Welfare implications of nominal GDP targeting in a small open economy

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Highlights

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GDP targeting improves welfare in open economies with rigidities. Simple NGDP rules outperform inflation and wage inflation targets.

Welfare implications of nomimal GDP targeting in a small open economy

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Abstract

Nominal GDP targeting (NGDP) rules have gained attention as a potential alternative to traditional models of monetary policy. In this paper, we extend the analysis of the welfare implications of NGDP rules within a New Keynesian model with nominal price and wage rigidities. Using a welfare function derived from the utility of consumers, we compare the NGDP target with a domestic inflation target, a CPI inflation target, and a Taylor rule in a small open economy scenario. Our simulations reveal that NGDP rules confer advantages on a central bank when the economy faces supply shocks, while their performance against demand shocks is comparable to that of a CPI target rule. These findings suggest that NGDP targeting could be a useful policy framework for central banks seeking to enhance their ability to stabilize the economy.

Keywords: Optimal monetary policy, General equilibrium, open economy macroeconomics.

JEL: E32, F31, F41, F43, F44.

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1. Introduction

Monetary policy is essential for maintaining economic stability and welfare. The COVID-19 pandemic tested traditional policy rules, while climate change and supply chain disruptions pose new challenges for small economies. In this context, alternative policies, such as nominal GDP targeting (NGDP), have gained interest due to their potential benefits in reacting to different shocks.

NGDP targeting rules have generated interest in the literature as a monetary policy alternative due to their potential benefits over traditional policy rules when reacting to different shocks. These benefits include greater clarity in explaining policy objectives, fewer problems in measuring the target variable, and improved performance against shocks.

This paper examines the preference for NGDP targeting within a New Keynesian model with price and wage rigidities in a small open economy, compared to traditional policy rules. We extend the analysis of the welfare implications of NGDP rules by examining a small open economy scenario. Using welfare comparisons under different scenarios, we show that NGDP targeting generates lower welfare losses in the face of supply shocks, while performing similarly to inflation targeting in the face of demand shocks.

Unlike previous research, we analyze under which conditions NGDP is an optimal rule in a small open economy. We calculate optimal rules under various parameterizations and perform welfare comparisons. We also calibrate the model using parameters from the Peruvian economy to define the NGDP preference for that country. Finally, we explain the transmission mechanism that allows an NGDP rule to have optimal results.

The research approach is mainly theoretical in the sense that it seeks to define the conditions under which NGDP is an optimal rule in the defined open economy model. For this purpose, this policy rule will be analyzed under different parameterizations such as the degree of openness, and the level of rigidities. The optimal rules will be calculated under numerical methods and welfare comparisons will be made. However, we also consider the Peruvian case, calibrating the model with parameters from the literature that replicate the basic characteristics of the Peruvian economy.

Overall, the paper contributes to the literature by analyzing under which type of monetary policy rule the minimum welfare loss occurs in a small open economy with price and wage rigidities. The results of this study can be useful for policymakers in small open economies in selecting an optimal monetary policy rule. The present paper has the following structure: In Section 1, a review of the literature relevant to the different traditional policy measures is presented in order to compare them with respect to the NGDP monetary policy. In Section 2, a standard Neo Keynesian open economy model with rigidities is presented, together with the monetary policy equations to be compared. Then, the respective methodology is clarified in which, through a welfare function, the optimal rule is determined under different calibrations, from which impulse response functions will be obtained. Section 3 shows the results of the simulations under the different shocks analyzed, after which robustness tests will be carried out. Finally, conclusions and recommendations to extend the present work are presented in the final section.

1.1. Literature review

Monetary policy in Neo-Keynesian models: The literature has widely analyzed monetary policy under Neo-Keynesian models, which can compare different monetary policy rules. In a closed economy with nominal rigidities, Gertler et al. (1999) present a monetary policy analysis showing that the optimal monetary policy incorporates a target inflation rule to reduce time-volatility. The optimal rule effectively accommodates demand shocks; however, in the presence of supply shocks, it presents a trade-off between inflation and economic activity (output gap).

Gali and Monacelli (2005) expand the analysis by studying monetary policy in a Neo-Keynesian model with an open economy and price rigidities. This model incorporates a trade-off between stabilizing the nominal exchange rate and the terms of trade, in addition to stabilizing domestic inflation and the output gap. To determine the optimal monetary policy, they show analytically that in the particular case of a logarithmic utility function and unit elasticity of substitution, a rule that strictly minimizes domestic inflation is the optimal monetary policy.

However, these models demonstrate that monetary policy cannot fully stabilize fluctuations despite their simplicity. The inclusion of additional rigidities such as wages, as demonstrated by Erceg et al. (2000), adds new elements that must be considered to maintain stability in an open economy. Furthermore, the optimal rule for monetary policy ceases to be a domestic inflation target, as shown by Campolmi (2014).

Traditional inflation rules: Monetary rules are preferred over discretion by central banks because the latter may result in inaccuracies in expectations, thereby exacerbating the trade-off between inflation and output gap. Monetary policy rules also enable the public to better understand the bank's objectives since the central bank is bound to comply with them, thereby allowing for frictions in the measurement of variables (Garín et al. (2016)). Traditional inflation rules that meet the aforementioned characteristics are the Taylor rule, strict domestic inflation, and strict consumer price index (CPI). While the application of these rules in emerging economies has led to improvements, they have also attracted criticism for their performance. According to Frankel (2010), after the emergence of inflation targeting (IT) in 1971, emerging economies that adopted it experienced a decline in inflation and less volatility in growth. However, after the 2008 crisis, other types of anchors, such as CPI targeting, were introduced to pay attention to other nominal variables, including asset prices, exchange rates, and commodity prices, as they predict future inflation.

Inflation targeting was designed for developed economies and is not as well-suited for emerging countries, such as small open economies, as they face exogenous shocks with poor external account conditions and are required to finance their trade deficit. Such countries experience higher volatility of supply shocks, such as commodity or energy prices, and their booms feature capital inflows, currency overvaluation, and associated current account deficits, followed by crashes, sharp depreciation, and recession. After such scenarios, the weight of nominal GDP was split between inflation and output, aiming at a "core" CPI target instead of CPI alone, in emerging countries (Frankel, 2010). However, this complicates the explanation of core CPI inflation target and undermines credibility, especially in emerging countries. According to Céspedes et al. (2014), the use of nontraditional policies during the 2008 crisis showed that central banks had the ability to counteract external shocks and keep recessions short and shallow. Therefore, monetary and exchange rate policies have deviated from the textbook IT paradigm.

In the literature, Nominal GDP Targeting (NGDP) has emerged as a potential policy alternative to Inflation rules or the Taylor rule, with several possible advantages. Firstly, an NGDP rule is relatively easy to communicate to the public, and therefore easier for the central bank to commit to (McCallum, 2015; Sumner, 2014). Secondly, NGDP can be more effective in stabilizing cost shocks than regimes that react only to inflation (Garín et al., 2016). Thirdly, while NGDP also reacts to inflation and output, it responds to a single variable (nominal output, which is a combination of both), giving it an advantage over rules that respond to both variables separately (Chen, 2021). Finally, NGDP is easier for the central bank to observe than the output gap, which is subject to greater estimation error (Beckworth and Hendrickson, 2020).

Garín et al. (2016) use simulations to evaluate the properties of NGDP, both in levels (NGDP-LT) and growth (NGDP-GT), in a Neo-Keynesian closed economy model with price and wage rigidities. Using a function that measures welfare loss from different shocks, they compare the NGDP-GT rule with strict inflation targeting, strict output gap targeting, and a conventional Taylor rule. The authors find that NGDP-GT dominates inflation targeting and the Taylor rule, particularly in the presence of supply shocks.

Chen (2021) extends these results in a model with growth and productivity trends in the presence of supply and demand shocks. He compares inflation targeting with NGDP-LT and NGDP-GT, and shows that NGDP-GT generates lower welfare loss than the other rules, subject to different shocks and conditions.

The literature suggests that Nominal GDP Targeting (NGDP) may have advantages over Inflation rules or the Taylor rule. One of these advantages is its simplicity in terms of explanation to the public, which facilitates the central bank's compliance under commitment (McCallum, 2015; Sumner, 2014). Additionally, NGDP is more efficient at stabilizing cost shocks than regimes that react to inflation (Garín et al., 2016). Another advantage of NGDP is that it responds to both inflation and output, while only responding to one variable, as nominal output is a combination of both (Chen, 2021). Furthermore, NGDP is easier for the central bank to observe than the output gap.

While output estimates have a larger margin of error that may translate into less efficient policy responses (Beckworth and Hendrickson, 2020), simulations by Garín et al. (2016) using a Neo Keynesian closed economy model with price and wage rigidities show that NGDP-GT dominates inflation targeting and the Taylor rule, especially in the presence of supply shocks. Similarly, Chen (2021) extend these results in a model with growth and productivity trends in the presence of supply and demand shocks, showing that NGDP-GT generates lower welfare loss relative to the rest.

Measurement problems with the output gap variable also suggest advantages of an NGDP rule.

Garín et al. (2016) evaluate this issue through a model that includes a noise variable in the output gap, finding that given a certain threshold of noise in the variables, an NGDP-GT target is preferable. Further exploration of the correct measurement of the target variable is conducted by Beckworth and Hendrickson (2020), who show that one cannot consider an NGDP rule as a special case of the Taylor rule in the face of imperfect information. Thus, they argue that a proper comparison between the two rules must consider the information problem. Through simulations with measurement error in the output gap, they determine that an NGDP rule is preferable to the Taylor rule.

The advantage of an NGDP target is its ability to respond to two variables through a single variable. The NGDP target is composed of inflation and real GDP, similar in structure to a Taylor rule, but does not suffer from the information problem of the output gap. Therefore, NGDP should generate a response similar to inflation targeting in the face of demand shocks. However, the main advantage of NGDP is in its response to supply shocks, where it produces lower welfare losses. Unlike inflation targeting, NGDP gives equal weight to both deviations, providing a smoother response to supply shocks that benefits the real sector of the economy.

2. The Model

To determine the optimal monetary policy rule from a welfare loss minimization perspective, we use a Neo Keynesian model for a small open economy proposed by Galí and Monacelli (2005). This model is modified to include nominal wage rigidities developed by Erceg et al. (2000) and further adapted to the needs of NGDP-GT (hereafter referred to simply as NGDP) by Garín et al. (2016).

The analytical framework provides a useful tool to recognize different dynamics, which are relevant when defining the optimal monetary policy. Currently, we face a trade-off between exchange rate control and inflation in an open economy and a trade-off between stabilizing the real part of the economy and inflation due to nominal rigidities. This latter trade-off is critical, and NGDP is an interesting alternative because it responds to shocks while balancing these two objectives. This balance is achieved because wage rigidities amplify the effect of inflation on the economy and generate additional distortions to prices.

The model includes households, firms producing intermediate goods, and firms producing final goods.

2.1. Households

The economy is inhabited by a representative household that seeks to maximize the following intertemporal utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, N_t(h), Z_t\right) \tag{1}$$

where $N_t(h)$ denotes labor hours for different types of labor, Z_t is an exogenous preference, and β is a discount factor. C_t is a consumption index consisting of consumption of domestic goods ($C_{H,t}$) and consumption of foreign goods ($C_{F,t}$) that takes the following form:

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + (\alpha)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{2}$$

where $\eta > 0$ measures the degree of substitution between goods from different countries, and $1-\alpha$ measures the degree of home bias (if $\alpha = 0$ we have the closed economy case), and aggregate consumption takes the following form:

$$C_{H,t}(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}}\right]^{-\epsilon_p} C_{H,t} \tag{3}$$

$$C_{i,t}(j) = \left[\frac{P_{i,t(j)}}{P_{i,t}}\right]^{-\epsilon_p} C_{i,t} \tag{4}$$

$$C_{i,t} = \left[\frac{P_{i,t}}{P_{F,t}}\right]^{-\gamma} C_{F,t} \tag{5}$$

The equations in (3) and (4) represent the demand for local good j (or sector j), and demand for good j from country i, respectively. The parameter ϵ_p is the substitution elasticity between different consumer goods in the same market. Equation (5) shows the demand for the total goods of the country i as a function of foreign (or imported) consumption, γ represents the degree of substitution between foreign goods.

From the cost minimization problem we obtain the following demands as a function of total consumption:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \tag{6}$$

$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \tag{7}$$

From these demands we arrive at an expression of the price index (or CPI) which aggregates the prices of local ($P_{H,t}$) and foreign or imported goods ($P_{F,t}$):

$$P_t = \left[(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{8}$$

From these equations, the household budget constraint is determined:

$$P_t C_t + E_t[\Omega_{t,t+1} D_{t+1}] \leq D_t + W_t(h)N_t(h) + \Pi_t \tag{9}$$

In the model, the variables $\Omega_{t,t+1}$, D_t, Π_t, and $W_t(h)$ represent the stochastic discount factor, the payout of the bonds, the income of the firm, and the wages paid to the household, respectively. The stochastic discount factor is equal to the inverse of the interest rate of a bond ($\frac{1}{R_t}$). The household's utility function is specified as follows:

$$U(C_t, N_t(h), Z_t) = \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t(h)^{1+\varphi}}{1+\varphi}\right) Z_t \tag{10}$$

where the relative risk aversion coefficient is denoted by σ and the inverse of the elasticity of the Frisch labor supply is represented by ϕ. By optimizing (1) with respect to consumption, subject to the budget constraint (9), we obtain the Euler equation:

$$C_t^{-\sigma} = \beta E_t\left[C_{t+1}^{-\sigma}\frac{Z_{t+1}}{Z_t}\frac{1}{\Omega_{t,t+1}}\frac{P_t}{P_{t+1}}\right] = \beta E_t\left[C_{t+1}^{-\sigma}\frac{Z_{t+1}}{Z_t}\frac{R_t}{1+\pi_{t+1}}\right] \tag{11}$$

Where $1+\pi_{t+1} = \frac{P_{t+1}}{P_t}$

2.1.1. Wage Setting

Households hold some bargaining power when offering their different wages to the firms operating in various sectors. The firm's demand for labor in sector j can be found by minimizing wage costs. The labor supply for a household is represented as follows:

$$N_t(h) = N_t \left[\frac{W_t(h)}{W_t}\right]^{-\varepsilon_w} \tag{12}$$

where ϵ_w is the elasticity of substitution between different types of labor, N_t aggregates the entire labor supply, and W_t is an index that aggregates all wages. As stated in Erceg et al. (2000), only a fraction $(1-\theta_w)$ of households can optimally change their wage to maximize their utility, while the remaining fraction θ_w keeps their wage constant. By incorporating these conditions into the utility function and the budget constraint, we can obtain:

$$\begin{aligned}\mathcal{L} = \mathrm{E}_t \sum_{s=0}^{\infty} \beta\theta_w \Bigg\{ \left(- \frac{\left(\frac{w_t(h)\pi_{t,t+s}^{-1}}{w_{t+s}}\right)^{-\varepsilon_w(1+\phi)} N_{t+s}^{1+\varphi}}{1+\varphi} \right) Z_{t+s} + \\ \lambda_{t+s} P_{t+s} \left[w(h)_t \pi_{t,t+s}^{-1} \left(\frac{w_t(h)\pi_{t,t+s}^{-1}}{w_{t+s}}\right)^{-\varepsilon_w} N_{t+s}^{1+\varphi} \right]\end{aligned} \tag{13}$$

The Lagrangian in real terms of the household under wage rigidities, a la Calvo, can be expressed as follows, where we only show the wage-related variables. w_t represents the real wage $\frac{w_t}{p_t}$, and $\pi_{t,t+s}$ represents the cumulative inflation s periods ahead. In this optimization problem, the household faces the probability θ_w of not being able to update its wage in each period, acting as an additional discount factor for β. The optimal wage at time t is given by:

$$w_t^{\#,1+\varepsilon_w\varphi} = \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{E_t \sum_{s=0}^{\infty} (\beta\theta_w)^s w_{t+s}^{\varepsilon_w(1+\varphi)} \pi_{t,t+s}^{\varepsilon_w(1+\varphi)} N_{t+s}^{1+\varphi} Z_{t+s}}{E_t \sum_{s=0}^{\infty} (\beta\theta_w)^s C_{t+s}^{-\sigma} Z_{t+s} w_{t+s}^{\varepsilon_w} \pi_{t,t+s}^{\varepsilon_w - 1} N_{t+s}} \tag{14}$$

Given the updated wage in each period (14), we can determine the dynamics of wages. Specifically, the aggregate wage is a weighted average of the updated wage and the rigid wage. It is worth noting that, in the equation for the dynamics of real wages, the overall price level P_t affects the evolution of those who fail to re-optimize.

$$w_t^{1-\varepsilon_w} = (1-\theta_w) w_t^{\#,1+\varepsilon_w \varphi} + \theta_w (1+\pi_{t+1})^{\varepsilon_w - 1} w_{t-1} \tag{15}$$

In the case where there are no rigid wages ($\theta_w = 0$), the optimal wage would be $w_t = \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{N_t^{\varphi}}{C_t^{-\sigma}}$, where there is a mark-up on the marginal rate of substitution between consumption and labor. If $\varepsilon_w \to \infty$, meaning there is substitutability between different types of labor, we obtain the flexible wage case presented by Gali and Monacelli (2005): $w_t = C_t^{\sigma} N_t^{\varphi}$.

2.1.2. Real exchange rate and terms of trade

The terms of trade, denoted by S_t, is defined as the ratio of the price of foreign goods to the price of domestic goods, where we assume that the law of one price holds. The bilateral nominal exchange rate between the domestic and a foreign country, denoted by P_t, can be expressed as the product of the nominal exchange rate of the domestic currency with respect to the foreign currency and the foreign price level, denoted by $E_{i,t}$ and P_t^i, respectively. The real exchange rate, denoted by Q_t, is defined as the ratio of the foreign and domestic consumer price indices, where we assume that the prices are quoted in the domestic currency.

$$Q_{i,t} = \frac{E_{i,t} P_t^i}{P_t} \tag{16}$$

2.1.3. International equity risk

Under the assumption of a complete set of internationally traded state-contingent assets, the Euler equation must hold for the remaining households in the world. Thus, given an identical function it takes the following form:

$$\beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{Z_{t+1}}{Z_t} \frac{1}{\Omega_{t.t+1}} \frac{P_t}{P_{t+1}} \right] = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{Z_{t+1}}{Z_t} \frac{1}{\Omega_{t.t+1}} \frac{E_{i,t} P_t}{E_{i,t+1} P_{t+1}} \right]$$

2.2. Firms

The economy's supply side can be divided into two sectors: firms producing intermediate goods and those producing final goods. The output of the latter depends on the aggregate inputs produced by the former, which are imperfect substitutes. There is a market for intermediate goods where firms compete under monopolistic competition to the extent that their products are different, giving them market power. However, they cannot freely adjust prices in every period but rather face a stochastic process for price adjustment (a la Calvo).

2.2.1. Final Goods Firm

In the final goods market, firms participate under perfect competition. The input they use is intermediate good j. From the profit maximization problem we obtain the demand for this product j which depends on the relative price of intermediate good j, the elasticity of substitution between intermediate goods, and a proportion of the aggregate product Y_t:

$$Y(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}}\right]^{-\varepsilon_p} Y_t \tag{17}$$

2.2.2. Intermediate Goods Firm

A typical household firm produces a differentiated good with the following production function and technology:

$$Y_t(j) = A_t N_t(j) \tag{18}$$

Labor is an essential factor of production and is incurred by firms as a common wage cost. Firms determine their labor demand by minimizing costs for a given level of technology, which leads to the expression of real marginal cost as $mc_t = \frac{W_t}{A_t P_{H,t}}$.

2.2.3. Price determination

As in the case of nominal rigid wages, a firm in each period has a probability of $1 - \theta_p$ of optimally changing its wage, while it has a probability of θ_p of sticking with its previous period's price. Given this, each period t, the firm must take this probability into account when discounting its revenue. This can be expressed as follows:

$$\max E_t \sum_{s=o}^{\infty} \Lambda_{t+s}[P_{H,t+s}(j)Y_{t+s} - W_{t+s}N_{t+s}(j)] \tag{19}$$

Where $\Lambda = (\beta\theta_p)^s \frac{U'(C_{t+s})}{U'(C_t)}$ is a stochastic discount factor. By obtaining the first-order conditions to the optimization problem, we arrive to an equation that describes the dynamics of prices:

$$P_{H,t}^{\#} = \frac{\varepsilon_p}{\varepsilon_p - 1} \frac{E_t \sum_{s=0}^{\infty} \Lambda_{t+s} mc_{t+s} Y_{t+s} P_{H,t+s}^{\varepsilon_p}}{E_t \sum_{s=0}^{\infty} \Lambda_{t+s} Y_{t+s} P_{H,t+s}^{\varepsilon_p - 1}} \tag{20}$$

In the special case where prices are flexible ($\theta_p = 0$), the above expression can be re-expressed as: $P_{H,t} = \frac{\varepsilon_p}{\varepsilon_p - 1} \frac{W_t}{A_t}$, i.e., it depends on the nominal marginal cost over the "mark-up".

We can represent the dynamics of aggregate price as:

$$P_{H,t}^{1-\varepsilon_p} = (1 - \theta_p) P_{H,t}^{\#,1-\varepsilon_p} + \theta_p P_{H,t-1}^{1-\varepsilon_p} \tag{21}$$

Dividing (20) by $P_{H,t}^{\#,1-\varepsilon_p}$ we can arrive at the inflation dynamics:

$$(1 + \pi_{H,t})^{1-\varepsilon_p} = (1 - \theta_p) \left(\frac{P_{H,t}^{\#}}{P_{H,t}} \right)^{-\varepsilon_p} + \theta_p \tag{22}$$

2.3. Equilibrium Equations

In equilibrium, domestic production must satisfy domestic and foreign demand (exports):

$$Y_t = C_{H,t} + X_t \tag{23}$$

On the other hand, the equilibrium in the intermediate goods market requires that the supply meets the demand, and together with equation (2.2.3), we can obtain an expression for price dispersion.

$$\Delta_{w,t} = (1 - \theta_p) \left(\frac{P_{H,t}^{\#}}{P_{H,t}} \right)^{-\varepsilon_p} + \theta_p (1 + \pi_t)^{\varepsilon_w - 1} \Delta_{p,t-1} \tag{24}$$

Finally, in order to achieve labor market equilibrium, it is necessary to determine the following expression for wage dispersion, by setting supply equal to demand:

$$\Delta_{w,t} = (1-\theta_w)\left(\frac{w_t^{\#}}{w_t}\right)^{-\varepsilon_w(1+\varphi)} + \theta_w\left((1+\pi_t)\frac{w_t}{w_{t-1}}\right)^{\varepsilon_w-1}\Delta_{w,t-1} \tag{25}$$

2.4. Exogenous variables

In the model, there are two exogenous processes, the shock of household preference, Z_t, and the shock of firm productivity, A_t. These shocks are assumed to follow AR(1) processes.

$$\begin{aligned} \ln(Z_t) &= \rho_Z \ln(Z_{t-1}) + \sigma_Z \epsilon_{Z,t} \\ ln(A_t) &= \rho_A \ln(A_{t-1}) + \sigma_A \epsilon_{A,t} \end{aligned} \tag{26}$$

2.5. Central Bank and Monetary Policy

We study four different monetary policy rules:

i) **General Taylor rule:** $i_t = \rho + \phi_\pi(\pi_t - \pi) + \pi_X X_t$

ii) **Strict domestic inflation rule:** $i_t = \rho + \phi_{\pi,H}(\pi_{H,t} - \pi_H)$

iii) **CPI inflation rule:** $i_t = \rho + \phi_\pi(\pi_t - \pi)$

iv) **NGDP rule:** $i_t = \rho + \phi_g g_t$, where $g_t = \pi_t * \frac{Y_t}{Y_{t-1}}$

3. Methodology

3.1. Model Calibration

To obtain the results of the study, a combination of calibration and parameter estimation is required. Table 1 presents the calibrated parameters for the endogenous dynamics of the model, excluding those related to monetary policy rules, which will be estimated to obtain optimal rules. The paper's main objective is to analyze the welfare properties of NGDP in an open economy, so standard parameters from the literature were initially used for calibration. For simulation of the Peruvian economy, the calibration presented by Castillo et al. (2009) was used.

Table 1: Calibrated Parameters

Parameter	Coefficient	Name
σ	1	Risk Aversion
η	0.8	Home-foreign Substitution
γ	1	Substitution among foreigners
φ	2.2	Frisch Inverse Elasticity
ε_p	3.8	Elasticity of substitution (goods)
ε_w	4.3	Elasticity of substitution (labor)
θ_p	0.8	Calvo index of prices
θ_w	0.8	Calvo index of wages
β	0.99	Discount factor
α	0.3	Openness
ρ_A	0.74	TFP Autocorrelation
ρ_Z	0.6	Preferences Autocorrelation
σ_A	0.0064	Standard deviation of technology process
σ_Z	0.0289	Standard deviation of preferences process

Source: Own elaboration

For the purpose of examining the robustness of the model results, we will estimate the model with different parameter values that vary within a specific range. This will enable us to determine whether the normative properties of a rule are maintained across various parameter values or whether they are parameter-specific. In particular, we will focus on the parameters related to the substitution between domestic and foreign goods, the degree of openness, and the Calvo index parameters for prices and wages. This approach is similar to the one adopted by Garín et al. (2016).

To calculate optimal policy rules and subsequent welfare analyses, it is necessary to explain the methodology of welfare calculation under nonlinear models. In the literature, there are two types of approaches for calculating optimal monetary rules and welfare: analytical and computational.

The analytical approach uses log-linearizations and specific parameter assumptions to arrive at an analytical welfare expression. For example, Campolmi (2014) used the LQ method to derive a welfare function in an open economy with price and wage rigidities. The disadvantage of this approach is that the analytical calculation of the welfare function only considers specific cases of parameters and does not allow for analysis of more general cases given the complexity of each case. Moreover, the LQ approach does not capture the full dynamics of the second-order approximation to the linear restrictions.

To overcome these limitations, researchers make use of full second-order approximations through the perturbation method, which allows for obtaining the first and second moments of the variables. This computational approach approximates the welfare function for different parameters and allows for obtaining more general results. The calculated welfare is re-expressed in terms of consumption utility to facilitate comparisons (Adjemian et al., 2022; Born and Pfeifer, 2020).

$$\mathrm{E}_0\left[\sum_{t=0}^{\infty}\beta^t U(C_t, N_t)\right] = \mathrm{E}_0\left[\sum_{t=0}^{\infty}\beta^t U\left((1-\omega_c)C_t^{flex}, N_t^{flex}\right)\right] \tag{27}$$

The left-hand side of (26) represents the utility in the case where nominal rigidities exist. The right-hand side represents the utility without rigidities (deterministic steady state), but which is discounted by $1-\omega_c$, where ω_c is the cost or welfare loss associated with a specific model.

3.1.1. Optimal Rules

Based on the approaches for calculating welfare, we proceed to determine the optimal rules by obtaining the parameters that minimize welfare loss for each monetary rule. To achieve this, we use a recursive algorithm, which is explained in Appendix 1. We then simulate the models using these optimal parameters and compare the resulting welfare losses in the results section.

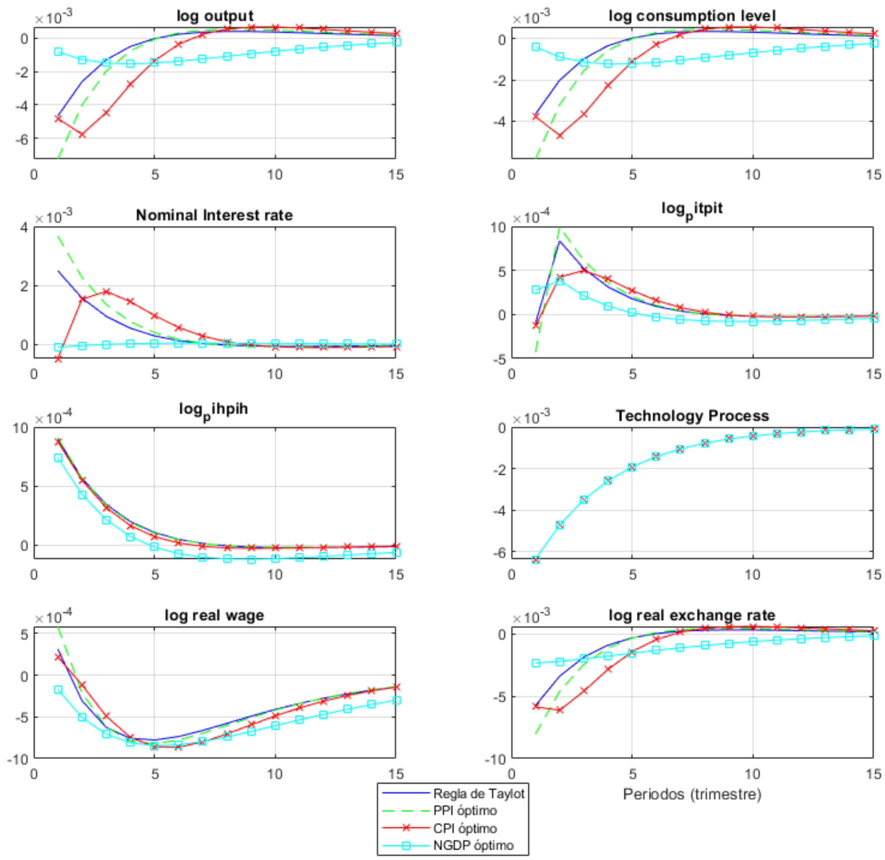
3.1.2. Simulations

The following are the preliminary impulse response function (IRF) dynamics of four models: Taylor rule, inflation targeting, CPI inflation targeting, and NGDP targeting. The x-axis of the simulations shows the periods in quarters, and the y-axis shows deviations in percentage points from the equilibrium value.

The figure above (Figure 1) illustrates the dynamics of the impulse response function (IRF) for four different monetary policy rules: Taylor rule, inflation targeting, CPI inflation targeting, and NGDP targeting. The simulations show the response of the economy to a negative productivity shock, where the x-axis represents the time in quarters and the y-axis represents deviations in percentage points from the equilibrium level.

The results indicate that under the three traditional rules (Taylor rule, inflation targeting, and CPI inflation targeting), the output and consumption levels decline in response to a negative productivity

Figure 1: Productivity shock



Source: Own elaboration

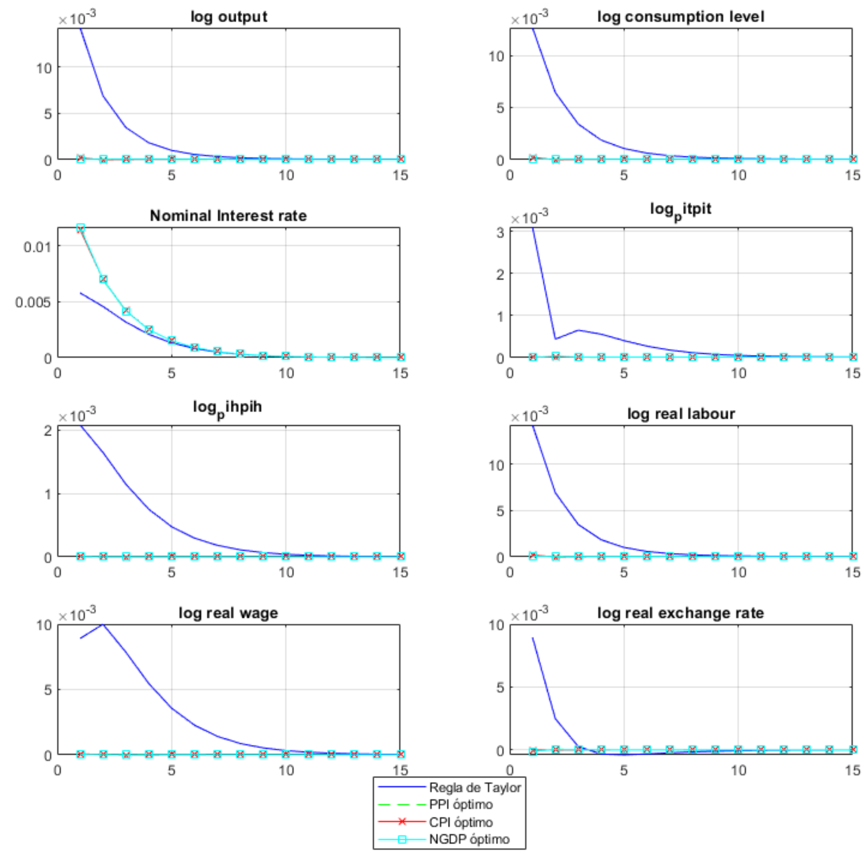
shock. The Central Bank raises interest rates to reduce inflation, but this leads to a further decline in real output. In contrast, the NGDP targeting rule weighs the decline in real output with the rise in prices, resulting in a lower impact on the equilibrium level. However, the recovery time is longer under the NGDP targeting rule.

The nominal interest rate decreases slightly at the outset under the NGDP targeting rule, while it increases temporarily under the traditional rules. Real wages rise under the CPI and Taylor monetary policy rules, but decline rapidly under the PPI rule. The NGDP targeting rule initially experiences a decline in real wages, which allows for the maintenance of jobs and output. However, all rules maintain negative real wages after the second quarter, with a gradual recovery only after the fifth quarter.

The real exchange rate decreases under the three classical rules, indicating that a depreciation leads to an increase in the amount of domestic goods required per unit of foreign goods, making the foreign good relatively more expensive than the domestic one, thereby affecting the level of consumption adversely.

In contrast, the NGDP targeting rule causes a relatively smaller fall in the real exchange rate due to the slight decrease in interest rates. This result implies that the NGDP targeting rule is less sensitive to the degree of openness of the economy, a finding that will be further evaluated later. For more information on the changes in endogenous variables, please refer to Appendix 2.

Figure 2: Preferences shock



Source: Own elaboration

Positive preference shocks generally have a similar effect on output in the CPI, PPI, and NGDP rules, but the parameterized Taylor rule results in an increase in output. This is because nominal interest rates were high in this scenario, while the parameterized Taylor rule was lower.

When it comes to real labor levels, real wage levels, and real exchange rates around equilibrium, the CPI, PPI, and NGDP rules behave similarly. However, the parameterized Taylor rule often leads to increases in real labor and real wages (with a curvature in the following quarters), as well as an increase in the real exchange rate. These effects usually diminish between the second and third quarters. In the case of the real exchange rate, there is a fall in the second and third quarters when there is a preference shock.

4. Results Analysis

4.1. Comparison of Models Based on Welfare Calculation

This section compares the performance of different monetary policy rules based on the calculation of welfare loss for different specifications of price and wage rigidities.

4.1.1. Supply Shock

Table 2 presents the results for the optimal rules for domestic inflation (PPI), total inflation (CPI), and NGDP, for different values of price and wage rigidities. It is observed that the preference for one rule over the other varies depending on the level of rigidities.

Notably, when both price and wage rigidities are set at $\theta_w = 0.75$ and $\theta_p = 0.75$, the results break with the case presented by Gali Montanelli. In this case, the NGDP rule generates the smallest welfare loss of 0.29 percent of consumption, followed by the optimal CPI rule with a welfare loss of 1.18 percent, and finally, the optimal PPI (or inflation targeting) rule with a welfare loss of 1.58 percent of consumption.

Table 2: Welfare loss due to supply shock

θ_p θ_w	0.75 0	0.75 0.25	0.75 0.75	0.50 0.75	0.25 0.75	0.5 0.5
PPI	0.0001	0.6043	1.5781	2.6282	2.8845	2.1438
CPI	0.1059	0.4108	1.1847	2.502	2.7856	1.4925
NGDP	0.8869	1.0969	0.8018	0.5067	0.2935	0.5167

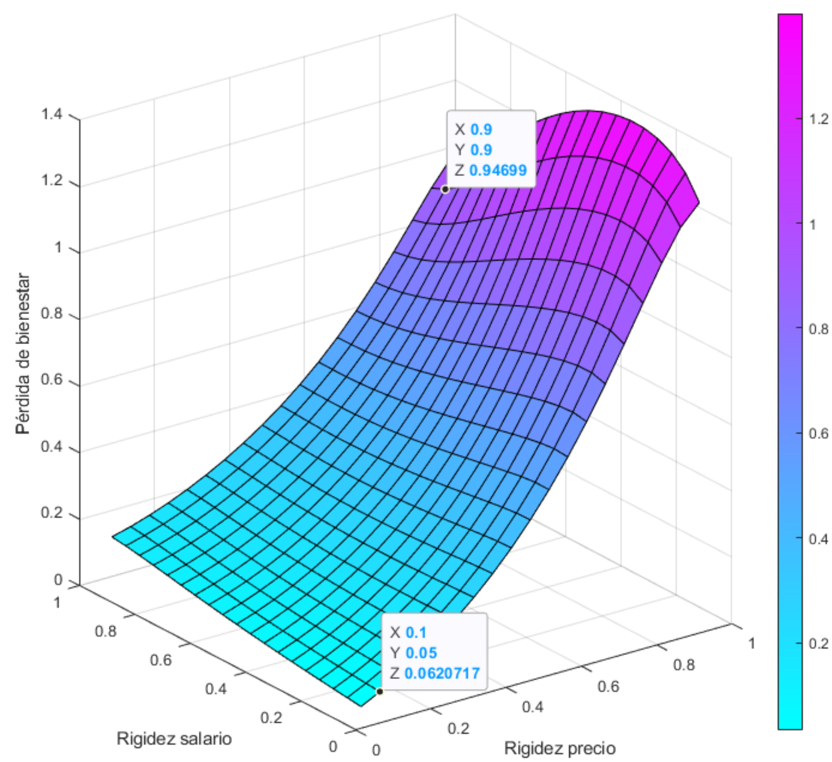
Source: Own elaboration

It is worth noting a clear pattern in the results. With the inclusion of wage rigidities, the NGDP rule becomes the optimal policy rule in almost all cases. When $\theta_p = 0.75$ and $\theta_w = 0.25$, the welfare loss is 11

The results on the performance of PPI and CPI rules are not particularly novel, as they are already theorized and demonstrated by Erceg et al. (2000) and Campolmi (2014). The novel result is that adding an NGDP monetary policy rule to the open economy model with wage rigidities shows that it generates a smaller welfare loss in the presence of rigidities.

Figure 3 illustrates how the performance of an NGDP targeting rule varies with changes in the rigidity parameters. In general, it is observed that NGDP tends to accommodate supply shocks better when there is greater wage rigidity than price rigidity. This result is due to the fact that inflation directly affects the evolution of wages because if workers expect a rise, they will demand an increase, which affects the firm, especially when wages are highly rigid, and it cannot operate optimally, thus increasing the welfare loss.

Figure 3: Nominal rigidities and welfare in model with NGDP *targeting*



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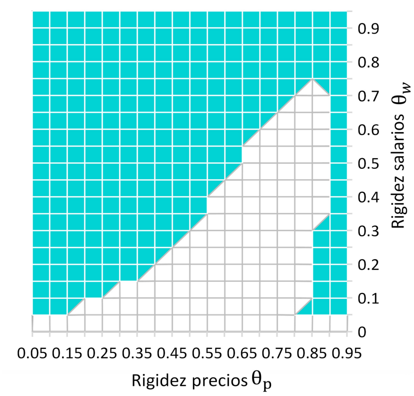
One alternative way to present the comparison between the performance of the NGDP and CPI rules in the presence of supply shocks is through Figure 4. This graph provides a clear visualization of the values of the rigidity parameters for which the welfare generated by NGDP is higher than that generated by the CPI rule. Specifically, the figure displays a locus of points where the welfare losses under both rules are equal, and the region above this locus represents the values of the parameters for which the NGDP rule outperforms the CPI rule in terms of welfare.

It is worth noting that this comparison reinforces the findings discussed in the previous section, which indicate that an NGDP targeting rule generally performs better than a CPI targeting rule in the presence of supply shocks and wage rigidities. Moreover, the figure highlights the sensitivity of the results to the values of the rigidity parameters, indicating that the optimal policy rule depends crucially on the underlying structural features of the economy.

Figure 4: Nominal GDP vs CPI inflation target



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4.1.2. Demand Shock

Table 3 shows the simulation results for a positive preference shock (demand shock) in the economy. As expected, the welfare loss is relatively similar across the different policy rules considered. The results show that the NGDP targeting rule generates the lowest welfare loss, followed by the CPI rule and, finally, the PPI rule. This finding is consistent with the results for the supply shock, which suggest that an NGDP targeting rule is the most efficient monetary policy in the presence of wage rigidities.

Table 3: Welfare loss due to demand shock

θ_p	0.75	0.75	0.75	0.50	0.25	0.5
θ_w	0	0.25	0.75	0.75	0.75	0.5
PPI	0.0081	0.0056	2.9985	3.616	5.2055	0.2741
CPI	0.0079	0.0052	0.0054	0.0054	0.0055	0.0054
NGDP	0.0081	0.0056	0.0056	0.0056	0.0056	0.0056

Source: Own elaboration

The results presented in Tables 2 and 3 indicate that each of the three monetary policy rules evaluated in this study can effectively stabilize the economy in response to a positive supply or demand shock, resulting in a significant reduction of welfare losses. Notably, the results suggest that the choice of monetary policy is more critical in response to supply shocks than to demand shocks.

When examining the impact of wage rigidities, it is evident that the PPI rule becomes less effective when the degree of wage rigidity increases. However, the PPI rule still performs comparably to the CPI and NGDP target rules in minimizing the negative effects of a shock. Importantly, the findings demonstrate that, in cases where the economy faces primarily supply shocks and when wage rigidities are not negligible, the NGDP target rule may be an efficient alternative.

In sum, the results of this study highlight the importance of selecting an appropriate monetary policy rule in response to different types of shocks and wage rigidities. These findings may have practical implications for policymakers in formulating monetary policy strategies that can effectively stabilize the economy and minimize welfare losses in the face of adverse shocks.

4.2. Robustness tests

In this section we study how the results previously found vary with different calibrations of the model, analyzing the persistence of shocks, *home bias* and the intertemporal elasticity of substitution.

5. Conclusions and Recommendations

This paper presents a DSGE model simulation of a small open economy using various monetary policy rules, including the Taylor rule and an alternative NGDP rule. The results demonstrate that the NGDP targeting rule is more effective in responding to negative productivity shocks when wage and price rigidities exist in most of the scenarios analyzed. Additionally, the performance of NGDP targeting is similar to that of other Taylor rules in the presence of demand shocks, with no significant differences observed.

The findings are consistent with previous studies on optimal monetary policy, particularly Campolmi (2014) which shows that optimal CPI performs better, and Garín et al. (2016) which indicates that NGDP targeting has lower welfare loss compared to other monetary policy alternatives in a closed economy. However, this paper extends the analysis to a small open economy and demonstrates that NGDP targeting can also achieve the smallest welfare loss in this context.

These results highlight the importance of considering NGDP targeting as an alternative monetary policy approach, particularly in dealing with supply shocks, which are difficult for central banks to address. As supply shocks are expected to become more recurrent due to technological and climate changes in the future, NGDP targeting may prove to be a valuable tool for policymakers.

The finding that NGDP targeting is effective in dealing with supply shocks compared to classical alternatives is significant for policy discussions, given the challenges that central banks face in responding to such shocks. This becomes even more pertinent in light of the expected increase in recurrent supply shocks due to technological and climatic changes in the future.

The results suggest that NGDP should be considered as an alternative policy option, though there are costs associated with changing from one rule to another, such as the loss of confidence and the costs borne by households in adjusting to new rules. An interesting extension of this research would be to conduct simulations that calculate the losses associated with switching from one monetary policy to another within the model, to provide further evidence on the viability of NGDP as an alternative in the future.

Moreover, the versatility of NGDP targeting, as demonstrated in our model, makes it an appealing option to consider in situations where traditional monetary policies are ineffective, such as in the case of the Zero Lower Bound.

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Appendices

A. Appendixes

A.1. Appendix 1: Algorithm to obtain optimal rule

a Determine vector with initial values and range of possible values for monetary rule parameters, which are used for simulation:

$$[\phi_i] \in [1.1; x]; \phi_i = 1.1$$

b Using perturbation method, the welfare loss level under the rule is obtained for the first set value, and stored in vector **W**:

$$\mathrm{E}_0 \left[\sum_{t=0}^{\infty} \beta^t U \left(C_t(\phi_i), N_t(\phi_i) \right) \right] = \mathrm{E}_0 \left[\sum_{t=0}^{\infty} \beta^t U \left((1-\omega_c) C_t^{flex}, N_t^{flex} \right) \right]$$

$$\rightarrow \boldsymbol{W_c} = \boldsymbol{\omega_c(i)}$$

c After this, we proceed to test the next value within the range of values set in a.

d The model is solved again as in b. The process is repeated while approaching the maximum of the function.

e The value of the parameter that gives the lowest welfare loss is chosen. An overall maximum.

$$\phi_{i,optimal} = \phi_i \left(min\{W_c\} \right)$$

A.2. Appendix 2: Variance of endogenous variables to shocks

B. Figures

Figure 5: Eurozone: Evolution of goods and services shares in total private consumption, 1995-2021

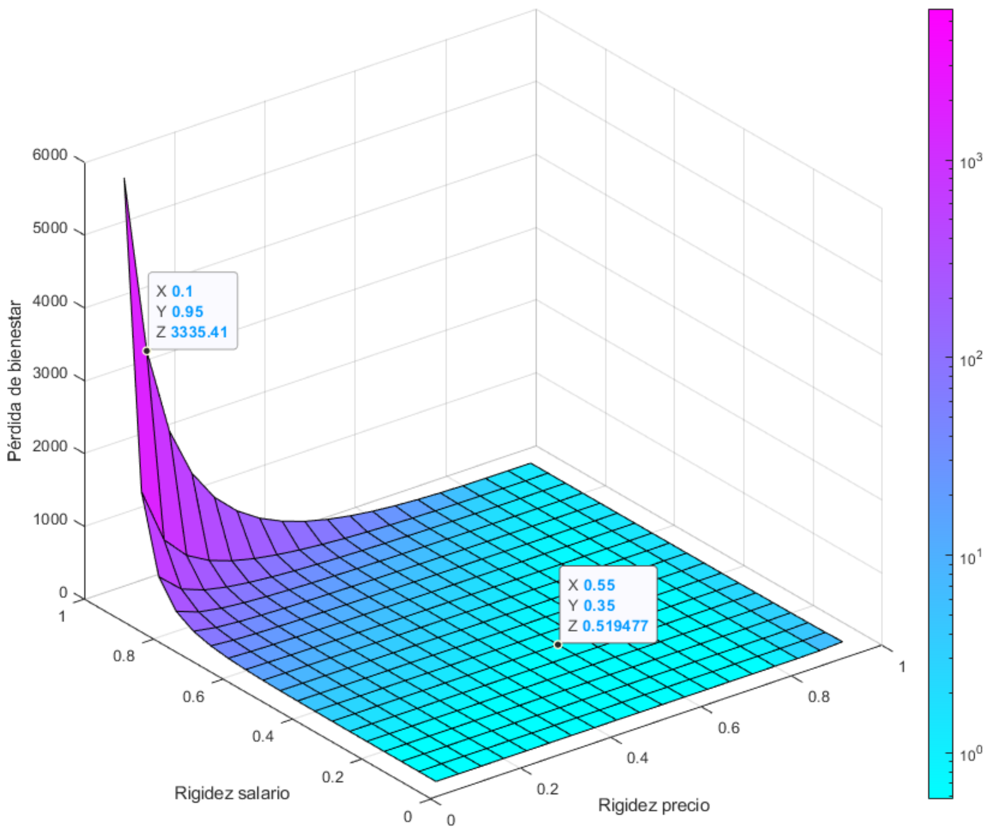

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Figure 6: Eurozone: Evolution of goods and services shares in total private consumption, 1995-2021

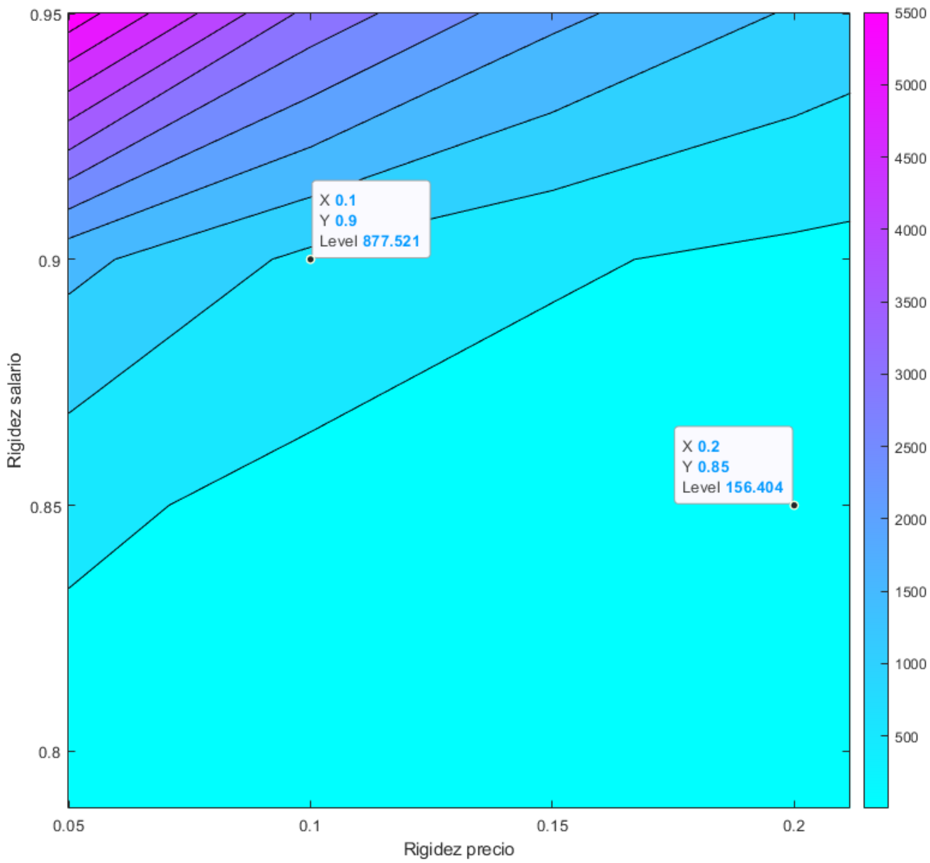

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Figure 7: Eurozone: Evolution of goods and services shares in total private consumption, 1995-2021

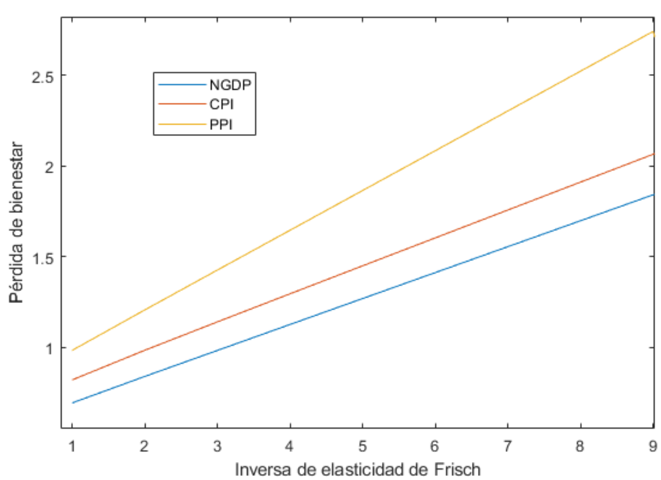

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Figure 8: Eurozone: Evolution of goods and services shares in total private consumption, 1995-2021

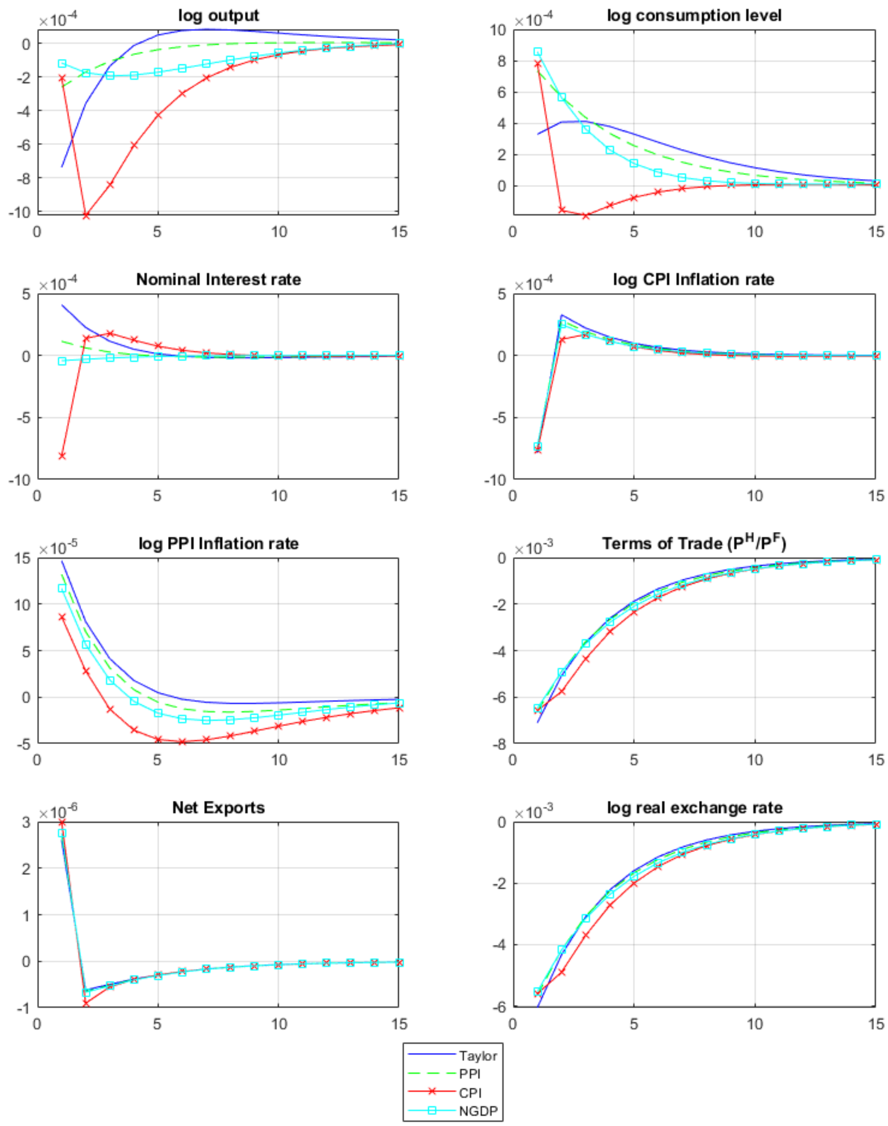

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Figure 9: Eurozone: Evolution of goods and services shares in total private consumption, 1995-2021

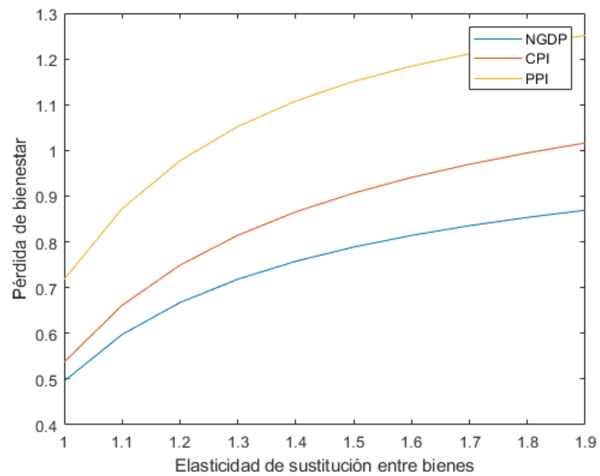

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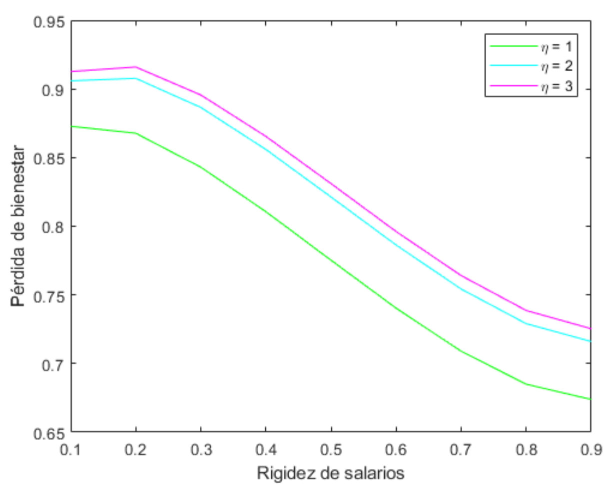
Figure 10: Eurozone: Evolution of goods and services shares in total private consumption, 1995-2021



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