma_\omega)$ Std. Financial Wealth	1.00230	0.61687	0.55882	0.63494
Welfare Loss	<b>0.00959</b>	<b>0.00627</b>	<b>0.00567</b>	<b>0.00625</b>
<b>Panel B: Demand Shock</b>				
	Commitment FIT	Discretion	Commitment	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.00000	0.02200	0.01816	0.04591
$(\sigma_x)$ Std. Output gap	0.00000	0.19726	0.21906	0.41157
$(\sigma_\omega)$ Std. Financial Wealth	0.44185	0.27194	0.24617	0.08734
Welfare Loss	<b>0.00186</b>	<b>0.00122</b>	<b>0.00110</b>	<b>0.00231</b>
<b>Panel C: Financial Shock</b>				
	Commitment FIT	Discretion	Commitment	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.00000	0.02936	0.02421	0.02827
$(\sigma_x)$ Std. Output gap	0.00000	0.26323	0.29211	0.25339
$(\sigma_\omega)$ Std. Financial Wealth	0.58963	0.36289	0.32870	0.37136
Welfare Loss	<b>0.00332</b>	<b>0.00217</b>	<b>0.00196</b>	<b>0.00216</b>
<b>Panel D: Simultaneous shocks</b>				
	Commitment FIT	Discretion	Commitment	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.00000	0.06196	0.05105	0.07187
$(\sigma_x)$ Std. Output gap	0.00000	0.55542	0.61609	0.64425
$(\sigma_\omega)$ Std. Financial Wealth	1.24413	0.76570	0.69380	0.74125
Welfare Loss	<b>0.01478</b>	<b>0.00966</b>	<b>0.00874</b>	<b>0.01072</b>

Source: Author's calculations. This table shows the welfare loss for different regimes: flexible price allocations, optimal policy under discretion, and optimal policy under commitment. The values presented in the table were scaled by the factor  $10^3$ .



### Sensitivity to asset-prices as a target in the loss function.

In the previous section, we found that an augmented rule responding to asset prices is effective in approximating the optimal policies outcomes in the face of productivity shocks and financial shocks. However, under a demand shock such rule quantitatively underperforms, in terms of its ability to reduce the welfare loss, with respect to a simple monetary rule. While this result could be a property of the parsimonious representation of the rule, it could be also that stabilizing stock-price fluctuations in the face of demand shocks moves away the allocations from the optimal outcomes.

In this section we explore whether approximating the social welfare loss only through asset prices can bring quantitatively suboptimal outcomes. By using the definition of financial wealth (i.e.  $\omega_t = \beta q_t + (1 - \beta)d_t$ ), this exercise consists in computing an approximation of the social welfare loss considering only the response to asset prices and avoiding the terms associated with dividends. In this way, the welfare loss that a central bank tries to minimize is a suboptimal approximation to the loss welfare loss. By quantifying the approximated welfare loss and comparing to the true welfare loss, we try to discern whether the limited welfare loss reduction of the monetary rule is because stabilizing stock-price fluctuations is an imperfect target in the face of demand shocks.

Therefore the loss function considered is the following

$$\mathcal{L}_{\pi,x,q} = \frac{(1+\varphi)\nu}{2\vartheta} \mathbb{E}_t \left\{ \sum_{t=0}^{\infty} \beta^t (x_t^2 + \alpha_{\pi} \pi_t^2 + \alpha_{\omega} \beta^2 q_t^2) \right\}, \quad (38)$$

notice that this function is an approximation of the true social welfare functions because  $\mathcal{L}_{\pi,x,\omega} = \mathcal{L}_{\pi,x,q} + 2\beta(1 - \beta)q_t d_t + (1 - \beta)^2 d_t^2$ . Hence, we explore by pursuing optimal policy over  $\mathcal{L}_{\pi,x,q}$  the central bank can attain outcomes as in  $\mathcal{L}_{\pi,x,\omega}$ .

For each panel representing a shock, the first two column table 6 shows the optimal social welfare loss  $\mathcal{L}_{\pi,x,\omega}$  when the authority follows optimal policies (i.e. discretion and commitment) minimizing the loss associated with asset price fluctuations  $\mathcal{L}_{\pi,x,q}$ . By comparing the first (second) and third (fourth) column, for all the shocks, we observe that even when the authority is minimizing an incorrect loss function, they are very close to the optimal outcomes. Interestingly, this property holds, even for the demand shock. This result suggest that aiming to stabilize fluctuations in  $q$  with the augmented rule is not necessarily an in correct variable to track. However, probably this effect can be fixed by allowing introducing modifications in term of the relative response of other parameters  $\phi_q$  and  $\phi_x$  or modifying the timing in the response to  $q_t$ .



Table 6: Welfare loss for different shocks.

<b>Panel A: Productivity Shock</b>					
	Discretion $q_t$	Commitment $q_t$	Discretion	Commitment	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.05062	0.04149	0.04991	0.04114	0.04757
$(\sigma_x)$ Std. Output gap	0.45378	0.49756	0.44746	0.49647	0.42647
$(\sigma_\omega)$ Std. Financial Wealth	0.61142	0.55723	0.61687	0.55882	0.63494
Welfare Loss	<b>0.00628</b>	<b>0.00568</b>	<b>0.00627</b>	<b>0.00567</b>	<b>0.00625</b>
<b>Panel B: Demand Shock</b>					
	Discretion $q_t$	Commitment $q_t$	Discretion	Commitment	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.02254	0.01849	0.02200	0.01816	0.04591
$(\sigma_x)$ Std. Output gap	0.20204	0.22173	0.19726	0.21906	0.41157
$(\sigma_\omega)$ Std. Financial Wealth	0.26782	0.24356	0.27194	0.24617	0.08734
Welfare Loss	<b>0.00122</b>	<b>0.00110</b>	<b>0.00122</b>	<b>0.00110</b>	<b>0.00231</b>
<b>Panel C: Financial Shock</b>					
	Discretion $q_t$	Commitment $q_t$	Discretion	Commitment	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.03008	0.02466	0.02936	0.02421	0.02827
$(\sigma_x)$ Std. Output gap	0.26962	0.29568	0.26323	0.29211	0.25339
$(\sigma_\omega)$ Std. Financial Wealth	0.35739	0.32520	0.36289	0.32870	0.37136
Welfare Loss	<b>0.00218</b>	<b>0.00197</b>	<b>0.00217</b>	<b>0.00196</b>	<b>0.00216</b>
<b>Panel D: Simultaneous shocks</b>					
	Discretion $q_t$	Commitment $q_t$	Discretion	Commitment	Augmented Rule
$(\sigma_\pi)$ Std. Inflation	0.06305	0.05167	0.06196	0.05105	0.07187
$(\sigma_x)$ Std. Output gap	0.56524	0.61962	0.55542	0.61609	0.64425
$(\sigma_\omega)$ Std. Financial Wealth	0.75725	0.68993	0.76570	0.69380	0.74125
Welfare Loss	<b>0.00969</b>	<b>0.00875</b>	<b>0.00966</b>	<b>0.00874</b>	<b>0.01072</b>

Source: Author's calculations. This table shows the welfare loss for different regimes: flexible price allocations, optimal policy under discretion, and optimal policy under commitment. The values presented in the table were scaled by the factor  $10^3$ .



## 5 Conclusion

In this article, we study the potential of monetary rules to attain optimal policy outcomes in a New Keynesian non-Ricardian model. This model proposes a macro-financial channel where the value of financial assets impacts household's wealth and, consequently, aggregate demand. Within this model, the social welfare loss incorporates increases in financial wealth volatility as a source of loss.

We extend this model to incorporate shocks to household's marginal utility, i.e. demand shocks, and shocks affecting asset price equations, i.e. financial shocks. We quantify the reduction in the welfare loss that a central bank can face if transits from a strict IT regime to one that pursues optimal policy intended to reduce the social welfare loss. Consistent with the finding of Nisticò (2016) for productivity shocks, we find that these reductions are sizeable for both demand and financial shocks.

Also, we study whether monetary rules can attain the optimal outcomes for an economy that tracks the natural rate implied from the IT regime. Again, the purpose is to show the welfare benefits that a central bank pursuing an strict IT regime obtain by allowing to respond to macroeconomic and financial variables. We find that simple rules responding to inflation and output gap does not attain better outcomes than the flexible-price allocations. However, in the face of productivity and financial shocks, introducing a response to asset prices allows to reproduce the outcomes of pursuing optimal policy under discretion. However, under demand shocks, the reduction in welfare loss is minor.

Finally, it is important to mention that our conclusions are specific to the model used and for the calibration of the United States. In our model, we use a small scale New Keynesian model which abstract from capital accumulation, financial intermediation, or open economy considerations. These are key elements that could drive different results than the those presented in this paper. Also, our results cannot be necessarily extended to other countries as different macro-financial linkages can play more important roles than the one studied here.



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