Essays on monetary policy for commodity-exporting economies

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Abstract

The first chapter conducts an optimal monetary policy evaluation for a small open economy with a commodity-producing sector, under flexible prices but financial frictions. Commodity-producing firms face collateralized borrowing constraints for international loans. Confronted with correlated commodity prices and world activity shocks, the best monetary policy rule is a feedback rule that targets consumer price inflation under a standard ad hoc loss function. However, under a second ad hoc loss function that adds the nominal exchange rate volatility, the best monetary policy rule is given by a feedback nominal exchange rate targeting rule.

The second chapter characterizes the constrained efficient- and -time-invariant optimal monetary policy under full commitment for a small open economy with a commodity sector, financial frictions and sticky prices through a recursive Ramsey policy approach. In response to correlated commodity price and world activity shocks, the simple and implementable rule that comes closest to the constrained efficient optimum is a strict domestic inflation targeting rule. Despite borrowings being set in foreign currency, nominal exchange rate targeting rules (and exchange rate peg rules) are (highly) welfare detrimental. Under the optimal policy, greater price flexibility is associated with higher nominal exchange rate volatility and welfare losses.

The last chapter characterizes the optimal sustainable policy through its operational optimal quasi-sustainable policy for a small open- and -commodity-exporting economy with financial friction set as a foreign nominal borrowing limit. Contrasting the quasi-sustainable policy against predictions of the optimal commitment and the optimal discretionary policies in response to positive commodity price shocks, the optimal quasi-sustainable policy coincides with the optimal commitment policy. This implies that the reputation assumption under the first policy corresponds to the commitment assumption made under the second policy. Furthermore, the sustainable equilibrium under the first policy is consistent with the competitive equilibrium attained under the second policy.

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To my Lord, my God and my King: Yahweh of Hosts. The living and true God, whom I love and serve. The One who has always been with me and upheld me with His mighty right hand of righteousness. All the Honor and Glory be to Thee forever and ever! Amen.
(1 Timothy 1:17, Isaiah 41:10, 1 Thessalonians 1:9).

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Author's declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References. The first chapter has been presented at the CIMS Conference 2021 (organized by the University of Surrey). The second chapter has been presented at the LACEA-LAMES Annual Meeting 2022 Conference (organized by The Econometric Society, the Latin American and Caribbean Economic Association - LACEA and the Universidad del Pacífico) and submitted to the Journal of International Economics for eventual publication (at the time of submission of the present dissertation, the referred article was under review). Likewise, the second chapter has also been presented at the Thursday Workshop, organized by the Department of Economics and Related Studies of the University of York.

Introduction

Galí and Monacelli's (2005, also referred to as GM) seminal work on monetary policy and the nominal exchange rate volatility in small open economies set up the common wisdom that the main difference among policy regimes not only resides in the implied welfare loss under each policy regime but also in the implied volatility of the nominal exchange rate. Since that time, the profession has advanced in the characterization of optimal monetary policy for small open economies in general and with specific features (Corsetti and Pesenti, 2001; Benigno and Benigno, 2003; Faia and Monacelli, 2008; De Paoli, 2009; Corsetti, Dedola and Leduc, 2010; Monacelli, 2013; Ozkan and Unsal, 2014).

The characterization of the business cycle of small open- and -commodity-exporting economies (SOCEEs) has been a research avenue that has been recently explored (Shousha, 2016; Fernández, Schmitt-Grohé and Uribe, 2017; Drechsel and Tenreyro, 2018; Fernández, González and Rodríguez, 2018; Bergholt, Larsen and Seneca, 2019; Kohn, Leibovici and Tretvoll, 2021); as so is the case of the optimal monetary policy characterization for these type of economies (Bejarano and Charry, 2014; Garcia Cicco, Kirchner, Carrillo, Rodríguez, Pérez Forero, Gondo, Montoro and Chang, 2017).

In particular, Ferrero and Seneca (2019, also referred to as FS) characterize the optimal monetary policy for a small open- and -commodity-exporting economy by extending GM's model through the addition of a commodity-producing sector. While Drechsel, McLeay and Tenreyro (2019, also referred to as DMT) add an exogenous financial friction in the form of a static earning-based borrowing constraint to the commodity-producing sector proposed by FS. Relying on a linear-quadratic approximation framework à la Clarida, Galí and Gertler (1999), these two papers document the assessment of the optimal monetary policy under full commitment. In terms of results, both papers find that the optimal monetary policy responds to a positive commodity price shock by raising the nominal interest rate and allowing nominal and real appreciations of the exchange rate that propitiate relative prices to adjust so that real and nominal macroeconomic variables are optimally stabilized and reallocated. Thus, the tightening monetary conditions of the economy seek to efficiently address the policy trade-off introduced by the commodity boom.

However, once the optimal responses and volatilities of the nominal exchange rate suggested by FS and DMT's papers are analyzed, one realizes that they are the highest in comparison to the ones indicated by the simple and implementable monetary policy rules that these authors evaluate. Moreover, thinking about the relevance that the role of the nominal exchange rate plays in the business nature of a commodity-producing and -exporting sector in this type of economies, one notes that the model of these authors miss currency mismatch considerations. Subsequently, this fact leads one to wonder about the potential challenges that the prediction of their models could have in light of the related literature. Accordingly, that is the case in terms of the 'fear of floating' phenomena stylized facts (as documented by Calvo and Reinhart, 2002); and the stream that points out that these types of economies (SOCEEs) that usually experiment such type of phenomena considerable prefer a smoother volatility of their nominal exchange rate (Frankel, 2003). Moreover, this latter observation resembles the conventional wisdom in the literature that the economy that experiences miss currency mismatch episodes tends to have a less volatile nominal exchange rate. Therefore, the present conjecture invites further research on this issue.

The first chapter of this thesis contributes to the literature by providing two types of endogenous financial frictions in the commodity sector that account for currency mismatch considerations and that prove to be relevant for monetary policy. Namely, it provides a macroeconomic model that endogenously rationalizes the business nature of a commodity-producing sector (where currency mismatch considerations apply) along the real business cycle of a SOCEE. To that end, unlike DMT authors, it is assumed that the representative commodity firm faces an endogenous dynamic asset-based borrowing constraint in the spirit of Kiyotaki and Moore (1997). Concretely, international nominal borrowings are denominated in foreign currency, as DMT, but in order to access foreign loans, creditors require assets as collateral. Analogously, the second type of financial friction is proposed: an earning-based borrowing constraint (also known as an income-based borrowing constraint) along the lines of the same referred spirit and according to the importance that similar type of financial friction takes in the business of general-type of firms (as in Drechsel, 2018). Then, under this setup, optimal simple and monetary policy rules are tested under two ad hoc loss functions in the quest of (–a sort of agnostic or–) preliminary results to an optimal monetary policy evaluation.

The second chapter of this thesis adds to the literature by implementing an optimal Ramsey monetary policy evaluation approach à la Marcet and Marimon (2019) to the similar SOCEE of the previous chapter but relying on the endogenous dynamic earning-based borrowing constraint also introduced (and evaluated) in the previous chapter. As a result, the second chapter provides a cross-validation framework for the optimal monetary policy evaluation under full commitment performed by FS and DMT, where these authors rely on a different approach, as mentioned before. Moreover, this chapter is the first study to document the implementation of the recursive Ramsey-type methodology to a SOCEE. Previous works miss a commodity sector in the economy: Khan, King and Wolman (2003) apply it to the case of a closed economy; Faia and Monacelli (2008), to a small open economy; and Faia (2009), to a closed economy but with labor market frictions. Furthermore, the chapter is the first to document the implementation of the endogenous earning-based constraint (introduced in the first chapter) where borrowings are nominal and denominated in foreign currency, and where the constraint accounts for currency mismatch considerations and is relevant for monetary policy. In the same order, this chapter contributes by extending the analysis and evaluating alternative Taylor-type rule specifications, by performing simulations related to the role of the nominal exchange rate under different policy regimes and relevant parameterizations of the baseline model. Additionally, the baseline model built in this chapter is directly contrasted against an alternative one whose commodity sector is assumed to be exactly the same to that from DMT to test the traditional claim that the economy with currency mismatch considerations exhibits a lower nominal exchange rate volatility.

The last chapter of this thesis hands over advances to the literature by conducting an optimal sustainable and optimal discretionary monetary policy evaluation for a small open- and -commodity-exporting economy. Such an outcome turns this research work into the first study that implements Kurozumi's (2008) approach together with Sunakawa's (2015) quantitative method to evaluate the optimal sustainable monetary policy to the SOCEE proposed by DMT. In particular, the results attained by DMT under full commitment are contrasted to the predictions formulated by the optimal sustainable and optimal discretionary policies. Moreover, it is tested whether the reputational technology assumption under the optimal sustainable policy could ease the commitment steadfastness assumption technology held under the optimal commitment policy. In turn, it is also examined whether this latter possible outcome could deliver a lower (or the same or higher) volatility of the nominal exchange rate. Additionally, simulations varying relevant parameterization of the model are effectuated (close to the ones undertaken in the previous chapter). In this fashion, this chapter seeks to check the robustness and complement the results attained along the two-former chapters and on the conclusions arrived by FS and DMT.

The remaining of the thesis proceeds with the development of the three aforementioned chapters, an overall conclusion, appendices for each chapter and consulted references (that are consigned in the Bibliography).

Chapter 1

Endogenous dynamic borrowing constraints and monetary policy for commodity-exporting economies

1.1 Introduction

Throughout time most commodity prices have become more related to international macroeconomic fluctuations. This, as a result of the economic integration, globalization and financialization processes (Shousha, 2016; Fernández, Schmitt-Grohé and Uribe, 2017; Drechsel and Tenreyro, 2018). In particular, such a relationship has been more relevant for commodity-exporting countries (54% out of 189 countries in the world; UNCTAD, 2019). Correlated shocks between commodity prices and world economic activity affect relative prices, terms of trade and exchange rates of these types of countries. Consequently, these episodes are relevant for the monetary authority of these countries, who usually seek to stabilize inflation and output –and, to some extent, the nominal exchange rate as well–.

In the quest of an optimal monetary policy design for small open economies (SOEs) with a significant commodity-exporting sector, recent studies have focused on the supply side of these economies (Bejarano and Charry, 2014; Bergholt, Larsen and Seneca, 2019; Ferrero and Seneca, 2019). Specifically, it has been found that exogenous and static borrowing constraints in the financial structure of commodity-producing firms help to explain the economic cycle of these types of countries (Drechsel, McLeay and Tenreyro, 2019).

This paper follows the same strand but focuses on the role of endogenous and dynamic borrowing constraints in the commodity sector and their implications for monetary policy. Two main questions are set. Firstly, what monetary policy rule could be optimal for a small open economy with a commodity-producing sector that faces an endogenous dynamic borrowing constraint for international collateralized borrowings and that is subject to a simultaneous commodity price shock and world shock? Secondly, what is the role of the endogenous dynamic collateralized borrowing constraint within the business cycle of the SOE?

A small-open-economy real business cycle model with a commodity-producing sector is developed and simulated. This sector displays financial friction in the form of a constraint for inter-temporal international borrowings that are collateralized by the firm's capital stock and that account for the nominal exchange rate dynamics. The model environment is characterized by fully flexible prices and perfectly competitive markets to isolate the financial friction's effect and determine its implications for monetary policy.

The main contributions of this research are that: (i) it introduces asset-based and earning-based borrowing constraints in the commodity-producing sector that accounts for possible currency mismatch episodes; (ii) it shows how the asset-based and the earning-based borrowing constraints work as a transmission channel of commodity price shocks and world shocks along the business cycle of the SOE; (iii) it recommends optimized simple monetary rules under a fully-flexible price environment that could work as a benchmark for future studies on optimal monetary and macroprudential policies for economies with similar or different features.

The closest related work to the one presented here, is that of Drechsel, McLeay and Tenreyro (2019, hereinafter referred to as DMT), who conduct an optimal monetary policy analysis by assuming a static earning-based borrowing constraint tied to the income of a commodity-producing firm of a small open economy that has staggered prices à la Calvo (1983). The setup of their model is based upon Ferrero and Seneca's (2019, hereinafter referred to as FS) framework, who included a commodity-exporting sector to the New Keynesian model formulated by Galí and Monacelli (2005, hereinafter referred to as GM).

DMT conclude that in response to a simultaneous commodity price shock and world activity shock, the optimal monetary policy is given by a strict CPI targeting rule. This leads the monetary authority to raise the nominal interest rate and allows for a nominal exchange rate appreciation.

The first principal departure with respect to DMT's work is that instead of relying on an exogenous static earning-based borrowing constraint, an asset-based borrowing constraint in the spirit of Kiyotaki and Moore (1997, henceforth referred to as KM) is proposed here. Secondly, DMT do not take into account the nominal interest rate within their borrowing constraint because they consider foreign-intratemporal borrowings to finance inputs of the commodity-producing firms, and subsequently, they do not even consider any possible fluctuation of the nominal exchange rate. Here instead, this research sets asset-based and earning-based borrowing constraints that intrinsically reckon the correspondent foreign nominal interest rate and nominal exchange rate.

The reason for considering an asset-based (or an earning-based) borrowing constraint and the feature of inter-temporal borrowings has to do with the characteristics of the credit markets in SOEs and small emerging open economies (SEOEs). They are usually cataloged as shallow and are more probably to be tied to asset-based (or earning-based) collateralized borrowings. Thus, the manner in which commodity-producing firms fund their operations becomes a relevant link between monetary policy measures and the business cycle.

Thirdly, while DMT assume that commodity-producing firms optimize profits at each period (statically), here, it is supposed that these type of firms optimize (dynamically) by taking into account the present and future value of the firm (the net worth of the firm, for all periods). Moreover, here in the baseline model with asset-based borrowing constraint, the commodity firm demands capital by considering the domestic nominal interest rate and the expected dynamic of the nominal exchange rate. All of this, in addition to other common factors that the demand for intermediate goods of DMT also consider, but statically.

Fourthly, a real business cycle model is set here to serve as a benchmark for further studies and future monetary policy analysis. The first reason for this choice is that is necessary to check whether there are nominal rigidities or frictions coming from the borrowing constraint of commodity-producing firms. As a matter of the fact, that is the only friction introduced in the model. Then, after muting this channel, it is proven that the model cannot generate frictions within the model that help to explain the transmission mechanism of a foreign interest rate shock within the SOE.

Although in this paper is assumed that households have state-contingent securities within international perfect competitive markets, the literature contemplate former works that assume financial frictions within specific sector of their economy. They are even within households or firm or government sectors. As a result, one could say that this paper is not out of the range of these type of assumption in the literature.

The main result here is that a feedback CPI inflation rule that stabilizes inflation and consumption volatilities seems to be the first-best welfare-improving monetary policy rule. However, when one analyzes the implied standard deviation for the nominal exchange rate and the high response that this variable displays to a simultaneous commodity price shock and world activity shock, makes one think about the "fear of floating" results and consider an alternative mandate for the monetary authority that besides inflation and consumption volatilities stabilization also cares about the change in the nominal exchange rate volatility stabilization. In such a case, the first-best monetary policy is given by a feedback rule that targets the nominal exchange rate and that yields a response and volatility for this targeting variable that are lower and usually more comfortable for policymakers.

The main conclusion of the paper is that, under a fully-flexible price environment, in response to a correlated shock (a simultaneous commodity price shock and world activity shock), the monetary authority should follow a feedback rule that targets the nominal exchange rate and that leads to this authority to lower the nominal interest rate and allow a lower and smoother appreciation of the nominal exchange rate. This conclusion does not change when an endogenous and dynamic earning-based borrowing constraint is assumed.

Ultimately, the model set here is able to explain the role of the asset-based borrowing constraint of the commodity-producing sector in the real business cycle of a SOE. Moreover, the model constitutes a framework for optimal monetary policy evaluation where the nominal exchange rate and relative prices adjustments play a key role as factors that contributes to absorb shocks and help to stabilize the economy.

The rest of the document proceeds with Section 1.2, which develops on the relevant literature review for the approach and findings of this paper. Section 1.3 presents the theoretical aspects of the SOE-RBC model. Section 1.4 describes the main quantitative findings on the optimal monetary policy evaluation and on the role that the borrowing constraint plays in the economy. Finally, Section 1.5 concludes.

1.2 Related literature

This paper adds to the strand of the literature on international macroeconomics that studies how monetary policy in commodity-exporting countries should react to commodity price shocks or to this type of shock that is simultaneously correlated with a world activity shock. It also contributes to research in the profession about models that can rationale the "fear of floating" phenomenon in the nominal exchange rate fluctuation. Moreover, the contributions also go in the line with those studies that propose borrowing constraints as a transmission mechanism of shocks that can affect and play a role in the business cycle of SOEs.

The influential paper of Calvo and Reinhart (2002) shows that most policymakers of emerging economies that claim to have a floating nominal exchange rate regime do not allow for a full floating. Then, after almost two decades since the first report on the "fear of floating" phenomenon, Ilzetzki, Reinhart and Rogoff (2020) argue that such a practice is still present and that it is the norm for the majority of the official ("*de jure*") floating exchange rate regimes. There are several reasons for this phenomenon, but the main ones are the dollarization of liabilities and the pass-through from the exchange rate to prices. In episodes of high nominal exchange rate fluctuations, these factors led to currency mismatches that, eventually, ended in periods of crisis, and especially, in the case of SEOEs.

In particular, in the model of this paper, it is assumed that there are dollarized liabilities and complete pass-through from the nominal exchange rate to prices in the context of complete markets and perfectly international risk sharing. In addition, and as it was mentioned before, the commodity-producing firm in the model assumes a borrowing constraint for international-collateralized borrowings. As a result, it can be seen that there are assumptions and features of the SOE-RBC model set here that help to provide an adequate environment to obtain potential results in line with the stylized "fear of floating" facts. When an objective function (that also considers the minimization of the change in the nominal exchange rate volatility) is set jointly with a feedback rule that targets the nominal exchange rate, the response and change in the volatility of the nominal exchange rate demonstrate to be lower and in line with the aforesaid stylized facts.

In the literature, one finds that Heipertz, Mihov and Santacreu (2020) arrive at a similar conclusion. A monetary policy rule that besides output and CPI inflation also targets nominal exchange rate fluctuations outperforms traditional Taylor-type rules and yields higher welfare. These authors base their monetary policy evaluation on an *ad hoc* welfare loss function and simple rules. The setting of their model is based on GM with an *ad hoc* subtle change introduced in the uncovered interest rate parity to account for the nominal exchange rate risk premium. Moreover, they also add habits in consumption and a new set of policy rules.

Another close result to the one obtained in this paper, and in line with the "fear of floating" predictions, is that of de Ferra, Mitman and Romei (2020). They find that a fixed exchange rate regime is the optimal monetary policy response to a sudden stop and unexpected current account reversal for a SOE. They argue that a monetary policy that seeks to achieve full employment and allow for a sizable nominal exchange rate devaluation, under those circumstances, is detrimental from a welfare perspective (this latter, measured in consumption terms). Despite their analysis being conducted under a Heterogeneous-Agent New Keynesian Small Open Model Economy (HANKSOME), their results are consistent with the model adopted here and their hard peg policy is very close to the feedback rule that targets the nominal exchange rate that is proposed here as an optimal monetary policy.

In the same direction, Iyer's (2016) findings suggest that a hard peg nominal exchange rate regime is the best monetary policy rule when there is a high proportion of hand-to-mouth agents in a SOE that suffers cost-push shocks. Her optimal rule is relatively preferable to domestic and CPI inflation targeting rules. Her conclusion is based on a New Keynesian model à la GM that accounts for two types of households: those who are financially included and those who are not.

One possible explanation for getting the feedback rule that targets the nominal exchange rate as the first-best welfare-improving rule here (in this present paper), would have to do with the role that this targeting variable (the nominal exchange rate) plays within the borrowing constraint of commodity-producing firms, and ultimately, in the economy, as it will be seen.

Another feasible justification that one could think about would be that the assumption of exclusive international borrowings in the commodity-producing sector, somehow, would implicitly be reflecting the "original sin hypothesis" of Eichengreen and Hausmann (1999). In such a proposition, it is assumed that unhedged foreign currency borrowings result as a consequence of scarce or nil access to domestic currency borrowings in SEOEs. This latter reason is also taken as one alternative explanation for the "fear of floating" phenomenon, and within the model of this paper, the commodity-producing sector does not contract state-contingent borrowings.

Another important point to dig into the literature is the use of borrowing constraints as a friction factor that can generally provide potential explanations for the business cycle of SEOEs.

Firstly, Iacoviello (2005) studies how nominal loans and collateral constraints tied to housing values amplify the business cycles in response to demand shocks. In doing so, he proposes a New Keynesian model with a representative patient household that demands houses and that can borrow or lend money. Likewise, an entrepreneur sector that produces homogeneous intermediate goods and that is subject to a borrowing constraint, collateralized by the real estate that this sector uses as a production input. To achieve a binding constraint for this sector, this author assumes that households are more patient for consumption in comparison to entrepreneurs. In the present research, such an assumption it is not necessary because the designed borrowing constraint is binding at the steady state and along the dynamic of the model. Another difference between both setups is that, here, the framework consists of a small-open-economy real business cycle model, while the other, of a closed economy New Keynesian model.

The previous paper is directly related to the one of KM, who provide micro-foundation for the borrowing constraint as a limit amount to debtors (borrowers) to prevent a repudiation of the debt and considerable losses to the creditor. Thus, this micro-founded borrowing constraint is exploited by Iacoviello and applied to the case of a representative entrepreneur that uses its real estate as collateral and as a production factor. Here, in the present paper, the essence of such a borrowing constraint is applied to the case of a firm sector that pledges its capital stock as a collateral instrument and that uses it as a production input as well.

Regarding the collateralized borrowing constraint and the small-open-economy real business cycle model environment, the work of Li and Dressler (2011) is another close study. They focus on the case of small-open economies where an international borrowing constraint occasionally binds and they simulate it under the framework of a real business cycle model. Notwithstanding, the differences between their work and the one presented here emerge from the fact that their model is a modified version of the small open economy of Mendoza (1991). Consequently, it has not a dual-producing sector like the model set here (the non-traded final goods firm and the commodity-producing firm), which is based on the models of FS and this latter, in turn, on the one of GM. Consequently, they do not study the case of a small open economy with a commodity-producing sector, nor can examine the effects of commodity price shocks over the business cycle. The model setup of these authors is basically in line with their aim of explaining asymmetries in the business cycles in response to productivity shocks. Clearly, in this paper, as it was mentioned before, the purpose is different (to understand how commodity price shocks and world activity shocks affect the business cycles in the presence of borrowing constraints), and subsequently, the model setup is also distinct (as it will be seen).

Concerning the international borrowing constraint, Li and Dressler use the classical one and assume that such a constraint is for the whole country. Namely, it is collateralized by a fraction of the country's capital stock, motivated by sovereign risk, enforcement and information frictions in international capital markets. Here instead, as explained before, the novelty comes from the addition of the expected nominal exchange rate quotation which is an important factor for indebtedness decisions within the commodity-producing firm.

Wang et al. (2017) set a New Keynesian model for the Chinese economy to simulate heterogeneous production sectors, given by a representative private firm and state-owned firm sectors. They assume that the state-owned sector has full access to international bank financing, while the other one (the private firm sector) faces discriminatory borrowing constraints (as here, à la classical form of an asset-based type constraint). The purpose of these authors is to understand the implications of the borrowing constraint as a transmission mechanism for monetary and fiscal policies. In terms of the borrowing constraint of these authors and the one from here, the difference is given by the expected nominal exchange that the present paper adds as a novelty.

Another nearby work that is worthy to mention is the one of Drechsel (2018), which compares the performance of earning-based borrowing constraints with respect to the traditional assets-based borrowing constraints under investment shocks. Estimating a NK model for the case of an advanced economy (the US), this author concludes that, given the credit market and macroeconomic features of the US, earning-based borrowing constraints achieve to explain a major proportion of the output dynamic in comparison to the other financial friction; this, under aforementioned shocks.

Regarding the difference between the asset-based borrowing constraint presented by the former author with the one exposed here, is that this latter considers international borrowings, and subsequently, accounts for the fluctuations of the expected nominal exchange rate and foreign interest rate dynamics. This comes as a consequence of focusing the research on the case of a small open economy subjected to distinct disturbances, namely, commodity price shocks, a foreign interest rate shock and a correlated shock (a simultaneous commodity price shock and world activity shock). This constitutes another contribution of this paper because, to the best of the author's knowledge, the use of this type of asset-based borrowing constraint accounting for the expected nominal exchange rate effects and its application to the case of a small open economy has not been previously studied.

1.3 The model

The model presented here is a small-open-economy real business cycle model (SOE-RBC). Its basic structure follows FS and GM setups under the theoretical framework of a two-country dynamic general equilibrium model, but under fully flexible prices and a perfectly competitive market environment.

In this setup, the world is inhabited by a continuum of countries of units mass, given by the segments $[0, n)$ and $(n, 1]$. There, taking the limit to the size of one country to become enough small (i.e., a SOE), that country is defined as the home (h) country, and the rest of the countries as the foreign country ($f \in (n, 1]$) block. An alternative denomination for these two blocks would be given by the small open economy and the rest of the world blocks, respectively.

The home economy compounds a household sector and a productive sector (with two types of firms). Households consume, provide hours of work and hold a portfolio of state-contingent securities acquired from complete asset markets. The first type of firm corresponds the non-traded final goods sector. This, demands labor and produces goods for domestic consumption and investment. Investment is intended as an input for the second type of firm. This latter corresponds to the commodity-producing sector that exports all its output to the rest of the world while facing financial frictions. In the baseline model, such frictions are given by an endogenous dynamic asset-based borrowing constraint for international borrowings that are collateralized by the capital stock of the firm. Thus, the capital stock performs a double role within the model: as a production factor and as a collateral instrument.[1]

All contracts and prices of the model are written in nominal terms. Consumption basket compositions between the home and foreign countries change over time, consequently, money works as a unit of account for contracts in this cashless economy.[2]

1.3.1 Households

Representative agents from the home small open economy and the rest of the world have isomorphic preferences. In particular, the representative household of the SOE seeks to maximize its respective sequence of consumption, hours at work and state-contingent securities $\left\{C_t, N_t, B_{h,t+1}, B^f_{h,t+1}\right\}_{t=0}^{\infty}$, derived from the expected lifetime utility

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left(\ln C_{t+s} - \frac{N_{t+s}^{1-\varphi}}{1-\varphi} \right), \tag{1.1}$$

subject to the sequence of budget constraints

$$P_t C_t + \mathbb{E}_t Q_{t,t+1} B_{h,t+1} + \mathbb{E}_t \mathcal{E}_t Q^*_{t,t+1} B^h_{f,t+1} \leq W_t N_t + B_{h,t} + \mathcal{E}_t B^h_{f,t} + \Phi_t. \tag{1.2}$$

In the objective function, $\mathbb{E}_t$ is the conditional expectation operator, $\beta \in (0,1)$ is the subjective time discount factor and $\varphi > 0$ is the inverse

[1] In the alternative specification of the model, the financial friction takes the form of an endogenous dynamic earning-based borrowing constraint in which case the expected income of the commodity-producing firm works as collateral. Find more about this version of the model in Appendix 1.1.5.

[2] Variables written with asterisk superscripts refer to the rest of the world economy.

Frisch elasticity of labor supply.

In the budget constraint, P_t is the consumer price index (CPI), $Q_{t,t+1}$ and $Q^*_{t,t+1}$ are the stochastic discount factors (or prices) of the domestic ($B_{h,t+1}$) and foreign ($B^f_{h,t+1}$) portfolio of state-contingent assets, respectively. W_t denotes the nominal wage for the supplied labor, and Φ_t represents profits received from the ownership of commodity-producing firms. Here, it is assumed that commodity profits are lump-sum to the households.

The overall real home consumption (basket) index, C_t, is given by the Cobb-Douglas sub-utility aggregator function[3]

$$C_t \equiv \frac{C_{h,t}^{1-v} C_{f,t}^{v}}{(1-v)^{1-v} v^v}, \tag{1.3}$$

where $C_{h,t}$ and $C_{f,t}$ are the consumption baskets of home and foreign goods, respectively. The parameter determining the weight in the foreign basket block, $v \in (0,1)$, is a measure of the preference between foreign and home consumption goods. Usually, $(1-v)$ is referred to as the "home bias" parameter because it indicates the share of domestic consumption goods allocated to imported goods. Similarly, v is also considered a natural measure of economy openness. For instance, a value of $v = 0$ gives place to the autarky economic scenario in which the trade balance and the international assets position of the home country are nil.

The consumption-base home-currency price index (or CPI) is a weight between home-currency prices of domestic goods ($P_{h,t}$) and prices of foreign goods ($P_{f,t}$):

$$P_t \equiv P_{h,t}^{1-v} P_{f,t}^{v}. \tag{1.4}$$

Given the assumption that the rest of the world (the foreign country, f) has similar preferences and analogous sequence of budget constraints and price indexes (eqs.[1.1]-[1.4]) like the small open economy (country h), it is possible to assume that the law of one price holds: $P_{f,t} = \mathcal{E}_t P^*_{f,t}$ (where $\mathcal{E}_t$ is the nominal exchange rate). This implies that there is a fully passed-through effect from changes in the exchange rate (i.e., there is no stickiness in the price-setting behavior for imported goods that are domestically sold).

Moreover, it is also supposed that the home country does not export

[3]This form of the sub-utility aggregator is a special case of the constant elasticity substitution (CES) function when the parameter of substitutability between domestic and foreign goods from the viewpoint of the consumers is unitary. The same can be said about the CPI index case.

domestic manufacturing goods. This suggests that the consumption of foreign goods for the rest of the world is nil ($v^* = 0$), as well as that its respective price level is the same as the one of the whole economy ($P^*_{f,t} = P^*_t$).

The aforementioned assumptions allow to define the effective bilateral terms of trade ($\mathcal{T}_t$) and its relations with the real exchange rate (S_t) definition as follows:

$$\mathcal{T}_t \equiv \frac{P_{f,t}}{P_{h,t}} \tag{1.5}$$

$$S_t \equiv \frac{\mathcal{E}_t P^*_t}{P_t} = \frac{\mathcal{E}_t P^*_{f,t}}{P_t} = \frac{P_{f,t}}{P_t} = \frac{P_{h,t}\mathcal{T}_t}{P_t} = \mathcal{T}_t^{1-v}. \tag{1.6}$$

From previous relations (1.4-1.6), it is also clear that $\mathcal{T}_t^{-v} = P_{h,t}/P_t$ and that $\mathcal{T}_t^{1-v} = P_{f,t}/P_t$.

Usual expenditure minimization problems yield optimal allocations for domestic ($C_{h,t}$) and foreign ($C_{f,t}$) bundles of consumption goods and the terms of trade relations allow to write:

$$C_{h,t} = (1-v)\left(\frac{P_{h,t}}{P_t}\right)^{-1} C_t = (1-v)\mathcal{T}_t^{v} C_t \tag{1.7}$$

$$C_{f,t} = v\left(\frac{P_{f,t}}{P_t}\right)^{-1} C_t = v\mathcal{T}_t^{v-1} C_t. \tag{1.8}$$

In turn, household's optimality condition for hours at work yield the labor supply choice relation

$$\frac{W_t}{P_t} = N_t^{\varphi} C_t, \tag{1.9}$$

whilst the first-order condition for consumption and the state-contingent assets gives the conventional stochastic Euler equation

$$1 = \beta \mathbb{E}_t \frac{Q^{-1}_{t,t+1}}{\Pi_{t+1}} \left(\frac{C_{t+1}}{C_t}\right)^{-1}, \tag{1.10}$$

where $\Pi_t = P_t/P_{t-1}$ is the gross CPI inflation rate.

Analogously, there is an intratemporal Euler equation adjusted by the nominal exchange rate for the representative household of the rest of the world. The main analogous preferences for the rest of the world (or the foreign country f) are exposed in Appendix 1.1.1.

Under the assumption of complete markets for securities traded internationally, perfect international risk-sharing implies that the ratio of consumption across countries is proportional to the real exchange rate

$$C_t = \vartheta C_t^* S_t = Y_t^* \mathcal{T}_t^{1-\upsilon}, \tag{1.11}$$

and given that it is also assumed that there is a symmetric initial condition of the relative net asset position for the representative agents of the rest of the world (i.e. zero net foreign asset holdings and *ex ante* identical environment), the constant that depends on the initial net asset position, $\vartheta = 1$.

Then, considering the small open economy assumption ($C_t^* = Y_t^*$), and the no-arbitrage condition, the nominal net return on a one-period risk-free bond (i_t), denominated in domestic and foreign currencies, satisfies $1 + i_t = \frac{1}{\mathbb{E}_t Q_{t,t+1}}$ and $1 + i_t^* = \frac{1}{\mathbb{E}_t Q_{t,t+1}^*}$, respectively.[4]

As of the aforementioned conditions, the uncovered interest rate parity (UIP) of the model (in log-linearized terms) turns out to be equal to

$$i_t = i_t^* + \mathbb{E}_t\{e_{t+1} - e_t\}. \tag{1.12}$$

Finally, it is important to mention that the household sector's setting allows the macroeconomic environment of the model to show relevant aggregate properties (such as the law of one price, the PPP, the UIP, the international perfect risk sharing condition, etc.) for the analysis of the role of commodity-producing firms in the business cycle, and ultimately, for the optimal monetary policy evaluation.

1.3.2 Firms

In this small open economy, there are two sectors that produce homogeneous goods. Namely, they are the final non-traded home goods (composed of consumption and investment goods) and commodity goods. The first is completely consumed within the economy, while the last one is totally exported.

[4] The two latter conditions hold for the households and they are necessary requirements to achieve stationarity within the model. Moreover, they are key conditions that must hold so that the UIP condition of the model be also true.

Non-traded final home goods sector

The representative firm of the sector produces homogeneous manufactured goods which are domestically intended for consumption and investment.[5] This latter is used as an intermediate good (input) within the commodity-producing sector.

As this sector operates in a perfectly competitive market, the representative firm takes prices as given and chooses the sequences of labor $\{N_t\}_{t=0}^{\infty}$ that maximizes the expected present discounted value of profits

$$V_{h,t} = \mathbb{E}_t \sum_{s=0}^{\infty} Q_{t,t+s} \Phi_{h,t+s}, \tag{1.13}$$

where the profit function $\Phi_{h,t} = P_{h,t} Y_{h,t} - W_t N_t$, comprises the competitive price $P_{h,t}$ at which this sector sells its produced goods by using a constant return to scale technology, $Y_{h,t} = A_{h,t} N_t$. Within this production function, $A_{h,t}$ is the total factor productivity (TFP) of the sector and the output elasticity of labor (or labor's share of output) is supposed to be unitary.[6]

The full summary of this sector is presented in Appendix 1.1.1.

Commodity-producing sector

The main departure from GM, FS and DMT is the presence of a commodity-producing sector that is perfectly competitive and faces financial frictions. Such frictions are materialized by an asset-based borrowing constraint.

In particular, the borrowing constraint is based on the principle of the seminal work of KM on credit cycles. These authors state that creditors ensure that the value of their outstanding loan never be over the current liquidation value of borrowers' assets. In terms of the model presented here, that fact materializes in the manner commodity-producing firms use their capital stock as financial collateral for the borrowings they take. Thus, these firms fund their operations of the current period (t) and repay their borrowings in the next period with the selling of their products (in $t + 1$).

[5]As FS, the aim is to keep the model as simple as possible. Subsequently, it is assumed that this sector does not export or import goods.

[6]Given the nature of the problem, it can be supposed that $s = 0$ and that $Q_{t,t} = 1$.

As a commodity exporter firm, this sector naturally faces prices that are determined in international markets. Now, given that such a determination goes beyond the scope of this paper, it is simply assumed that commodity prices are determined outside of the model and that they follow an exogenous process. Here, it is also supposed that the commodity price index is expressed in a foreign currency denomination, $P^*_{o,t}$.

At the domestic level, by the law of one price, the commodity price is given by $P_{o,t} = \mathcal{E}_t P^*_{o,t}$, whilst the real commodity price and its relations with the real exchange rate and with the terms of trade are defined as:

$$\frac{P_{o,t}}{P_t} = \frac{\mathcal{E}_t P^*_{o,t}}{P_t} = \frac{\mathcal{E}_t P^*_{o,t} S_t}{P_{f,t}} = \frac{P^*_{o,t} S_t}{P^*_{f,t}} = \frac{P^*_{o,t} S_t}{P^*_t} = \frac{P^*_{o,t}}{P^*_t} \mathcal{T}_t^{1-v}. \tag{1.14}$$

Within this environment, the representative commodity-producing firm chooses the respective sequences of capital, investment and international borrowing $\{K_{t+1}, I_t, B_{f,t}\}_{t=0}^{\infty}$ that maximize the expected present discounted value of profits

$$V_{o,t} = \mathbb{E}_t \sum_{s=0}^{\infty} Q_{t,t+s} \Phi_{o,t+s}, \tag{1.15}$$

where $\Phi_{o,t}$ represents the profit function that summarizes the firm's budget constraint for every period. Namely, it is defined as

$$\Phi_{o,t} = P_{o,t} Y_{o,t} + \mathcal{E}_t B_{f,t} - \big[P_{h,t} I_t + \mathcal{E}_t (1 + i^*_{t-1}) B_{f,t-1}\big]. \tag{1.16}$$

In turn, this is subject to the following borrowing constraint

$$(1 + i^*_t) B_{f,t} \leq \kappa (1 - \delta) \mathbb{E}_t \frac{P_{h,t+1}}{\mathcal{E}_{t+1}} K_{o,t}, \tag{1.17}$$

and to the respective capital's law of motion and production function

$$K_{o,t+1} = I_t + (1 - \delta) K_{o,t}, \tag{1.18}$$

$$Y_{o,t} = A_{o,t} K_{o,t}^{\alpha_k}. \tag{1.19}$$

In the value of the firm (1.16), one can see that the firm funds its operations through the income resulted from the sale of the total commodity production ($Y_{o,t}$) and from contracting new international borrowings ($B_{f,t}$) expressed in local currency through the nominal exchange rate ($\mathcal{E}_t$). By means of such sources, the firm incurs investment expenses (I_t) and the repayment of the principal and interests of foreign borrowings of the last period ($[1+i^*_{t-1}]B_{f,t-1}$), also expressed in domestic currency. For the sake of simplicity, it is important to remark again that everything that this sector produces is exported.

Following KM, the borrowing constraint in (1.17) states that a firm's borrowings cannot exceed the value of the depreciated capital stock that it provides as a collateral instrument. Specifically, the firm can be indebted (including principal and interests: $[1+i^*_t]B_{f,t}$) from international creditors at most up to its current depreciated capital stock ($[1-\delta]K_{o,t}$) weighted by the loan-to-value ratio (κ) parameter and valued at the expected foreign currency quotation of the next period ($\mathbb{E}_t P_{h,t+1}/\mathcal{E}_{t+1}$). In other words, the company takes collateralized borrowings backed up by the expected value of its current capital stock expressed in foreign currency.[7] Thus, capital stock plays a double role: as a production factor and as a collateral for borrowings.

Similar to KM (p. 221) and Iacoviello (2005, p. 743), here such debt is limited by a maximum amount of borrowing ($B_{f,t}$) which is given by $\kappa(1-\delta)\mathbb{E}_t\{(P_{h,t+1}K_{o,t})/(\mathcal{E}_{t+1}[1+i^*_t])\}$. This upper bound value limits the representative commodity-producing firm agent's credit capacity and serves as a guarantee to the lenders when they have to repossess the borrower's assets by paying a proportional transaction cost $(1-\kappa)(1-\delta)\mathbb{E}_t\{P_{h,t+1}K_{o,t}/\mathcal{E}_{t+1}\}$ when borrowers default or repudiate their debt obligations or renegotiate a new credit contract. The parameter κ is also referred to as the entrepreneurial "loan-to-value" ratio as it implies that collateralized credits cannot exceed a κ proportion of the value of the depreciated firm's capital stock that pledges as collateral.

The collateralized borrowing constraint turns out to be a key factor that has certain effects on how the firm conducts its business. Namely, its own financial condition as well as national and foreign macroeconomic variables would influence its business decisions. For instance, a lower international interest rate or a smaller capital stock depreciation rate or higher expectations of domestic prices or higher expectations about the exchange rate appreciation or lower transaction costs; each one of these factors working (separately or jointly) toward the aforementioned directions would loosen the borrowing constraint (in [1.17]).

Within the model, the borrowing constraint is the only financial friction channel for commodity price shocks and for foreign financial shocks, like those coming from the foreign interest rate and through the nominal

[7] Note that it is assumed that international creditors are able to meet all the required credit demand from commodity-producing firms.

exchange rate.

Henceforth, one can see that the collateralized borrowing constraint constitutes a potential channel for macroeconomic variables and shocks that affect agents' production decisions of this sector, and eventually, the real business cycle of small open economies. And even more, of those countries whose commodity-exporting sectors are relevant in relation to their whole exports, and/or ultimately, to the whole size of their economy. The relevance of this channel would be even stronger for emerging countries where the peculiarity of collateralized borrowings could be more prevalent, given the shallowness and development of their financial markets.

Proceeding with the assumptions for this sector, it is important to indicate that the capital stock belongs to the firm and that this latter, owns to home households. The capital stock evolves according to (1.18) and it depreciates at a rate $\delta \in (0, 1)$. Furthermore, the production function in (1.19) shows decreasing returns to scale $\alpha_k < 1$, which describes the intrinsic characteristic of this industry.

Likewise, all assets and liabilities must be nil. Technically, these following transversality constraints hold

$$\lim_{t\to\infty} \mathbb{E}_t Q_{t,t} \frac{\mathcal{E}_t B_{f,t}}{(1+i_t^*)^t} = 0 \ , \ \lim_{t\to\infty} \mathbb{E}_t Q_{t,t+1} K_{o,t+1} = 0 \ , \ \lim_{t\to\infty} \mathbb{E}_t Q_{t,t} V_{o,t} = 0. \tag{1.20}$$

Because firms of this sector are owned by home households, the stochastic discounted factor $Q_{t,t+s}$ is used to obtain the present value of the firm. Whilst, to calculate the interests to pay for international borrowings, the correspondent foreign interest rate i_t^* is used for such a purpose.

The full summary (the first-order conditions of this sector, the demand for capital stock and the dynamic multipliers) are presented in Appendix 1.1.1.

Note that in this model there is no need to assume that firms have to possess lower subjective discount factors than the households. This fact is a difference between KM and Iacoviello's works, which needed to assume that firms had lower subjective discount factors in comparison to households to obtain a binding borrowing constraint at the steady state. Nevertheless, in the model presented here, borrowings come from international capital markets and the borrowing constraint (the borrowing shadow price) in (A.1.15) is positive (binding) at the steady state.[8]

[8] In the section of quantitative results, one can see in the IRF plots of the model that the real borrowing shadow price is positive (binding) along the simulated dynamics.

A final point to stress out is that the only friction that exists in this model is the one coming from the borrowing constraint. This feature helps to isolate any effect arising from such a friction.

1.3.3 Closure conditions of the model

The closure of the model is given by the market clearing (equilibrium) conditions and stochastic process definitions.

Regarding the equilibrium of the model, the non-traded final goods sector provides (at the same price, $P_{h,t}$) consumption for households and investment goods used in the commodity-producing sector. Thus, the market clearing requires that $Y_{h,t} = C_{h,t} + I_t$. Likewise, the international risk-sharing condition, the symmetric initial conditions and the small open economy assumption assure that the foreign market resource constraint is in equilibrium, $Y_t^* = C_t^*$.

The shocks of the model are all assumed to follow an AR(1) stochastic process. Such processes are assumed for the productivity shocks of the non-traded final goods-producing sector ($A_{h,t}$) and the commodity-producing sector ($A_{o,t}$). Likewise, for the foreign macroeconomic variables. Specifically, the foreign interest rate (i_t^*), the foreign CPI index (P_t^*), the foreign commodity price ($P_{o,t}^*$) and the foreign total consumption (C_t^*). Appendix 1.1.2 shows the details of these processes.

Finally, domestic nominal macroeconomic variables like the gross domestic product (Y_t), the value added of the commodity-producing sector ($TB_{o,t}$) and the overall trade balance (TB_t) are specified in Appendix 1.1.2 as well.

1.4 Quantitative results

This section presents the results of the optimal monetary policy evaluation under the prescriptions of the baseline model built with the asset-based borrowing constraint in the commodity-producing sector, as presented in the previous section. Here, the calibration of the baseline model, the characterization of its dynamics and the role of the asset-based borrowing constraint along the business cycle are also presented. Finally, the results of the alternative model with the earning-based borrowing constraint specification in the commodity-producing sector are shown in the last subsection.

1.4.1 Optimal monetary policy evaluation

In conducting the optimal monetary policy evaluation, two shock scenarios are set here to assess four simple monetary policy rules under two *ad hoc* quadratic loss functions. All of these, under the framework of the model with financial friction in the form of a collateralized borrowing constraint in the commodity-producing sector, as presented in the model section.

The first *ad hoc* quadratic loss function minimizes inflation and consumption volatilities, while the second one adds the change in the nominal exchange rate volatility to the previous loss function.

The first scenario to perform the optimal policy evaluation under both quadratic loss functions is a correlated shock scenario which assumes a simultaneous commodity price shock and world activity shock. This constitutes the baseline scenario throughout the whole paper. While the second scenario, analyzed under both loss functions as well, is given by a commodity price shock under uncorrelated shocks.

The four simple monetary policy rules are given by: a feedback CPI inflation-based Taylor-type rule with the output and the nominal interest rate smoothing (inertial) term (FCPITR); a feedback domestic inflation-based Taylor-type rule with the output and the nominal interest rate smoothing term (FDITR); a feedback nominal exchange rate rule with the nominal interest rate smoothing term (FNERTR); and, a pegged nominal exchange rule (PEG). Note that this latter rule is also known as a hard peg rule or as a fixed exchange rate rule, while the feedback rule that targets the nominal exchange rate is known as a soft peg rule as well.[9]

Appendix 1.1.4 offers explanations –based on the literature– and rationale for the assumptions adopted here for the two functional forms of the *ad hoc* quadratic loss functions, the simple monetary policy rules and for the two shock scenarios.

Summarizing, the two functional forms of the *ad hoc* quadratic loss func-

[9] A soft peg regime is established in between of a hard peg and fully floating regimes.

tions are given by:

$$L_{(\pi_t,c_t)} = var(\pi_t) + var(c_t), \tag{1.21}$$
$$L_{(\pi_t,c_t,\Delta e_t)} = var(\pi_t) + var(c_t) + var(\Delta e_t). \tag{1.22}$$

Note that the variances in the loss functions are assumed to have equal weight, are expressed in quarterly frequency, and are asymptotic variances (i.e., $\mathbb{V} = \mathbb{E}\sum_0^\infty \beta^t L[\cdot]$, and in the limit, the common factor $1/(1-\beta)$ can be ignored).

Both loss functions minimize the volatilities of (the CPI) inflation ($var[\pi_t]$) and consumption ($var[c_t]$), while the last one, also minimizes the change in the nominal exchange rate volatility ($var[\Delta e_t]$). All the variables consigned in the loss functions represent the welfare cost associated to their respective fluctuation.

The functional forms of the simple monetary policy rules used here are:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_t + \phi_y y_t), \tag{1.23}$$
$$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_{h,t} + \phi_y y_t), \tag{1.24}$$
$$i_t = \rho_i i_{t-1} + \phi_e e_t, \tag{1.25}$$
$$e_t = 0, \tag{1.26}$$

where i_t is the nominal interest rate, π_t is the CPI inflation, $\pi_{h,t}$ is the domestic inflation, y_t is the output (measured by deviations of the real GDP with respect to its steady state) and e_t is the nominal exchange rate. Parameters are given by ρ_i, which is the interest rate smoothing coefficient that accounts for feedback of this variable, ϕ_π is the parameter that measures the reaction to inflation deviations from its steady state, ϕ_y is the parameter that measures the reaction to output deviations from its steady state, and ϕ_e is the reaction coefficient to deviations in the nominal exchange rate with respect to its steady state.[10]

Calibration

Most of the calibrated parameters follow standardized values of the literature. Two special calibrations are borrowed from FS. They set the parameters for the Norwegian economy. Namely, the share of commod-

[10] Note that $\phi_e \equiv (1-\rho_i)\phi_{e'}$ accounts for the product between the original reaction parameter to deviations in the nominal exchange rate with respect to its steady state value ($\phi_{e'}$) and the smoothing term for the interest rate $(1-\rho_i)$.

ity inputs with respect to the output of the non-traded final goods sector (inv/y_h) is set to 15%, and the share of commodity output to real GDP (y_o/y) to 20%.

The first calibration value of FS imposes the restriction that the total production of the non-traded final goods sector has to be divided between final consumption goods and investment goods ($c_h/y_h + inv/y_h = 1$). These latter goods are used as inputs for the commodity-producing sector. Thus, given the calibration value of $inv/y_h = 15\%$, the majority of the production of this sector is intended to satisfy domestic consumption. This calibration value is also employed by DMT.

Concerning the second calibration value, the share of commodity output to real GDP (set to 20%), one can verify that such a calibration is within the value range of those developed, emerging and developing economies that are classified as commodity-exporting dependent countries in the UNCTAD's (2019, pp. 22-219) statistic report. Consequently, this calibration value is empirically supported for these types of economies.[11]

Other key parameters related to the economic structure are the domestic and foreign subjective discount factors ($\beta = \beta^* = 0.996$), the inverse Frisch elasticity rate ($\phi = 3$) and the foreign consumption bias ($\nu = 0.6$). They are all taken from DMT. While the last two parameters have classical values, as in the tradition of GM.

With respect to the commodity-producing sector, its main parameters are given by the capital stock depreciation rate ($\delta = 0.1255$) which is borrowed from Garcia-Cicco et al. (2010). Although they set that value for two SEOEs (México and Argentina), the dimension of this parameter would still be useful for comparison purposes.

Another important parameter of the commodity-producing sector is the returns to scale of the production factor of this sector ($\alpha_k = 0.38$). It reflects the decreasing returns of the sector and it is set according to DMT.

Likewise, the loan-to-value ratio ($\kappa = 0.89$) is present in the borrowing constraint of the representative firm of this sector. It determines the fraction of capital that pledges as collateral for borrowings and its value is set following Iacoviello (2005). This author uses the same value in

[11] Indeed, according to UNCTAD's (2019, pp. 1, 5) statistic report, "more than a half of all countries and two-thirds of developing countries are commodity-dependent... [while] ...only 13 percent of developed countries are commodity-dependent". A country is labeled as commodity-dependent when more than 60 percent of its total exports are composed of commodities.

the context of housing and firm's installations pledged as guarantees for loans. Given the closeness to the role of this parameter between the former author's work and the one presented here, its calibration is also used here.

The stochastic shock of the foreign commodity price follows an AR(1) exogenous process. The values for the persistence ($\rho_{p_o^*} = 0.9$) and standard deviation ($\sigma_{p_o^*} = 0.1$) of this variable is drawn from DMT.

As one can see, the calibration seeks to be in line with former studies for comparative purposes. For instance, many of the exogenous processes value calibration are retrieved from García-Cicco et al. (2014), while others from other sources. The rest of the calibrated parameters and their sources are fully detailed in Table A.1.1 of Appendix 1.1.4.

A correlated shock scenario

The first ad hoc quadratic loss function

As it was mentioned before, the first *ad hoc* quadratic loss function seeks to minimize inflation and consumption volatilities.

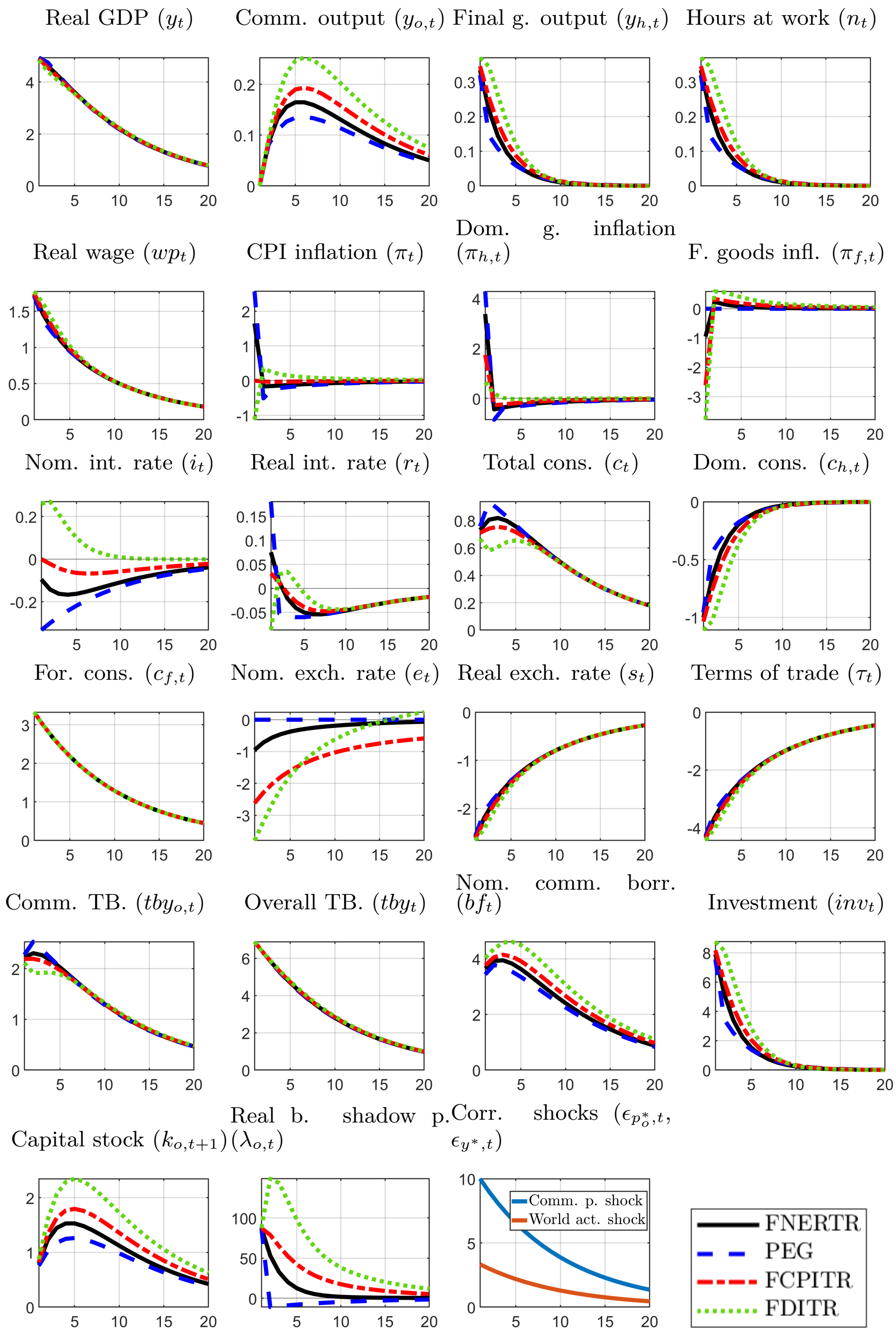
Figure 1.1 shows the responses to a simultaneous commodity price shock and world activity shock. This scenario constitutes the benchmark in the paper.

The mechanism

In response to a correlated shock (a bigger international demand and higher commodity prices), the commodity-producing sector seeks to increase its offer and generate more income by selling more units of commodities at a higher price. In doing so, the commodity-producing firm requires more funding to expand its production. Thus, it borrows from abroad to increment its investment and accumulate more capital stock to bolster its production.

Funds are obtained from abroad by contracting more collateralized borrowings. This is mainly possible thanks to the appreciation of the nominal exchange rate that loosens the borrowing constraint of the firm of this sector and allows it to raise more funds. Note that the real borrowing shadow price, which is positive at the steady state, becomes even more positive (it rises), indicating a binding borrowing constraint within the

Figure 1.1: Optimized monetary policy rules to a correlated commodity price shock and world activity shock ($L_{(\pi_t,c_t)}$)



Note: The correlated shocks are set to a 10% positive commodity price shock and 3.33% positive world activity shock. Both shocks are equivalent to one standard deviation percentage from their respective steady state. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. $L_{(\pi_t,c_t)}$ = the loss function minimizes the sum of inflation and consumption variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule.

model.[12]

[12]The nominal borrowing shadow price is even more positive but it is not reported

The nominal appreciation of the exchange rate is a result of improvements in the terms of trade. Namely, the increment of the demand for investment goods (inputs for the commodity sector) exerts pressure on its price and real wages of the sector, changing the relative prices of the economy and causing domestic inflation. Now, higher domestic prices in the economy improve the terms of trade and this generates a real exchange rate appreciation. Exports of commodity goods increase more than imported consumption goods and a positive overall trade balance is observed.

The nominal appreciation of the exchange rate passes-through the price of imported goods and the consumption of these goods increases. In contrast, domestic consumption goods decreases (as a consequence of the domestic inflation occasioned by the higher demand for inputs from the commodity-producing sector). As a result, an expenditure-switching effect takes place in the economy. Note that the higher demand for investment goods leads to a higher output, hours at work and real wages in the non-traded final goods sector.

Total consumption grows positively, thanks to higher foreign consumption goods that offsets the fall in domestic consumption goods. The higher consumption of foreign goods is thanks to the expansion of the world activity (shock) that lowers the prices of imported goods. Hence, lower relative domestic prices and higher domestic commodity prices and output of the commodity-producing sector compensate for the fall in consumption of domestic goods and boost the real GDP.

The reaction of the monetary authority depends on its policy regime. Specifically, if the central bank's rule is to target CPI inflation or the nominal exchange rate or to completely stabilize the nominal exchange rate (a hard peg policy), it reacts according to its targeted variable by lowering the nominal interest rate. However, its response differs when its rule targets domestic inflation; it raises its nominal interest rate.

Under a feedback policy rule that targets domestic inflation (FDITR), the central bank shows its tightest response. It immediately reacts to the pressures over the price of the non-traded final goods sector, caused by higher demand from the commodity-producing sector for more inputs (investment goods). The authority raises its nominal interest rate, and this response exacerbates the appreciation of the nominal exchange rate. This latter eases even more the collateralized borrowing constraint of the

here.

commodity-producing sector, taking it to borrow more, demand more inputs and produce more. These actions make the non-traded final goods sector more dynamic. Its output, hours at work and real wages are higher, in comparison to the other policy regime responses. Under this regime (FDITR), there is more volatility of the nominal exchange rate, the expenditure-switching effect is stronger, and consequently, the fall in domestic consumption is bigger. The resultant real GDP of the economy shows a similar response as the other policy regimes because the notorious increase of the commodity-producing output is compensated by a bigger fall in domestic consumption, valued at a lower relative domestic price.

In comparison to the other remaining central bank's responses, under the pegged nominal exchange rate regime (PEG), the fall of the nominal interest rate needs to be higher (the loosest policy stand) because the role of the nominal exchange rate as a dynamic factor that absorbs shocks to the economy is nullified. In this case, the ease in the borrowing constraint of the commodity-producing firm is at its minimum. Subsequently, the responses of borrowings, investment, capital stock and output of the commodity sector are also at their minimum. A seemed ranked dynamic is observed for variables of the non-traded final goods sector. Regarding prices, it can be seen that CPI and domestic inflation are the highest, as a result of the loosest stand of the monetary authority. The expenditure switching effect is the weakest, and domestic consumption shows the smallest fall. Such a smallest fall in domestic consumption and higher domestic relative price are contrasted by the lowest increment in the commodity-producing sector. As a result, the real GDP response is close to the other ones under different regimes.

With respect to the feedback nominal exchange rate and the CPI targeting rules (FNERTR and FCPITR, respectively), one can advert that the macroeconomic variable responses are very close. Furthermore, they act as intermediate policy responses in comparison to the other two regimes (FDITR and PEG), which in turn, stand as upper and lower bound regimes, respectively. The main difference between the feedback CPI and nominal exchange rate targeting rules is the appreciation of the nominal exchange rate that is double under the feedback CPI targeting rule. Thus, one could figure out that the rule that gives the second minimum nominal exchange rate volatility, after the pegged nominal exchange targeting rule (with zero volatility), is the one that targets this variable (the FNERTR regime).

The best simple monetary policy rule

Table 1.1: Optimized monetary policy rules to a correlated commodity price shock and world activity shock ($L_{(\pi_t,c_t)}$)

Panel (a): Monetary policy rule specifications

Rule / Optimized coefficients		ρ_i	ϕ_π	ϕ_y	ϕ_e
FCPITR	$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_t + \phi_y y_t)$	0.75	3.1	0.001	–
FDITR	$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_{h,t} + \phi_y y_t)$	0.75	1.1	0.001	–
FNERTR	$i_t = \rho_i i_{t-1} + \phi_e e_t$	0.75	–	–	0.1
PEG	$e_t = 0$	–	–	–	–

Panel (b): Optimized loss function values
($L_{(\pi_t,c_t)} = var(\pi_t) + var(c_t)$; variances in %)

Variable / Rule	FCPITR	FDITR	FNERTR	PEG
Total consumption	0.183	0.177	0.182	0.202
Overall CPI inflation	0.002	0.039	0.015	0.068
Total	0.185	0.216	0.197	0.270

Panel (c): Standard deviations (%)

Variable / Monetary policy rule	FCPITR	FDITR	FNERTR	PEG
Total consumption	4.29	4.20	4.27	4.49
Real gross domestic product	10.39	10.46	10.39	10.37
Non-traded final goods output	5.84	5.73	5.86	5.93
Commodity-producing output	8.55	8.73	8.50	8.67
Investment	26.39	27.96	26.09	34.18
Domestic inflation rate	3.09	2.68	4.10	4.82
Overall CPI inflation	0.39	1.99	1.21	2.61
Domestic nominal interest rate	0.53	1.21	0.60	2.01
Change in the nominal exchange rate	3.73	4.99	2.73	0.00
Real exchange rate	4.04	4.30	4.02	4.12
Terms of trade	10.11	10.75	10.05	10.31
Commodity trade balance	19.15	18.37	19.25	22.56
Overall trade balance	15.83	16.38	15.80	15.80
Foreign commodity price index	22.94	22.94	22.94	22.94

Notes: The correlated shocks are set to a 10% positive commodity price shock and 3.33% positive world activity shock. Both shocks are equivalent to one standard deviation percentage from their respective steady state. $L_{(\pi_t,c_t)}$ = the loss function minimizes the sum of inflation and consumption variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule. The grids used for the coefficients in the rules are $\phi_\pi \in [1.1, 3.1]$, $\phi_y \in [0.001, 1]$ and $\phi_e \in [0.001, 5.1]$, respectively, and they increase at a 0.1 step.

Table 1.1 shows the optimized policy rules to a (correlated) simultaneous commodity price shock and world activity shock under the minimum value of the *ad hoc* quadratic loss function that penalizes for inflation and consumption volatilities ($L_{(\pi_t,c_t)}$).

Panel (a) presents the parameter values for each one of the simple monetary policy rules considered in this paper. As of them, one can realize that the CPI and domestic inflation targeting rules follow the "Taylor Principle" by attributing more weight to inflation deviations from its steady state. In other words, these two rules are much less of those about "leaning against the wind"-type, in the sense that the weight granted to the real GDP gap is practically nil. In fact, they are much more in the line of a "hawkish" policy stand. The nominal exchange rate targeting rule, in turn, points out that the weight given to the deviations of this variable with respect to its steady state is low (close to zero). The pegged nominal exchange rule does not require parameters.

Panel (b) shows the minimum values for each one of the *ad hoc* quadratic loss functions that seeks to minimize inflation and consumption volatilities. Considering the smallest "Total" value, one can verify that the best simple monetary policy rule under correlated shocks is the one that targets the CPI inflation and smooths the nominal interest rate (FCPITR). While the second-best rule is given by the one that targets the nominal exchange rate and smooths the nominal interest rate (FNERTR). Thus, the feedback rules that target domestic inflation (FDITR) and pegs the nominal exchange rate (PEG) turn out to be less optimal simple rules.

A close result to the one obtained here under the correlated commodity price shock and world activity shock is that achieved by DMT. With almost the same structure of the model but without the endogenous dynamic asset-based borrowing constraint as set here, and under a New Keynesian model environment that they set, they derive the model-based quadratic loss function which minimizes inflation and output gap volatilities and conclude that the best simple monetary policy rule is the one that strictly targets the CPI inflation. The difference between their result and the one gotten here is given by the simple rule that they set that does not account for the interest rate smoothing term as here. Moreover, the objective function they derive considers the output gap volatility rather than consumption volatility as it is done here. Thus, despite the differences in the model framework (RBC vs NK; fully-flexible prices vs. sticky prices), its structure (in the borrowing constraint of the commodity-producing sector), in the optimal monetary policy evaluation (an *ad hoc* quadratic loss function that minimizes inflation and consumption volatilities vs a model-based quadratic loss function that minimizes inflation and output gap volatilities) and in the policy rules (a feedback CPI inflation targeting rule vs a strict CPI inflation targeting), the result of the present paper agrees with the one obtained by DMT. Regarding the size of the appreciation of the nominal exchange rate, DMT's model predicts an appreciation rate between 3.8% and 2.0%, while the model of this paper, a lower one, between 2.8% and 0.8%.

Panel (c) indicates the standard deviation of the main macroeconomic variables of this SOE under each one of the monetary policy regimes. As it can be seen, the biggest difference is in the standard deviation of the change in the nominal exchange rule (or change in the volatility) under each regime.

The second ad hoc quadratic loss function

The second *ad hoc* quadratic loss function aims to minimize inflation, consumption and the change in the nominal exchange rate volatilities.

The only thing that changes now with respect to the former exercise is the objective function of the central bank. As a result, the mechanism of the correlated shocks remains unchanged as explained before.

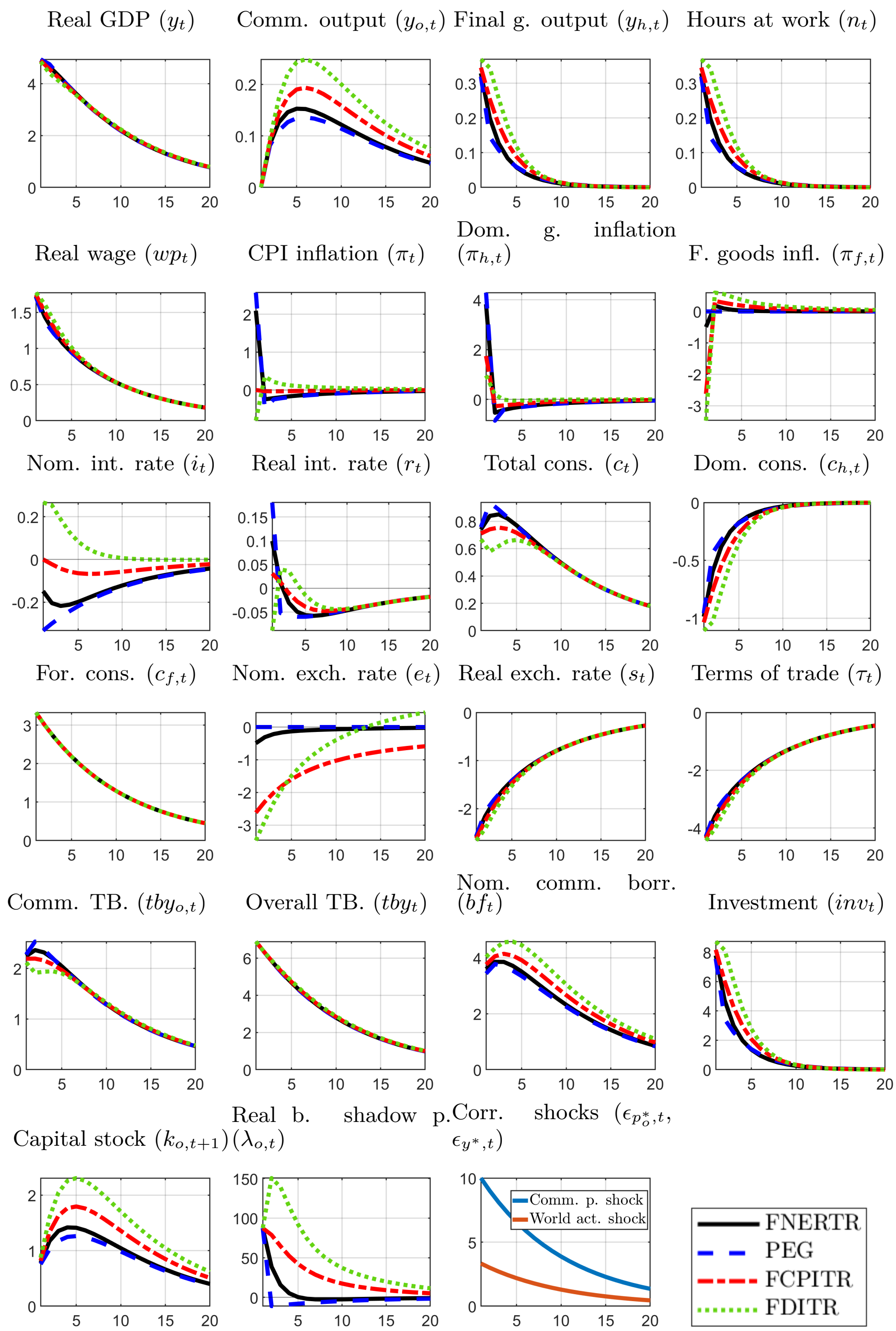
The macroeconomic variable responses of the model to the correlated shocks (a simultaneous commodity price shock and world activity shock) can be seen in Figure 1.2. In comparison to the former Figure, the change now is given in the nominal exchange rate response of the optimized rule for the nominal exchange targeting rule that also smooths the nominal exchange rate (FNERTR). According to this rule, the appreciation of the nominal exchange rate is lesser than before, while the other appreciation rates remain unaltered. In this case, the appreciation range goes from 0.6% to 0.0%.

The best simple monetary policy rule

Table 1.2 confirms that the only optimized simple rule that changes is the feedback nominal exchange rate targeting rule (FNERTR; Panel a). Moreover, it indicates that now the best simple monetary policy rule in response to a correlated shock (a simultaneous commodity price shock and world activity shock) is to target the nominal exchange rate and smooth the nominal interest rate (FNERTR; Panel b).

Given that the central bank's objective function now also minimizes the change in the nominal exchange rate volatility, it turns out that the simple rule that targets the CPI inflation and smooths the nominal exchange rate (FCPITR) is not anymore the first-best simple rule, but the third-best. Now, the second-best simple policy rule that maximizes welfare is the one that pegs the nominal exchange rate (PEG; Panel b). Furthermore, the reported welfare losses according to the CPI and domestic inflation rates are even considerably higher than before (when the loss

Figure 1.2: Optimized monetary policy rules to a correlated commodity price shock and world activity shock ($L_{(\pi_t, c_t, \Delta e_t)}$)



Note: The correlated shocks are set to a 10% positive commodity price shock and 3.33% positive world activity shock. Both shocks are equivalent to one standard deviation percentage from their respective steady state. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. $L_{(\pi_t, c_t, \Delta e_t)}$ = the loss function minimizes the sum of inflation, consumption and change in the nominal exchange rate variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule.

function only accounted for inflation and consumption volatilities).

Table 1.2: Optimized monetary policy rules to a correlated commodity price shock and world activity shock ($L_{(\pi_t,c_t,\Delta e_t)}$)

Panel (a): Monetary policy rule specifications

Rule / Optimized coefficients		ρ_i	ϕ_π	ϕ_y	ϕ_e
FCPITR	$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_t + \phi_y y_t)$	0.75	3.1	0.001	–
FDITR	$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_{h,t} + \phi_y y_t)$	0.75	1.1	0.001	–
FNERTR	$i_t = \rho_i i_{t-1} + \phi_e e_t$	0.75	–	–	0.7
PEG	$e_t = 0$	–	–	–	–

Panel (b): Optimized loss function values
($L_{(\pi_t,c_t,\Delta e_t)} = var(\pi_t) + var(c_t) + var(\Delta e_t)$*; variances in %)*

Variable / Rule	FCPITR	FDITR	FNERTR	PEG
Total consumption	0.183	0.177	0.188	0.202
Overall CPI inflation	0.002	0.039	0.046	0.068
Change in the Nom. exch. rate	0.139	0.249	0.022	0.000
Total	0.324	0.465	0.256	0.270

Panel (c): Standard deviations (%)

Variable / Monetary policy rule	FCPITR	FDITR	FNERTR	PEG
Total consumption	4.29	4.20	4.34	4.49
Real gross domestic product	10.39	10.46	10.37	10.37
Non-traded final goods output	5.84	5.73	5.87	5.93
Commodity-producing output	8.55	8.73	8.52	8.67
Investment	26.39	27.96	27.44	34.18
Domestic inflation rate	3.09	2.68	4.69	4.82
Overall CPI inflation	0.39	1.99	2.14	2.61
Domestic nominal interest rate	0.53	1.21	1.14	2.01
Change in the nominal exchange rate	3.73	4.99	1.48	0.00
Real exchange rate	4.04	4.30	4.02	4.12
Terms of trade	10.11	10.75	10.04	10.31
Commodity trade balance	19.15	18.37	19.73	22.56
Overall trade balance	15.83	16.38	15.74	15.80
Foreign commodity price index	22.94	22.94	22.94	22.94

Notes: The correlated shocks are set to a 10% positive commodity price shock and 3.33% positive world activity shock. Both shocks are equivalent to one standard deviation percentage from their respective steady state. $L_{(\pi_t,c_t,\Delta e_t)}$ = the loss function minimizes the sum of inflation, consumption and change in the nominal exchange rate variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule. The grids used for the coefficients in the rules are $\phi_\pi \in [1.1, 3.1]$, $\phi_y \in [0.001, 1]$ and $\phi_e \in [0.001, 5.1]$, respectively, and they increase at a 0.1 step.

Looking at the standard deviations (Panel c) one observes that the change in the nominal exchange rate is lower now under FNERTR regime and that remains the same under the rest of the regimes (FCPITR, FDITR and PEG). Nevertheless, total consumption and the CPI inflation rate are more volatile now under the FNERTR, while they remain the same under the other regimes.

A commodity price shock scenario

The main findings under this scenario indicate that the monetary policy should follow a feedback rule that targets the nominal exchange rate and that smooths the nominal interest rate (FNERTR). Thus, a softened appreciation of the nominal exchange rate to stabilize inflation and consumption volatilities (and the change in the nominal exchange rate volatility) should take place. The same policy prevails under both objective functions of the central bank.

The results under this scenario are exposed in Appendix 1.1.4.

1.4.2 The role of the collateralized borrowing constraint

The role of the endogenous dynamic asset-based borrowing constraint of the commodity-producing firm in the business cycle (–the only friction in the model–) is analyzed by muting this channel. Specifically, the baseline model (that has the asset-based borrowing constraint) is compared to a frictionless version of itself (which has not such a constraint; details on that model are available in Appendix 1.1.3).

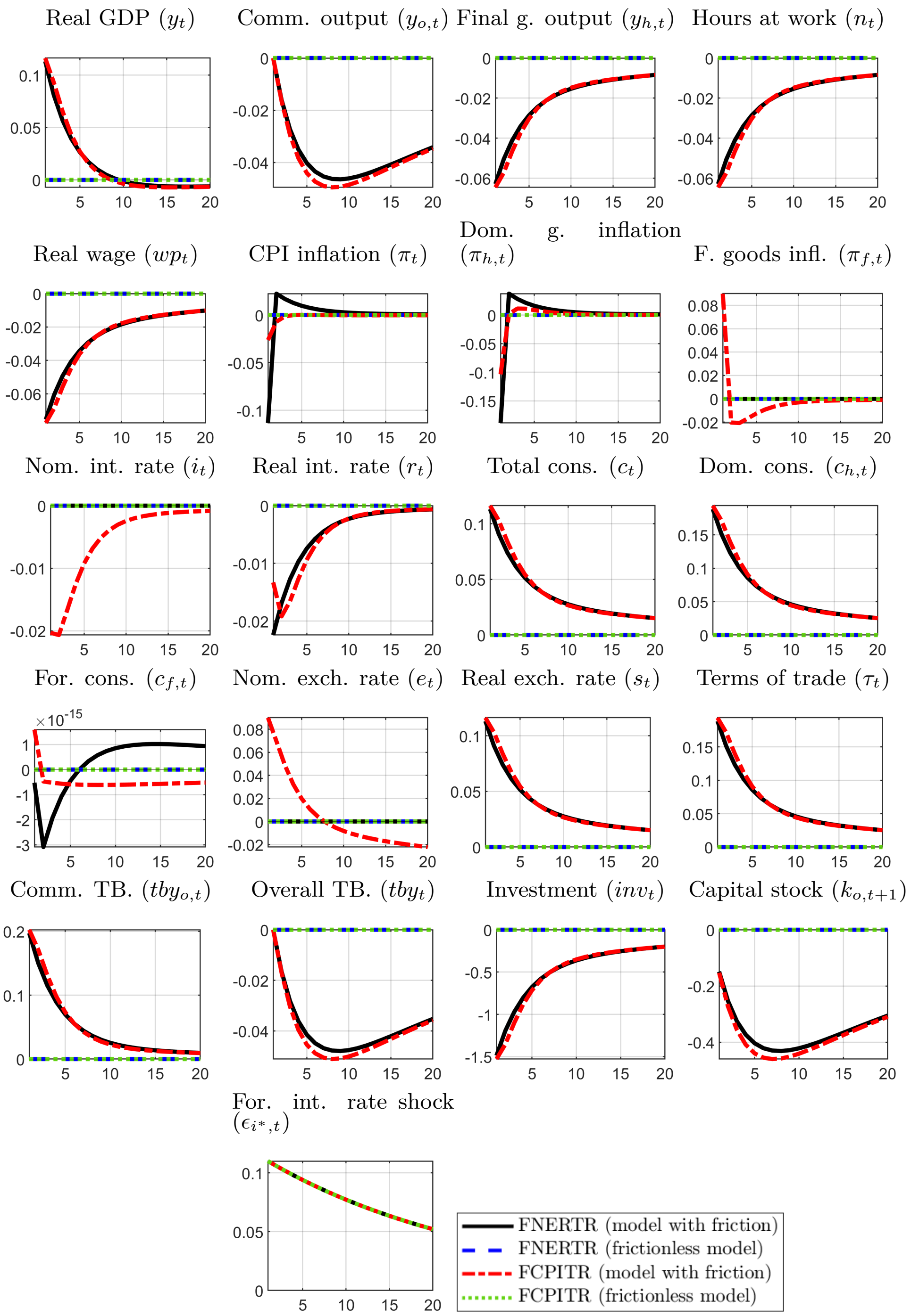
A foreign interest rate shock scenario

In the case of a foreign interest rate shock, the frictionless version of the baseline model fails to mimic the response of the macroeconomic variables, as expected. However, the baseline model, which accounts for the fluctuation of the foreign interest rate within the endogenous dynamic asset-based borrowing constraint of the commodity-producing firm, is successful in replicating the dynamic of this shock.

Two optimized monetary policy rules to a foreign interest rate shock according to the models (the one with friction and the one without friction), and under the first quadratic loss function that minimizes inflation and consumption volatilities ($L_{(\pi_t,c_t)}$) are shown in Figure 1.3.[13] Tables 1.1 and A.1.2 show that in response to an uncorrelated or correlated shocks, the two best simple monetary policy rules are given by a feedback rule that targets the nominal exchange rate (FNERTR) and by a feedback

[13]This result is independent of the correlated shock scenario (a simultaneous commodity price shock and world activity shock) and from the commodity price shock scenario.

Figure 1.3: Two optimized monetary policy rules to a foreign interest rate shock according to the model with and without friction ($L_{(\pi_t, c_t)}$)



Note: IRFs to a 0.11% positive foreign interest rate shock, which is equivalent to one standard deviation percentage from the steady state. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. $L_{(\pi_t, c_t)}$ = the loss function minimizes the sum of inflation and consumption variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule.

rule that targets the CPI inflation (FCPITR), respectively. Accordingly, in Figure 1.3 both rules provide close responses, although they differ more in the case of the nominal exchange rate and the measures for inflation rate.

A positive foreign interest rate shock increases borrowing costs. Subsequently, the commodity-producing firm borrows less now, and in front of unchanged prices of its products, it invests less, accumulates less capital stock and produces less. Lower demand for inputs makes hours at work, real wages and output of the sector fall. Relative prices of the sector fall and so do domestic inflation and the CPI inflation. These stimulate domestic consumption, total consumption and real GDP. This, despite the decline in the commodity output. In turn, lower domestic prices cause a deterioration of the terms of trade (it increases) and real and nominal depreciations of the exchange rate.

In the case of a feedback CPI inflation targeting rule (FCPITR), the monetary authority lowers its nominal interest rate to contain the fall of its targeting variable (the CPI inflation rate) and allows for a nominal depreciation of the exchange rate that passes-through to local inflation of foreign goods that is not enough to discourage foreign consumption goods (it does not change).

In the case of a feedback rule that targets the nominal exchange rate (FNERTR), most of the dynamic is accounted for a deeper fall in CPI inflation. Such a fall avoids a nominal depreciation of the exchange rate, it leaves this latter variable unchanged and leads to the monetary authority to keep its nominal interest rate invariant. Despite the fall in the commodity-producing output, exports of this sector are not enough to avoid a deficit in the overall trade balance.

A commodity price shock and a correlated shock scenarios

Figures A.1.3 and A.1.4 in Appendix 1.1.4 illustrate the comparison between the responses of the friction and frictionless models under a correlated shock (a simultaneous commodity price shock and world activity shock) and a commodity price shock scenarios, respectively. Both scenarios are studied assuming a central bank's objective function that minimizes inflation and consumption volatilities.

As one can verify, although the friction and frictionless models provide similar responses, it is visible that the model with friction displays stiffer responses for variables that are directly affected by the borrowing constraint. Namely, for investment, capital stock, production and the value added (or trade balance) of the commodity sector.

1.4.3 Additional results: robustness check

The Online Supplementary Material to "Endogenous dynamic borrowing constraints and monetary policy for commodity-exporting economies" (see Appendix 1.1.5) introduces an earning-based borrowing constraint to the baseline model presented here and performs additional simulations that provide a robustness check to the results obtained here. In such a model specification, there is no more capital stock in the commodity-producing sector that works as collateral. In this version, the same sector uses inputs (intermediate goods) to produce commodity goods, and the collateral for international nominal borrowings is now given by the expected income of the next period.

The results obtained under such a specification support the same conclusions attained in this document under an uncorrelated CPS and under a correlated CPS and WAS and under the same two ad hoc loss functions. This, despite all parameters in the Taylor-type rule are all optimized in this new specification of the model with earning-based borrowing constraints. The optimized Taylor-type rules continue to highlight the importance of targeting the nominal exchange rate and the persistence of the nominal interest rate used as an instrument of monetary policy.

1.5 Conclusion

This paper undertakes an optimal monetary policy evaluation for a small open economy with a commodity-producing sector that faces financial friction in the form of an endogenous dynamic (asset-based and earning-based) borrowing constraint for international collateralized borrowings. It sets a real business cycle model that is able to explain the dynamic of this economy in response to a commodity price shock and to a correlated shock (a simultaneous commodity price shock and world shock). The results of this study are obtained through the optimization of Taylor-type rules under two *ad hoc* quadratic loss functions. The first of them seeks to minimize inflation and total consumption volatilities, while the second adds the change in the nominal exchange rate volatility to the former loss function.

Under a simultaneous commodity price shock and world activity shock scenario, the first-best response from the monetary authority is to ease monetary conditions of the economy by lowering its nominal interest rate and allowing for a nominal exchange rate appreciation. This is so, according to the first loss function and to its feedback CPI inflation targeting rule that smooths the nominal interest rate. However, once one considers the second loss function (that besides inflation and consumption volatilities also accounts for the change in the nominal exchange rate volatility), the first-best response is defined by a feedback rule that targets the nominal exchange rate and smooths the nominal interest rate. Under this policy rule prescription, the monetary authority keeps its stance unchanged and the adjustment of the shocks are absorbed by changes in the relative prices.

Under a commodity price shock scenario, the monetary authority should allow for a soft appreciation of the nominal exchange rate to stabilize inflation and consumption volatilities. This is also true once one considers the change in the nominal exchange rate volatility as well. The first-best monetary policy response is given by a feedback rule that targets the nominal exchange rate and that smooths the nominal interest rate. This, regardless what of the two *ad hoc* quadratic loss functions is being considered.

Finally, the model proves that the asset-based borrowing constraint for international borrowings of commodity-producing firms constitutes a transmission channel that helps to explain the business cycle of small open economies and that is an alternative framework for monetary policy design for these types of countries. While the earning-based borrowing constraint provides similar dynamics to the economy (in response to the correlated commodity price shock and world activity or an uncorrelated commodity price shock) to the ones accounted under the asset-based borrowing constraint.

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Chapter 2

Ramsey monetary policy for commodity-exporting economies

2.1 Introduction

Commodity price fluctuations and those correlated to world activity dynamics have generated more volatile and disruptive business cycles for small open economies, and in particular, for commodity exporters (Fernández, Schmitt-Grohé and Uribe, 2017; Drechsel, McLeay and Tenreyro, 2019). Drechsel and Tenreyro (2018) document higher levels of consumption, investment, and production after a positive commodity price shock occurs. Moreover, recent work conducted by Ferrero and Seneca (2019) and Drechsel, McLeay and Tenreyro (2019) show that a rise in commodity prices –correlated or not with global economic dynamics– introduces an inefficient reallocation in the economy and a stabilization trade-off for the policymaker. Namely, higher commodity prices boost the demand for inputs of the commodity sector in detriment of the demand for home consumption goods (affecting the efficient allocation of resources), changing relative prices, improving the terms of trade, appreciating the nominal and real exchange rates and expanding output beyond its welfare-maximizing level. Thus, with domestic inflation dropping (as a result of a lower demand for home consumption goods) and the output gap rising (due to the commodity production boom), the monetary authority faces a stabilization trade-off. Therefore, to close the inefficient wedge allocation, the output gap (from above) and to return domestic inflation to the target (from below), the optimal monetary policy prescribes an increment in the interest rate accompanied by a nominal and real appreciations of the exchange rate that gradually reverses over time.

In the case of Drechsel et al.'s (2019) model, because foreign nominal borrowings and its corresponding borrowing constraint in the commodity sector are intra-temporal, the model of these authors misses currency mismatch episodes and they exclusively focus on studying the persistence of a commodity shock. Here, in the present paper, those mentioned features are jointly analyzed instead to determine whether exchange rate targeting rules could approximate the optimal monetary policy once currency mismatch considerations apply. Accordingly, the conventional wisdom in the literature points out that small open economies, and specially, commodity-exporting countries usually fear floating exchange rate regimes and tend towards hard fixed exchange rate policy schemes as a credible commitment by the monetary authority to avoid inflationary and depreciation episodes through the influence over the expectations on wage and price settings, as well as capital flow dynamics (Frankel, 2003). Therefore, such conventional wisdom together with the stylized facts of the 'fear of floating phenomena' (documented by Calvo and Reinhart, 2002)[1] invite further research.[2]

This paper adopts a nearby small open- and -commodity-exporting economy (SOCEE) structure as the one set by Drechsel et al. (2019), but with endogenous financial friction and a different welfare-based monetary policy evaluation methodology. Concretely, setting an endogenous income-based borrowing constraint for nominal loans denominated in foreign currency and relying on a recursive Ramsey policy approach, this paper aims to determine whether the optimal welfare-based monetary policy would still be given by a (simple and implementable) rule that strictly targets the consumer inflation rate (as Drechsel, McLeay and Tenreyro, 2019) –or by a domestic inflation targeting rule as in the case

[1]Note that the 'fear of floating phenomena' predict lower nominal exchange rate volatilities in economies where currency mismatch episodes are possible scenarios that policymakers would like to avoid in their economies. Such phenomena are more frequently found in developing and emerging economies, however, they are still registered in some developed countries; and overall, in those economies where the CPI targeting regime is implemented.

[2]During 2013–2017 period, 102 out of 189 countries (54%) were commodity-dependent economies (UNCTAD, 2019). Among commodity-dependents, 13% were developed countries and 64% were developing and transition economies. A country is labeled as commodity-dependent when more than 60% of its total exports are composed of commodities. Note that Frankel (2003) also points out that most of commodity-exporters are developing countries.

of Ferrero and Seneca (2019)–, despite nominal borrowings are denominated in foreign currency; or, if it would be given by an optimal (simple and implementable) rule that would account for a certain type of stabilization rule for the nominal exchange rate that could shed light about any potential consistency with the 'fear of floating' stylized facts.

The SOCEE analyzed here is exposed to two type of shocks: on the one hand, to a correlated commodity price shock (CPS) and world activity shock (WAS); and on the other hand, to an uncorrelated CPS. The structure of the SOCEE addressed here features three frictions: sticky prices and imperfect competition (present in non-traded final goods firms); and an endogenous income-based borrowing constraint denominated in nominal foreign currency (that conditions the commodity-producing sector). Likewise, the economy displays three more characteristics: complete markets for internationally traded state contingent securities, a cashless environment and a distorted steady state equilibrium with a non-zero inflation rate.

The optimal monetary policy evaluation undertaken here follows a welfare-based approach where the Ramsey planner is solved as a saddle-point functional equation problem, as proposed by Marcet and Marimon (2019). Welfare is approximated by the representative household's utility that the planner maximizes subject to the resource constraint of the economy and to private constraints (those restraining the two productive sectors and the representative household); all of this, while the planner accounts for each one of the distortions characterizing the dynamics of the economy along the cycle and in the long-run. The resulting Ramsey policy under full commitment works as a welfare-based benchmark to rank eight simple and implementable monetary policy rule regimes.

The main novelties that this paper introduces can be outlined as follows. First, this is the first paper that uses the endogenous income-based borrowing constraint that is proven to generate frictions in a fully flexible price environment in the context of a real business cycle model with a commodity-producing sector, as proposed by Báez (2021). Here, such a borrowing constraint is implemented in the same SOCEE structure, but in the context of price rigidity and monopolistic power. The referred borrowing constraint is relevant for the monetary policy authority because, in spite of the frictions it causes, it is denominated in nominal terms and involves the expected nominal exchange rate and the expected domestic price of the economy. Consequently, currency mismatch implications as well as their effects on the business cycle of the commodity firm and the economy as a whole are taken into account.

Second, the Ramsey-type methodology applied here has not been implemented yet in the context of SOCEEs. Although the nearest antecedents are the works of Khan et al. (2003), Faia and Monacelli (2008) and Faia (2009), their model economies miss a commodity-producing sector. Specifically, the first study addresses a closed economy; the second, a standard small open economy with home bias; and the last one, a closed economy with labor market frictions. Moreover, none of these studies uses the Ramsey policy to rank simple and implementable rules in an analogous fashion as carried out by Schmitt-Grohé and Uribe (2007).[3]

Third, the results obtained here work as a cross-validation check for the optimal monetary policy results attained by Ferrero and Seneca (2019), but differs from those obtained by Drechsel et al. (2019). Both studies adopt a linear-quadratic approach for identical SOCEEs, albeit there are narrow differences between the economies of these last two studies and the one addressed here. In particular, the closest model economy to the one studied here is the one set by Drechsel et al. (2019), while the only difference between this former and Ferrero and Seneca (2019) is that the first adds a static working capital to the commodity sector analyzed in the referred second study.

Comparing the SOCEE set here to the one specified by Drechsel et al. (2019), there are key features that can be distinguished. Namely, here the budget constraint of the commodity-producing firm is dynamic; while static in the other. Here, there is an inter-temporal income-based borrowing constraint in the commodity sector; while an intra-temporal working capital constraint in the other. Here, currency mismatch considerations apply, while not in the other. Here the economy has staggered prices à la Rotemberg (1982); and in the other, prices are set à la Calvo (1983). Here, a non-zero inflation steady state is assumed; while a zero inflation steady state in the other. Here, no assumption is made to address the distorted steady state, while a labor subsidy is assumed in the other. Here, the welfare-based monetary policy evaluation relies on the recursive Ramsey-type approach à la Marcet and Marimon (2019); while on the linear-quadratic approximation à la Clarida et al. (1999) in the other. Here, the model is solved by employing a second-order approximation;

[3]Note that Schmitt-Grohé and Uribe (2007) rank simple and implementable rules in the context of a closed economy and relying on the Ramsey planner solved by following the *timeless perspective* approach (Schmitt-Grohé and Uribe, 2012). Here, the Ramsey planner is solved following the recursive approach as proposed by Marcet and Marimon (2019) instead.

while a first-order approximation in the other. Here, the optimal simple and implementable rule is the one that targets the domestic inflation rate, while the one that targets the consumer inflation rate in the other.

In this paper, the best simple rule is determined by ranking the conditional welfare measurements of eight simple and implementable rules, using Ramsey's conditional welfare measurement as benchmark. As pointed out by Schmitt-Grohé and Uribe (2007), by 'simple' one refers to policy rules that monitor for specific observable macroeconomic variables; while by 'implementable', to the fact that the model economy delivers a unique rational expectation equilibrium.

As discussed above, the main result from the monetary policy evaluation is that the best simple and implementable policy rule is the one that strictly targets the domestic inflation rate. The highest welfare level is achieved under this regime because it mimics the Ramsey planner's optimal path (and volatility) for the economy in response to a correlated CPS and WAS (and to an uncorrelated CPS shock as well). Certainly, the constrained efficiency condition of the Ramsey plan attempts to minimize the distortions coming from the commodity and monopolistic sectors while penalizing for any deviation from commitments made in the past. The reason why the strict domestic inflation targeting rule delivers a close macroeconomic dynamic to the Ramsey policy obeys to the fact that once frictions in the economy are minimized by the planner, as well as deviations from past commitments penalized (if required), what remains in the constrained efficiency condition for the domestic inflation rate is to (strictly) target it.

In contrast to the result that borrowing constraints denominated in foreign currency could rationale nominal exchange rate targeting rules as optimal simple and implementable monetary policy rules (as suggested by Báez, 2021 in the context of the same SOCEE but with fully-flexible prices), the findings obtained here for the same economy but with price rigidity and monopolistic competition power indicate that (under these two different frictions) such a result does not hold anymore. Therefore, it is clear that the monetary policy evaluation is not innocuous to the presence or absence of price rigidity and monopolistic competition power assumptions. This assertion is congruent to the one argued by Schmitt-Grohé and Uribe (2004), but in the context of a closed economy (and without a commodity sector).

The current paper also finds that Taylor rules that target deviations in the domestic inflation rate can still be sub-optimal but not too welfare detrimental. Furthermore, targeting a certain appreciation/depreciation rate of the nominal exchange rate is better in terms of welfare than targeting a specific level. Among the eight policy rule regimes set here, hard peg nominal exchange rate rules that are fixed to a certain level or to a determined appreciation/depreciation rate yield the highest welfare losses. Moreover, Taylor rules that respond to deviations in the real GDP with respect to its steady state level are also welfare detrimental for a SOCEE. This latter finding matches the same particular result obtained by Schmitt-Grohé and Uribe (2007), but in the context of a closed economy (and without a commodity sector).

Other findings are that the optimal volatility of the nominal exchange rate is higher under the Ramsey policy and the best simple rule that strictly targets domestic inflation. While in contrast, the simple rule that strictly targets CPI inflation delivers the lowest volatility (after a hard exchange rate peg rule, naturally). This latter result evidences that policymakers, probably, opt for a CPI targeting regime because, in spite of being a sub-optimal regime, it still allows them to have a relatively low nominal exchange rate volatility. Subsequently, this alleviates the fear to float, to some extent. The volatility measurements obtained here under the best simple rule are consistent with those documented by Calvo and Reinhart (2002) on such a phenomenon (provided the respective time-frequency conversion is taken into account).

Finally, welfare-based analysis under the Ramsey policy reveals that lower leverage in the commodity sector as well as a higher home consumption bias and a higher price rigidity in the economy not only enhance welfare but also improve (lower) the optimal volatility of the nominal exchange rate.

The rest of the document proceeds with Section 2.2 where theoretical aspects of the SOCEE model are presented. Section 2.3 addresses theoretical and technical aspects of the Ramsey-type approach implemented here. Section 2.4 describes the main quantitative findings and details about the optimal monetary policy evaluation. Section 2.5 concludes.

2.2 The model

The economic model adopted here is composed of two entities: a small open economy and the rest of the world. The first can be indistinctly referred to as the home economy, while the second, as the foreign economic block or simply as the foreign country. Each economy is inhabited by infinitely lived agents and the whole measure of the world economy is normalized to one. Thus, home and foreign blocks have a size of n and $(1 - n)$, respectively. As usual, the home country size is taken to the limiting case $(n \to 0)$ to model it as a small open economy with respect to the rest of the world.

In terms of the design of the model, this follows the standard structure of that proposed by Galí and Monacelli (2005) and Faia and Monacelli (2008) with respect to the representative household and the final goods firm sector settings. However, the model addressed here differs from this latter sector because it adds one more type of firm. Specifically, a representative commodity-producing firm that displays key differences with the ones proposed by Ferrero and Seneca (2019) and Drechsel et al. (2019) under a commodity-exporting country environment.

The Representative Agent New Keynesian Small Open Model Economy for Commodity-Exporting Economies (RANK-SOME-CEE) presented here introduces endogenous financial friction in the form of an income-based borrowing constraint in the commodity-producing sector. Such a constraint is based on the expected income that the commodity-producing firm pledges as collateral for international borrowings that it contracts every period to finance its operations.

In this cashless economy, money works as a unit of account for contracts because consumption basket compositions between home and foreign countries change over time. Variables written with asterisk superscripts refer to the rest of the world economy, while all contracts and prices of the model are written in nominal terms.

2.2.1 Households

The representative household of the SOE consumes (foreign and domestic consumption goods), provides hours of work, and holds a portfolio of (foreign and domestic) state-contingent securities acquired from complete asset markets. This respective sequence of allocations $\{C_t, N_t, B_{h,t+1}, B_{f,t+1}\}_{t=0}^{\infty}$ results from the maximization of the expected lifetime utility of this agent

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t - \frac{N_t^{1+\phi}}{1+\phi} \right), \tag{2.1}$$

subject to its sequence of budget constraints

$$P_tC_t+\mathbb{E}_tQ_{t,t+1}B_{h,t+1}+\mathbb{E}_t\mathcal{E}_tQ^*_{t,t+1}B_{f,t+1} \leq W_tN_t+B_{h,t}+\mathcal{E}_tB_{f,t}+\Psi_t, \quad (2.2)$$

where P_t is the consumer price index (CPI), $\mathbb{E}_t$ is the conditional expectation operator, $Q_{t,t+1}$ and $Q^*_{t,t+1}$ are the stochastic discount factors (or prices) of the domestic ($B_{h,t+1}$) and foreign ($B_{f,t+1}$) portfolio of state-contingent assets, respectively.[4] W_t denotes the nominal wage for the supplied labor, and $\Psi_t = \int_0^1 \Psi_{h,t}(i) + \Psi_{o,t}$ represents nominal profit payments from the ownership of intermediate goods firms (in the non-traded final goods sector) and the representative commodity-producing firm, respectively.[5] Note that it is assumed that commodity profits are lump-sum to the households, that the labor market is perfectly competitive and that the wages are fully flexible.

In the objective function, $\beta \in (0,1)$ is the subjective time discount factor and $\phi > 0$ is the inverse Frisch elasticity of labor supply.

The optimality conditions deliver the leisure-labor supply equation of the representative agent

$$C_tN_t^{\phi} = \frac{W_t}{P_t}, \quad (2.3)$$

and the consumption Euler equation

$$1 = \beta\mathbb{E}_t\frac{Q^{-1}_{t,t+1}}{\Pi_{t+1}}\left(\frac{C_{t+1}}{C_t}\right)^{-1}, \quad (2.4)$$

where $\Pi_{t+1} = P_{t+1}/P_t$ is the gross consumer price index inflation and $Q_{0,t} = 1$. There, the consumer price index (P_t) is defined as a weight between home-currency prices of domestic goods ($P_{h,t}$) and prices of foreign goods ($P_{f,t}$)

$$P_t \equiv P_{h,t}^{1-\alpha}P_{f,t}^{\alpha}. \quad (2.5)$$

The consumption basket of the representative household (C_t) is composed of the basket of domestic and foreign consumption goods ($C_{h,t}$ and $C_{f,t}$, respectively)

$$C_t \equiv \frac{C_{h,t}^{1-\alpha}C_{f,t}^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}. \quad (2.6)$$

Usual expenditure maximization with respect to $C_{h,t}$ and $C_{f,t}$ yields their

[4] The non-Ponzi game condition is simultaneously satisfied through the transversality condition for these two type of securities.

[5] Each household owns the same share of domestic monopolistic firms. Note that international trade in shares is rule out here for simplicity reasons as in Faia and Monacelli (2008).

optimal allocations,

$$C_{h,t} = (1-\alpha)\left(\frac{P_{h,t}}{P_t}\right)^{-1} C_t = (1-\alpha)\mathcal{T}_t^{\alpha} C_t, \tag{2.7}$$

$$C_{f,t} = \alpha\left(\frac{P_{f,t}}{P_t}\right)^{-1} C_t = \alpha\mathcal{T}_t^{\alpha-1} C_t, \tag{2.8}$$

where the term $(1-\alpha)$ represents the home bias consumption, while α, the foreign bias consumption. If $\alpha = 0$, then the consumption of foreign goods in the home economy would be nil.

The assumption that representative agents from the small open economy and the rest of the world have isomorphic preferences, analogous sequences of budgets constraints and price indexes, makes possible to state that the law of one price holds, $P_{f,t} = \mathcal{E}_t P^*_{f,t}$. This latter implies that there is a fully passed-through from changes in the nominal exchange rate ($\mathcal{E}_t$). Hence this last variable is the price of foreign currency in terms of home currency, a drop in this price corresponds to an appreciation.

For simplicity reasons, it is also assumed that households from the rest of the world do not consume manufactured goods imported from the small open economy ($\alpha^* = 0$). Therefore, one can write that $P^*_t = P^*_{f,t}$.

Based on the above, the effective bilateral terms of trade ($\mathcal{T}_t \equiv P_{f,t}/P_{h,t}$) and its relations with the real exchange rate (S_t) can be read as: $S_t \equiv \mathcal{E}_t P^*_t / P_t = \mathcal{T}_t^{1-\alpha}$.

The no-arbitrage condition for state-contingent securities ensures that the gross nominal return on a one-period risk-free bond denominated in home and foreign currencies satisfy these two respective identities: $R_t = \mathbb{E}_t Q^{-1}_{t,t+1}$ and $R^*_t = \mathbb{E}_t Q^{*-1}_{t,t+1}$. Then, this macroeconomic framework allows for the Uncovered Interest Rate Parity (UIP) condition to hold ($R_t/R^*_t = \mathbb{E}_t\mathcal{E}_{t+1}/\mathcal{E}_t$).

The trading of state-contingent securities between households from the home country and the rest of the world in complete international markets gives rise to the perfectly international risk-sharing condition, $C_t = \vartheta C^*_t S_t = Y^*_t \mathcal{T}_t^{1-\alpha}$. That is to say, the ratio of consumption across countries is proportional to the real exchange rate. Then, in such a condition, the assumption of a symmetric initial condition for the relative net asset position among countries ($\vartheta = 1$) and the assumption of a small open economy allows to state that the rest of the world is in equilibrium

($C_t^* = Y_t^*$). As a result, one can simply write

$$C_t = C_t^* \mathcal{T}_t^{1-\alpha}. \tag{2.9}$$

2.2.2 Firms

There are two productive sectors in this small open economy: one compounded by the non-traded final home goods firms, and the other, by the representative commodity-producing firm.

Non-traded final home goods sector

This sector is composed of retail and wholesale firms. Retailers –also called assemblers– operate in perfectly competitive markets selling aggregate final goods ($Y_{h,t}$) that are produced as of (differentiated) intermediate goods ($Y_{h,t}(i)$) that are elaborated by wholesale firms.

Wholesale firms, in turn, are a continuum of firms that operate in monopolistic competitive markets, employing a variety of labor ($N_t(i)$) and the homogeneous technology of the sector ($A_{h,t}$) to produce differentiated intermediate goods ($Y_{h,t}(i)$). The firm i of this sector exhibits a (linear) production function that displays constant returns to scale that is given by,

$$Y_{h,t}(i) = A_{h,t} N_t(i). \tag{2.10}$$

Each wholesale firm faces adjustment costs à la Rotemberg (1982), and therefore, sets its price on a staggering basis. This implies that the change in the company's production price is subject to a cost that takes the quadratic form: $\theta/2\Big(P_{h,t}(i)/P_{h,t-1}(i) - \Pi_h\Big)^2 P_{h,t}$, where Π_h is the (domestic) inflation rate of the sector at the steady state (also known as the adjustment cost parameter [$\Pi_h^{AC} \equiv \Pi_h$]).[6] The parameter θ is a measure of the degree of price stickiness. The higher the value of θ, the stickier the adjustment in nominal prices. Thus, if $\theta = 0$, one gets the flexible price environment.

The nominal profit of the wholesale firm i is defined as $\Psi_{h,t}(i) = P_{h,t}(i)Y_{h,t}(i) - W_t N_t(i) - \theta/2\Big(P_{h,t}(i)/P_{h,t-1}(i) - \Pi_h\Big)^2 P_{h,t}$. Thus, a firm i in this sector chooses a plan for its price setting $P_{h,t}(i)$ that maximizes

[6] Analogously to Faia and Monacelli (2007), here it is assumed that $\Pi_h > 1$. The form of the quadratic adjustment cost agrees with the one specified by Faia and Monacelli (2008). Note that one could also have set $\Pi_h = 1$, as usual.

the current market value of its expected sequence of nominal profits,

$$\mathbb{E}_0\Bigg\{\sum_{t=0}^{\infty} Q_{0,t}\Bigg[P_{h,t}(i)Y_{h,t}(i)-W_tN_t(i)-\frac{\theta}{2}\Big(\frac{P_{h,t}(i)}{P_{h,t-1}(i)}-\Pi_h\Big)^2 P_{h,t}\Bigg]\Bigg\}, \quad (2.11)$$

subject to its technology constraint (2.10) and to the sequence of demand for final goods of the assemblers ($Y_{h,t}$),

$$Y_{h,t}(i) = \left(\frac{P_{h,t}(i)}{P_{h,t}}\right)^{-\epsilon} Y_{h,t}, \quad (2.12)$$

taking wages (W_t) as given. In (2.11), $Q_{0,t}$ is the stochastic discount factor for nominal payoffs (state-contingent securities) at the initial period and $\epsilon > 1$, is the elasticity of substitution between non-traded final home goods.

Observe that no subsidy term is included in (2.11) to nullify the inefficiency introduced by imperfect competition in products and markets. This latter is consistent with Schmitt-Grohé and Uribe (2007) who seek to avoid any unrealistic assumptions that could erode the role of the monetary policy as an instrument of stabilization along the business cycle and around a distorted steady state equilibrium. As a result, the absence of the referred subsidy term in this sector is a feature that differs from the setting of this sector as proposed by Ferrero and Seneca (2019) and Drechsel et al. (2019).

The efficiency condition for each wholesale firm under a symmetric equilibrium among firms ($P_{h,t}(i) = P_{h,t}$, $\forall t$ and $\forall i$) delivers the (modified) non-linear forward-looking New Keynesian Phillips Curve (NKPC)

$$\Pi_{h,t}\Big(\Pi_{h,t}-\Pi_h\Big) - \left[\tfrac{W_t}{P_t}\tfrac{\mathcal{T}_t^{\alpha}}{A_{h,t}} - \tfrac{\epsilon-1}{\epsilon}\right]\tfrac{\epsilon}{\theta}Y_{h,t} = \beta\mathbb{E}_t\Bigg\{\left(\tfrac{\mathcal{T}_{t+1}^{\alpha}}{\mathcal{T}_t^{\alpha}}\tfrac{C_{t+1}}{C_t}\right)^{-1}\Pi_{h,t+1}\Big(\Pi_{h,t+1}-\Pi_h\Big)\Bigg\}. \quad (2.13)$$

Final goods assemblers of this sector intend non-traded final home goods ($Y_{h,t}$) for domestic consumption goods ($C_{h,t}$) and intermediate goods ($M_{h,t}$). These latter goods are demanded by commodity-producing firms; while the first ones, by households. From this statement, one can check that firms of this sector do not export their products. Such an assumption is made to keep the model simple, in accordance with Ferrero and Seneca (2019) and Drechsel et al. (2019). Lastly, the remaining proportion of this sector's output also covers the costs of adjusting the price of their products.

Commodity-producing sector

The representative commodity-producing firm operates in perfectly competitive markets facing an earning-based borrowing constraint over foreign credits that are contracted to finance its operations.

For simplicity reasons it is assumed that everything this sector produces is exported and that international creditors can meet all credits demanded from the representative firm of this sector. Likewise, it is also supposed that international commodity prices are determined in perfectly international markets and that they are expressed in foreign currency denominations. On that basis, the ratio between the foreign commodity price index and the foreign CPI index is denoted as $P^*_{o,t}/P^*_t$, and it is supposed to follow a first-order exogenous process. Thus, the relation of this variable with the term of trade and the rest of the relevant prices, from the home economy perspective, is given by: $P_{o,t}/P_t = \mathcal{E}_t P^*_{o,t}/P_t = \mathcal{T}_t^{1-v} P^*_{o,t}/P^*_t$.

The representative commodity-producing firm chooses the respective sequences of intermediate goods (or inputs) and international borrowings $\{M_{h,t}, B_{o,t}\}_{t=0}^{\infty}$ that maximize the expected discounted value of profits of the firm

$$\mathbb{E}_0 \sum_{t=0}^{\infty} Q_{0,t} \Psi_{o,t}$$

where $\Psi_{o,t}$ represents the difference between sources and uses in the profit function

$$\Psi_{o,t} = P_{o,t} Y_{o,t} + \mathcal{E}_t B_{o,t} - [P_{h,t} M_{h,t} + \mathcal{E}_t R^*_{t-1} B_{o,t-1}], \tag{2.14}$$

given the production technology

$$\mathbb{E}_0 Y_{o,t+1} = A_{o,t} M^{\nu}_{h,t}, \tag{2.15}$$

and the earning-based borrowing constraint of the firm

$$R^*_t B_{o,t} \leq \chi \mathbb{E}_0 \frac{P_{o,t+1}}{\mathcal{E}_{t+1}} Y_{o,t+1}. \tag{2.16}$$

As one can verify in (A.1.27), the income ($P_{o,t} Y_{o,t}$) derived from the selling of commodity goods ($Y_{o,t}$) together with international borrowings ($\mathcal{E}_t B_{o,t}$) denominated in foreign currency denomination compound the sources with which the firm finances its expenditures. These latter, in turn, are integrated by the purchasing of inputs ($P_{h,t} M_{h,t}$) and the repayment of debts incurred during the last period in combination with their respective accrued interests ($\mathcal{E}_t R^*_{t-1} B_{o,t-1}$).

Note that the production function in (2.15) displays the decreasing returns to scale of the sector ($0 < \nu < 1$), and that it also showcases one period lag in order to approximate the required 'time to build' (or produce) this type of goods ($\mathbb{E}_0 Y_{o,t+1}$), using the available technology ($A_{o,t}$) of the sector at time t (and inputs, $M_{h,t}$).

Along the same sectoral characteristics, the proposed endogenous borrowing constraint in (2.16) seeks to resemble the fashion this type of firm funds its operations. In that regard, besides the income obtained from the selling of commodity goods ($P_{o,t} Y_{o,t}$) in time t, the firm requires more working capital ($\mathcal{E}_t B_{o,t}$) to produce for more goods in the next period ($\mathbb{E}_0 Y_{o,t+1}$). For this reason, foreign creditors require to commodity-producing firms a χ proportion of their expected income at the next period valued in foreign currency denomination ($\mathbb{E}_0 Y_{o,t+1} P_{o,t+1} / \mathcal{E}_{t+1}$) to be pledged as collateral for the principal and interests of the intended loan ($R^*_t B_{o,t}$).[7,8]

The parameter χ is usually known as the loan-to-value ratio because it limits the maximum amount of borrowings as a proportion of the total income that pledges as collateral. In particular, it is assumed that the firm of this sector (in the baseline model) can only access collateralized loans ($0 < \chi \lesseqqgtr 1$). Furthermore, Ponzi schemes in this sector are also a ruled out possibility thanks to the transversality conditions for borrowings, $\lim_{t \to \infty} \mathbb{E}_0 Q_{0,t} \mathcal{E}_t B_{o,t} / R^*_t = 0$.

Given the environment of this sector, it is opportune to explain the proposed mechanism. Once the commodity-producing firm observes higher commodity prices, $P_{o,t}$, it will seek to obtain higher future incomes by increasing its production level ($\mathbb{E}_t Y_{o,t+1}$) for the following period. With that purpose in mind, in time t, the commodity-producing firm (optimizes) decides its input demand allocation ($M_{h,t}$). Consequently, then it also decides how much more to borrow ($B_{o,t}$) in order to finance the purchasing of more inputs ($P_{h,t} M_{h,t}$). On the other hand, lenders in the

[7] It is important to point out that one could also have assumed a fraction of the expected production that could be lost due to some issues/losses/depletion/shrinkage during the harvest and/or transportation (that could be caused by plagues or any other factors/events). However, for the sake of simplicity, the paper abstracts from this possibility. Additionally, another assumption that is also ruled out for the same reason is the presence of adjustment costs for the use of inputs in the commodity-producing sector.

[8] The borrowing constraint of the commodity-producing sector is binding at the steady state because the borrowing shadow price is positive at such state. Moreover, this constraint is still binding because it is assumed that this multiplier is positive yet within the neighborhood of its steady state.

quest for assurance to loans they conceive, require borrowers to pledge a χ proportion of their expected income as collateral. Then, this circuit can start over by assuming higher or lower commodity prices along the business cycle.

First-order conditions for this firm provide the demand for intermediate goods,

$$\mathrm{M}_{h,t}^{1-\nu} = \nu A_{o,t}\mathbb{E}_t \tfrac{P^*_{o,t+1}}{P^*_{t+1}} \mathcal{T}_{t+1}\Pi_{h,t+1}\Big\{[1-\chi]\mathbb{E}_t \tfrac{Q_{t,t+1}}{Q_{t,t}} + \chi\mathbb{E}_t Q^*_{t,t+1}\Big(\tfrac{\mathcal{T}_{t+1}}{\mathcal{T}_t}\Big)^{-1}\Pi^{-1}_{h,t+1}\Pi^*_{t+1}\Big\}, \tag{2.17}$$

and borrowings,

$$\frac{B_{o,t}}{P_t} \leq \chi \frac{A_{o,t}M^{\nu}_{h,t}}{\mathcal{T}^{\alpha}_t}\mathbb{E}_t Q^*_{t,t+1}\frac{P^*_{o,t+1}}{P_{t+1}}\mathcal{T}^{\alpha}_{t+1}\Pi_{h,t+1}. \tag{2.18}$$

As of these two optimal allocations ($M_{h,t}$ and $B_{o,t}$), one can see that commodity-producing firms have forward-looking expectations about key macroeconomic variables and not just over variables and parameters of the sector (see equations [2.17] and [2.18]). In other words, commodity-producing firms conduct their businesses having into account future (expected) domestic and foreign economic conditions, and in turn, their decisions –to some extent– also end by affecting (some) real allocations and prices in the economy.

2.2.3 Closure conditions of the model

The present model setting is completed with the monetary policy rule prescription, the market clearing (equilibrium) conditions and the set of exogenous shock processes.

The monetary authority of this small open economy follows a policy rule that is characterized by this expression,[9]

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\alpha_R}\left[\left(\frac{\aleph_t}{\aleph}\right)^{\alpha_\aleph}\left(\frac{Y_t}{Y}\right)^{\alpha_Y}\left(\frac{\Xi_t}{\Xi}\right)^{\alpha_\Xi}\right]^{(1-\alpha_R)}, \tag{2.19}$$

where $\aleph \in \{\Pi, \Pi_h\}$ can take one of two variables (in the set): Π for the overall consumer price index inflation rate or Π_h for the domestic inflation rate; while $\Xi \in \{\mathcal{E}, \Delta\mathcal{E}\}$ can take one of two variables (in the set): $\mathcal{E}$ for

[9] Although all the alternative policy regimes are based on the concept of 'optimal simple and implementable rules', as proposed by Schmitt-Grohé and Uribe (2007); they are technically specified according to Faia and Monacelli (2007) and Bergholt et al. (2019). The distorted equilibrium of the economy addressed here rationalizes the adoption of such rule types.

the level of the nominal exchange rate or $\Delta\mathcal{E}$ for the change in the level of the nominal exchange rate. Additionally, four simple and implementable rules are also considered. Specifically, a strict CPI inflation rate targeting rule, a strict domestic inflation rate targeting rule, a hard peg rule for the level of the nominal exchange rate, and a hard peg rule for the change in the level of the nominal exchange rate.

While the rest of the world is assumed to be in equilibrium ($C_t^* = Y_t^*$), the equilibrium condition for the home economy is given by its resource constraint[10]

$$A_{h,t}N_t = (1-\alpha)\mathcal{T}_t^{\alpha}C_t + M_{h,t} + \frac{\theta}{2}\Big(\Pi_{h,t} - \Pi_h\Big)^2, \qquad (2.20)$$

where $Y_{h,t} = A_{h,t}N_t$.

The set of shocks, $\mathcal{X} \in \{A_{h,t}, A_{o,t}, R_t^*, C_t^*, \Pi_t^*, P_{o,t}^*/P_t^*\}$, that hits the economy is composed of exogenous processes that were already introduced along with the description of the model. Such shocks are assumed to follow an AR(1) process under this stationary functional form,

$$\ln(\mathcal{X}_t) = \rho_{\mathcal{X}} \ln(\mathcal{X}_{t-1}) + \epsilon_{\mathcal{X},t}. \qquad (2.21)$$

From what has been stated so far, the following definition applies.

Definition 1. For a given policy sequence $\{R_t\}_{t=0}^{\infty}$ and a set of exogenous processes $\{A_{h,t}, A_{o,t}, R_t^*, C_t^*, \Pi_t^*, P_{o,t}^*/P_t^*\}_{t=0}^{\infty}$, a determinate recursive (imperfectly) competitive equilibrium is a sequence of allocations $\{C_t, N_t, C_{h,t}, M_{h,t}, \mathbb{E}_t Y_{o,t+1}, Y_{h,t}, Y_t\}_{t=0}^{\infty}$ and prices $\{MC_t, \mathbb{E}_t Q_{t,t+1}, \mathcal{E}_t, \mathcal{T}_t, \mathbb{E}_t Q_{t,t+1}^*, \Pi_{h,t}, \Pi_t\}_{t=0}^{\infty}$ that, by satisfying households and firms constraints ([2.3], [2.4], [2.9], [2.13], [2.17] and [2.18]), it propitiates the market clearing in this distorted economy.

Finally, additional definitions like the real gross domestic product (GDP) and trade balance to GDP ratio can be also calculated (see Appendix 2.1.1).

2.3 The Ramsey planner

This section describes the Ramsey planner approach implemented in this paper to undertake the optimal monetary policy evaluation of the eco-

[10] The resource constraint of the home economy is similar to the one defined in Faia and Monacelli (2008), who also set a staggered price setting à la Rotemberg (1982).

nomic model presented in the former section.

The Ramsey-type optimal monetary policy evaluation conducted here follows the methodological approach introduced by Marcet and Marimon (2019). This method has the advantage of transforming economic optimization problems that are intrinsically non-recursive into a recursive problem that yields a unique and sufficient solution.[11]

2.3.1 Dynamics under the Ramsey plan

The Ramsey planner considers how to maximize the welfare of the representative agent given the distortions and the feasibility (or implementability) constraints of the economy.

In particular, in the model economy addressed here, one knows that there are three main features that introduce inefficiencies. Two of them (the monopolistic power and sticky price setting) are present in the non-traded final goods-producing sector, and one (the borrowing constraint), in the commodity-producing sector.

As a result, the set of constraints that characterizes the Ramsey planner's problem for this small open economy can be consigned in the next optimization program.

Let $\Lambda_{\Re,t} \equiv \{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}, \lambda_{5,t}\}_{t=0}^{\infty}$ minimize and $\Xi_{\Re,t} \equiv \{C_t, N_t, \mathcal{T}_t, \Pi_{h,t}, M_{h,t}, \mathbb{E}_t Q_{t,t+1}\}_{t=0}^{\infty}$ maximize the following non-recursive

[11] Application examples of this approach under a small open economy setting can be found in Faia and Monacelli (2008), while under a closed economy framework, in Khan et al. (2003) and Faia (2009).

Lagrangian.

$$
\begin{aligned}
&\min_{\{\Lambda_{\Re,t}\}_{t=0}^{\infty}} \max_{\{\Xi_{\Re,t}\}_{t=0}^{\infty}} \mathbb{E}_0 \Bigg\{ \sum_{t=0}^{\infty} \beta^t \Bigg\{ \ln C_t - \frac{N_t^{1+\phi}}{1+\phi} \qquad (2.22)\\
&+\lambda_{1,t} \Bigg[\Bigg\{ \Pi_{h,t}\Big(\Pi_{h,t} - \Pi_h\Big) - \Big[\frac{W_t}{P_t}\frac{\mathcal{T}_t^{\alpha}}{A_{h,t}} - \frac{\epsilon-1}{\epsilon}\Big]\frac{\epsilon}{\theta} A_{h,t} N_t \Bigg\} (\mathcal{T}_t^{\alpha} C_t)^{-1} \\
&\qquad - \beta \mathbb{E}_t \Bigg\{ (\mathcal{T}_{t+1}^{\alpha} C_{t+1})^{-1} \Pi_{h,t+1}\Big(\Pi_{h,t+1} - \Pi_h\Big) \Bigg\} \Bigg] \\
&+\lambda_{2,t} \Big[\frac{B_{o,t}}{P_t} - \chi \frac{A_{o,t} M_{h,t}^{\nu}}{\mathcal{T}_t^{\alpha}} \mathbb{E}_t Q_{t,t+1}^* \frac{P_{o,t+1}^*}{P_{t+1}} \mathcal{T}_{t+1}^{\alpha} \Pi_{h,t+1} \Big] \\
&+\lambda_{3,t} \Bigg[M_{h,t}^{1-\nu} - \nu A_{o,t} \mathbb{E}_t \frac{P_{o,t+1}^*}{P_{t+1}^*} \mathcal{T}_{t+1} \Pi_{h,t+1} \Big\{ \\
&\qquad [1-\chi] \mathbb{E}_t \frac{Q_{t,t+1}}{Q_{t,t}} + \chi \mathbb{E}_t Q_{t,t+1}^* \Big(\frac{\mathcal{T}_{t+1}}{\mathcal{T}_t}\Big)^{-1} \Pi_{h,t+1}^{-1} \Pi_{t+1}^* \Big\} \Bigg] \\
&+\lambda_{4,t} \Big[C_t - C_t^* \mathcal{T}_t^{1-\alpha} \Big] \\
&+\lambda_{5,t} \Bigg[A_{h,t} N_t - (1-\alpha) \mathcal{T}_t^{\alpha} C_t - M_{h,t} - \frac{\theta}{2}\Big(\Pi_{h,t} - \Pi_h\Big)^2 \Bigg] \Bigg\} \Bigg\}.
\end{aligned}
$$

Inspecting the problem set in (2.22), one verifies that the first constraint is the efficiency condition of the non-traded final goods sector that is given by the non-linear (augmented) forward-looking New Keynesian Phillips Curve. This condition shows how firms optimally set their prices in the presence of pricing adjustment costs, given the demand that retailers receive from households and the commodity-producing firm. To some extent, this constraint accounts for the optimal decisions taken by households and the non-traded final goods sector.

The second constraint is given by the income-based borrowing constraint that the representative commodity-producing firm faces in its sector, as it was previously explained (see subsection 2.2.2). The third constraint, in turn, indicates how this representative firm optimally decides how much intermediate goods to demand, and implicitly, how much output to produce and borrow to finance such a production.

The fourth constraint is given by the relation between the home economy aggregate consumption and the one from the foreign economy that is summarized by the perfectly international risk-sharing condition.

Finally, the planner's problem is closed with the resource constraint of the economy in the fifth constraint. This constraint sums up all the goods that the economy produces (consumes or uses) domestically.

In essence, one can infer that the general setup for the Ramsey-type optimal policy design seeks social welfare to prevail in the economy by aligning the optimal decisions taken by the agents (at a sectoral level) to its foremost objective: to maximize the whole economy's welfare.

A definition consistent with the problem presented above is that of a constrained efficient allocation that reads as follows.

Definition 2. For a given set of exogenous processes $\{A_{h,t}, A_{o,t}, R_t^*, C_t^*, \Pi_t^*, P_{o,t}^*/P_t^*\}_{t=0}^{\infty}$, and a sequence of Lagrangian multipliers $\{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}, \lambda_{5,t}\}_{t=0}^{\infty}$ on the constraints (2.13), (2.17), (2.18), (2.9), (2.20), respectively, a constrained efficient allocation (or constrained competitive equilibrium) is defined by a plan for the sequences of control variables $\{C_t, N_t, \mathcal{T}_t, \Pi_{h,t}, M_{h,t}, \mathbb{E}_t Q_{t,t+1}\}_{t=0}^{\infty}$ and co-state variables $\{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}, \lambda_{5,t}\}_{t=0}^{\infty}$ that optimize the problem posed in (2.22).

Based on the former definition and the referred methodology, a saddle-point functional equation (SPFE) framework is applied to solve for the non-recursive problem laid in (2.22). The basic idea is to rewrite the same problem under a recursive formulation that gets rid of forward-looking variables. As Kydland and Prescott (1977) and Calvo (1978) points out, these latter variables are the source of the problem's non-recursiveness.

Under the SPFE structure, the recursive formulation delivers a time-consistent solution with a policy that is always optimal because it is updated at each time. This is done through the addition of co-state variables that track the fulfillment of past commitments, and if necessary, penalize for any deviation from them at each current time. Therefore, the resulting optimal policy is time-invariant. This latter is a key feature that makes this method a more desirable approach, in comparison to the Ramsey policy derived under the *timeless perspective* approach (Marcet and Marimon, 2019; Jensen and Mccallum, 2010).

The formal recursive formulation of the planner's problem in conjunction with their respective optimality conditions deliver the optimal Ramsey policy for the constrained efficient allocation (or constrained competitive equilibrium) of this small open- and -commodity-exporting economy (see Appendix 2.1.2).

2.3.2 The optimal long-term inflation rate

The optimality condition of the recursive formulation of the planner set in (2.22) with respect to the domestic inflation rate yields its optimal welfare-improving dynamic path. Imposing the steady state to that specific condition, it turns out that its corresponding deterministic Ramsey steady state prescribes an optimal long-term inflation rate plan given by

$$\frac{1}{\lambda_5 \theta}\left(\lambda_2 \chi \frac{\beta^*}{\Pi^*}\frac{P_o^*}{P}\mathcal{T}^{\alpha} + \lambda_3 \nu \frac{P_o^*}{P^*}\mathcal{T}[1-\chi]\right) = \Pi_h - \Pi_h^{AC}. \tag{2.23}$$

From the equation above, one confirms that in case the policy maker imposes the same steady state of the competitive equilibrium version of the model (given in section 2.2) to the deterministic Ramsey steady state (derived from the recursive formulation of [2.22]), the endogenous steady state of the domestic inflation rate (Π_h) equates the adjustment cost parameter (Π_h^{AC}) of the NKPC. Then, if that is the case, what is left to the planner is to neutralize any distortion coming from the commodity-producing sector (the leverage χ and the decreasing constant returns scale parameter ν) and the rest of internal and external parameters that are stated in the left-hand side of the aforementioned equation. Accordingly, the optimal domestic inflation long-term plan is $\Pi_h = \Pi_h^{AC}$.

Under the assumption of equal steady states between the competitive equilibrium version of the model and its respective deterministic Ramsey steady state, the optimal Ramsey policy for the long-term inflation rate is to set $\Pi_h = \Pi_h^{AC}$. This policy prescription is the same regardless one is considering a zero net inflation rate or not (at the steady state). Here, the Ramsey planner cannot leverage on the domestic inflation rate as an instrument to offset inefficiencies coming from imperfectly competitive markets, and the effective goal of the planner turns out to be to minimize the cost of adjusting prices ($\Pi_h = \Pi_h^{AC}$).

The former theoretical result (and inference) is analogous to the ones obtained by Faia and Monacelli (2008) and Faia (2009) under zero gross inflation rates (Π_h^{AC}=1), but under different structural model specifications that miss a commodity-producing sector. Namely, a small open economy and a closed economy with labor market frictions, respectively.

The case that is not being addressed here is the one that does not impose any competitive steady state over the deterministic Ramsey steady state. In such a case, one should consider that the endogenous gross domestic inflation (Π_h) rate could be higher or lower than the value implied by the adjustment cost parameter (Π_h^{AC}). Certainly, that value would depend on the parameter values of the competitive equilibrium version of the model and on the steady state for the other endogenous variables and shadow prices (or co-state variables) of the optimization program posed in (2.22).

2.4 Optimal monetary policy evaluation

Before presenting the results obtained under the optimal Ramsey-type monetary policy evaluation that are contrasted against alternative monetary policy regimes, this section describes the implemented solution approach, calibration considerations and the welfare criteria. The aforesaid evaluation is considered under two types of shock scenarios. Namely, a correlated commodity price shock (CPS) and world activity shock (WAS) scenario; and a CPS scenario.

2.4.1 Solution strategy and calibration

As the model section of the present paper indicates, this small open- and-commodity-exporting economy displays a distorted steady state in which frictions stemming from markets and products cannot be overridden (in its competitive equilibrium version).

The former assumption is one of the main differences between this study and those undertaken by Ferrero and Seneca (2019) and Drechsel et al. (2019) –who under a close economic model setup to the one set here–, assume a labor subsidy that nullifies distortions coming from monopolistic competitive markets and impose a fully-flexible price setting. Here, except for the two previous discrepancies, most of the remaining parameters are calibrated according to these authors, for comparability reasons.

Accordingly, the assumption about a symmetric equilibrium between the home and foreign blocks in terms of the subjective discount factors and inflation rates at the steady state also holds here. The time unit of the model is set to quarterly frequency and calibrated parameters are fit to the Norwegian economy, bounding the data sample to the period 1978Q1-2017Q4.[12]

[12]More details about calibrated parameters and data sources are specified in Appendix 2.1.3.

The gross domestic inflation rate (Π_h) and the nominal gross interest rate (R) come from data and they deliver the subjective discount factor β in quarterly terms. Respective values accounts to $1.0359^{\frac{1}{4}}$, $1.0713^{\frac{1}{4}}$ and 0.9916.

The input demand from the commodity-producing sector (M_h) relative to the production of the non-traded final goods sector (Y_h) is set to 15% (according to Ferrero and Seneca, 2019 and Drechsel et al., 2019). As a result, the home consumption bias $(1-\alpha)$, the return to scale parameter in the commodity-producing sector (ν) and the loan-to-value ratio χ are calibrated accordingly. The calibration of these parameters also ensures that the economic resource constraint holds. Respective values for these parameters are 0.71, 0.19 and 2.94 under the constrained competitive equilibrium version of the model.[13] Note that the value loan-to-value ratio is not far from the elasticity considered by Drechsel et al. (2019), which is equal to 2.

The logarithmic utility function of the representative household implies a unitary risk aversion parameter, and in concordance with Bergholt et al. (2019), the Frisch inverse elasticity rate (ϕ) for this economy is calibrated to 1.

The Rotemberg adjustment cost parameter (θ) is parameterized along the lines of Faia and Monacelli (2007), Faia and Monacelli (2008), Ascari and Rossi (2012) and Leith and Liu (2016). Note that the first pair of authors assume a non-zero steady state inflation rate. The normalization of this parameter (through the sectoral output) and the log-linearization of the NKPC allows the comparability between this curve and the one resulted under Calvo's (1983) approach. The (normalized) elasticity of the domestic inflation to the real marginal cost takes the form of $(\epsilon-1)/\widetilde{\theta}$, where $\widetilde{\theta}$ is the (Calvo's) probability of fixing prices in each quarter. Then, given this premise, the adjustment cost parameter satisfies the condition of being measurable in terms of the aggregate non-traded final home goods, $\theta = \widetilde{\theta}(\epsilon-1)/[(1-\widetilde{\theta})(1-\beta\widetilde{\theta})]Y_h$, yielding a parameter ($\theta$) calibrated to 48.8.

Like Ferrero and Seneca (2019) and Drechsel et al. (2019), here it is assumed that the average expected duration of price contracts lasts one year and that the net desired mark-up of prices over marginal costs is 20%. As a result, the probability of not re-setting prices ($\widetilde{\theta}$) and the elasticity

[13]Under the recursive Ramsey plan (but with the constrained competitive equilibrium steady state being imposed) the referred parameters values are 0.71, 0.18 and 0.53, respectively.

of substitution between varieties (ϵ) are set to 0.75 and 6, respectively.

Close to Schmitt-Grohé and Uribe (2007) and Faia and Monacelli (2007), coefficients of the set of Taylor-type rules are constrained to specific intervals. Strictly speaking, those that represent the reaction to deviations of the CPI and domestic inflation rates from their targeted steady state values are (respectively) specified as $\{\alpha_{\Pi}, \alpha_{\Pi_h}\}$ ∈[0,3.1]. While those coefficients that represent the same type of deviation but for the real GDP, the level of the nominal exchange rate and the change in this latter, their corresponding intervals are set as $\{\alpha_Y, \alpha_{\mathcal{E}}, \alpha_{\Delta\mathcal{E}}\}$ ∈[0,1]. Lastly, the interval for the smoothing term of the interest rate rule is set as $\{\alpha_R\}$ ∈[0,0.9]. During the optimization process for each policy rule, each parameter value increases at a 0.1 step within its designated grid.

The exogenous process for the relative commodity price ($P^*_{o,t}/P^*_t$) it is assumed to have a first-order autocorrelation of 0.90 and standard deviation of 0.10. These two values are in accordance with Drechsel et al. (2019). The parameterization for the rest of the exogenous processes is detailed in 2.1.3.

Finally, the competitive equilibrium model as well as its constrained competitive equilibrium version are solved by relying on a second-order approximation of the policy function (Schmitt-Grohé and Uribe, 2004) around a perfect foresight steady state with a positive inflation rate, market power and monitoring costs.

2.4.2 Welfare criteria

Welfare is approximated through the utility function of the representative agent of the home small open economy.

Two usual indicative measurements for welfare are computed here: the conditional and the unconditional ones. The conditional welfare is used as the main reference measurement for comparative purposes (and ranking) among different policy regimes. While the unconditional welfare it is also computed, it is not used as a benchmark measure aimed to rank or compare different monetary policy regimes. Its use is merely indicative and complementary.

The relevant (baseline or benchmark) welfare for comparative (or ranking) purposes is the conditional measure attained under the Ramsey planner. Moreover, it is imposed that the deterministic Ramsey steady state equates to the one obtained under the competitive equilibrium version of the model. The referred imposition applied over the deterministic Ramsey steady state agrees with the strategy adopted by Schmitt-Grohé and Uribe (2007) when conducting an optimal welfare-based monetary and fiscal policies evaluation. Here, the steady state of the competitive equilibrium version of the model is unique or invariant, regardless of which specific exogenous monetary policy rule is being implemented.

The baseline conditional welfare ($\mathscr{W}^b_{0,t}$) is defined as the one associated with the equilibrium implied by the Ramsey planner, conditional on being at the steady state of the economy in period 0. In recursive terms, the aforementioned welfare measure is given by

$$\mathscr{W}^b_{0,t} = U(C_{b,t}, N_{b,t}) + \beta \mathbb{E}_0 \mathscr{W}^b_{0,t+1}, \tag{2.24}$$

where $U(\cdot)$ is the utility function of the representative household under the Ramsey planner.

To compare alternative monetary policy regimes with respect to the baseline conditional welfare function ($\mathscr{W}^b_{0,t}$), one defines the conditional compensating cost (Ω^C) that measures the fraction of consumption required to equate the conditional welfare under the baseline policy regime ($\mathscr{W}^{C,b}_0$) to the one achieved under another policy rule ($\mathscr{W}^{C,o}_0$). Accordingly, as Faia and Monacelli (2007), the conditional welfare under the alternative policy regime is defined as

$$\mathscr{W}^{C,o}_0 = \mathbb{E}_0 \Big\{ \sum_{t=0}^{\infty} \beta^t U((1+\Omega^C)C_{b,t}, N_{b,t}) \Big\}, \tag{2.25}$$

and the conditional compensating cost as

$$\Omega^C = \exp\{(1-\beta)(\mathscr{W}^{C,o}_0 - \mathscr{W}^{C,b}_0)\} - 1. \tag{2.26}$$

Analogously to Schmitt-Grohé and Uribe (2007), but still in accordance to the definition line set by Faia and Monacelli (2007), the unconditional welfare ($\mathscr{W}^{U,o}_0$) is measured as

$$\mathscr{W}^{U,o}_0 = \mathbb{E} \Big\{ \sum_{t=0}^{\infty} \beta^t U((1+\Omega^U)C_{b,t}, N_{b,t}) \Big\}, \tag{2.27}$$

while the corresponding unconditional compensating cost (Ω^U) as

$$\Omega^U = \exp\{(1-\beta)(\mathscr{W}^{U,o}_0 - \mathscr{W}^{U,b}_0)\} - 1. \tag{2.28}$$

2.4.3 Correlated shock scenario results

This subsection presents the results under a correlated commodity price shock (CPS) and world activity shock (WAS). In total, four cases of interest are analyzed under the baseline calibration of the constrained competitive equilibrium model (the Ramsey model) and one under the competitive equilibrium model.

The first case corresponds to the welfare-based monetary policy evaluation. The second analyzes the welfare implications of varying the loan-to-value ratio for foreign borrowings in the commodity-producing sector. The third and fourth cases focus on examining welfare variations when home consumption bias and price rigidity in the economy change, respectively. Lastly, the case under the competitive equilibrium model assesses welfare costs derived from the deviation of optimized Taylor-type policy rules as an attempt to respond to sub-optimal targets.

Welfare-based optimal monetary policy

As stated before, the welfare-based optimal monetary policy assessment is carried out by contrasting eight alternative monetary policy regimes against the theoretical and optimal Ramsey policy (or simply the Ramsey policy or Ramsey regime) which works as a comparison point.

The optimal simple and implementable monetary policy rule (or simply referred to as the simple rule) is identified by contrasting each one of the conditional compensating cost (or conditional welfare measurements) against the one attained under the Ramsey regime. Accordingly, it turns out that *strictly targeting the domestic inflation rate is the best simple rule* that this small open- and -commodity-exporting economy that faces a correlated CPS and WAS can implement.

The former result can be verified by inspecting Panel (a) of Table 2.1 which displays in columns the conditional and unconditional measures for the welfare and their respective compensating costs for each one of the eight simple rules (listed on the rows).

Among simple rules, the strict domestic inflation targeting regime delivers the maximum conditional welfare (or the minimum conditional welfare loss, -41.825), which is also consequent with the minimum conditional compensating cost (-0.049%).

The intuition for why the Ramsey regime highlights the strict domestic

Table 2.1: Optimized monetary policy rules to a correlated CPS & WAS scenario

Panel (a): Welfare evaluation

Regime (policy rule)	C. Welfare $\mathscr{W}_0^{C,b}$	C. C. cost Ω^C (%)	U. Welfare $\mathscr{W}_0^{U,b}$	U. C. cost Ω^U (%)	Optimized parameters α_R	α_Π	α_{Π_h}	α_Y	$\alpha_\mathcal{E}$	$\alpha_{\Delta\mathcal{E}}$
Ramsey	-41.766	0.000	-41.777	0.000	–	–	–	–	–	–
Strict CPI (Π_t)	-42.054	-0.240	-42.063	-0.239	–	–	–	–	–	–
Strict domestic ($\Pi_{h,t}$)	-41.825	-0.049	-41.830	-0.044	–	–	–	–	–	–
NER ($\mathcal{E}_t$)	-43.486	-1.428	-43.524	-1.451	–	–	–	–	–	–
NER change ($\Delta\mathcal{E}_t$)	-43.486	-1.428	-43.524	-1.451	–	–	–	–	–	–
Taylor rule 1	-41.986	-0.184	-41.997	-0.183	0.5	3.0	–	0.0	0.0	–
Taylor rule 2	-41.986	-0.184	-41.997	-0.183	0.5	3.0	–	0.0	–	0.0
Taylor rule 3	-41.868	-0.085	-41.874	-0.081	0.0	–	3.1	0.0	0.0	–
Taylor rule 4	-41.868	-0.085	-41.874	-0.081	0.0	–	3.1	0.0	–	0.0

Panel (b): Second moments

Regime	Standard deviation (%) Y_t	$Y_{h,t}$	$Y_{o,t}$	C_t	Π_t	$\Pi_{h,t}$	$\Delta\mathcal{E}_t$	R_t	RR_t	N_t	$\mathscr{W}_{0,t}^C$
Ramsey	6.67	3.55	6.86	2.57	1.73	0.24	6.28	1.27	0.83	0.78	0.34
	[0.76]	[0.37]	[0.62]	[0.26]	[0.12]	[0.03]	[0.43]	[0.10]	[0.06]	[0.09]	[0.03]
Strict CPI (Π_t)	12.27	5.37	8.73	3.93	0.00	0.75	3.49	1.08	1.08	3.78	0.51
Strict domestic ($\Pi_{h,t}$)	11.47	5.63	8.45	3.90	1.45	0.00	5.86	1.00	0.72	1.26	0.50
NER ($\mathcal{E}_t$)	13.34	6.56	8.90	4.78	2.36	2.42	0.00	1.31	1.19	6.27	0.52
NER change ($\Delta\mathcal{E}_t$)	13.34	6.56	8.90	4.78	2.36	2.42	0.00	1.31	1.19	6.27	0.52
Taylor rule 1	11.89	5.01	8.67	3.60	0.45	0.61	3.89	0.87	0.80	3.05	0.50
Taylor rule 2	11.89	5.01	8.67	3.60	0.45	0.61	3.89	0.87	0.80	3.05	0.50
Taylor rule 3	11.40	5.28	8.50	3.61	1.35	0.36	5.55	1.13	0.61	1.41	0.49
Taylor rule 4	11.40	5.28	8.50	3.61	1.35	0.36	5.55	1.13	0.61	1.41	0.49

Note. CPS = commodity price shock; WAS = world activity shock; C. = Conditional; U. = unconditional; C. cost = compensation cost; CPI = consumer price index; NER = nominal exchange rate. Panel (a): rules are evaluated under the same steady state. A dash indicates the absence of the respective parameter in the specified rule. Parameter values increase at 0.1 step within its respective grid, which is defined as $\{\alpha_R\} \in[0,0.9]$, $\{\alpha_\Pi, \alpha_{\Pi_h}\} \in[0,3.1]$ and $\{\alpha_Y, \alpha_\mathcal{E}, \alpha_{\Delta\mathcal{E}}\} \in[0,1]$. Note that the Ramsey plan is taken as the conditional or unconditional welfare baseline measure ($\mathscr{W}_0^{\{C,U\},b}$). Panel (b): standard deviations are in percentage and correspond to the percentage deviation of each variable with respect to its respective steady state. The row of numbers in brackets under the Ramsey second moments are the standard deviation of the simulation of 2000 replications for 20 periods corresponding to each variable.

inflation targeting regime as the best implementable policy rule is that it mimics the planner's solution. In short, as both regimes end targeting the domestic inflation[14], both deliver similar welfare levels and compensating cost measurements.

Regarding Taylor rules, one notices that targeting real output and/or the nominal exchange rate is welfare-detrimental. However, a specification that attributes a high weight to CPI inflation and maintains certain gradualism in policies is less suboptimal. Now, when targeting domestic inflation, gradualism is not recommendable in terms of welfare. The targeting should be strict.

[14]See the explanation for the case of the Ramsey planner in subsection 2.3.2.

Lastly, hard peg regimes' performance in terms of welfare is the worst. These findings are in line with those documented by Ferrero and Seneca (2019) and Drechsel et al. (2019).

Second moments

Panel (b) of Table 2.1 displays the second moments of selected macroeconomic variables under each monetary policy regime (in quarterly frequency).

The optimal stabilization policy given by the Ramsey policy achieves the minimum macroeconomic volatility in terms of the conditional welfare (0.34% of standard deviation) in comparison to any other simple rule regime. Such a record is lower than those registered under the simple rules (around 0.5%]).

The minimum volatility achieved under the Ramsey policy is also observed for consumption (C_t), hours at work (N_t), and outputs of the non-traded final goods sector ($Y_{h,t}$), the commodity-producing sector ($Y_{o,t}$), and of the whole economy (Y_t, which stands for the real GDP).

Regarding the domestic inflation rate ($\Pi_{h,t}$), it can be stated that although the Ramsey policy does not fully stabilize this price index variation rate, it is the second (best) welfare-based stabilization policy (with 0.24% of standard deviation). This comes right after the best simple rule that strictly targets domestic inflation (with a zero percentage of standard deviation).

As in Schmitt-Grohé and Uribe (2007), the reason for domestic inflation not being zero is due to the non-distorted steady state of the economy. Specifically, a labor subsidy has not been assumed to offset the inefficiency effects resulting from monopolistic competition in product markets and the commodity sector. These observations are consistent with the constrained efficiency condition for domestic inflation, derived under the Ramsey planner.

The Ramsey policy implies the highest appreciation/depreciation rate of the nominal exchange rate ($\Delta\mathcal{E}$) among the rest of the policies and it is also the second regime with the most volatile nominal interest rate (R_t). Concerning the volatility of the monetary conditions of the economy (RR_t), the Ramsey policy ranks in the middle of the simple rules. As of these facts, one could infer that the nominal exchange rate plays a role in the monetary transmission policy by helping relative prices (or the terms of trade) to work as a tool that re-adjusts real allocations in an optimally welfare-based fashion.

As already stated, the Ramsey policy has the highest volatility of the appreciation/depreciation rate of the nominal exchange rate among policies. The same applies to the best simple rule that strictly targets the domestic inflation rate. However, note that the regime that targets the CPI inflation rate has the least volatility of the appreciation/depreciation rate of the nominal exchange rate ($\Delta\mathcal{E}$). To some extent, this result could shed light on why monetary authorities of small open- and commodity-exporting economies prefer to implement a sub-optimal policy, like the CPI inflation targeting regime, instead of the best simple rule that strictly targets the domestic inflation rate. Such a preference could be linked to the "fear of floating" phenomenon, as documented by Calvo and Reinhart (2002) and Ilzetzki et al. (2020).

In fact, the measurements for the volatility of the nominal exchange rate under different policy regimes are below the quarterly volatility rate threshold of 4.78%, which in monthly frequency terms is equivalent to the 2.5% volatility rate threshold pointed out by Calvo and Reinhart's (2002) research on the fear of floating phenomena.[15]

A high nominal exchange rate volatility, as suggested by the Ramsey policy and the best simple rule under full commitment leads one to wonder how such measurements would change under a limited commitment regime, and under a discretionary policy regime as well. The referred policy regimes could provide lower volatilities for the nominal exchange that could be closer to the one obtained under the (strictly) CPI inflation rate targeting regime, in contrast to the Ramsey policy regime. This exercise, not addressed in the current paper, would also shed light on the explanation of why policymakers prefer lower nominal exchange rate volatilities.

On the other hand, two additional comments could be made here about the simple and implementable rules. The first is that the reason why the strict CPI inflation rate rule achieves a lower nominal exchange rate volatility than the strict domestic inflation targeting regime, could be the fact that targeting the CPI inflation rate implies targeting weighted

[15] To convert the standard deviation from monthly to quarterly frequency, data from the FRED Saint Louis for the nominal exchange rate (NOK/USD) for the period 1979Q1-2017Q4 are used. Standard deviations are calculated using the cycle component of the variable obtained with the HP-Filter. The smoothing parameter is set to 1600 and 14400 for quarterly and monthly data frequencies, respectively. The conversion factor is calculated as $\psi = \ln(12/4) \div \ln(\sigma_q/\sigma_m)$, $1.69 = \ln(12/4) \div \ln(4.40/2.30)$. Then, a 2.5% monthly volatility rate is equivalent to a 4.78% $[= 2.5\%(12/4)^{(1/1.69)}]$ quarterly volatility rate.

domestic and foreign price consumption baskets, and by doing so, it ends up achieving a lower nominal exchange rate volatility.

Secondly, the nominal exchange rate plays an important role as a transmission channel and tool of the monetary policy that contributes to stabilizing the economy. In this regard, note how under the hard peg rules the volatilities of the nominal exchange rates are zero (a situation when this transmission channel is switched off), the volatilities of real and nominal macroeconomic variables are the highest. Note that this latter is sort of the opposite case under the strict domestic inflation targeting rule (and exactly of the optimal Ramsey policy regime).

Notes on sub-optimized Taylor-type rules

The four optimized Taylor-type rule specifications detailed in Panel (a) of Table 2.1 provide two main lessons that are worth to keep in mind in the context of a correlated CPS and WAS scenario.

First, it is welfare detrimental for the economy to target deviations of the real GDP or of the nominal exchange rate with respect to their correspondent steady state values. Second, targeting for a determined level of the nominal exchange rate is worse in terms of welfare than targeting for a certain appreciation/depreciation rate of the nominal exchange rate.[16]

Figure A.2.1 in Appendix 2.1.4 depicts the summarized lessons stated in the former paragraph. The plot in Panel (a) supports the first statement, while Panel (b) of the same Figure backs the remaining three assertions.

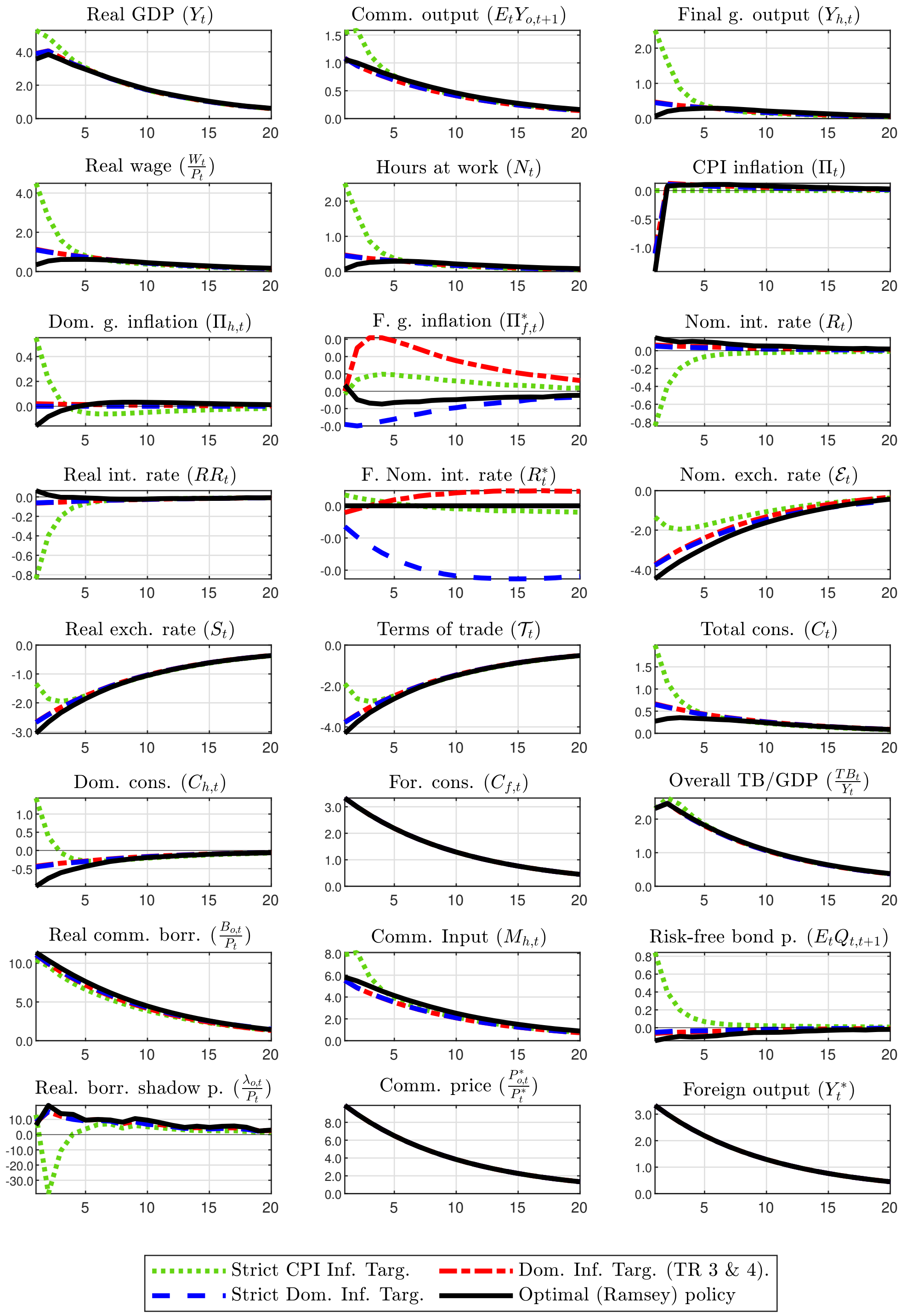
The lesson concerning the policy on targeting real GDP aligns with those identified by Schmitt-Grohé and Uribe (2007), despite the dissimilarities in the economic structures that were studied. As for the other lessons, no analogous exercises were discovered in the literature, according to the author of this paper. Nevertheless, these findings can potentially enrich research on monetary policy for economies that rely on commodity exports.

Dynamics under selected optimized policy regimes

Figure 2.1 depicts the economy's dynamics in response to a correlated CPS and WAS under four selected optimized policy regimes. Namely, the Ramsey plan, the best simple rule that targets domestic inflation, the rule that strictly targets the CPI inflation, and the optimized Taylor-type rule

[16] This last assertion could be related –to some extent– to the concept and use of crawling peg rules that allows the nominal exchange rate to fluctuate within a band of appreciation and depreciation rates.

Figure 2.1: IRFs to a correlated CPS & WAS scenario under selected policy regimes (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock and 3.33% positive world activity shock. Both shocks are correlated and equivalent to a one standard deviation percentage from their respective steady state. The correlation between both shocks is set to 0.99. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. An appreciation corresponds to a drop in the nominal or real exchange rates.

(that targets the domestic inflation, [TR 3 & 4]).

In order to comprehend the way correlated shocks are spread throughout the economy's dynamics, it would be useful to initially discuss *how the transmission mechanism works with the optimized Taylor-type rule (TR 3 & 4).* Following that, we can proceed to outline the distinctions among policy regimes and their impact on the business cycle.

After a correlated CPS and WAS hits the economy, *ceteris paribus*, the commodity-producing sector observes a higher (commodity) price for their products (at time t). In the search for maximization of profits (and zero stock of products at time t), this firm decides to produce and sell more products (in the next period, $t+1$). To this end, the firm requires funds to purchase intermediate goods (commodity inputs), and subsequently, it borrows from abroad (at time t).

International (real) borrowings that are collateralized by the expected income of the commodity firm increase jointly with its (real) shadow price. Once funds are available, the commodity-producing firm demands more intermediate goods and its expected output rises.

Given a higher demand for intermediate goods, firms in the non-traded final goods sector increment the price of their product and contract more hours at work (real wages rise) and the output of the sector increases. Subsequently, the economy observes a small increase in domestic inflation.

A higher domestic price level modifies the relative price of the home economy and the terms of trade improve (drop) causing a real and nominal appreciation of the exchange rate. These conditions ease the borrowing constraint on the commodity-producing sector and allow it to continue borrowing.

Home consumption goods compete with intermediate goods because both are produced by the non-traded final goods sector. With higher domestic prices, the demand for domestic consumption goods dampens and consumers decide to substitute home goods with imported consumption goods. Thanks to the appreciation of the nominal exchange rate, imported consumption goods are relatively less expensive. As a result, an expenditure-switching effect takes place.

Total consumption rises because the positive increment in foreign consumption goods offsets the fall in domestic consumption goods. Note that this effect over total consumption is also thanks to the perfectly international risk-sharing condition, the loosen monetary conditions in the economy (under this regime), and as a consequence of the type of shocks hitting the economy (the correlated CPS and WAS).

The risk-free security price response mirrors the behavior of nominal interest rates in the market, and the global effect on the overall trade balance is positive.

Finally, as monetary conditions tighten and the correlated shocks' effects dissipate, the economy gradually returns to its steady state.

Focusing now on *the (theoretical and optimal) Ramsey policy*, one verifies that the distortionary effects on (real) allocations caused by frictions (sticky prices, a monopolistic competitive market power, a non-zero steady state inflation rate and nominal borrowing limits set in foreign currency) in the economy are (efficiently) minimized.

As expected, under this regime (real) allocation responses (output, consumption goods, commodity input demand, etc.) to the correlated shocks are the least among all the selected policy regimes (see Figure 2.1 and Panel [b] of Table 2.1). Nevertheless, most of the stabilization of the economy occurs through price adjustments.

In particular, borrowing conditions (measured by the real borrowing shadow price) under the Ramsey plan are the tightest ones. This, despite the highest appreciation of the nominal and real exchange rates (that are expected to ease the borrowing constraint in that context). However, that is not the case because the tightest monetary conditions imposed by the planner on the economy prevail (compare the real interest rate responses across regimes). Accordingly, this latter fact rationalizes why the domestic inflation rate is the only one that drops under this regime (note that the domestic consumption goods fall the most under this regime while real wages increase the least). The same fact explains why the CPI inflation rate falls the most and why the responses of (real) allocations (output, consumer goods, hours at work, etc.) for each sector of the economy and as a whole are minimal.

A correlated CPS and WAS boosts the demand for inputs of the commodity sector, increases the final domestic goods supply and dampens domestic consumption goods (causing a drop in the domestic price level), changing relative prices (affecting the efficient allocation of resources), improving the terms of trade, appreciating the nominal and real exchange rates and expanding output (beyond its distorted steady state).

Moreover, as imported consumption goods get less expensive, households' demand for home consumption goods drops, leading domestic inflation to drop. Then, with domestic inflation dropping and output rising, the monetary authority faces a stabilization trade-off. Therefore, to return output to its steady state level (from above) and to return domestic inflation to the target (from below), the Ramsey policy prescribes an increment in the interest rate that must allow for a nominal and real appreciation of the exchange rate that is gradually reversed over time. The implementation of such a monetary policy optimally constrains the commodity sector boom, while stabilizing the economy and bringing it back to its steady state.

Now, taking into account *the best simple rule that strictly targets the domestic inflation rate*, one observes that the macroeconomic variable responses under this regime are in between the Ramsey policy and the Taylor rule that targets the same inflation measure (TR 3 & 4). This result resides upon the fact that both specification rules are close to what the Ramsey plan does, as explained above.

The main difference between the strict domestic inflation rate targeting rule and the Ramsey plan is that, under the first, the monetary policy stance is expansionary, while under the second one, contractionary. Such a discrepancy is due to the structure of the Ramsey planner that implements adjustments (sanctions to deviations from past commitments and inefficiencies derived from the commodity boom) in the search for optimal welfare.

As depicted in Figure 2.1, the best simple rule that strictly targets domestic inflation achieves macroeconomic variable responses (and volatilities) that are close to the Ramsey policy (Table 2.1).

Lastly, examining the dynamics under *the Taylor rule that strictly targets the CPI inflation*, it is clear that this regime offers a higher volatility in the response of most of the macroeconomic variables, on the one hand. While the lowest volatilities for other macroeconomic variables, on the other hand. This latter is the case for the nominal exchange rate. Observe that it displays a quarterly appreciation rate (3.49%, equivalent to 1.82% [$= 3.49\%(12/4)^{-(1/1.69)}$] in monthly terms). That could be appealing for policymakers with preferences influenced by the 'fear of floating' phenomenon (as mentioned earlier in this subsection). The documented variation range for the monthly appreciation/depreciation rates of the nominal exchange rate in many countries where such a phenomenon takes place is ±2.5% (Calvo and Reinhart, 2002, approximately equivalent to ±4.78% [$= \pm 2.5\%(12/4)^{(1/1.69)}$] in quarterly terms). Therefore, the result obtained here could give an idea on why countries (like commodity-exporting economies) would opt for a CPI targeting rule (a sub-optimal regime instead of the optimal one).

Note that there is a difference between the quarterly volatility for the nominal exchange rate under the Ramsey policy and the threshold suggested by the fear of floating phenomenon. In quarterly frequency, the Ramsey policy suggest a volatility of 6.28%, while Calvo and Reinhart's threshold, 4.78% ($= 2.5\%(12/4)^{(1/1.69)}$). In monthly frequency terms, both numbers are equal to 3.27% ($[= 6.28\%(12/4)^{-(1/1.69)}]$) and 2.5%, respectively. As it can be noticed, the suggested volatility rate under the Ramsey policy is relatively higher than the threshold set to study the fear of floating phenomenon.

Additional comparisons

Despite the differences in terms of the economic assumptions, methodological approaches and the resulting best simple obtained under the model developed here and the one proposed by Drechsel et al. (2019), the dynamics of both commodity-exporting economies under the theoretical optimal policies are very similar in response to a correlated CPS & WAS scenario. In both referred studies, the monetary conditions of the economy tighten when following the prescription of both respective (theoretical and optimal) policies. Moreover, all macroeconomic variables agree on the direction of their responses after the correlated shocks take place.

An additional comparison between the model developed here and a modified version of DMT's model is presented in the online appendix.[17] To make the comparison as close as possible to the model developed here, DMT's model is assumed to be non-linear, to have prices à la Rotemberg (1982) and a distorted steady state (zero inflation rate and labor subsidies assumptions do not apply).

Given such settings, the main difference between the model developed here and the modified version of DMT's model is that the latter does not account for currency mismatch episodes while the first does. That is to say, given that the working capital of the commodity firm in DMT's model is static, and that borrowings are intra-temporal, they exclude currency mismatch considerations from their analysis (while the model

[17]The modified version of DMT's model and the referred comparison are made by the author of this present paper (see the supplementary material section in Appendix 2.1.6), and not by DMT.

developed here does not). Then, the remaining structure of the original version of DMT's model is left without changes (as in their paper).

The main result of that exercise is that, in response to a correlated commodity price shock and world activity shock, the economic model that accounts for currency mismatch episodes –the model developed here– displays a smoother exchange rate volatility under different monetary policy regimes. These results are in line with Calvo and Reinhart's (2002) and Frankel's (2003) findings, and with the conclusion that small open- and -commodity-exporting economies also fear to float (see the supplementary material section in Appendix 2.1.6).

Another result to mention is the one attained by Báez (2021) for the same SOCEE but with a fully flexible price environment and relying on an *ad hoc* welfare loss function approach. In response to the same correlated CPS and WAS, the optimal monetary policy in that study is to target the CPI inflation while accounting for past policies (i.e., the smoothing term for the interest rate is present in the rule). Comparing variables' responses under this optimal rule with the one that strictly targets CPI inflation, one observes that the dynamics of the economies are very similar to the ones shown here. Nevertheless, under price rigidity (as in the present study), nominal variables have a smoother and longer transition; while real variables, a slightly higher but shorter response dynamics. Additionally, the same can be verified once rules that target domestic inflation are compared in both studies.

Lastly, unlike Báez (2021), here one corroborates that in the presence of sticky prices, rules that target for the nominal exchange rate perform poorly in terms of welfare (Table 2.1). Therefore, the premise that simple and implementable rules that target the nominal exchange rate (like an exchange rate peg rule) would be potential welfare-enhancing (optimal monetary policy) regimes, only holds in the context of (the same economy) with fully-flexible prices (as shown by Báez, 2021). While here, it is proven not to be true in the context of (the same economy structure, but with) price rigidity and monopolistic competition. As a result, it is evidently that these two last frictions of the economy are relevant (and not innocuous aspects) to be considered in a monetary policy evaluation framework, as Schmitt-Grohé and Uribe (2004) argue.

Variations of the leverage in the commodity sector

An increment in the leverage of the commodity sector is welfare detrimental. As a result, the Ramsey monetary policy prescribes tighter monetary conditions of the economy in comparison to the baseline scenario, under the same correlated CPS and WAS.

When the representative commodity-producing firm is allowed to contract a higher amount of international credits as a proportion of its total expected income that is pledged as collateral, the loan-to-value ratio increases. Then, the parameter χ in the borrowing constraint of the commodity sector is supposed to augment from 0.5 (as calibrated for the baseline scenario) to 1.3.

Under the Ramsey planner, higher leverage in the commodity sector worsens welfare because it introduces higher price volatility in the economy (through the effects of the demand for commodity inputs) and constraints even more (real) allocation responses to the correlated shocks (see Table 2.2).

Table 2.2: Optimal (Ramsey) policy to a higher loan-to-value ratio (χ)

LR	C. Welfare	U. Welfare	Standard deviation (%)										
χ	$\mathscr{W}_0^{C,b}$	$\mathscr{W}_0^{U,b}$	Y_t	$Y_{h,t}$	$Y_{o,t}$	C_t	Π_t	$\Pi_{h,t}$	$\Delta\mathcal{E}_t$	R_t	RR_t	N_t	$\mathscr{W}_{0,t}^{C,b}$
0.5	-41.77	-41.78	6.67	3.55	6.86	2.57	1.73	0.24	6.28	1.27	0.83	0.78	0.34
			[0.76]	[0.37]	[0.62]	[0.26]	[0.12]	[0.03]	[0.43]	[0.10]	[0.06]	[0.09]	[0.03]
1.3	-41.80	-41.81	6.62	3.56	6.82	2.54	1.81	0.29	6.55	1.42	0.94	0.80	0.34
			[0.75]	[0.38]	[0.61]	[0.26]	[0.13]	[0.04]	[0.46]	[0.12]	[0.08]	[0.09]	[0.03]

Note. LR = loan-to-value ratio (χ); C. = conditional; U. = unconditional; $\mathscr{W}_0^{\{C,U\},b}$ = {conditional, unconditional} welfare baseline measure (b). Optimal (Ramsey) monetary policy under a correlated commodity price shock and world activity shock. Both shocks are positive and set to 10% and 3.33%, respectively. Standard deviations are in percentage and correspond to the percentage deviation of each variable with respect to its respective steady state. The row of numbers in brackets are the standard deviation of the simulation of 2000 replications for 20 periods corresponding to each variable.

In the alternative scenario (when $\chi = 1.3$) it can be seen more volatile nominal exchange rate and domestic prices. The monetary conditions of the economy are also more volatile.

Accordingly, in terms of the optimal policy, the Ramsey planner raises the nominal interest rate more than it is done under the baseline scenario, in response to the same correlated CPS and WAS (see Figure A.2.2 in Appendix 2.1.4). A similar result can also be appreciated in the study conducted by Drechsel et al. (2019), although their analysis is based on (an uncorrelated) commodity price shock scenario and under the best simple policy rule (which is a strict CPI inflation targeting regime).

Varying the home consumption bias

The small open- and -commodity-exporting economy's welfare improves when the home consumption bias rises. However, with a higher home consumption bias and under a correlated CPS and WAS scenario, the Ramsey policymaker tightens, even more, the monetary conditions of the economy, in comparison to the baseline scenario.

The proportion of consumption of domestic goods $(1 - \alpha)$ is calibrated to 0.71, under the baseline scenario; while under the alternative one, it is set to 0.75. This change affects the steady state of the planner, under the alternative scenario, and larger levels of total consumption and real GDP are observed. In consequence, welfare of the economy increases (see Table 2.3). Note that the proportion of domestic goods over the total output of the non-traded final domestic goods is still the same under both scenarios.

An economy with a larger home consumption bias is more sensible to the effects (or distortions) coming from its commodity-producing sector. That is to say, households are now less prone to change home consumption goods for imported goods, given the larger proportion of domestic goods that is demanded now. Therefore, the competition between the demand for home consumption goods (from households) and the demand for intermediate goods (from the commodity sector) becomes even tougher.

When a correlated CPS and WAS hits the economy, the observed volatilities in total consumption and in the output of the commodity sector are higher, and as explained in the former paragraph, welfare is more volatile in the alternative scenario (Table 2.3).

The superior exposition to potential effects derived from the commodity boom leads to the planner to exert more control over fluctuations of most of the macroeconomic variables (Table 2.3) by tightening even more the monetary conditions (see Figure A.2.3 in Appendix 2.1.4).

As found by Faia and Monacelli (2008) under the Ramsey policy for a (standard) small open economy (without a commodity sector), the same two predictions are verified here (but under the SOCEE presented here). In particular, the required appreciations of the nominal and real exchange rates are increasing in the home consumption bias (Figure A.2.3 in Appendix 2.1.4); and the (theoretical and optimal) volatility of the

Table 2.3: Optimal (Ramsey) policy to a higher home consumption bias $(1-\alpha)$

HCB	C. Welfare	U. Welfare	Standard deviation (%)										
$1-\alpha$	$\mathscr{W}_0^{C,b}$	$\mathscr{W}_0^{U,b}$	Y_t	$Y_{h,t}$	$Y_{o,t}$	C_t	Π_t	$\Pi_{h,t}$	$\Delta\mathcal{E}_t$	R_t	RR_t	N_t	$\mathscr{W}_{0,t}^{C,b}$
0.71	-41.77	-41.78	6.67	3.55	6.86	2.57	1.73	0.24	6.28	1.27	0.83	0.78	0.34
			[0.76]	[0.37]	[0.62]	[0.26]	[0.12]	[0.03]	[0.43]	[0.10]	[0.06]	[0.09]	[0.03]
0.75	-36.06	-36.07	6.33	3.51	6.98	2.65	1.50	0.25	6.25	1.10	0.75	0.59	0.41
			[0.72]	[0.38]	[0.63]	[0.28]	[0.10]	[0.03]	[0.42]	[0.09]	[0.06]	[0.07]	[0.04]

Note. HCB = home consumption bias $(1-\alpha)$; C. = conditional; U. = unconditional; $\mathscr{W}_0^{\{C,U\},b}$ = {conditional, unconditional} welfare baseline measurement (b). Optimal (Ramsey) monetary policy under a correlated commodity price shock and world activity shock. Both shocks are positive and set to 10% and 3.33%, respectively. Standard deviations are in percentage and correspond to the percentage deviation of each variable with respect to its respective steady state. The row of numbers in brackets are the standard deviation of the simulation of 2000 replications for 20 periods corresponding to each variable.

nominal exchange improves (drops) as the home consumption bias rises (Table 2.3).

When price rigidity varies

The Ramsey plan determines that when price rigidity in the commodity-exporting economy decreases, welfare worsens. Under that condition and the presence of correlated CPS and WAS, the Ramsey policy tightens even more monetary conditions (at the beginning), in comparison to the baseline scenario.

When prices in the economy become more flexible, adjustment costs decrease. Then, under the alternative scenario, the relevant parameter (θ) in the NKPC that is set to 48.8 (under the baseline calibration), now it is parameterized to 4.6 (under the alternative scenario).

Although the economy experiences less price stickiness, the frictions that are present in the monopolistic sector and the commodity sector contribute to adding more volatility in the economy, and correspondingly, worsen welfare. Additionally, more flexible prices (with higher volatility) contribute also to making (real) allocations (like consumption, output, hours at work, etc.) more volatile (see Table 2.4).

Under the alternative scenario (with prices that are close to the fully-flexible environment) but that still is inefficient (due to frictions), one verifies that the volatility of the nominal exchange rate is also higher. Such a result is consistent with the study conducted by Báez (2021) under a fully-flexible price framework and under a close competitive equilibrium

Table 2.4: A lower price rigidity (θ)

AC	C. Welfare	U. Welfare	Standard deviation (%)										
θ	$\mathscr{W}_0^{C,b}$	$\mathscr{W}_0^{U,b}$	Y_t	$Y_{h,t}$	$Y_{o,t}$	C_t	Π_t	$\Pi_{h,t}$	$\Delta\mathcal{E}_t$	R_t	RR_t	N_t	$\mathscr{W}_{0,t}^{C,b}$
Optimal (Ramsey) policy regime													
48.8	-41.77	-41.78	6.67	3.55	6.86	2.57	1.73	0.24	6.28	1.27	0.83	0.78	0.34
			[0.76]	[0.37]	[0.62]	[0.26]	[0.12]	[0.03]	[0.43]	[0.10]	[0.06]	[0.09]	[0.03]
4.60	-42.05	-42.20	6.85	3.69	6.90	2.66	2.41	1.27	6.67	2.14	0.81	0.86	0.34
			[0.79]	[0.39]	[0.62]	[0.28]	[0.26]	[0.19]	[0.52]	[0.24]	[0.08]	[0.11]	[0.04]
Strict domestic inflation targeting regime													
48.8	-41.83	-41.83	11.47	5.63	8.45	3.90	1.45	0.00	5.86	1.00	0.72	1.26	0.50
4.60	-41.83	-41.83	11.47	5.63	8.45	3.90	1.45	0.00	5.86	1.00	0.72	1.26	0.50
Strict CPI inflation targeting regime													
48.8	-42.05	-42.06	12.27	5.37	8.73	3.93	0.00	0.75	3.49	1.08	1.08	3.78	0.51
4.60	-41.87	-41.79	11.58	5.44	8.53	3.85	0.00	1.25	4.29	0.70	0.70	1.67	0.50

Note. AC = adjustment cost parameter (θ); C. = conditional; U. = unconditional; $\mathscr{W}_0^{\{C,U\},b}$ = {conditional, unconditional} welfare baseline measure (b). Optimal (Ramsey) monetary policy under a correlated commodity price shock and world activity shock. Both shocks are positive and set to 10% and 3.33%, respectively. Standard deviations are in percentage and correspond to the percentage deviation of each variable with respect to its respective steady state. The row of numbers in brackets are the standard deviation of the simulation of 2000 replications for 20 periods corresponding to each variable.

model (as the one addressed here).[18]

In terms of policy, the Ramsey plan indicates tighter monetary conditions (at the beginning) for the economy as a means to dampen distortions that are still coming from the monopolistic power and the borrowing constraint of the commodity sector (see Figure A.2.4). However, along the transition monetary conditions ease faster and turn more expansionary than in the baseline scenario.

There are additional points that can be mentioned about Table 2.4. Concretely, under a strict domestic inflation targeting rule, a change in the adjustment cost parameter does not affect welfare nor the macroeconomic conditions of the economy (regardless of which scenario is being considered). In other words, given that the rule always targets domestic inflation, any variation in its fundamental parameters is simply eliminated by the rule itself (i.e., no matter what variation domestic inflation suffers because the rule targets such a variation anyway).

On the other hand, under a strict CPI inflation targeting regime, it can be verified that welfare and macroeconomic conditions point out a counterwise result. Specifically, when price rigidity lowers, welfare improves

[18]Again, this consistency supports the claim made about the importance on how price rigidity and monopolistic power are not innocuous frictions in the context of a monetary policy evaluation. Their effect and implications in terms of policy optimality are direct (remember the points made in the part 'a brief comparison' at subsubsection 2.4.3 and the argument made by Schmitt-Grohé and Uribe, 2004 on this issue).

and most (real) allocations tend to have lower volatility. However, regarding prices, the nominal exchange rate is one of the main prices that account for higher volatility.

All in one, the main inference under this particular analysis is that more price rigidity contributes to observing lower nominal exchange rate volatility, under the Ramsey planner and the strict CPI inflation targeting regimes. Under the strict domestic inflation regime, such volatility is the same.

2.4.4 Commodity price shock scenario results

In the same way that the previous subsection performs the optimal evaluation of welfare-based monetary policy, the four former exercises (or cases) are analyzed also here, but under the (uncorrelated) commodity price shock scenario. Full results are available in Appendix 2.1.5 and the main conclusions under this baseline scenario state as follows.

Contrasting against other policy regimes, the welfare benchmark set by the Ramsey policy regime points out that the best simple rule is again the one that strictly targets domestic inflation (Table A.2.1).[19] Note that the welfare-based monetary policy ranking rule does not change under this particular scenario. Moreover, results (and comments) regarding welfare and second moments under alternative regimes remain the same. This, in comparison to the correlated CPS and WAS scenario (presented in Table 2.1).

Considering the volatility of the nominal exchange rate, one observes that this is still the highest under the optimal policy and the best policy rule. While at the other extreme, the CPI inflation targeting regime still delivers the minimum (non-zero) volatility for this variable (Table A.2.1). This, in turn, makes again this regime an attractive option for monetary policymakers influenced –to some extent– by the 'fear of floating' phenomenon. A particular observation about the former points is that, the suggested quarterly volatilities by the two optimal aforementioned regimes are closer to the fear of floating quarterly threshold of 4.78% (and they might not be so different under this particular scenario). Namely, such volatilities for the nominal exchange rate are 5.46%

[19] This same result is the one obtained by Ferrero and Seneca (2019) for their commodity-exporting economy without any financial friction but under a linear quadratic approximation framework for their welfare-based monetary policy evaluation. However, it differs from the one attained by DMT.

and 5.41%, respectively. While, for the CPI inflation targeting regime is 3.38%. Note how the volatility of this variable in question under this latter regime is still consistent with the quarterly threshold accounted by fear of floating.[20]

Under the (uncorrelated) commodity price shock, the Ramsey policy tightens even more the monetary conditions of the economy (Figure A.2.5). However, in spite of tougher conditions and a drop in total consumption, sectoral outputs and the real GDP of the economy achieve to expand more (than in the case of a correlated CPS and WAS scenario). In particular, the CPS boosts even more the demand for inputs of the commodity sector, causing a higher increase of the final domestic goods supply (and a deeper drop in domestic price levels), changing relative prices (affecting the efficient allocation of resources), improving the terms of trade, appreciating the nominal and real exchange rates, easing borrowing conditions and expanding output (beyond its distorted steady state). The fall in total consumption is because in the absence of the correlated WAS, the appreciation of the real and nominal exchange rates are smaller. Henceforth, households cannot effectuate an expenditure switching (between domestic and foreign consumption goods) that helps to prevent a fall in total consumption.

Optimized Taylor-type rules confirm that it is sub-optimal to target deviations in the real GDP and deviations in the level or in the change of the level of the nominal exchange rate (Figure A.2.6).

In the presence of (uncorrelated) commodity price shocks the Ramsey policy indicates that: an increment in the leverage of the commodity sector dampens welfare (Table A.2.2); that a rise in the home consumption bias enhances welfare (Table A.2.3); and that, more flexibility in prices deteriorates welfare (Table A.2.4). Along the same lines as before, but in terms of the monetary policy conditions in the economy, respective stances are: contractionary for the two first cases (Figures A.2.7 and A.2.8), and expansionary, in the last case (Figure A.2.9).

[20]This last result is stronger and more consistent than the volatility measurements delivered by Drechsel et al.'s (2019) and Ferrero and Seneca's (2019) models that are below 1% in monthly terms (while the fear of floating volatility threshold is set to 2.5% in monthly terms).

2.5 Conclusion

A welfare-based optimal monetary policy for a small open- and -commodity-exporting economy with nominal frictions is studied here through the lens of a Ramsey-type approach à la Marcet and Marimon (2019).

The (theoretical and optimal) Ramsey policy maximizes welfare (proxied by the representative household utility) while minimizing all distortions of the economy coming from price rigidity and monopolistic power (present in the non-traded home goods sectors), an income-based borrowing constraint (in the commodity sector) and a non-zero inflation rate (at the steady state), giving private and aggregate resource constraints.

In response to a correlated commodity price shock and world activity shock, the Ramsey policy tightens the monetary conditions of the economy, by softening real macroeconomic variables' responses to the shock and by allowing a real and nominal appreciation of the exchange rate. In contrast to eight alternative simple and implementable policy rules, the best simple rules is to strictly target domestic inflation. This latter regime is close to mimicking the Ramsey plan because distortions coming from the nominal frictions in the economy are minimized by the planner and what remains, according to the efficiency conditions of the planner, is to target domestic inflation. As a consequence of this latter similarity, both regimes deliver close conditional welfare measurements, dynamics and volatilities for the economy, albeit the monetary policy stance for the strict domestic targeting regime is slightly expansionary (and slightly contractionary, under the other).

Another relevant result that emerges from the aforementioned monetary policy evaluation is the fact that the suggested nominal exchange rate volatility under the Ramsey policy and the best simple rule is the highest among all the regimes considered under full commitment. Conversely, considering the lowest regimes in the same ranking list, the strict CPI inflation targeting rule turns out to be the simple and implementable rule that delivers the lowest volatility. This, after the hard peg regimes (with zero volatility, naturally). The implications of these results with respect to the nominal exchange rate volatility point out to think about why small open- and -commodity-exporting countries pursue to have a sub-optimal CPI inflation targeting regime instead of an optimal one under full commitment (but whose nominal exchange rate volatility is the highest).

As of the last considerations, this study allows to explore several possible extensions. First, under the model framework, one could analyze how the optimal monetary policy results change when the policymaker operates under discretion or under limited commitment. Second, relying on the Ramsey-type approach, one could also find out the optimal policy when there are more financial frictions in the economy and what would be the implied volatilities of the nominal exchange rate under each optimized regime and/or degrees of commitment.

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Chapter 3

Optimal sustainable monetary policy for commodity-exporting economies

3.1 Introduction

As pointed out by Clarida, Galí and Gertler (1999), the optimal monetary policy under the full commitment approach (initially proposed by Currie and Levine, 1993 and Woodford, 1998) is the most common framework used in the literature to undertake a welfare-based monetary policy evaluation. Accordingly, making use of such an approach, Drechsel, McLeay and Tenreyro (2019, also referred to as DMT) conducts a welfare-based optimal monetary policy analysis under full commitment for a small open- and -commodity-exporting economy (SOCEE).

In response to a positive commodity price shock (CPS) and under the (theoretical) optimal commitment policy, DMT find that the policymaker has to tighten monetary conditions and allow for an appreciation of the nominal exchange rate to optimally accommodate for the inefficiencies introduced by the shock. Furthermore, in such a context, the responses and volatilities of the domestic inflation and the domestic output gap are the lowest in comparison to those obtained under simple and implementable policy rules. While in the case of the nominal exchange rate, the same measures result to be the highest ones.

Considering Frankel's (2003) observation that small open- and -commodity-exporting economies also fear to float (i.e., policymakers in such countries prefer policy rules that smooth out fluctuations in the nominal exchange rate as much as possible), the present paper wonders whether the results obtained by DMT would change if the optimal sustainability policy framework à la Kurozumi (2008) is used instead of the standard optimal commitment policy à la Clarida et al. (1999). Specifically, this paper asks whether the optimal sustainable policy framework would achieve a lower response and volatility for the nominal exchange rate, while at the same time if it would still obtain the lowest responses and volatilities for the domestic inflation rate and the domestic output gap.

The optimal sustainable policy framework is an optimal monetary policy approach that delivers an optimal sustainable equilibrium based on the policymaker's reputation rather than its commitment. Such a framework is inspired on Chari and Kehoe's (1990) optimal sustainable plans concept, derived from policy games between competitive private agents and their government in infinite-horizon economies. In such games, these authors characterize the entire set of sustainable equilibrium outcomes, find the worst sustainable equilibrium and conclude that the optimal government's strategy requires the continuation as an outcome –or policy–, provided it has been adopted in the past; otherwise, the strategy requires to opt for the worst sustainable equilibrium outcome.

As of Chari and Kehoe's (1990) optimal sustainable plans outcome resulted from policy games, Kurozumi (2008) extrapolates that theory to the optimal monetary policy welfare-based design framework and shows that the optimal sustainable monetary policy is a policy strategy that only requires the policymaker's reputation and dispenses with the commitment technology (or assumption). Moreover, this author also shows that the optimal sustainable policy can be implemented by an operational optimal quasi-sustainable policy scheme. Where, this latter is derived from a welfare-based approach in which there is a sustainability constraint stating that the highest welfare comes from an optimal commitment policy, while the worst sustainable equilibrium policy, from the optimal discretionary policy.

As a result of the optimal sustainable policy framework, this paper performs the optimal monetary evaluation policy by contrasting the optimal quasi-sustainable policy, the optimal commitment policy and the discretionary policy regimes. To that end, the analysis is set on the small open-and -commodity-exporting economy proposed by DMT. In the model, the representative commodity sector (introduced by Ferrero and Seneca, 2019 to the small open economy proposed by Galí and Monacelli, 2005) faces (ad hoc) borrowing limits to nominal foreign loans contracted from international markets in foreign currency denomination. To obtain a numerical solution to DMT's model in the presence of the occasionally binding constraint of the sustainability constraint condition (introduced by the optimal quasi-sustainable policy scheme), the numerical solution strategy follows Sunakawa (2015) by implementing a variant of the policy function iteration method as proposed by Kehoe and Perri (2002).

Selected macroeconomic variable responses of the economy to a CPS as well as the slackness condition of the sustainability constraint are analyzed. Then, it is corroborated that the optimal quasi-sustainable policy coincides with the optimal commitment policy, implying three main results –under the assumptions introduced to DMT's model–. Firstly, the competitive equilibrium achieved by the optimal commitment policy is consistent with the sustainable equilibrium obtained under the optimal quasi-sustainable policy. Secondly, the reputation technology (assumed under the optimal quasi-sustainable policy) corresponds to the commitment technology (assumed under the optimal commitment policy). And lastly, business cycle fluctuations are more volatile under the optimal discretionary policy, as expected.

The coincident equilibrium between the optimal quasi-sustainable policy and the optimal commitment policy is a result in line with the findings documented by Sunakawa (2015). In concrete, such a result comes from the standard calibration value assigned in the literature to the subjective discount factor of the economy, which implies realistic real interest rates for the economies. Consequently, such high values of the subjective discount factor (or low real interest rate values) prevent the sustainability constraint to bind and observe any possible difference between the optimal quasi-sustainable policy and the optimal commitment policy. With all of that, this paper also finds that in the face of a CPS, the optimal sustainable policy framework delivers the same responses and volatilities (for the nominal exchange rate, the domestic inflation, the domestic output gap and other selected macroeconomic variables) that are accounted under the optimal commitment policy.

Two additional results in response to a CPS are worth mentioning. The first is that as the inelasticity of foreign nominal borrowings with respect to international commodity prices increases, the business cycle of the economy is more volatile. Second, as the commodity inputs share in the economy increases, the business cycle also turns to be much more volatile.

The rest of the document proceeds with Section 3.2 where theoretical aspects of the SOCEE model and those of the optimal monetary policy approaches are presented and discussed. Section 3.3 describes the main quantitative findings and details about the optimal monetary policy evaluation. Section 3.4 concludes.

3.2 The model

This section presents particularities of the commodity-exporting economy that are relevant to the monetary welfare-based evaluation conducted under the optimal commitment, optimal discretionary and optimal sustainable policy approaches. Subsequently, the solution method and calibration applied to the model are described as well.

3.2.1 The commodity-exporting economy model

As mentioned before, Drechsel, McLeay and Tenreyro's (2019) model builds upon the one of Ferrero and Seneca (2019), and this in turn, upon Galí and Monacelli's (2005) model. Consequently, the basic structure of DMT's model is given by a two-country dynamic general equilibrium model for a small open economy with sticky prices, competitive markets and a non-distorted steady state where zero inflation rate and labor subsidy are assumed. The economy compounds a representative household sector, a sector of non-traded final goods firms, a representative commodity-producing firm, a foreign sector and a monetary authority agent.[1]

The representative household consumes a basket of foreign and domestic consumption goods, provides hours of work, keeps a portfolio of (foreign and domestic) state-contingent securities, and receives rebated dividend profits from the firms. The macroeconomic environment is characterized by a cash-less economy with complete asset markets where the international perfect risk-sharing condition holds, the law of one price holds,

[1] Given the main goal of undertaking a welfare-based monetary policy evaluation using DMT's model under the optimal commitment, the optimal discretionary and the optimal sustainable policies, the reader is advised to consult Drechsel et al.'s (2019) paper for details on their model that are not presented here.

there is a fully passed-through effect from changes in the nominal exchange rate to imported goods prices and the uncovered interest rate parity (UIP) condition holds.

The productive sector of the economy has two firm sectors: the non-traded final goods firms and the representative commodity-producing firm. The first sector is integrated by retail and wholesale firms. Retail firms operate in perfectly competitive markets selling aggregate final goods that are produced as of intermediate goods. Wholesale firms, in turn, are composed of a continuum of firms that produce intermediate goods, operate in monopolistic competitive markets employing labor and the homogeneous technology of the sector to produce differentiated goods, using a linear production function technology (with constant returns to scale, CRS), and pricing their products à la Calvo (1983). Final goods from this sector are destined for domestic consumption goods (demanded by households), and intermediate goods/inputs (demanded by the commodity-producing sector). The optimality condition for this sector delivers the New Keynesian Phillips Curve (NKPC) for this commodity-exporting economy,

$$\pi_{h,t} = \beta E_t \pi_{h,t+1} + \xi x_{h,t} + \xi (y^e_{h,t} - y^n_{h,t}), \tag{3.1}$$

where $\pi_{h,t}$, $x_{h,t}$, $y^e_{h,t}$ and $y^n_{h,t}$ represent the domestic inflation rate, the relevant output gap of the economy and the efficient and natural outputs, respectively. All these four variables are expressed in log-linearized terms and in deviation with respect to its respective steady state level. For its part, ξ measures the slope of the NKPC which, in this case, it is also weighting the gap between the efficient and natural outputs ($y^e_{h,t}$ and $y^n_{h,t}$).

The representative commodity-producing firm operates in perfectly competitive markets producing (commodity) goods by using intermediate goods (inputs) and a decreasing returns to scale production function. Everything that this sector produces is exported and it is implicitly assumed that international creditors are able to meet all the required credit demanded by the representative commodity-producing firm. This agent faces an ad hoc working capital constraint over foreign credits that finance the purchase of intermediate goods. Thus, the international borrowings/loans ($L_{c,t}$) cover for intermediate goods purchases ($P_{h,t}M_{h,t}$)

$$L_{c,t} = P_{h,t}M_{h,t},$$

that are constrained by a time-varying proportion ($[\cdot]$) of the working capital ($P_{c,t}Y_{c,t}$),

$$L_{c,t} \leq \Big[\bar{\chi}\Big(\frac{P^*_{c,t}}{P^*_t}\Big)^{\chi}\Big] P_{c,t}Y_{c,t},$$

where χ is an elasticity that measures borrowing conditions with respect to international commodity prices ($P^*_{c,t}/P^*_t$) and $Y_{c,t}$ is the constant returns to scale production function of the sector, $Y_{c,t} = A_{c,t}M_{h,t}$. Where $A_{c,t}$ is the total factor productivity of the sector. The optimality conditions deliver the demand of intermediate goods and borrowings/loans that maximize the discounted value of the firm.

It is assumed that international commodity prices ($p^*_{c,t}$) are determined in international markets, that they follow an exogenous process, and that they are expressed in foreign currency denomination. The real commodity price shock $p^*_{c,t}$ follows a first-order autoregressive exogenous process[2]

$$p^*_{c,t} = \rho_{p^*_c} p^*_{c,t-1} + \epsilon_{p^*_c,t}, \tag{3.2}$$

where $\epsilon_{p^*_c,t} \sim (0, \sigma^2_{p^*_c})$ is bounded (i.e., there is a $B > 0$ such that $|p^*_{c,t}| < B$), independent and identically distributed with zero mean and $\sigma^2_{p^*_c} > 0$ standard deviation. Observe that the persistence of the process is given by $\rho_{p^*_c} \in (-1, 1)$ and an initial condition $p^*_{c,t-1|t=0} = 0$.

Regarding the rest of the exogenous processes that characterize the foreign sector as well as the total factor productivity processes of the two producing sector of this economy, unlike DMT, here, it is assumed that they are nil. Namely, the foreign output process, the foreign interest rate process, the foreign inflation rate process and the productivity processes of the commodity sector and the non-traded final domestic goods sector are all nil.

Given the last set of assumptions, it is possible then to re-express the term $\xi(y^e_{h,t} - y^n_{h,t})$ in the NKPC (3.1) only in terms of the commodity price shock (CPS) as

$$\xi(y^e_{h,t} - y^n_{h,t}) = \xi\Big(\frac{-\frac{s_{c,ss}s_{m,ss}\nu}{\mathcal{W}_{ss}(1-v)^2}}{\frac{\lambda_\tau}{\mathcal{W}_{ss}} + \phi\mathcal{W}_{ss}} - \frac{\frac{s_{m,ss}}{1-\nu}}{1+\phi\mathcal{W}_{ss}}\Big)(1-\chi)p^*_{c,t} \equiv \omega p^*_{c,t}, \tag{3.3}$$

where ω can be positive if $\chi > 1$; zero if $\chi = 1$; or negative if $\chi < 1$. Note that ω embraces all the structural parameters of the model written in the middle of the last equality. By inspection, one verifies that the

[2]Note that $p^*_{c,t} \equiv \ln(P^*_{c,t}/P^*_{c,ss})/\ln(P^*_t/P^*_{ss})$ where $P_{c,ss}$ and P^*_{ss} are the foreign commodity price and the foreign consumer price index at their steady state values.

weighted gap between the efficiency and natural outputs in this economy is being determined by the borrowing elasticity of the commodity sector (χ), the constant returns to scale in the commodity-producing sector (ν), the slope of the NKPC (ξ), the share of domestic consumption goods produced in the economy ($s_{c,ss}$), the share of domestic intermediate goods produced in the economy for the commodity sector ($s_{m,ss}$), and the wedge at the steady state ($\mathcal{W}_{ss}$).[3]

As a result of a new equivalent expression for the term $\xi(y^e_{h,t} - y^n_{h,t})$, the same short-run aggregate supply curve (or NKPC) can be rewritten as a weighted function of the CPS,

$$\pi_{h,t} = \beta E_t \pi_{h,t+1} + \xi x_{h,t} + \omega p^*_{c,t}. \tag{3.4}$$

Note the particular effect that the weighting parameter ω in (3.4) could have over the CPS (and subsequently over the NKPC). Moreover, note that the CPS shock effect over the NKPC depends on ω's sign, and indirectly, on the sign (and value) of the financial channel parameter (χ). A priori, when borrowing conditions in the commodity sector are unfavorable ($\chi < 1$, $\omega < 0$), a positive CPS would displace the NKPC downwards. In the opposite case, under favorable borrowing conditions in the commodity sector ($\chi > 1$, $\omega > 0$), but under the same positive CPS, the DMT's model predicts that the NKPC would be displaced upwards.

Finally, the policymaker's block closes the equilibrium conditions of DMT's model. The optimal monetary policy under full commitment in the spirit of Clarida et al. (1999) is obtained by choosing the state contingent sequences of domestic inflation rate and output gap $\{\pi_{h,t}, x_{h,t}\}_{t=0}^{\infty}$ that maximizes social welfare under full commitment subject to the NKPC (3.1). In particular, the problem of the policymaker is solved here using the reformulated NKPC (3.4). The welfare function is obtained through a second-order approximation to the representative household's expected utility (coming from the consumption basket of domestic and foreign goods and the disutility from labor or hours at work: $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \{\ln C_t - N_t^{1+\phi}/[1+\phi]\}$) in period zero, given by

$$-E_0 \sum_{t=0}^{\infty} \beta^t \frac{\Omega}{2} (\pi^2_{h,t} + \lambda_x x^2_{h,t}). \tag{3.5}$$

[3]Note that $\xi \equiv \kappa(1+\phi\mathcal{W}_{ss})/\mathcal{W}_{ss}$, $\kappa = (1-\theta)(1-\beta\theta)/\theta$, $\mathcal{W}_{ss} \equiv s^e_{c,ss} + 1/(1-\nu)s^e_{m,ss} > 1$, $\lambda_\tau = s_{c,ss} + s_{m,ss}/(1-\nu)^2$, where β is the subjective discount factor, ϕ is the inverse Frisch elasticity labor supply and $1-\theta$ is the Calvo price re-set probability.

Observe how in the second-order approximation (or welfare loss function) Ω weights for the entire squared sum of the domestic inflation and domestic output gap sequences deviations with respect to their steady state values, while λ_x exclusively tries to stabilize the domestic output gap relative to domestic inflation.[4]

3.2.2 Optimal monetary policy approaches

In this subsection, three approaches for optimal commitment, discretionary and sustainable policies are presented and derived to analyze the economic predictions according to DMT's model.

Optimal commitment policy

The design of the optimal monetary policy under full commitment implies that the policymaker announces to implement a state-contingent rule and stick to it forever in order to achieve a certain set of pre-established policy goals. Such a commitment implies the assumption of perfect credibility in the policymaker as head of the central monetary institution.

Under DMT's model framework, whenever a CPS hits the economy its monetary authority faces a policy trade-off that challenges the fulfillment of the commitment made to economic agents. In fact, a CPS changes the efficient allocation of the economy by boosting the demand for inputs in the commodity sector, increasing the supply of domestic goods, causing a domestic inflation fall, but an expansion of the output gap due to the commodity boom. Thus, with domestic inflation dropping and the output gap rising, the monetary authority faces a trade-off and must stabilize the economy. Such a duty has to be accomplished given its state-contingent policy rule, the commitment to its ultimate goals and the expectations (or beliefs) of forward-looking private agents that turn the policymaker's monetary policy design into a time-consistency problem. This issue is usually known as 'stabilization bias' as well.[5]

On the other hand, as it was stated before, DMT's model rules out the possibility of 'inflation bias', given that subsidies are assumed to offset

[4]See that $\Omega = (1-\alpha)\epsilon/(\kappa\mathcal{W}_{ss})$ and that $\lambda_x = \kappa/\epsilon(\lambda_\tau/\mathcal{W}_{ss}^2 + \phi)$, where α is the foreign consumption bias and ϵ is the elasticity of substitution between home and foreign consumption goods.

[5]Technically, private rational expectations (or belief) on future domestic inflation behavior ($\beta E_t \pi_{h,t+1}$) is consigned in the NKPC (3.4). Note, however, that the CPS term ('$\omega p_{c,t}^*$') of this SOCEE setting is also present there.

the monopolistic distortion to obtain an efficient steady state (with a zero output gap and zero domestic inflation at the steady state). Therefore, no inflation bias is present and the stabilization bias is the only source of time-inconsistency.

The usual fashion in which the optimal monetary policy problem under full commitment is solved, as mentioned in the previous section, is by choosing the state contingent sequences of domestic inflation rate and output gap $\{\pi_{h,t}, x_{h,t}\}_{t=0}^{\infty}$ that maximize the welfare gains stated in (3.5) subject to the NKPC presented in (3.4). Under full commitment, the resulting optimality condition for domestic inflation policy rule in terms of the domestic output gap is determined as

$$\pi_{h,0} = -\frac{\lambda_x}{\xi} x_{h,0}, \quad \text{and} \quad \pi_{h,t} = -\frac{\lambda_x}{\xi}(x_{h,t} - x_{h,t-1}), \, \forall t > 0. \tag{3.6}$$

As it can be appreciated in (3.6), the optimality condition for the policy rule prescribes that the monetary authority must stabilize the domestic inflation whenever the economy experiences a boom. Moreover, the optimality condition for the policy rule in (3.6) is different for the initial period (at $t = 0$) from the one stated for the first period and on ($t > 0$). Then, because of such difference in the optimality condition for the policy rule throughout time, the policy is time-inconsistent and a stabilization bias case takes place. Note that the timing subscript t refers to the period since the policy begins its implementation. That is to say, no previous commitment to period zero are made (which implies that no commitment previous to $t < 0$ is made about the output gap, $x_{h,-1} = 0$; though this not implies a zero output gap in period $t = -1$ or $t < 0$). Subsequently, the time by which the policy is being implemented is independent from (and may even be parallel to) the period in which the economy is going through. Accordingly, note that the optimality condition in (3.6) also requires an initial condition for the output gap ($x_{h,0}$) that may be distinct from zero (Kurozumi, 2008).

The time-inconsistency policy problem addressed here is also referred to as the 'time-0 perspective' commitment policy (see Sunakawa, 2015) and it differs from the 'timeless perspective' commitment policy approach formulated by Woodford (2003). The main difference between the two is that the last one overcomes the time-inconsistency policy issue by assuming that the optimal policy has already been implemented a long time ago (in the past). However, because of such an assumption, the resulting time-consistent 'optimal' policy under this later approach may not always be the (optimal –and updated/required–) best policy. Sometimes, even the discretionary policy may outperform the policy recommended under the timeless perspective approach (Dennis, 2010; Sauer, 2010). For this reason, the time-0 perspective approach is the only policy design under full commitment that is being addressed here.

The system for the optimal monetary policy under full commitment for the commodity-exporting economy is determined by the welfare gains (3.5), the NKPC (3.4), the CPS process (3.2) and the initial conditions for the output gap and the shock. Once the system is solved a unique rational expectation equilibrium is attained.

The optimal commitment policy rule for the output gap ($x^c_{h,t}$) as a function of the commodity price shock is given by

$$x^c_{h,t} = b^- x^c_{h,t-1} + \omega \frac{-\frac{\xi}{\lambda_x}}{\beta(b^+ - \rho_{p^*_c})} p^*_{c,t} \equiv \omega a_x p^*_{c,t} + b_x x^c_{h,t-1}, \tag{3.7}$$

where $a_x < 0$ and $b^- = b_x \in (0,1)$.[6] While the optimal commitment policy rule for the domestic inflation is given by,

$$\pi^c_{h,t} = \frac{\lambda_x}{\xi}(1 - b^-) x^c_{h,t-1} + \omega \frac{1}{\beta(b^+ - \rho_{p^*_c})} p^*_{c,t} \equiv \omega a_\pi p^*_{c,t} + b_\pi x^c_{h,t-1}, \tag{3.8}$$

where $b_\pi > 0$ and $a_\pi > 0$.

As it can be noted in (3.7) and (3.8), the sign of the parameter ω (and indirectly the borrowing conditions to the commodity sector, given by χ in [3.3]) exerts an influence over the responses of the domestic inflation and the output gap to a CPS. Correspondingly, under unfavorable circumstances to borrowings emanating from the commodity sector ($\chi < 1$, $\omega < 0$), a positive CPS would lead domestic inflation to show a negative response (a negative deviation with respect to its steady state level) that would reverse over time as the CPS dissipates. However, in the case of the output gap, a positive response (a positive deviation with respect to its steady state level) would be observed in response to the same CPS and calibrations ($\chi < 1$, $\omega < 0$).

Note that according to (3.7) and (3.8), DMT's model predicts opposite responses (positive and negative responses) for the domestic inflation and output gap (respectively) under opposite (favorable) financial cir-

[6]Note that the system yields $f(b) \equiv \beta b^2 - (1 + \beta + \xi^2/\lambda_x)b + 1 = 0$, where $b^\pm = \{(1 + \beta + \xi^2/\lambda_x) \pm [(1 + \beta + \xi^2/\lambda_x)^2 - 4\beta]^{\frac{1}{2}}\}/(2\beta)$ are the two (different) real roots $0 < b^- < 1 < b^+$.

cumstances ($\chi > 1$, $\omega > 0$) but in the presence of the same positive CPS. In other words, given the same positive CPS, domestic inflation would display a positive response that would be similar to the case of a 'cost-push shock' (as introduced by Clarida et al., 1999) or to the 'inefficient supply shock' case (as referred to by Woodford, 2003). Note, however, that in such case, the positive response displayed by the domestic inflation to a positive CPS, as it is predicted by DMT's model, would challenge empirical evidences.[7] Such a latter prediction would not be necessarily wrong because it should be contrasted by data about the true measurement of the financial conditions under which foreign borrowings are conceived to the commodity sector. That is to say, whether the borrowing elasticity parameter χ is elastic (> 1) or inelastic (< 1). Then, in case data about the financial parameter certify its respective measurement (> 1 or < 1), the predictions of DMT's model would also be validated for the case when $\chi > 1$.

Optimal discretionary policy

The policymaker adopts an optimal discretionary policy when decides to implement a measure that is the best at the time and in the current circumstances without considering future consequences or the expectations of private agents about future policies. Under such a scenario it is impossible for the policymaker to commit to any future action.

The optimal discretionary policy rule is found by choosing the state contingent sequences of domestic inflation rate and output gap $\{\pi_{h,t}, x_{h,t}\}_{t=0}^{\infty}$ that maximize the welfare gains in (3.5) subject to the NKPC in (3.4) and by taking forward-looking variables (private agent's expectations) as given. Under discretion, the optimality condition for the domestic inflation policy rule in terms of the domestic output is simply defined as

$$\pi_{h,t} = -\frac{\lambda_x}{\xi} x_{h,t}, \, \forall t \geq 0. \tag{3.9}$$

Given that the optimality condition in (3.9) is unique throughout time, there is no time-inconsistency problem under the optimal discretionary policy. According to that condition, whenever the economy experiences a deviation with respect to its steady state level at the present time, the policymaker will try to stabilize inflation at the same period.

[7] Bergholt et al. (2019) find that a negative domestic inflation response to a CPS is consistent with the structural model they estimate.

The system for the optimal monetary policy under full commitment for the commodity-exporting economy is determined by the welfare gains (3.5), the NKPC (3.4), the CPS process (3.2) and the initial condition for the shock. Once the system is solved a unique rational expectation equilibrium is attained. The optimal policy rule under discretion for the domestic inflation rate ($\pi^d_{h,t}$) is defined as

$$\pi^d_{h,t} = \frac{1}{1-\beta\rho_{p^*_c}+\frac{\xi^2}{\lambda_x}}\omega p^*_{c,t} \equiv \omega c_\pi p^*_{c,t}, \tag{3.10}$$

where $c_\pi > 0$; while the optimal discretionary policy rule for the output gap ($x^d_{h,t}$) as

$$x^d_{h,t} = \frac{-\frac{\xi}{\lambda_x}}{1-\beta\rho_{p^*_c}+\frac{\xi^2}{\lambda_x}}\omega p^*_{c,t} \equiv \omega c_x p^*_{c,t}, \tag{3.11}$$

where $c_x < 0$.

Comparing the optimal policy rules under discretion ([3.10] & [3.11]) against the ones prescribed under the optimal commitment policy ([3.7] & [3.8]), one can verify that the responses to the CPS are smaller under the commitment regime since the response to the shocks under that regime are diminished by the lagged term of the domestic output gap. Moreover, the same comments about the influence of the sign of the parameter ω (and χ) made about ([3.7] & [3.8]) apply over the optimal discretionary policy rules ([3.10] & [3.11]).

Optimal sustainable policy

So far, two polarized policy approaches have been presented: the optimal commitment and the optimal discretionary policies. Both policy regimes, respectively, imply the assumption of full commitment technology and the total absence of such a technology. However, in the real world, no monetary authority implements a full commitment policy nor a full discretionary policy forever.

The concept of the optimal sustainable policy emerges as a suitable approach that allows the monetary authority to find itself in between both referred policies (or by implementing one of both) in the absence of the commitment technology assumption. The optimal sustainable policy outcome still achieves an optimal welfare-based policy that produces a sustainable equilibrium and a higher welfare level than the one delivered by the discretionary policy. In that context, the worst welfare level is the one resulted under the optimal discretionary policy, while the highest one, under the optimal commitment policy.

As Sunakawa (2015) points out, the optimal sustainable policy is the solution to 'a policy game between an infinite number of private agents and the policymaker' that delivers a sustainable equilibrium that overcomes the time-inconsistency issue, present in the optimal commitment policy.

The sustainable equilibrium

In the policy game of this infinite-horizon economy, the policymaker acts first and the private agent's actions follow later.[8] The history of commodity price shocks and output gaps up to period t is recursively defined as $h_t = (h_{t-1}, x_{h,t-1}, p^*_{c,t}),\ \forall t > 0$ and $h_0 = p^*_{c,0}$.[9]

On the one hand, given the history h_t, the policymaker formulates its strategy by setting the current domestic output $x_{h,t}$ (as a function of the history, $x_{h,t} = \sigma(h_t)$) together with a contingent plan $(\sigma_s)_{s \geq t+1}$ for future domestic output gaps and possible future histories. On the other hand, given current history $(h_t, x_{h,t})$ and the policymaker's contingent plan $(\sigma_s)_{s \geq t+1}$, private agents formulate their strategy specifying current domestic inflation $\pi_{h,t}$ as a function of the history and the domestic output gap $\pi_{h,t} = f_t(h_t, x_{h,t})$ and a contingent plan $(f_s)_{s \geq t+1}$ for any possible future histories. Then, given the aforementioned setting, the sustainable equilibrium for the economy can be defined as follows.

Definition 3. The pair of strategies (σ, f) formulated by the monetary authority and private agents, respectively, is a sustainable equilibrium that

(i) satisfies the continuation condition of private agents' reaction function f given by the optimality condition

$$f_t(h_t, x_{h,t}) = \beta E_t[f_{t+1}(h_{t+1}, \sigma_{t+1}(h_{t+1}))] + \xi x_{h,t} + \omega p^*_{c,t}, \quad t \geq 0,$$

$$f_s(h_s, \sigma_s(h_s)) = \beta E_s[f_{s+1}(h_{s+1}, \sigma_{s+1}(h_{s+1}))] + \xi \sigma_s(h_s) + \omega p^*_{c,s}, \quad s \geq t+1,$$

given the policy strategy (σ) and the current history $(h_t, x_{h,t})$ for all possible future histories induced by σ;

(ii) solves the policymaker's problem (by choosing the current and future policy strategy $(\sigma_s)_{s \geq t}$ subject to private agents' reaction function f and current history h_t) defined as

$$\max_{(\tilde{\sigma}_s)_{s \geq t}} \quad -E_t \sum_{s=t}^{\infty} \beta^{s-t} \{[f_s(h_s, \tilde{\sigma}_s(h_s))]^2 + \lambda_x [\tilde{\sigma}_s(h_s)]^2\}$$

[8] The definition of the sustainable equilibrium closely follows Sunakawa (2015) and Kurozumi (2008).

[9] As in Chari and Kehoe (1990), Kurozumi (2008) and Sunakawa (2015) private agents are policy takers. Then, the history of domestic inflation $(\pi_{h,t})$ is excluded from public history and only the policymaker can deviate from its current policy.

$$s.t. \qquad f_s(h_s, \tilde{\sigma}_s(h_s)) = \beta E_s[f_{s+1}(h_{s+1}, \tilde{\sigma}_{s+1}(h_{s+1}))] + \xi\tilde{\sigma}_s(h_s) + \omega p^*_{c,t},$$

for all possible future histories induced by $(\tilde{\sigma}_s)_{s\geq t}$.

The sustainability constraint

Given the policy game setting, the policymaker acts according to the sustainability constraint:

$$W^c(p^*_{c,t}, x_{h,t-1|t=0}) \geq W^d(p^*_{c,t}), \tag{3.12}$$

trying to obtain the highest possible welfare level (the one achieved under the optimal commitment policy, $W^c(p^*_{c,t}, x_{h,t-1|t=0})$) or at least the worst sustainable equilibrium (attained under the optimal discretionary policy, $W^d(p^*_{c,t})$). The associated welfare measurements under the optimal commitment and the optimal discretionary policies are detailed in equations (A.3.1) and (A.3.2) of the Appendix 3.1.1.

Kurozumi (2008) shows that the worst sustainable equilibrium is the one delivered by the optimal discretionary policy rule by proving the two following propositions.

Proposition 1. The rational expectations equilibrium (REE) prescribed by the optimal discretionary policy is the worst sustainable equilibrium of the model.

This first proposition characterizes the entire set of outcomes generated by the sequences of functions $(\sigma, f) = \{(\sigma_t), (f_t)\}_{t\geq 0}$ that constitute the outcomes of the sustainable equilibria of the model. In particular, the sustainable equilibrium yields the pair of contingent sequences of domestic inflation rates and domestic output gaps, $(\pi_{h,t}, x_{h,t}) = \{(\pi_{h,t}), (x_{h,t})\}_{t\geq 0}$, known as the outcome of the equilibrium.

Proposition 2. Any arbitrary pair (π_h, x_h) of contingent sequences of domestic inflation rates and domestic output gaps are an outcome of a sustainable equilibrium if and only if:
(i) the pair (π_h, x_h) satisfies the NKPC in (3.4) every period $t \geq 0$; and,
(ii) the sustainability constraint in (3.12) holds in every period $t \geq 0$.

This second proposition provides a necessary and sufficient condition for the existence of a sustainable equilibrium whose outcome is the referred pair (π_h, x_h); while the constraints of this second preposition defines the entire set of sustainable equilibrium outcomes.

The aforestated propositions turn the optimal sustainable policy into a strategy for the best sustainable equilibrium in the absence of commitment technologies. According to Kurozumi (2008), "the optimal sustainable policy becomes a policy strategy which specifies to continue the optimal quasi-sustainable policy as long as it has been adopted in the past; otherwise, the strategy specifies to switch to the optimal discretionary policy forever".

Summarizing, the optimal sustainable policy does not require any commitment technology assumption, but a reputation technology (or assumption) instead (as in Chari and Kehoe, 1990). Secondly, the optimal sustainable policy is a regime that lies between the optimal commitment and the optimal discretionary policies, or that can even be equal to one of both regimes. Lastly, the optimal sustainable policy employs the optimal quasi-sustainable policy as a means to derive the best sustainable equilibrium outcome (but the latter policy does so in the presence of commitment technologies).

Characterization of the optimal sustainable policy

The optimal quasi-sustainable policy is obtained by maximizing the social welfare function (3.5) within the constraints (3.4) and (3.12) from period zero and on. Such a set of constraints defines the entire set of sustainable equilibrium outcomes as stated in Proposition 2.

The associated Lagrangian to the optimal quasi-sustainable policy is given by

$$\begin{aligned}\mathcal{L} \equiv & E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ -\frac{\Omega}{2}(\pi_{h,t}^2 + \lambda_x x_{h,t}^2) + \varphi_{1,t}(\pi_{h,t} - \beta E_t \pi_{h,t+1} - \xi x_{h,t} - \omega p_{c,t}^*) \\ & - \varphi_{2,t}[E_t \sum_{s=t}^{\infty} \beta^{s-t} \frac{\Omega}{2}(\pi_{h,s}^2 + \lambda_x x_{h,s}^2) + W^d(p_{c,t}^*)] \Big\}, \end{aligned} \tag{3.13}$$

where $\varphi_{1,t}$ and $\varphi_{2,t}$ are the Lagrangian multipliers on the constraints (3.4) and (3.12), respectively, for $t \geq 0$. Then, following Kurozumi (2008) and Sunakawa (2015), the same problem can be rewritten by applying the recursive formulation as proposed by Marcet and Marimon (2019) and Abel's summation formula. The recursive formulation can be written as

$$\begin{aligned}\mathcal{L} = & E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ -\Psi_t \frac{\Omega}{2}(\pi_{h,t}^2 + \lambda_x x_{h,t}^2) + (\varphi_{1,t} - \varphi_{1,t-1})\pi_{h,t} \\ & - \varphi_{1,t}(\xi x_{h,t} + \omega p_{c,t}^*) + \varphi_{2,t} W^d(p_{c,t}^*) \Big\}, \end{aligned} \tag{3.14}$$

where Ψ_t is the multiplier that recursively measures the sustainability constraint tightness ($\varphi_{2,t}$) and the fulfillment of past commitments (Ψ_{t-1}): $\Psi_t \equiv 1 + \sum_{i=0}^{t} \varphi_{2,i} = \Psi_{t-1} + \varphi_{2,t}$, $\forall t \geq 0$, with initial conditions for $\Psi_{t-1|t=0} = 1$ and $\varphi_{2,t|t=0} = 0$. The first-order conditions for $\pi_{h,t}$ and $x_{h,t}$ deliver the optimality condition for the optimal quasi-sustainable policy

$$\pi_{h,t} = -\frac{\lambda_x}{\xi}(x_{h,t} - \frac{\Psi_{t-1}}{\Psi_t} x_{h,t-1}),\ \forall t \geq 0, \tag{3.15}$$

where the ratio $\Psi_{t-1}/\Psi_t = \Psi_{t-1}/(\Psi_{t-1} + \varphi_{2,t}) \in (0, 1]$ can be interpreted as the commitment steadfastness measurement. This is so because if the sustainability constraint is binding, $\varphi_{2,t} > 0$, and $0 < \Psi_{t-1}/\Psi_t < 1$, and the optimal quasi-sustainable policy differs from the optimal commitment policy (the commitment technology is not necessary, but a reputational one instead). However, if the sustainability constraint is slack (not binding), $\varphi_{2,t} = 0$, $\Psi_{t-1}/\Psi_t = 1$, the optimal quasi-sustainable policy is consistent with the optimal commitment policy (and because of such equality, commitment and reputation are equally important technology assumptions).

Finally, note that the recursive formulation of the policymaker's problem under the optimal quasi-sustainable policy delivers a solution that has no time-inconsistency issues.

3.2.3 Solution method

The solution strategy as well as the numerical method and the calibration implemented to solve for the optimal monetary policies are described next.

Solving for the optimal policies

The optimal quasi-sustainable policy solution depends on the solution of the optimal commitment and the optimal discretionary policies. Accordingly, the system to be solved for the optimal quasi-sustainable policy compounds its relevant welfare level (which is given by the welfare under the optimal commitment policy),

$$W_t^c = -\frac{\Omega}{2}(\pi_{h,t}^2 + \lambda_x x_{h,t}^2) + \beta E_t W_{t+1}^c,$$

its optimality condition,

$$x_{h,t} = -\frac{\xi}{\lambda_x}\pi_{h,t} + z_t x_{h,t-1},$$

the NKPC,

$$\pi_{h,t} = \beta\pi_{h,t+1} + \xi x_{h,t} + \omega p^*_{c,t},$$

and the sustainability constraint,

$$W^c(p^*_{c,t}, x_{h,t-1|t=0}) \geq W^d_t(p^*_{c,t}),$$

where $z_t = \Psi_{t-1}/\Psi_t \in (0,1]$ is the commitment steadfastness measurement (as already commented in the last section) and the initial conditions are given by $x_{h,-1}$ and $\Psi_{-1} = 1$. The former system is a set of four endogenous variables $\{x_{h,t}, \pi_{h,t}, \Psi_t, \varphi_t\}^{\infty}_{t=0}$ and one exogenous variable $\{p^*_{c,t}\}^{\infty}_{t=0}$. Given the occasionally binding constraint of the sustainability constraint, the system is solved using a version of the policy function iteration method as implemented by Kehoe and Perri (2002) and Sunakawa (2015).[10]

The former system can be rewritten in a state-space representation notation by defining $u = (p^*_{c,t}, x_{h,-1}) \in P \times X$ where P and X as closed sets. Then, the relevant welfare level measure for the optimal quasi-sustainable policy may be written as

$$W^u(u) = -\frac{\Omega}{2}([\pi^u_h(u)]^2 + \lambda_x[x^u_h(u)]^2) + \beta\sum_{p^*_{c,t}{}'} p(p^*_{c,t}{}'|p^*_{c,t})W^u(p^*_{c,t}{}', x^u_h(u)),$$

its optimality condition,

$$x^u_h(u) = -\frac{\xi}{\lambda_x}\pi^u_h(u) + z(u)x^u_{h,-1},$$

the NKPC,

$$\pi^u_h(u) = \xi x^u_h(u) + \beta\sum_{p^*_{c,t}{}'} p(p^*_{c,t}{}'|p^*_{c,t})\pi^u_h(p^*_{c,t}{}', x^u_h(u)) + \omega p^*_{c,t},$$

and the sustainability constraint,

$$W^u(u) \geq \hat{W}^d(p^*_{c,t}),$$

[10] To solve for the optimal commitment policy and the optimal discretionary policy, note that one only needs to change the optimality condition for each regime and assume that the commitment steadfastness is unitary under commitment and zero under discretion ($\varphi_t = 0$, for both policies).

where $W^u(u)$, $\pi_h^u(u)$, $x_h^u(u)$ and $z(u)$ are the policy functions and $\hat{W}^d(p_{c,t}^*)$ is the numerically computed worst sustainable equilibrium value under the discretionary policy. The matrix $p(p_{c,t}^*{}'|p_{c,t}^*)$ represents the transition probability, which is approximated by a first-order auto-regressive process, as specified in equation (3.2).

The recursive structure in which the system is written for $W^u(u)$ and $\pi_h^u(u)$ allows to implement the policy function iteration method and addresses the occasionally biding constraint for the entire space $u \in P \times X$.

Appendix 3.1.2 provides more details about the implementation of the numerical algorithm.

Calibration

The baseline model uses the same parameter values that DMT have set. In turn, some calibrated parameters used by these authors (DMT) have the same value as those set by Ferrero and Seneca (2019) and Galí and Monacelli (2005).

In particular, the quarterly subjective domestic and foreign discount factors are calibrated to $\beta = \beta^* = 0.9963$, consistently with an annual real domestic and foreign interest rates of $r = r^* \approx 1.5\%$ and a zero inflation steady state. The home consumption bias of the economy $1 - \alpha$ is set to 60%, the elasticity substitution to 6, consistent with a desired markup of 20%. The Calvo price re-set probability is set to 25% and the inverse Frisch elasticity rate to 3.

The share of inputs (intermediate goods) used in the production of commodity goods s_m is set to 15%, while the share of the commodity-producing sector relative to the gross domestic product of the economy s_{yc} is set to 20%. The returns to scale in the commodity production function ν is calibrated to 0.38, while the elasticity of borrowing conditions relative to international commodity prices χ, to 0.5. In turn, the exogenous process parameters given by its persistence (auto-regressive) parameter $\rho_{p_c^*}$ and volatility of the shock $\sigma_{p_c^*}$ are set to 0.9 and 0.1, respectively.

Given the former parameters, the slope of the NKPC ξ and the weight to the output gap λ_x are equal to 0.3299 and 0.0567, respectively. Under the baseline calibration, the weight to the commodity price shock ω in the NKPC yields a negative value of -0.0137.

The value assigned to the upper bound of the disturbance $m\sigma_{p_c^*}$ for computational purposes is set to $m = 6$. Likewise, the maximum and minimum values of the grid for the domestic output gap grid X are consistently chosen using the same upper bound value for its optimal volatility. The number of grids for the commodity price shock $n_{p_c^*}$ is equal to 31, while equal to 15 for the output gap n_{x_h}. The exogenous process for the commodity price shock is approximated and bounded as a first-order auto-regressive process according to Tauchen's (1986) method.

3.3 Results

Results under the baseline and alternative calibrations of the model are presented in this section.

3.3.1 Results under the baseline calibration

Assuming that a commodity price shock (CPS) hits the small open- and -commodity-exporting economy, the responses of selected macroeconomic variables are analyzed under each one of the monetary policy regimes discussed in the previous section.

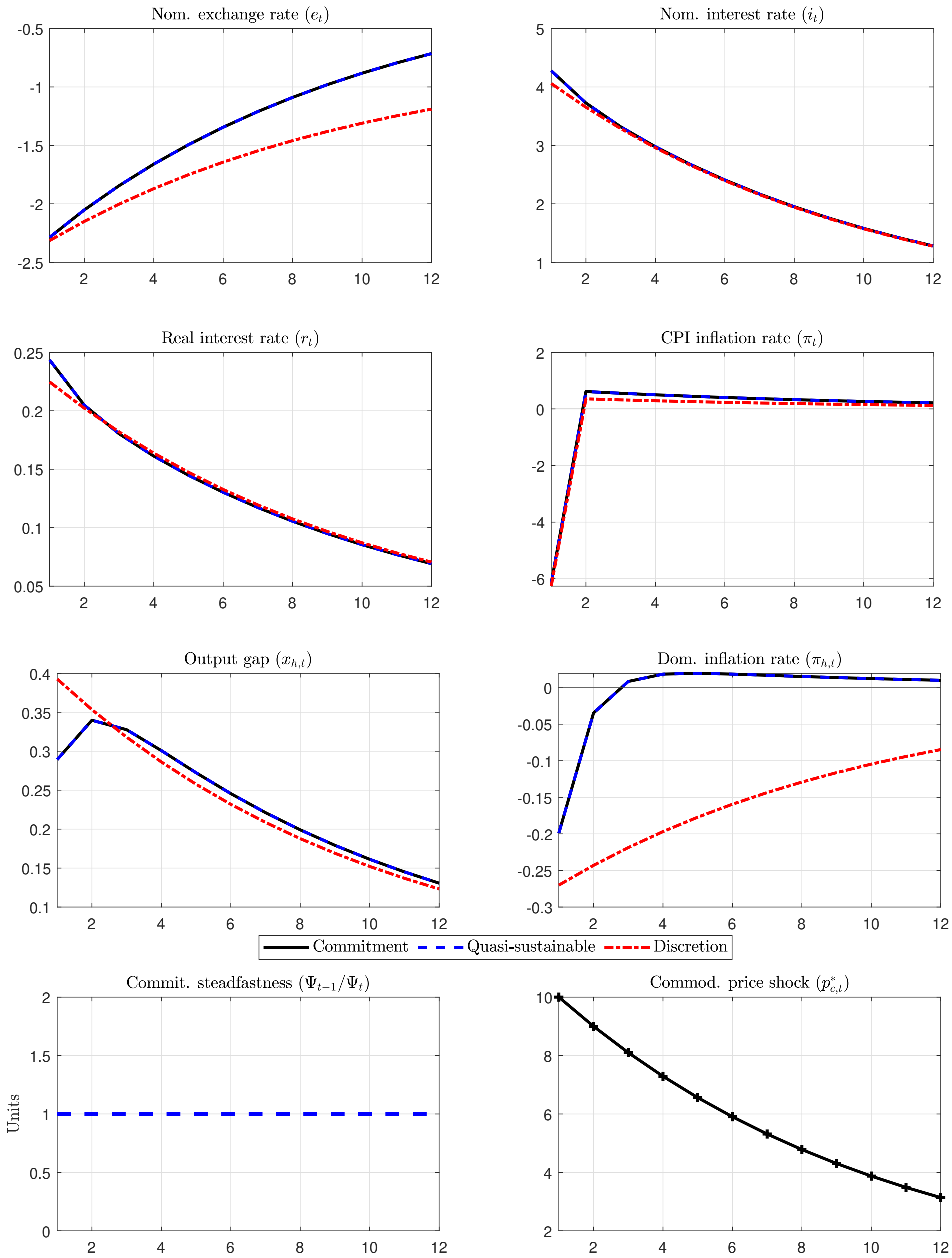
Figure 3.1 shows that the commitment steadfastness over the horizon the CPS hits the economy is always full (equal to the unity). As explained in the former section, a non-binding sustainability constraint implies that the optimal quasi-sustainable policy is consistent with the optimal commitment policy. Furthermore, the equilibria attained under both policy regimes coincide. That is to say, the sustainable equilibrium under the optimal quasi-sustainable policy is consistent with the competitive equilibrium delivered by the optimal commitment policy.

The fullness of the commitment steadfastness holds here because the high value of the subjective discount factor ($\beta = 0.9963$) prevents the sustainability constraint to bind. This latter finding is in line with that documented by Sunakawa (2015), who obtains the same conclusion but by examining a small open economy (without a commodity-producing sector) and using standard calibrations values provided by the literature (e.g., $\beta = 0.9913$).[11]

Observing the selected macroeconomic variable responses to a 10% CPS

[11] Read more about in subsection 3.3.2.

Figure 3.1: The baseline model under different optimal monetary policy regimes (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively.

shock under each optimal policy regime, one verifies that the biggest differences are displayed by the domestic inflation, the nominal exchange rate and the domestic output gap (Figure 3.1). As expected, the responses of these variables are lower under the optimal commitment and quasi-sustainable policies, while higher under the optimal discretionary policy. The differences among them are given by the technology assumptions behind each policy regime. As it is evident, the commitment and reputational technologies, reflected in their respected policy rules for domestic inflation and the output gap, contribute to smooth macroeconomic variable responses to the shock. Note that the domestic inflation and the output gap are key variables that directly affect the representative's welfare function of this economy. Therefore, the responses of these variables mark the differences in terms of welfare for one or another monetary policy regime.

In terms of second moments of the macroeconomic variables, it is verified that only the domestic inflation rate and the domestic output gap display statistically significant different volatilities. Such volatility measurements are accounted for under the optimal discretionary policy and the two-identical regimes (the optimal commitment and the optimal quasi-sustainable policies). Accordingly, Table A.3.1 shows simulated second moments of selected macroeconomic variables and F-tests for equal variances results for statistically significant differences at $p < 1\%$ (***), $p < 5\%$ (**) and $p < 10\%$ (*), respectively. As mentioned, in this baseline scenario, the statistically significant differences are verified for the domestic inflation and the domestic output gap under the referred policy regimes. While the volatility difference tests for the rest of the selected macroeconomic variables turn out not to be statistically significant.

On the other hand, regarding the monetary conditions of the economy in response to a positive CPS, it can be seen in Figure 3.1 that all the optimal policy regimes agree to tighten monetary conditions. The tightest initial conditions are those prescribed under the optimal commitment and the optimal quasi-sustainable policies, although over time they become less tightened compared to the optimal discretionary policy.

In the baseline scenario, whenever the representative commodity-producing sector observes a rise in international commodity prices, it decides to increase its production level to generate more profits. With that goal in mind, the firm contracts international borrowings denominated in nominal foreign currency to finance the purchase of inputs to produce more commodity goods. With a higher demand for inputs, the level of domestic prices increases, relative prices drop, the terms of trade improve (fall), and this latter appreciates the nominal and real exchange rates of the economy. With the change of relative prices, optimal allocations also change (e.g., total and domestic consumption goods decrease) and the non-traded final goods sector produces more, contracts more hours at work and the commodity boom leads to a positive output gap. Then, with domestic inflation dropping (due to the fall in total and domestic consumption demands) and the domestic output gap increasing (due to the commodity boom), the policymaker faces a trade-off to return the economy to the optimal equilibrium. The optimal monetary policy regimes analyzed here (the optimal commitment, the optimal quasi-sustainable and the optimal discretionary policies) agree to prescribe an increase of the nominal interest rate and allow appreciations of the nominal and real exchange rates that reverse over time.

3.3.2 Results under alternative calibrations

Three main variations to the baseline model are introduced in what follows. First, it is assumed that the financial channel of DMT's model varies. Secondly, it is examined what the model predicts when the commodity input share in the economy changes. Thirdly, alternative values for the subjective discount factor are evaluated in order to find out whether the commitment steadfastness decreases or not. Finally, some alternative modifications to the baseline model are analyzed as well and presented in the Appendix 3.1.1 and in the Supplementary Material 3.2.

Varying the financial channel

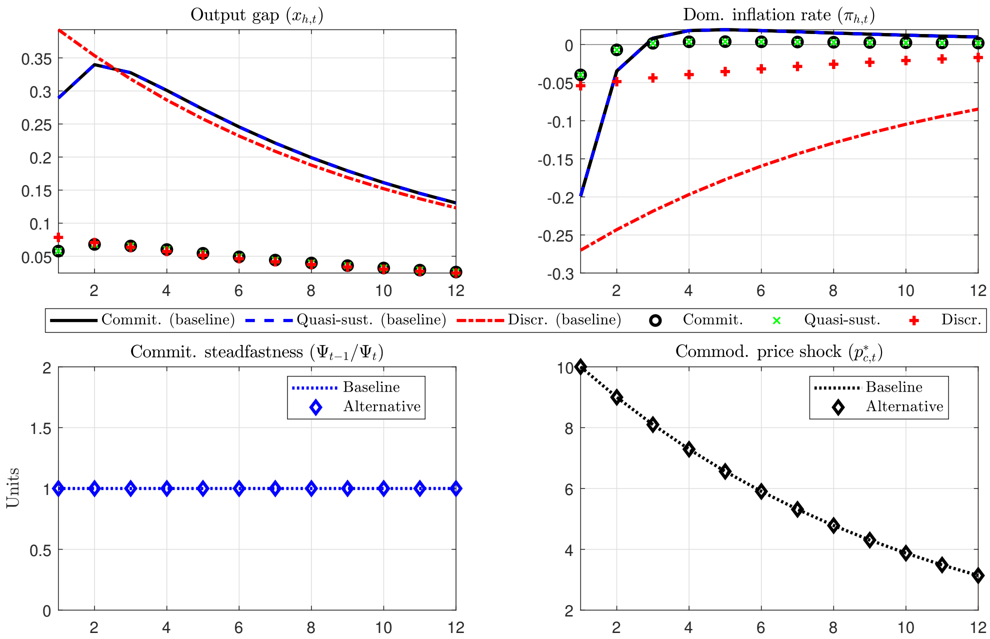
Small open- and -commodity-exporting economies are more sensitive to CPS as the inelasticity of borrowings with respect to international commodity prices condition increases. This implies that the higher inelasticity is, the higher the responses and volatilities of the domestic inflation and the output gap are.[12]

Comparing the baseline calibration ($\chi = 0.5$) with the alternative calibration ($\chi = 0.9$), one observes that as the elasticity of borrowings with respect to the international commodity prices condition tends to be unitary ($\chi \to 1$), the responses and volatilities of the domestic inflation and output gap decrease (see Figure 3.2 and Table A.3.1). And this takes place under all the policy regimes, where it is still verified that the sustainability constraint does not bind in any case; meaning that the optimal commitment policy is consistent with the optimal sustainable policy. Notice that the optimal discretionary policy continues offering the highest responses and volatilities for macroeconomic variables to the CPS.

The current analysis corroborates that the elasticity of borrowings with

[12] This prediction of DMT's model agrees with the one made by Báez's (2022) model.

Figure 3.2: Varying the financial channel: $\chi = \{0.5, 0.9\}$, $\omega = \{-0.01, -0.003\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

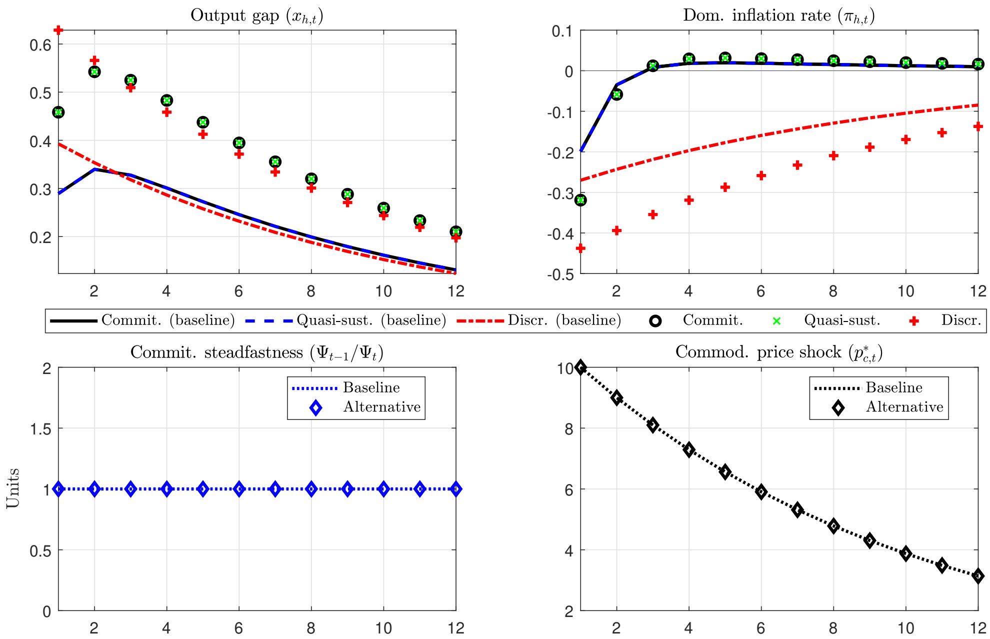
respect to the international commodity prices condition plays a key role as a financial amplification channel for monetary policy. In other words, when there are favorable factors that positively affect commodity prices in international markets, the representative commodity firm is able to borrow more, produce more and the commodity boom in the economy becomes a stronger driving force of the business cycle.

On the other side, in this alternative calibration, the monetary policy condition is expected to be less restrictive due to the lower variations in domestic inflation and the output gap in response to the same CPS. Moreover, regarding the nominal interest rate, the CPI inflation rate and the real and nominal exchange rates, the same assertion can be stated.

Varying the commodity inputs share

Small open- and -commodity-exporting economies are more sensitive to CPS as the share of commodity inputs increases. This means that the higher this ratio is, the more responsive and volatile domestic inflation and output gaps are.

Figure 3.3: Higher commodity inputs share: $s_m = \{0.15, 0.30\}$ (in %)



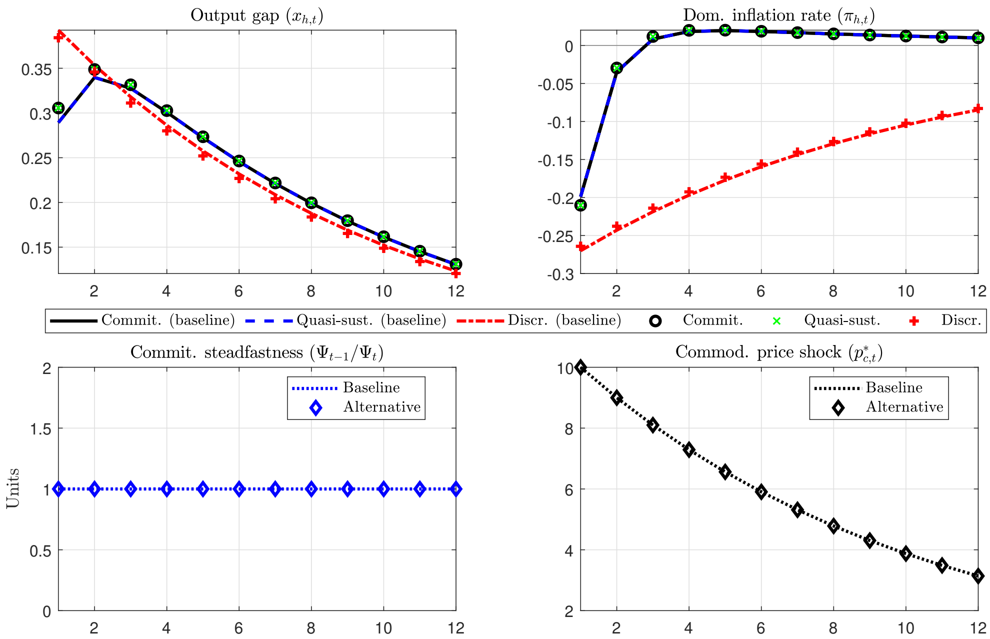
Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

An increase in the commodity inputs share (s_m) entails that intermediate goods (demanded by the representative commodity-producing firm) take a bigger proportion of the output manufactured by the non-traded final goods firms sector. This suggests that the proportion of final domestic consumption goods in the economy (s_c) declines, as both variety goods are produced by firms of the same sector.

When a CPS hits the economy, the higher proportion of domestic intermediate goods intended for the production of commodity goods exacerbates the deflationary process and the economic boom in the SOCEE (Figure 3.3). The fall in domestic inflation, and overall, the increase in the domestic output gap under the alternative calibration are notorious. While, in terms of the volatilities, the second moments for these two variables also show higher magnitudes under the current alternative calibrations (Table A.3.1). Moreover, note that the optimal discretionary policy regime delivers the highest volatilities for these two variables, as expected.

Here, it is confirmed again that the sustainability constraint does not bind and that, as a result, the optimal commitment policy is consistent

Figure 3.4: Varying the discount factor: $\beta = \{0.9963, 0.9\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

with the optimal sustainable policy (Figure 3.3). This, in spite of the relevancy that the commodity inputs share plays in the amplification of the same shock.

Varying the discount factor

The lower the discount factor, the higher responses of the output gap and domestic inflation are observed (Figure 3.4).

Standard calibrations for $\beta \geq 0.9$ (as those in the literature) imply that the optimal quasi-sustainable policy is consistent with the optimal commitment policy.[13] Specifically, it is assumed that the discount factor parameter (β) varies from 0.9936 to 0.900, which under DMT's model, approximately, imply annual (real) interest rates of the order of 1.5% and 52.4%, respectively (Figure 3.4).

The discount factor (and its relation with the nominal interest rate)

[13]As mentioned in subsection 3.3.1, this result is in line with the findings provided by Sunakawa (2015), although his conclusion is based on the analysis of a small open economy without a commodity-producing sector.

turns out to be a key parameter for economies in general and even for commodity-exporting economies. This, due to the fact that this parameter plays a fundamental role in the determination of welfare measures under the sustainability constraint condition (optimal commitment policy welfare $\geq$ optimal discretionary policy welfare). In particular, for the optimal commitment policy and the optimal discretionary policy.

A lower parameterization of the subjective discount parameter β, ($\beta = \{0.9963, 0.6\}$, $i_{ss} \approx \{1.5\%, 671.6\%\}$), supposes an even higher nominal interest rate at the steady state of the economy that, although unrealistic, shows how the commitment steadfastness is not equal to the unity (the sustainability constraint is binding). That is to say, under such a parameterization, now the optimal quasi-sustainable policy is not consistent anymore with the optimal commitment policy nor the respectively implied equilibria are identical anymore (Figure A.3.1 in Appendix 3.1.1).

The difference between the equilibrium achieved under the optimal quasi-sustainable policy and the optimal commitment policy not only holds because of the change made in the subjective discount factor, but also because of the optimal sustainable policy design itself. That is to say, the assumption of an infinite punishment period (as presented in section 3.2.2) with a lower welfare level (for moving from the optimal commitment policy to the optimal discretionary policy) explains such an outcome.

The aforementioned outcome leads one to expect that if the punishment period were finite instead of infinite, the optimal quasi-sustainable policy would have less frequently consistent equilibrium episodes with the optimal commitment policy. Therefore, reputation technology would play a more relevant role in monetary policy design.

In that regard, it is worth recalling that the idea of reputation and/or credibility as an alternative technology to commitment comes from Barro and Gordon (1983). They model optimal monetary policy under a one-punishment period. Once the policymaker seeks to obtain gains from unexpected inflation shocks, in consequence, faces inflation costs that negatively affect its reputation (or credibility). These authors also try to find a sustainable outcome by analyzing the conditions in which the best enforceable rule binds.

Accordingly, such a rule is the one that minimizes expected inflation costs subject to the 'enforceability constraint' that ensures enforcement (the present value of loss from transgressions) be at least as great as temptation costs (derived from reneging the rule). As can be noticed, the spirit of the sustainability constraint and the optimal sustainable policy treated here builds upon their setup. However, in the current paper, the optimal sustainable policy design under a finite number of punishment periods is left as an outstanding point in the research agenda.

Other predictions of the DMT model

Additional results and discussions about them can be found in the Supplementary Material 3.2 that accompanies the present paper. In particular, such a material analyzes specific results of the DMT model when the borrowing elasticity is elastic, when the share of the commodity sector to the GPD increases, among other alternative prescriptions from the model (like variations in the price rigidity, the desired markup price, the size of the CPS and the inverse Frisch elasticity rate).

3.4 Conclusion

A welfare-based optimal monetary policy for a small open- and -commodity-exporting economy is conducted under the concept of the optimal sustainable policy, as proposed by Kurozumi (2008).

Relying on Drechsel et al.'s (2019) model and assuming that a commodity price shock (CPS) hits the economy, the optimal sustainable policy is evaluated following Sunakawa's (2015) quantitative approach.

Using the optimal quasi-sustainable policy as an operational policy platform of the optimal sustainable policy concept, the first is contrasted against the optimal commitment and the optimal discretionary monetary policies. Under the baseline and alternative calibrations, it turns out that the optimal quasi-sustainable policy is always consistent with the optimal commitment policy. Implying that the competitive equilibrium (resulting under the optimal commitment policy) coincides with the sustainable equilibrium (attained under the optimal quasi-sustainable policy).

In response to the CPS, the monetary authority tightens economic conditions by raising the nominal interest rate and allowing an appreciation of the nominal and real exchange rates that helps to offset the inefficiencies introduced by the commodity boom. The responses and volatilities of the domestic inflation, the nominal exchange rate and the output gap are larger under the optimal discretionary policy, as expected. While subsequently smaller, under the optimal commitment and optimal quasi-sustainable policies.

There are two other key results to mention. First, small open- and -commodity-exporting economies with a more inelastic borrowing elasticity in their commodity sector experiment higher responses and volatilities in their domestic inflation and the output gap. Second, these types of economies also observe more responsive and volatile domestic inflation and output gap the higher the share of commodity inputs is.

Finally, there are two DMT's model assumptions that one could vary to find out whether the conclusions obtained here could still hold or not. The first has to do with the linear-quadratic approximation approach, and the second, with the exogeneity of the financial channel. On the one hand, one could drop the assumptions of the labor subsidy and the zero inflation at the steady state, and on the other hand, one could also drop the exogeneity assumption on DMT's financial channel. In this regard, Báez's (2022) non-linear model is a framework that overcomes the two aforementioned technical points and that could be used for such research aims. Namely, under the approach of the optimal sustainable policy à la Kurozumi (2008) one could examine the results from the optimal commitment, sustainable y discretionary policies, in an analogous fashion to Leith and Liu (2016) and Sunakawa (2015).

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Conclusion

Optimal monetary policy for small open- and -commodity-exporting economies aimed at stabilizing commodity price shocks (correlated or not with world activity shocks) is the topic addressed in this thesis and whose results are intended to contribute to this line of research in the literature.

The first chapter shows that, in the context of a fully-flexible price economy and under an ad hoc loss function that minimizes the total consumption and the consumer price index (CPI) inflation rate volatilities, the best simple and implementable monetary policy rule to a commodity price shock (correlated or not with a world activity shock) is given by a feedback rule that targets the CPI inflation rate. However, when the ad hoc loss function also accounts for the nominal exchange rate volatility, the best monetary policy rule is given by a feedback rule that targets this latter variable. Moreover, the chapter proves that the financial frictions in the form of endogenous and dynamic asset-based and earning-based borrowing constraints rationalize commodity-producing firms' decisions along the business cycle of the economy and that they play a relevant role as monetary policy transmission channels. Furthermore, such borrowing constraints can embrace currency mismatch considerations that enrich even more their role as financial frictions.

The second chapter documents that, in the context of an economy with staggered prices (à la Rotemberg, 1982), the optimal welfare-based Ramsey monetary policy (à la Marcet and Marimon, 2019) to a commodity price shock (correlated or not to a world activity shock) is to raise the nominal interest rate and allow nominal and real exchange rate appreciations. Such a policy attains to optimally stabilize the economy and reallocate real and nominal macroeconomic variables through relative price adjustments. In terms of simple and implementable rules, it is learned that strictly targeting domestic inflation is optimal as it is the closest policy to the optimal constrained efficiency condition. Moreover, the role of the nominal exchange rate highlights again. Not only as a monetary policy tool that makes possible relative prices to adjust and absorb shocks but also as one of the key macroeconomic variables that policymakers pay attention to. In this regard, the chapter proves that the economy that has into account currency mismatch considerations exhibits lower volatility and response of the nominal exchange rate to a commodity price shock (correlated or not to a world activity shock). Furthermore, it shows that CPI targeting regimes provide suboptimal welfare, but that policymakers may choose them because of the lower non-zero nominal exchange rate volatility that such a regime achieves (a result that is related to the "fear of floating" phenomenon, as documented by Calvo and Reinhart, 2002).

Finally, the last chapter finds out that the optimal sustainable policy (proposed by Kurozumi, 2008) does not quantitatively differ from the optimal commitment policy (à la Clarida, Galí and Gertler, 1999) in the context of a small open- and -commodity-exporting country under sticky prices and financial frictions (à la Drechsel, McLeay and Tenreyro, 2019). Using the optimal quasi-sustainable policy as an operational policy platform of the optimal sustainable policy concept, the first is contrasted against the optimal commitment and the optimal discretionary monetary policies. Under the baseline and alternative calibrations, it turns out that the optimal quasi-sustainable policy is always consistent with the optimal commitment policy. Implying that the competitive equilibrium (resulting under the optimal commitment policy) coincides with the sustainable equilibrium (attained under the optimal quasi-sustainable policy). In response to the commodity price shock, the monetary authority tightens economic conditions by raising the nominal interest rate and allowing an appreciation of the nominal and real exchange rates that helps to offset the inefficiencies introduced by the commodity boom. The responses and volatilities of the domestic inflation, the nominal exchange rate and the output gap are larger under the optimal discretionary policy, as expected. While subsequently smaller, under the optimal commitment and optimal quasi-sustainable policies.

Appendices

1.1 Appendix

1.1.1 Details of the baseline model

Home country's counterpart: the foreign country

The counterpart bundle of consumption goods and price indexes of the rest of the world (or country f) can be defined as:

$$C_t^* \equiv \frac{(C_{h,t}^*)^{v^*}(C_{f,t}^*)^{1-v^*}}{(1-v^*)^{1-v^*}(v^*)^{v^*}}, \tag{A.1.1}$$

$$C_{h,t}^* = (v^*)\left(\frac{P_{h,t}^*}{P_t^*}\right)^{-1} C_t^* = v^*(\mathcal{T}_t^*)^{(v^*-1)}C_t^* \tag{A.1.2}$$

$$C_{f,t}^* = (1-v^*)\left(\frac{P_{f,t}^*}{P_t^*}\right)^{-1} C_t^* = (1-v^*)(\mathcal{T}_t^*)^{v^*}C_t^*, \tag{A.1.3}$$

where, as it was mentioned, it is imposed that $v^* = 0$. The foreign price level (where $P_{f,t}^* = P_t^*$) is

$$P_t^* \equiv (P_{h,t}^*)^{v^*}(P_{f,t}^*)^{(1-v^*)}. \tag{A.1.4}$$

While, the foreign Euler equation is

$$1 = \beta\frac{(Q_{t,t+1}^*)^{-1}}{\Pi_{t+1}^*}\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-1}, \tag{A.1.5}$$

where $\Pi_t^* = P_t^*/P_{t-1}^*$ is the gross CPI inflation rate.

Summary of the non-traded final home goods sector

The representative agent of the non-traded final home goods sector maximizes the next sequence of profits.

$$\mathbb{E}_t\sum_{s=0}^{\infty} Q_{t,t+s}\Phi_{h,t+s}$$

$$\Phi_{h,t} = P_{h,t}Y_{h,t} - W_tN_t$$

Demand for labor

$$N_t = Y_{h,t}/A_{h,t}$$

Home price level (the first-order condition of the problem of the representative firm)

$$P_{h,t} = \frac{W_t}{A_{h,t}} = MC_{h,t}.$$

Equilibrium condition (what the goods of this sector are produced for)

$$Y_{h,t} = C_{h,t} + I_t.$$

Summary of the commodity-producing sector

The problem setting of the commodity-producing firm is as follows.

$$\begin{aligned}
\max_{K_{o,t+1},\ I_t,\ B_{f,t}} \quad & V_{o,t} = \mathbb{E}_t \sum_{s=0}^{\infty} Q_{t,t+s} \Phi_{o,t+s} \\
\text{Where} \quad & \Phi_{o,t} = P_{o,t} Y_{o,t} + \mathcal{E}_t B_{f,t} - [P_{h,t} I_t + \mathcal{E}_t (1 + i^*_{t-1}) B_{f,t-1}] \\
\text{s.t.} \quad & (1 + i^*_t) B_{f,t} \leq \kappa (1 - \delta) \mathbb{E}_t \frac{P_{h,t+1}}{\mathcal{E}_{t+1}} K_{o,t} \\
& Y_{o,t} = A_{o,t} K_{o,t}^{\alpha_k} \\
& K_{o,t+1} = I_t + (1 - \delta) K_{o,t} \\
& \lim_{t \to \infty} \mathbb{E}_t Q_{t,t} \frac{\mathcal{E}_t B_{f,t}}{(1 + i^*_t)^t} = 0\ ,\ \lim_{t \to \infty} \mathbb{E}_t Q_{t,t+1} K_{o,t+1} = 0\ , \\
& \lim_{t \to \infty} \mathbb{E}_t Q_{t,t} V_{o,t} = 0 \\
& K_{o,t+1} \geq 0\ ,\ K_{o,0} > 0 \\
& \delta \in (0,1)\ ,\ \alpha_k \in (0,1) \implies \alpha_k < 1
\end{aligned} \tag{A.1.6}$$

The Lagrangian for the problem of the firm

$$\begin{aligned}
\mathcal{L} = \mathbb{E}_t \sum_{s=0}^{\infty} Q_{t,t+s} \Big\{ & P_{o,t+s} A_{o,t+s} K_{o,t+s}^{\alpha_k} + \mathcal{E}_{t+s} B_{f,t+s} - P_{h,t+s} I_{t+s} \\
& - \mathcal{E}_{t+s} (1 + i^*_{t+s-1}) B_{f,t+s-1} \\
& + \widetilde{\Lambda}_{o,t+s} \big[(1 + i^*_{t+s}) B_{f,t+s} - \kappa (1 - \delta) \frac{P_{h,t+s+1}}{\mathcal{E}_{t+s+1}} K_{o,t+s} \big] \\
& + \widetilde{\mathcal{Q}}_{o,t+s} \big[I_{t+s} + (1 - \delta) K_{o,t+s} - K_{o,t+s+1} \big] \Big\}
\end{aligned} \tag{A.1.7}$$

First-order conditions

$$\begin{aligned}
K_{o,t+s+1} : \mathbb{E}_t Q_{t,t+s+1} & P_{o,t+s+1} A_{o,t+s+1} \alpha_k K_{o,t+s+1}^{\alpha_k - 1} \\
& - \kappa (1 - \delta) \mathbb{E}_t Q_{t,t+s+1} \widetilde{\Lambda}_{o,t+s+1} \frac{P_{h,t+s+2}}{\mathcal{E}_{t+s+2}} \\
& + \mathbb{E}_t Q_{t,t+s+1} \widetilde{\mathcal{Q}}_{o,t+s+1} (1 - \delta) - \mathbb{E}_t Q_{t,t+s} \widetilde{\mathcal{Q}}_{o,t+s} = 0
\end{aligned} \tag{A.1.8}$$

$$B_{f,t+s}: \mathbb{E}_t Q_{t,t+s}\mathcal{E}_{t+s} - \mathbb{E}_t Q_{t,t+s+1}\mathcal{E}_{t+s+1}(1+i^*_{t+s}) + \mathbb{E}_t Q_{t,t+s}\widetilde{\Lambda}_{o,t+s}(1+i^*_{t+s}) = 0 \quad \text{(A.1.9)}$$

$$I_{t+s}: -\mathbb{E}_t Q_{t,t+s}P_{h,t+s} + \mathbb{E}_t Q_{t,t+s}\widetilde{\mathcal{Q}}_{o,t+s} = 0 \quad \text{(A.1.10)}$$

$$\widetilde{\Lambda}_{o,t+s}: (1+i^*_{t+s})B_{f,t+s} - \kappa(1-\delta)\frac{P_{h,t+s+1}}{\mathcal{E}_{t+s+1}}K_{o,t+s} \leq 0 \quad \text{(A.1.11)}$$

$$\widetilde{\mathcal{Q}}_{o,t+s}: I_{t+s} + (1-\delta)K_{o,t+s} - K_{o,t+s+1} = 0 \quad \text{(A.1.12)}$$

$$\widetilde{\Lambda}_{o,t+s}\left[(1+i^*_{t+s})B_{f,t+s} - \kappa(1-\delta)\frac{P_{h,t+s+1}}{\mathcal{E}_{t+s+1}}K_{o,t+s}\right] = 0 \quad \text{(A.1.13)}$$

$$\widetilde{\Lambda}_{o,t+s} \geq 0 \quad \text{(A.1.14)}$$

The shadow price of borrowing (the dynamic multiplier)

$$\widetilde{\Lambda}_{o,t} = \frac{\mathbb{E}_t Q_{t,t+1}\mathcal{E}_{t+1}(1+i^*_t) - \mathbb{E}_t Q_{t,t}\mathcal{E}_t}{\mathbb{E}_t Q_{t,t}(1+i^*_t)}. \quad \text{(A.1.15)}$$

The shadow price of investment (the dynamic multiplier)

$$\widetilde{\mathcal{Q}}_{o,t} = P_{h,t}. \quad \text{(A.1.16)}$$

Equation (A.1.8) gives the optimal stock of capital, and the optimal production function. Thus, the demand for capital stock is determined by

$$\mathrm{K}_{o,t+1} = \left[\frac{\mathbb{E}_t Q_{t,t+1}P_{o,t+1}A_{o,t+1}\alpha_k}{\kappa(1-\delta)\mathbb{E}_t Q_{t,t+1}\widetilde{\Lambda}_{o,t+1}\frac{P_{h,t+2}}{\mathcal{E}_{t+2}} - (1-\delta)\mathbb{E}_t Q_{t,t+1}\widetilde{\mathcal{Q}}_{o,t+1} + \mathbb{E}_t Q_{t,t}\widetilde{\mathcal{Q}}_{o,t}}\right]^{\frac{1}{1-\alpha_k}}. \quad \text{(A.1.17)}$$

Equations (A.1.15) and (A.1.16) correspond to the borrowing and investment dynamic multipliers. Thereby, $\widetilde{\mathcal{Q}}_{o,t}$ is the shadow price of investment, whilst $\widetilde{\Lambda}_{o,t}$ is the shadow price of borrowing. Both parameters deliver the marginal price as the investment and borrowing constraints vary in one unity, respectively.

1.1.2 Closure of the model details

Exogenous shock processes

Exogenous shocks complete the setup of model. They are supposed to follow AR(1) processes.

In log-linearized terms, the shocks for the small open economy are composed of: the transitory productivity shock of the non-traded final goods sector

$$a_{h,t} = \rho_{a_h} a_{h,t-1} + \epsilon_{a_h,t}, \tag{A.1.18}$$

and the transitory productivity shock of the commodity-producing sector

$$a_{o,t} = \rho_{a_o} a_{o,t-1} + \epsilon_{a_o,t}. \tag{A.1.19}$$

Analogously, for the rest of the world, the exogenous processes are given by:

the foreign interest rate

$$i_t^* = \rho_{i^*} i_{t-1}^* + \epsilon_{i^*,t}, \tag{A.1.20}$$

the foreign CPI

$$p_t^* = \rho_{p^*} p_{t-1}^* + \epsilon_{p^*,t}, \tag{A.1.21}$$

the commodity price

$$p_{o,t}^* = \rho_{p_o^*} p_{o,t-1}^* + \epsilon_{p_o^*,t}, \tag{A.1.22}$$

and foreign consumption

$$c_t^* = \rho_{c^*} c_{t-1}^* + \epsilon_{c^*,t}. \tag{A.1.23}$$

Macro variable definitions

The overall output of the economy in final goods terms (the nominal gross domestic product) is given by the consumption of home-produced final goods and by the exports of commodities produced within the home economy,

$$P_t Y_t = P_{h,t} C_{h,t} + P_{o,t} Y_{o,t}. \tag{A.1.24}$$

As of the value of the commodity-producing firm, one can see that the value-added (the trade balance, $TB_{o,t}$) is given by the difference between the income generated by exports and inputs employed to produce commodities,[14]

$$TB_{o,t} = P_{o,t}Y_{o,t} - P_{h,t}I_t. \tag{A.1.25}$$

The overall trade balance (TB_t) of the economy can be calculated as usual, given by the difference between exports and imports,

$$TB_t = P_{o,t}Y_{o,t} - P_{f,t}C_{f,t}. \tag{A.1.26}$$

1.1.3 The baseline model without friction

In this subsection a version of the model without borrowing and its respective constraint is briefly presented. The only variations with respect to the baseline model (presented in section 1.3) take place in the commodity-producing sector and they are as follows.

The problem setting of the commodity-producing firm is:

$$\max_{K_{o,t+1},\ I_t} V_{o,t} = \mathbb{E}_t \sum_{s=0}^{\infty} Q_{t,t+s}\Phi_{o,t+s}$$

$$\text{Where} \qquad \Phi_{o,t} = P_{o,t}Y_{o,t} - P_{h,t}I_t \tag{A.1.27}$$

$$Y_{o,t} = A_{o,t}K_{o,t}^{\alpha_k} \tag{A.1.28}$$

$$K_{o,t+1} = I_t + (1-\delta)K_{o,t} \tag{A.1.29}$$

$$\lim_{t\to\infty} \mathbb{E}_t Q_{t,t+1}K_{o,t+1} = 0\ ,\ \lim_{t\to\infty} \mathbb{E}_t Q_{t,t}V_{o,t} = 0$$

$$K_{o,t+1} \geq 0\ ,\ K_{o,0} > 0\ ,\ \delta \in (0,1)\ ,\ \alpha_k \in (0,1)$$

The Lagrangian for the problem of the firm is

$$\mathcal{L}_{o,t} = \mathbb{E}_t \sum_{s=0}^{\infty} Q_{t,t+s}\Big\{P_{o,t+s}A_{o,t+s}K_{o,t+s}^{\alpha_k} - P_{h,t+s}I_{t+s} + \widetilde{\mathcal{Q}}_{o,t+s}\big[I_{t+s} + (1-\delta)K_{o,t+s} - K_{o,t+s+1}\big]\Big\}.$$

First-order conditions

$$K_{o,t+s+1} : \mathbb{E}_t Q_{t,t+s+1}P_{o,t+s+1}A_{o,t+s+1}\alpha_k K_{o,t+s+1}^{\alpha_k-1}$$

$$+\mathbb{E}_t Q_{t,t+s+1}\widetilde{\mathcal{Q}}_{o,t+s+1}(1-\delta) - \mathbb{E}_t Q_{t,t+s}\widetilde{\mathcal{Q}}_{o,t+s} = 0 \tag{A.1.30}$$

[14]Note that imports are zero for this sector.

$$I_{t+s} : -\mathbb{E}_t Q_{t,t+s} P_{h,t+s} + \mathbb{E}_t Q_{t,t+s} \widetilde{\mathcal{Q}}_{o,t+s} = 0 \qquad \text{(A.1.31)}$$

$$\widetilde{\mathcal{Q}}_{o,t+s} : I_{t+s} + (1-\delta) K_{o,t+s} - K_{o,t+s+1} = 0 \qquad \text{(A.1.32)}$$

The nominal shadow price of investment (the dynamic multiplier) is delivered by (A.1.31)

$$\widetilde{\mathcal{Q}}_{o,t} = P_{h,t}. \qquad \text{(A.1.33)}$$

Equation (A.1.34) gives the optimal demand for stock of capital using nominal prices,

$$K_{o,t+1} = \left[\frac{\mathbb{E}_t Q_{t,t+1} P_{o,t+1} A_{o,t+1} \alpha_k}{\mathbb{E}_t Q_{t,t} \widetilde{\mathcal{Q}}_{o,t} - (1-\delta) \mathbb{E}_t Q_{t,t+1} \widetilde{\mathcal{Q}}_{o,t+1}} \right]^{\frac{1}{1-\alpha_k}}. \qquad \text{(A.1.34)}$$

1.1.4 Additional simulated results

Full calibration details

Table A.1.1: Calibrated parameters

Parameter	Description and source	Value
β, β^*	Domestic and foreign subjective discount factors ($i = i^* \approx 0.5\%$) Drechsel, McLeay and Tenreyro (2019)	0.996
φ	Inverse Frisch elasticity rate Galí and Monacelli (2005), Ferrero and Seneca (2019), DMT (2019)	3.0
α_k	Returns to scale in the commodity-producing sector Drechsel, McLeay and Tenreyro (2019).	0.38
δ	Capital stock depreciation rate Garcia-Cicco, Pancrazi and Uribe (2010), Drechsel and Tenreyro (2018)	0.1255
κ	Loan-to-value ratio Iacoviello (2005)	0.89
ν	Foreign consumption bias Galí and Monacelli (2005), Drechsel, McLeay and Tenreyro (2019)	0.6
inv/y_h	Target ratio of commodity inputs to output of the final goods sector Ferrero and Seneca (2019), Drechsel, McLeay and Tenreyro (2019)	0.15
yo/y	Target share of commodity output to real GDP Ferrero and Seneca (2019)	0.20
ρ_{a_h}	Ac of the non-trade final goods sector Posterior value of Drechsel and Tenreyro (2018)	0.8277
ρ_{a_o}	Ac of the commodity-producing sector Posterior value of Drechsel and Tenreyro (2018)	0.5887
ρ_{c^*}	Ac of the overall foreign consumption Drechsel, McLeay and Tenreyro (2019)	0.9
ρ_{i^*}	Ac of the foreign nominal interest rate García-Cicco, Kirchner and Justel (2014)	0.9614
ρ_{p^*}	Ac of the foreign consumer price index García-Cicco, Kirchner and Justel (2014)	0.3643
$\rho_{p_o^*}$	Ac of the foreign commodity price index Drechsel, McLeay and Tenreyro (2019)	0.9
σ_{a_h}	Sdc of the non-trade final goods sector Posterior value of Drechsel and Tenreyro (2018)	0.1
σ_{a_o}	Sdc of the commodity-producing sector Posterior value of Drechsel and Tenreyro (2018)	0.1
σ_{c^*}	Sdc of the overall foreign consumption Drechsel, McLeay and Tenreyro (2019)	0.0333
σ_{i^*}	Sdc of the foreign nominal interest rate García-Cicco, Kirchner and Justel (2014)	0.0011
σ_{p^*}	Sdc of the foreign consumer price index García-Cicco, Kirchner and Justel (2014)	0.0273
$\sigma_{p_o^*}$	Sdc of the foreign commodity price index Drechsel, McLeay and Tenreyro (2019)	0.1

Notes: Ac = autoregressive coefficient. Sdc = standard deviation coefficient.

Optimal monetary policy considerations

Details and rationale for the monetary policy evaluation are provided below.

The two ad hoc quadratic loss functions

In this paper, as a first exercise approach to the optimal monetary policy evaluation, an *ad hoc* quadratic loss function is chosen instead of a micro-founded (true) loss function for the following two reasons.

Firstly, the model to be used here as an evaluation framework for optimal monetary policy is new in the literature, in the sense that it presents a new theoretical setup. It assumes that the endogenous dynamic collateralized borrowing constraint of the commodity-producing firm sector could constitute a factor that generates friction in the economy and that it could become a potential transmission channel for commodity price shocks, foreign interest rate shocks or nominal exchange rate fluctuations.

Secondly, despite that the optimal (or true or theoretical or the model-based or micro-founded) quadratic loss function provides a consistent framework (Paez-Farrell, 2014) for optimal monetary policy evaluation, it might not be proper to use it with the purpose of evaluating a new model that could be around the neighbor of the true model of the economy. In other words, when there is uncertainty about the true model of the economy and/or when there are possible misspecifications of the model to be used for such an assessment, the literature claims that *ad hoc* quadratic loss functions are robust to these two types of threads (Levin and Williams, 2003; Levin and Moessner, 2005; Paez-Farrell, 2014).[15] Consequently, in such a case/s *ad hoc* loss functions work as a good approximation of the true (micro-founded) loss function (Paez-Farrell, 2014). Moreover, the information they add in comparison to the model-based loss function is very competitive (Taylor and Williams, 2010, p. 28), and they are of common use in the literature.

Regarding the specifications of the *ad hoc* quadratic loss functions, for the first one, it is assumed that the central bank's objective function seeks to minimize consumption and inflation volatilities. While in the second one, the central bank also cares about the change in the nominal exchange rate volatility.

[15] For a discussion about monetary policy design when model uncertainty and model misspecification are present, see Qin et al. (2013).

The first reason for not adopting a standard *ad hod* quadratic loss function which contemplates inflation and output gap volatilities is because here it is assumed that the monetary authority is concerned not only about the inflation volatility, but also with the volatility of consumption. In other words, the assumption is that a second mandate for the monetary authority is to stabilize inflation and the representative household's consumption. Likewise, it is also supposed that consumption would work as a closer and better approximation to the welfare function.

The former assumptions are set because there is research showing that there are alternative specifications to the true (model-based) quadratic loss function that yields closer results to the first-best (see Debortoli, Kim, Lindé and Nunes, 2015).[16] However, later Debortoli, Kim, Lindé and Nunes (2019) find that, when designing optimal monetary policy, the best *ad hoc* quadratic loss function should include the output gap and have a higher weight relative to inflation. For the optimal monetary policy evaluation conducted here, this paper omits this latter finding by letting the assumptions made about the monetary authority's mandate (on inflation and consumption volatilities) prevail. Moreover, under the current setup of the baseline model used here, it is not clear what weight to assign to inflation or consumption.

Why the nominal exchange rate?

With respect to the inclusion of the change in the nominal exchange rate volatility in the second *ad hoc* loss function, it has to do with the fact that, in an open economy, the monetary authority "...must take into account the impact of the exchange rate on real activity and inflation." (Clarida et al., 2001, p. 1). Therefore, this second quadratic loss function embraces this statement as another mandate for the monetary authority which is totally independent and different from the first mandate. Thus, there are two *ad hoc* quadratic loss functions in total.

As it can be seen, in this paper the nominal exchange rate plays a key role. Specifically, this variable is present in its budget constraint (equation [1.16]) and in the endogenous dynamic borrowing constraint of the commodity-producing firm (equation [1.17]). The nominal exchange rate affects borrowings, investments and production decisions of the firm (equations [1.18] & [1.19]), and in turn, to the level of the overall output of the economy (the real GDP or income; equation [A.1.24]). Changes

[16] In this paper these authors find that an *ad hoc* quadratic loss function with nominal inflation and hours gap provides a better approximation to the true loss function in comparison to a standard loss function with inflation and output gap.

in the real sector alter relative prices, cause inflation (equations [1.7] & [1.8]) and affect consumption ([1.3]). Furthermore, profits coming from the commodity sector affect the representative household's budget constraint (equation [1.2]) and also consumption. Ultimately, changes in consumption (equation [1.1]) end up affecting the welfare of the representative household.

One more reason to think about the inclusion of the nominal exchange rate into the second *ad hoc* loss function is that monetary authorities of SOEs, and even more, those of SEOEs do not allow their nominal exchange rate floats totally free. In other words, the "fear of floating" phenomenon takes place in the true economic world (Calvo and Reinhart, 2002; Ilzetzki et al., 2020). Hence, given the model proposed in this paper and the empirical reality accounted for, the second *ad hoc* loss function could bring about plausible monetary policy recommendations for these types of economies.

The four simple monetary policy rules

Following the literature, this paper relies on Taylor-type monetary policy rules for a few reasons. First of all, they are generally characterized by a good performance in the real world and show robustness to model misspecifications in comparison to fully optimal or more complex policy rules (Williams, 2003; Taylor and Williams, 2010). Moreover, they show robustness when there is uncertainty about the true model (Levin et al., 2005).

Another argument in favor is the size of the model of this paper, which turns out to be one of a small scale. In this case, as Taylor and Williams (2010, p. 28) state, "...the optimal policy may be equivalent to a simple policy rule...". This means that the adoption of these types of rules would be useful to approximate the results to the optimum.

Additionally, the transparency of simple rules has the advantage of being clear, and subsequently, exerting certain pressure on the policymaker to commit and not deviate from its rule (Williams, 2003). As a result, this paper focuses on these types of rules under commitment (when the public knows the full specification of the rule).

As it was previously described, the first rule is a feedback CPI inflation-based Taylor-type rule with the output and the nominal interest rate smoothing (or inertial) term (FCPITR). The second is a feedback domestic inflation-based Taylor-type rule with the output and the nominal interest rate smoothing term (FDITR). The next is a feedback nominal exchange rate rule with the nominal interest rate smoothing term (FNERTR). The last one is a pegged nominal exchange rule (PEG).[17]

Note that, with exception of the pegged rule, all the other rules include the feedback interest rate term. Such terms are preferred to strict inflation targeting rules because efficient simple rules usually have the interest rate smoothing term as a feedback of anticipated policy actions to stabilize the targeted variables of the rule (Williams, 2003). Moreover, they are directly related to the degree of commitment (Debortoli, Maih and Nunes, 2014).

The two first rules targeting inflation rates and output are standard in the literature (equations [1.23] & [1.24]). The third one (equation [1.25]), is set here due to the relevant role that the nominal exchange rate plays in the model, as it was previously explained in this subsection. In addition to this, as Taylor and Williams (2010, p. 21) claim, it is advisable to have a simple rule that includes a variable that is also part of the central bank's objective function (like in the second quadratic loss function, for instance). As a result, setting a simple rule that targets the nominal exchange rate seems to be something compelling. The last rule (equation [1.26]), is set as a limiting case of a nominal exchange rate targeting rule that works as another comparative case within the analysis.

The two shock scenarios

As it was mentioned before, the benchmark (or baseline) scenario in the paper is given by a correlated shock scenario which assumes a simultaneous commodity price shock and world activity shock. This first scenario is set as the baseline one in the paper because there are studies providing evidence of a strong link between these two shocking variables.

The main factors that explain the association between commodity prices and world activity fluctuations are: the increasing link between commodity prices and other asset prices (DMT, 2019); an increasing correlation between the evolution of commodity prices and the economic growth rate of commodity-exporting countries, and especially for developing ones (Shousha, 2016; Fernández, Schmitt-Grohé and Uribe, 2017; Drechsel and Tenreyro, 2018; UNCTAD, 2019, p. 8; DMT, 2019; FS, 2019); and, a stronger relationship between commodity-price movements and financial conditions of commodity-exporting countries (Bastourre,

[17]It is important to remember that the FNERTR rule can be also called as the soft peg rule, while the PEG rule as the hard peg rule or as the fixed exchange rate rule.

Carrera, Ibarlucia and Sardi, 2012; Shousha, 2016; Fernández, Schmitt-Grohé and Uribe, 2017; Drechsel and Tenreyro, 2018).

Taking into account the aforementioned underpinnings for the baseline (or benchmark) scenario, the second one only focuses on presenting the case when a commodity price shock under uncorrelated shocks hits the economy. This scenario is left as one of secondary interest. Nonetheless, it is still very helpful to isolate the commodity price shock and understand the transmission mechanism within the model and its effects on the business cycle of commodity-exporting countries whose commodity-producing sector faces financial friction.

The grid search method

In conducting the optimal monetary policy evaluation, a procedure known as "grid search method" is implemented. It consists in establishing ranges of values (or grids) for the parameters stated in the simple monetary policy rules, calculating the *ad hoc* quadratic loss function value for every possible combination of parameters of the simple rule, recording them, and finally, choosing the minimum loss function value among the previously recorded ones. A similar procedure description can be found in (Williams, 2003).

Accordingly, the grids used for the coefficients in the simple monetary policy rules (equations [1.24] to [1.26]) are $\phi_\pi \in [1.1, 3.1]$, $\phi_y \in [0.001, 1]$ and $\phi_e \in [0.001, 5.1]$, respectively. The initial values for each parameter increase at a 0.1 step.

Note that the remaining parameter, ρ_i (from equation [1.24] to [1.25]), is not optimized but set to a fixed number ($\rho_i = 0.75$). This is done for comparative purposes. For instance, one can see that FS (2019) uses the same value when considering the feedback CPI and domestic inflation Taylor-type rules.

Results of the model with frictions

Results under the commodity price shock scenario

The first ad hoc quadratic loss function

Under the (uncorrelated) commodity price shock scenario, the same first *ad hoc* quadratic loss function seeks to minimize inflation and consumption volatilities. Figure A.1.1 in Appendix 1.1.4 displays the different macroeconomic variable responses to an uncorrelated commodity price shock under each policy rule.

Now that the world activity shock is not present anymore within the mechanism explained in the correlated shock scenario subsection. Now, the intensity in the responses of all variables changes, as well as the direction of some of the variable responses. With respect to changes in the direction of the responses, those variables are total consumption and the real and nominal interest rates.

The mechanism

As before, a commodity price shock incentives to the commodity-producing firm to produce more and contract more collateralized borrowings from international lenders. A bigger demand for inputs from the commodity-producing sector increases the output, hours at work and real wages of the non-traded final goods sector. The pressure over domestic prices changes relative prices generates domestic and CPI inflation. The increment in domestic prices improves the terms of trade (it falls) causing a real and nominal appreciation of the exchange rate. In turn, the nominal appreciation of the exchange rate loosens the endogenous dynamic asset-based borrowing constraint of the commodity-producing firm and that allows it to borrow and produce more.

Now, in the face of a scenario in which a world activity shock is absent (given the perfectly international risk-sharing condition and the rest of the world equilibrium condition), the fall (or improvement) in the terms of trade is considerably lesser, and therefore, the real and nominal appreciation of the exchange rates are also smaller and less durable. Thus, such a small nominal appreciation rate is not enough to stimulate the local consumption of foreign goods and this latter remains invariable. As a result, in the present case, there is no expenditure-switching effect. For this reason, the fall in domestic consumption of goods cannot be compensated, and in this scenario, total consumption falls. The decline in domestic consumption goods shows how the commodity price shock creates a reallocation of resources (more investment goods instead of more home consumption goods). This is despite the increment observed in the production of non-traded final goods. Clearly, this illustrates that a commodity price shock offsets or at least does not generate an income effect that prevails over a substitution effect. Given the drop in consumption, one can verify that a commodity price shock causes an inefficient allocation from the welfare perspective (where welfare can be measured in terms of consumption).

With a large decline in domestic consumption goods, lower domestic relative prices (with respect to the correlated shock scenario) and a higher commodity output, the resulting real GDP gap respond to the commodity price shock with a relatively lower increase (1% lower) in comparison to the correlated shock scenario.

The tightest response from the policymaker (where the increment in the real and nominal interest rates are the largest) is given under the domestic inflation targeting rule that also smooths the nominal interest rate (FDITR). In response to a higher pressure over domestic prices, the monetary authority raises its nominal interest rate and domestic inflation is contained. Then, the subsequent highest nominal and real appreciation of the exchange rates are observed under this rule. After a quicker process of relaxation of the monetary conditions of the economy (relative to the faster real interest rate drops under other regimes), domestic inflation and inflation of imported goods increase and translate to CPI inflation. The substantial rise in general prices explains the sharp nominal exchange rate depreciation.

The central bank's reaction under a feedback CPI inflation targeting rule (FCPITR) generates a similar but ameliorated dynamic response of macroeconomic variables. They are attenuated by a softer response of the monetary authority to the shock, and then, by a major contention of the CPI inflation that considerably mitigates the nominal depreciation process of the exchange rate.

Finally, the soft peg rule (or FNERTR) and the hard peg policy rule (or PEG) display overlapped dynamic responses. In terms of the central bank's objective function, both regimes deliver the highest CPI inflation rates but the lowest drop in total consumption. Moreover, the responses of the nominal exchange rate under both regimes are also the lowest, or nil as expected.

Regarding the size of the suggested appreciation of the nominal exchange rate in response to a commodity price shock, the result obtained here is close to the one of DMT. Namely, the predicted appreciation rates under the optimized rules, excluding the hard peg rule (or PEG), are close to 0.0% here; while in the case of DMT, they are between 2.5% and 0.7%.

The best simple monetary policy rule

According to Table A.1.2 of the Appendix 1.1.4, the best simple monetary policy rule in response to a commodity-price shock is the one that targets the nominal exchange rule and smooths the nominal interest rate (FNERTR; Panel b). While the second-best rule is given by the feedback CPI inflation targeting rule (FCPITR). The worst performance is reported under the feedback domestic inflation targeting rule (FDITR).

Regarding related works that evaluate optimal monetary policy responses to a commodity price shock, two are the closest ones to this paper: the works of DMT and FS. They perform their optimal monetary policy evaluations using a second-order approximation to the welfare function of the representative agent and set strict CPI and domestic inflation rates targeting rules and a hard peg rule. DMT conclude that the first-best simple monetary policy rule is the one that strictly targets CPI inflation, while FS, one that strictly targets domestic inflation (as in GM). As it can be seen, both studies disagree on their first-best simple monetary policy rules, but agree that in the face of commodity-price shocks the hard peg nominal exchange rate regime gives the worst results from a welfare optimization perspective. This latter result differs from the one obtained here in that the hard peg rule (PEG) is the third-best rule and that the worst one is the feedback rule that targets domestic inflation (FDITR; Panel b). However, it is important to have in mind that the model set here is under fully-flexible prices while those of the authors (DMT and FS) are under sticky prices.

As stated in the literature review section, the difference between the framework of this paper with those of DMT and FS, is that they set a SOE New Keynesian model à la GM (here, the setup is a RBC model version of DMT and FS's model). Both authors (DMT and FS) add a commodity-producing sector that exports all its production (the same as here). The model of DMT has an earning-based borrowing constraint while the one of FS does not (here, the model has an asset-based borrowing constraint). Both authors derive a model-based quadratic loss function while here, an *ad hoc* quadratic loss function is implemented. Both authors set strict inflation targeting rules, while here, the Taylor-type rules include the nominal interest rate smoothing term (also, as FS).

In Panel (c) can be observed that the changes in the nominal exchange rate volatility under the domestic and CPI inflation targeting rules (FDITR and FCPITR, respectively) are high. Whereas under the feedback rule that targets the nominal exchange rate is low.

The second ad hoc quadratic loss function

Now the commodity price shock scenario is analyzed under the second *ad hoc* quadratic loss function that seeks to minimize inflation, consumption and the change in the nominal exchange rate volatilities. Figure A.1.2 of the Appendix 1.1.4 shows the macroeconomic variable responses to a commodity price shock under each one of the optimized simple monetary policy rules.

Under the new central bank's objective function (given by the second *ad hoc* quadratic loss function) and the same shock that hits the economy (the commodity price shock), the transmission mechanism works as before (just as under the first loss function) and the same variable responses remain unchanged.

Looking at Table A.1.3 from Appendix 1.1.4, one can see that now the optimized simple rules that target domestic and CPI inflation rates and that smooth the nominal interest rates (FDITR and FCPITR, respectively) are more "dovish". This, in the sense that now they are more flexible and allow for more deviation of these inflation measures with respect to their correspondent steady states (Panel a).

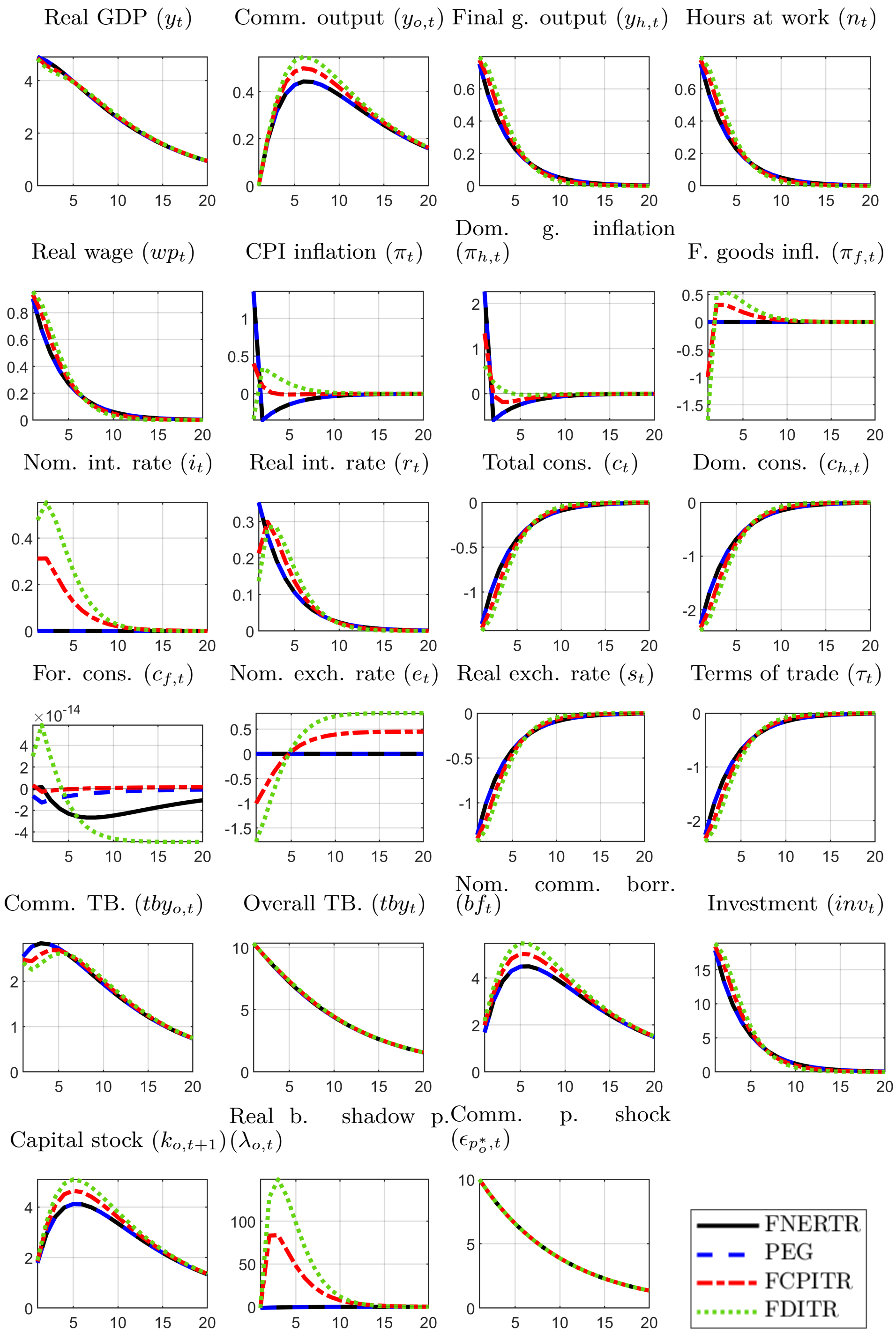
From the loss function perspective, the performances of the two aforementioned policy rules (FDITR and FCPITR) rank them in the last two places. Thus, the first- and second-best policy regimes are given by the rule that targets the nominal exchange rate and that smooths the nominal interest rate (FNERTR) and by the hard peg rule (PEG) that stabilizes the nominal exchange rate for complete.

Once more, the optimal monetary policy evaluation performed in this subsection yields a result in favor to the soft peg rule with feedback (FNERTR) as an instrument that allows to stabilize inflation, consumption and the change in the nominal exchange rate volatilities.

Friction vs frictionless model results

The model with borrowings and its respective endogenous dynamic asset-based borrowing constraint (the model with friction) is compared to a version without borrowings and its respective constraint (the model without friction). Both models are contrasted against correlated commodity price shock and world activity shocks (Figure A.1.3) and uncorrelated commodity price shock (Figure A.1.4).

Figure A.1.1: Optimized monetary policy rules to a commodity price shock ($L_{(\pi_t, c_t)}$)



Note: IRFs to a 10% positive commodity price shock, which is equivalent to one standard deviation percentage from the steady state. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. $L_{(\pi_t, c_t)}$ = the loss function minimizes the sum of inflation and consumption variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule.

Table A.1.2: Optimized monetary policy rules to uncorrelated shocks ($L_{(\pi_t,c_t)}$)

Panel (a): Monetary policy rule specifications

Rule / Optimized coefficients		ρ_i	ϕ_π	ϕ_y	ϕ_e
FCPITR	$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_t + \phi_y y_t)$	0.75	3.1	0.001	–
FDITR	$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_{h,t} + \phi_y y_t)$	0.75	1.5	0.001	–
FNERTR	$i_t = \rho_i i_{t-1} + \phi_e e_t$	0.75	–	–	0.1
PEG	$e_t = 0$	–	–	–	–

Panel (b): Optimized loss function values
($L_{(\pi_t,c_t)} = var(\pi_t) + var(c_t)$; variances in %)

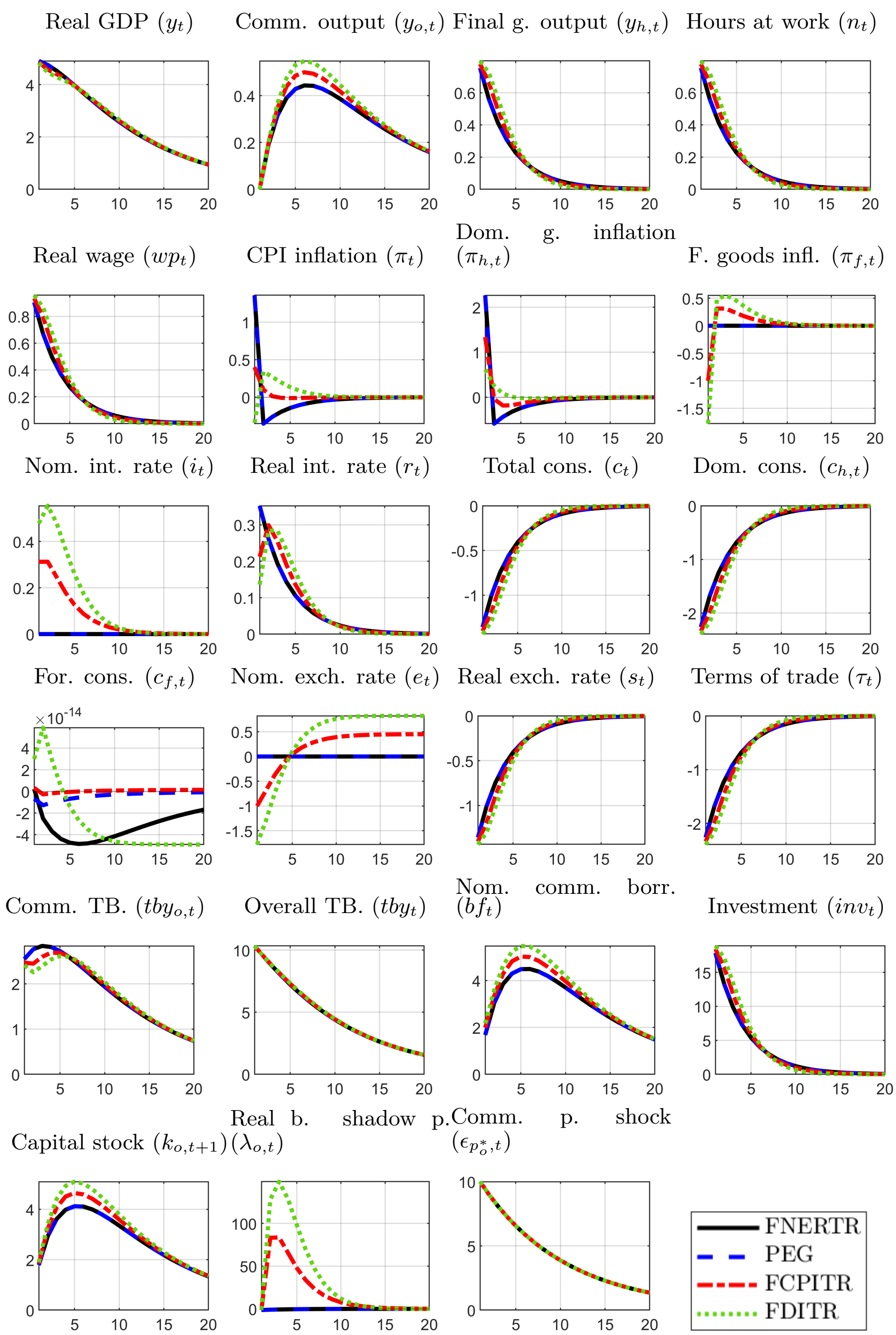
Variable / Rule	FCPITR	FDITR	FNERTR	PEG
Total consumption	0.369	0.383	0.352	0.374
Overall CPI inflation	0.006	0.063	0.021	0.054
Total	0.375	0.446	0.373	0.428

Panel (c): Standard deviations (%)

Variable / Monetary policy rule	FCPITR	FDITR	FNERTR	PEG
Total consumption	6.07	6.19	5.93	6.11
Real gross domestic product	9.17	9.27	9.12	9.13
Non-traded final goods output	6.07	6.06	6.04	6.13
Commodity-producing output	12.01	12.42	11.64	11.93
Investment	46.80	51.44	43.54	50.05
Domestic inflation rate	2.82	3.47	3.49	3.78
Overall CPI inflation	0.78	2.51	1.45	2.32
Domestic nominal interest rate	0.98	1.78	0.60	2.01
Change in the nominal exchange rate	3.48	4.59	2.73	0.00
Real exchange rate	3.23	3.49	3.18	3.35
Terms of trade	8.07	8.73	7.94	8.38
Commodity trade balance	26.34	27.57	25.64	28.38
Overall trade balance	26.45	26.98	26.06	26.28
Foreign commodity price index	22.94	22.94	22.94	22.94

Notes: Shocks are set to one standard deviation percentage from the steady state. $L_{(\pi_t,c_t)}$ = the loss function minimizes the sum of inflation and consumption variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule. The grids used for the coefficients in the rules are $\phi_\pi \in [1.1, 3.1]$, $\phi_y \in [0.001, 1]$ and $\phi_e \in [0.001, 5.1]$, respectively, and they increase at a 0.1 step.

Figure A.1.2: Optimized monetary policy rules to a commodity price shock ($L_{(\pi_t,c_t,\Delta e_t)}$)



Note: IRFs to a 10% positive commodity price shock, which is equivalent to one standard deviation percentage from the steady state. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. $L_{(\pi_t,c_t,\Delta e_t)}$ = the loss function minimizes the sum of inflation, consumption and change in the nominal exchange rate variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule.

Table A.1.3: Optimized monetary policy rules to uncorrelated shocks ($L_{(\pi_t, c_t, \Delta e_t)}$)

Panel (a): Monetary policy rule specifications

Rule / Optimized coefficients		ρ_i	ϕ_π	ϕ_y	ϕ_e
FCPITR	$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_t + \phi_y y_t)$	0.75	1.1	0.001	–
FDITR	$i_t = \rho_i i_{t-1} + (1-\rho_i)(\phi_\pi \pi_{h,t} + \phi_y y_t)$	0.75	1.5	0.001	–
FNERTR	$i_t = \rho_i i_{t-1} + \phi_e e_t$	0.75	–	–	1.1
PEG	$e_t = 0$	–	–	–	–

Panel (b): Optimized loss function values
($L_{(\pi_t, c_t, \Delta e_t)} = var(\pi_t) + var(c_t) + var(\Delta e_t)$; variances in %)

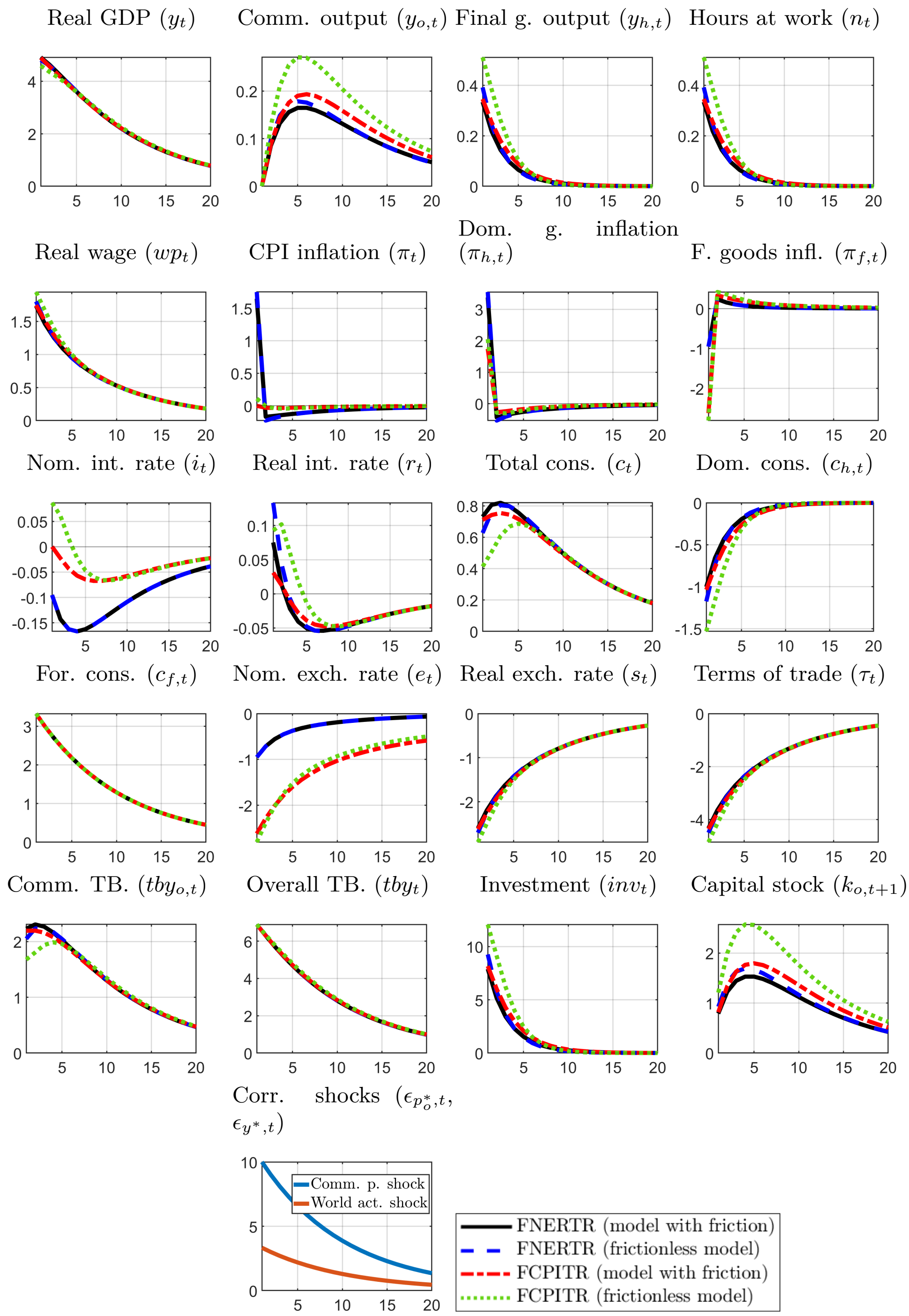
Variable / Rule	FCPITR	FDITR	FNERTR	PEG
Total consumption	0.379	0.384	0.361	0.374
Overall CPI inflation	0.073	0.063	0.042	0.054
Change in the Nom. exch. rate	0.194	0.211	0.014	0.000
Total	0.646	0.658	0.417	0.428

Panel (c): Standard deviations (%)

Variable / Monetary policy rule	FCPITR	FDITR	FNERTR	PEG
Total consumption	6.15	6.19	6.01	6.11
Real gross domestic product	9.17	9.27	9.11	9.13
Non-traded final goods output	6.03	6.06	6.07	6.13
Commodity-producing output	12.09	12.42	11.78	11.93
Investment	46.87	51.44	45.62	50.05
Domestic inflation rate	3.87	3.47	3.72	3.78
Overall CPI inflation	2.70	2.51	2.05	2.32
Domestic nominal interest rate	1.40	1.78	1.29	2.01
Change in the nominal exchange rate	4.40	4.59	1.20	0.00
Real exchange rate	3.18	3.49	3.21	3.35
Terms of trade	7.96	8.73	8.02	8.38
Commodity trade balance	26.31	27.57	26.25	28.38
Overall trade balance	26.53	26.98	26.17	26.28
Foreign commodity price index	22.94	22.94	22.94	22.94

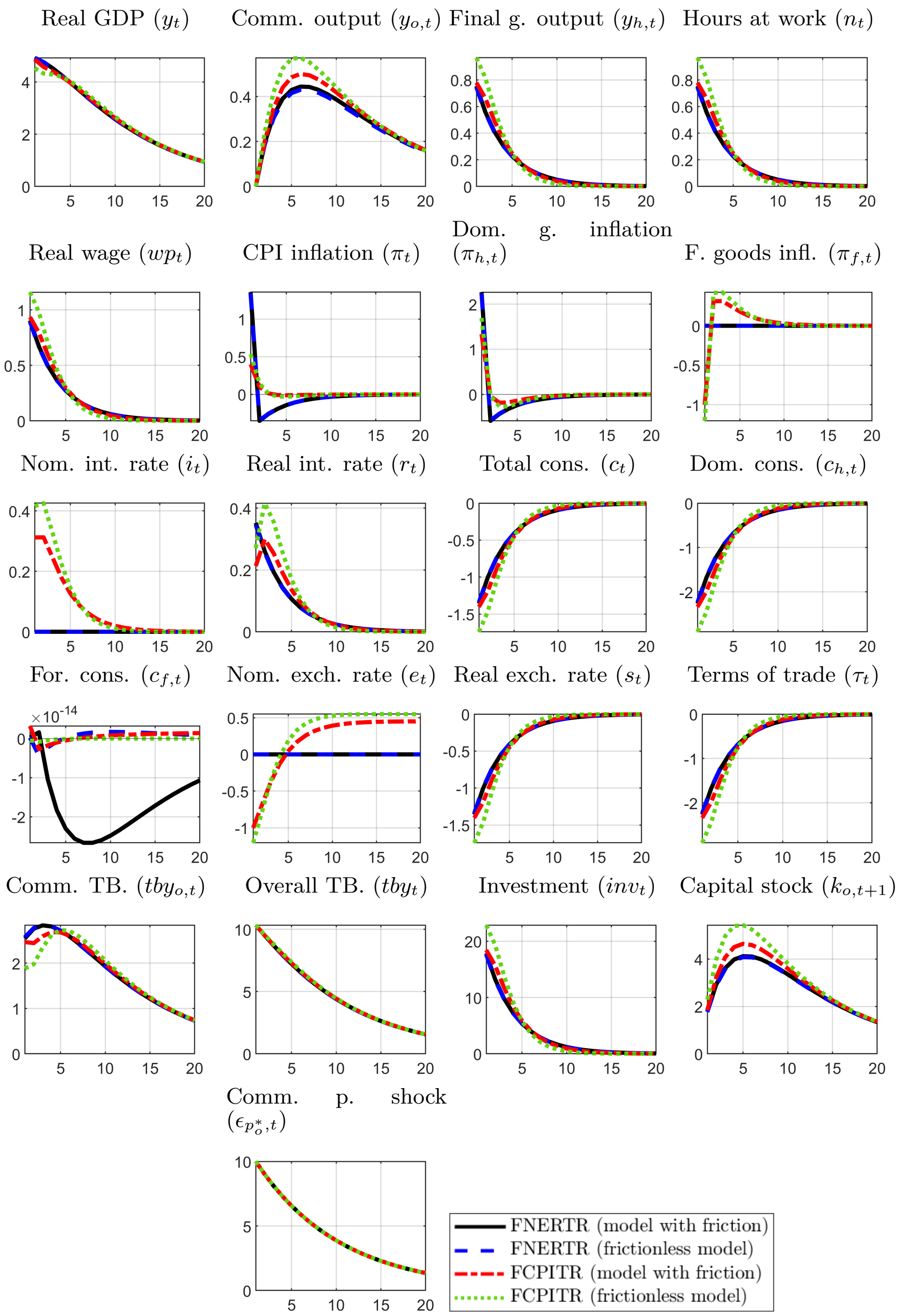
Notes: Shocks are set to one standard deviation percentage from the steady state. $L_{(\pi_t, c_t, \Delta e_t)}$ = the loss function minimizes the sum of inflation, consumption and change in the nominal exchange rate variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule. The grids used for the coefficients in the rules are $\phi_\pi \in [1.1, 3.1]$, $\phi_y \in [0.001, 1]$ and $\phi_e \in [0.001, 5.1]$, respectively, and they increase at a 0.1 step.

Figure A.1.3: Two optimized monetary policy rules to a correlated commodity price shock and world activity shock according to the model with and without friction ($L_{(\pi_t,c_t)}$)



Note: The correlated shocks are set to a 10% positive commodity price shock and 3.33% positive world activity shock. Both shocks are equivalent to one standard deviation percentage from their respective steady state. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. $L_{(\pi_t,c_t)}$ = the loss function minimizes the sum of inflation and consumption variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule.

Figure A.1.4: Two optimized monetary policy rules to a commodity price shock according to the model with and without friction ($L_{(\pi_t,c_t)}$)



Note: IRFs to a 10% positive commodity price shock, which is equivalent to one standard deviation percentage from the steady state. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. $L_{(\pi_t,c_t)}$ = the loss function minimizes the sum of inflation and consumption variances. FCPITR = feedback consumer price index inflation targeting rule. FDITR = feedback domestic inflation targeting rule. FNERTR = feedback nominal exchange rate targeting rule. PEG = nominal pegged exchange rate rule.

1.1.5 Supplementary Material

Supplementary material associated with this article can be found, in the online version, at (click here).

2.1 Appendix

2.1.1 Additional variable definitions

The aggregate output (or GDP) of the economy in nominal and value-added terms is obtained by aggregating the individual non-traded final goods from the monopolistic competitive sector and by adding the output of the representative commodity-producing firm (net of intermediate goods).

$$P_t Y_t = P_{h,t} Y_{h,t} + P_{o,t} Y_{o,t} - P_{h,t} M_{h,t}. \tag{A.2.1}$$

The trade balance to GDP ratio can be defined as

$$TBY_t = \frac{1}{P_t Y_t}\Big[P_{o,t} Y_{o,t} - P_{f,t} C_{f,t}\Big]. \tag{A.2.2}$$

2.1.2 The recursive Ramsey planner problem

The recursive formulation is achieved by enlarging the planner's state space. This is materialized by adding as many $Z_{i,t}$ co-state variables as many i constraints featuring expectations in the problem are. Such co-state variables are assumed to take the law of motion defined as $Z_{i,t+1} = \lambda_{i,t}$ ($\forall i = 1, 2, 3$); while the deterministic Ramsey steady state delivers the implied steady state for each $Z_{i,t}$ and $\lambda_{i,t}$ at time zero ($Z_{i,0} = \bar{Z}_i$ and $\lambda_{i,0} = \bar{\lambda}_i$), respectively.

Before writing the recursive formulation of the planner's problem, the objective function can be re-defined as

$$\mathcal{W}(C_t, N_t, \mathcal{T}_t, \Pi_{h,t}, M_{h,t}, \mathbb{E}_t Q_{t,t+1}, Z_{1,t}, Z_{2,t}, Z_{3,t}) \equiv \ln C_t - \tfrac{N_t^{1+\phi}}{1+\phi}$$

$$- Z_{1,t}(\mathcal{T}_t^{\alpha} C_t)^{-1} \Pi_{h,t}\Big(\Pi_{h,t} - \Pi_h\Big) - Z_{2,t}\chi Q^*_{t,t}\frac{P^*_{o,t}}{P_t}\mathcal{T}_t^{\alpha}\Pi_{h,t}$$
$$- Z_{3,t}\nu\frac{P^*_{o,t}}{P^*_t}\mathcal{T}_t\Pi_{h,t}\Big\{[1-\chi]\frac{Q_{t,t}}{Q_{t,t-1}} + \chi Q^*_{t,t}\Big(\frac{\mathcal{T}_t}{\mathcal{T}_{t-1}}\Big)^{-1}\Pi_{h,t}^{-1}\Pi^*_t\Big\}.$$

Then, following Marcet and Marimon (2019), the saddle-point stationary optimal policy plan in the amplified state space $\{\Lambda_{\Re,t}, \Xi_{\Re,t}, \mathcal{X}\}$ can be written below.[18]

Let $\Lambda_{\Re,t} \equiv \{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}, \lambda_{5,t}, Z_{1,t}, Z_{2,t}, Z_{3,t}\}_{t=0}^{\infty}$, $\Xi_{\Re,t} \equiv$

[18]Remember that $\mathcal{X}$ encompasses the set of exogenous processes that shock this economy, $\mathcal{X} \in \{A_{h,t}, A_{o,t}, R^*_t, C^*_t, \Pi^*_t, P^*_{o,t}/P^*_t\}$.

$\{C_t, N_t, \mathcal{T}_t, \Pi_{h,t}, M_{h,t}, \mathbb{E}_t Q_{t,t+1}\}_{t=0}^{\infty}$ to

$$\min_{\{\Lambda_{\Re,t}\}_{t=0}^{\infty}} \max_{\{\Xi_{\Re,t}\}_{t=0}^{\infty}} \mathbb{E}_0 \Bigg\{ \sum_{t=0}^{\infty} \beta^t \Bigg\{ \mathcal{W}(C_t, N_t, \mathcal{T}_t, \Pi_{h,t}, M_{h,t}, \\ \mathbb{E}_t Q_{t,t+1}, Z_{1,t}, Z_{2,t}, Z_{3,t}) \\ + \lambda_{1,t} \Bigg\{ \Pi_{h,t}\Big(\Pi_{h,t} - \Pi_h\Big) - \big[\frac{W_t}{P_t}\frac{\mathcal{T}_t^{\alpha}}{A_{h,t}} - \frac{\epsilon - 1}{\epsilon}\big]\frac{\epsilon}{\theta} A_{h,t} N_t \Bigg\} (\mathcal{T}_t^{\alpha} C_t)^{-1} \\ + \lambda_{2,t} \frac{\mathcal{T}_t^{\alpha}}{A_{o,t} M_{h,t}^{\nu}} \frac{B_{o,t}}{P_t} + \lambda_{3,t} \frac{1}{A_{o,t}} M_{h,t}^{1-\nu} + \lambda_{4,t} \Big[C_t - C_t^* \mathcal{T}_t^{1-\alpha} \Big] \\ + \lambda_{5,t} \Bigg[A_{h,t} N_t - (1-\alpha) \mathcal{T}_t^{\alpha} C_t - M_{h,t} - \frac{\theta}{2}\Big(\Pi_{h,t} - \Pi_h\Big)^2 \Bigg] \Bigg\} \Bigg\}.$$

The optimality conditions for the dynamics of the recursive Ramsey planner read as follows.

$$
\begin{aligned}
C_t :& \frac{1}{C_t} \quad - \lambda_{1,t}\Big\{\Pi_{h,t}\Big(\Pi_{h,t} - \Pi_h\Big) - [\frac{W_t}{P_t}\frac{\mathcal{T}_t^{\alpha}}{A_{h,t}} - \frac{\epsilon-1}{\epsilon}]\frac{\epsilon}{\theta}A_{h,t} \\
& N_t\Big\}\mathcal{T}_t^{-\alpha}C_t^{-2} + Z_{1,t}\mathcal{T}_t^{-\alpha}C_t^{-2}\Pi_{h,t}\Big(\Pi_{h,t} - \Pi_h\Big) \\
& + \lambda_{4,t} \quad - \lambda_{5,t}(1-\alpha)\mathcal{T}_t^{\alpha} = 0 \\
N_t :& - N_t^{\phi} \quad - \lambda_{1,t}[\frac{W_t}{P_t}\frac{\mathcal{T}_t^{\alpha}}{A_{h,t}} - \frac{\epsilon-1}{\epsilon}]\frac{\epsilon}{\theta}A_{h,t}(\mathcal{T}_t^{\alpha}C_t)^{-1} + \lambda_{5,t}A_{h,t} = 0 \\
\mathcal{T}_t :& - \alpha\lambda_{1,t}\Big\{\Pi_{h,t}\Big(\Pi_{h,t} - \Pi_h\Big) + \frac{\epsilon-1}{\epsilon}\frac{\epsilon}{\theta}A_{h,t}N_t\Big\}\mathcal{T}_t^{-\alpha-1}C_t^{-1} \\
& + \alpha Z_{1,t}\mathcal{T}_t^{-\alpha-1}C_t^{-1}\Pi_{h,t}\Big(\Pi_{h,t} - \Pi_h\Big) \\
& + \lambda_{2,t}\frac{\alpha\mathcal{T}_t^{\alpha-1}}{A_{o,t}M_{h,t}^{\nu}}\frac{B_{o,t}}{P_t} - Z_{2,t}\chi Q_{t,t}^{*}\frac{P_{o,t}^{*}}{P_t}\alpha\mathcal{T}_t^{\alpha-1}\Pi_{h,t} \\
& - Z_{3,t}\nu\frac{P_{o,t}^{*}}{P_t^{*}}\Pi_{h,t}[1-\chi]\frac{Q_{t,t}}{Q_{t,t-1}} \\
& - Z_{3,t}\nu\frac{P_{o,t}^{*}}{P_t^{*}}\Pi_{h,t}\chi Q_{t,t}^{*}\Big(\frac{\mathcal{T}_t}{\mathcal{T}_{t-1}}\Big)^{-1}\Pi_{h,t}^{-1}\Pi_t^{*} \\
& + Z_{3,t}\nu\frac{P_{o,t}^{*}}{P_t^{*}}\mathcal{T}_t\Pi_{h,t}\chi Q_{t,t}^{*}\Pi_{h,t}^{-1}\Pi_t^{*}\Big(\frac{\mathcal{T}_t}{\mathcal{T}_{t-1}}\Big)^{-2}[\frac{1}{\mathcal{T}_{t-1}} - \beta\frac{\mathcal{T}_{t+1}}{\mathcal{T}_t^{2}}] \\
& - \lambda_{4,t}C_t^{*}(1-\alpha)\mathcal{T}_t^{-\alpha} \quad - \lambda_{5,t}(1-\alpha)\alpha\mathcal{T}_t^{\alpha-1}C_t = 0 \\
\Pi_{h,t} :& \lambda_{1,t}(\mathcal{T}_t^{\alpha}C_t)^{-1}[2\Pi_{h,t} - \Pi_h] \quad - Z_{1,t}(\mathcal{T}_t^{\alpha}C_t)^{-1}[2\Pi_{h,t} - \Pi_h] \\
& - Z_{2,t}\chi Q_{t,t}^{*}\frac{P_{o,t}^{*}}{P_t}\mathcal{T}_t^{\alpha} \\
& - Z_{3,t}\nu\frac{P_{o,t}^{*}}{P_t^{*}}\mathcal{T}_t[1-\chi]\frac{Q_{t,t}}{Q_{t,t-1}} \quad - \lambda_{5,t}\theta\Big(\Pi_{h,t} - \Pi_h\Big) = 0 \\
M_{h,t} :& - \lambda_{2,t}\frac{\nu\mathcal{T}_t^{\alpha}}{A_{o,t}M_{h,t}^{1+\nu}}\frac{B_{o,t}}{P_t} \quad + \lambda_{3,t}\frac{1}{A_{o,t}}(1-\nu)M_{h,t}^{-\nu} \quad - \lambda_{5,t} = 0 \\
\mathbb{E}_tQ_{t,t+1} :& - Z_{3,t}\nu\frac{P_{o,t}^{*}}{P_t^{*}}\mathcal{T}_t\Pi_{h,t}\Big\{[1-\chi]\mathbb{E}_t\Big(\beta\frac{1}{Q_{t,t}} - \beta^2\frac{Q_{t,t+2}}{Q_{t,t+1}^{2}}\Big)\Big\} = 0.
\end{aligned}
$$

Imposing the steady state over the dynamic of the previous system of equations one obtains the denominated deterministic Ramsey steady state.

2.1.3 Calibration details

The time unit of the model is set to quarterly frequency and calibrated parameters are fit to the Norwegian economy, defining the data sample (if possible) to the period 1978Q1-2017Q4.

According to data, the (non-zero) annual net domestic inflation rate is

3.59%. This is approximated by the 'Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, Percent Change of (Index 1982-1984=100), Annual, Seasonally Adjusted'. Source: Federal Reserve Economic Data. Economic Research Division. Federal Reserve Bank of St. Louis.

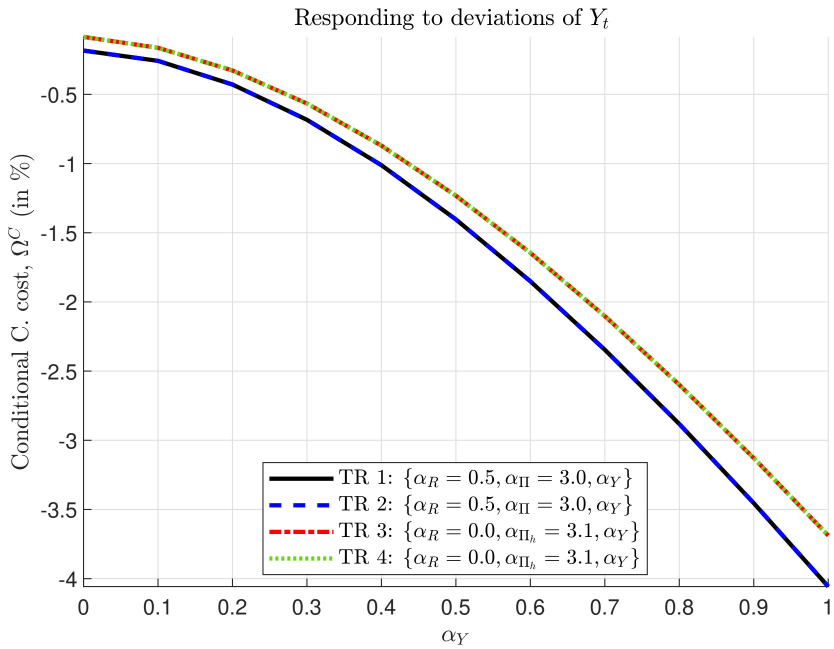
The annual nominal net interest rate is equal to $R_n = 7.13\%$. This is approximated by the 3-Month or 90-day Rates and Yields: Interbank Rates for Norway, Percent/100, Quarterly, Not Seasonally Adjusted. IR3TIB01NOM156N, 1979Q1-2017Q4. Source: Federal Reserve Economic Data. Economic Research Division. Federal Reserve Bank of St. Louis.

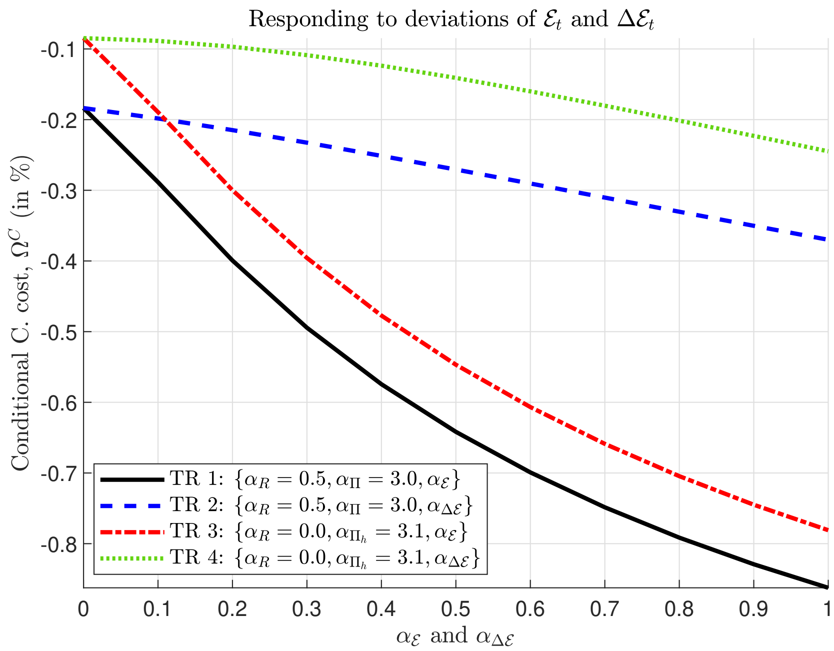
Home consumption bias historical average mean accounts for $1 - \alpha = 1 - 0.3153$ (which is within one standard deviation interval around the historical average mean of the economy in question). This is measured as of imports of goods and services (% of GDP). Imports of goods and services represent the value of all goods and other market services received from the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments. Source: World Development Indicators. Link: https://data.worldbank.org/indicator/NE.IMP.GNFS.ZS?locations=NO.

Given the set of exogenous processes, $\mathcal{X} \in \{A_{h,t}, A_{o,t}, R_t^*, C_t^*, \Pi_t^*, P_{o,t}^*/P_t^*\}$, first-order autocorrelation values are correspondingly assigned as $\rho_{\mathcal{X}} \in \{0.8277, 0.5887, 0.9614, 0.90, 0.3643, 0.90\}$. Likewise, the standard deviation for each process is respectively given by $\sigma_{\mathcal{X}} \in \{0.0295, 0.0525, 0.0011, 0.0333, 0.0273, 0.10\}$. The parameterizations for $A_{h,t}$ and $A_{o,t}$ follow (posterior values from) Drechsel and Tenreyro (2018); for R_t^* and Π_t^*, García-Cicco et al. (2014); and finally, for C_t^* and $P_{o,t}^*/P_t^*$, Drechsel et al. (2019).

2.1.4 Correlated shocks scenario: figures

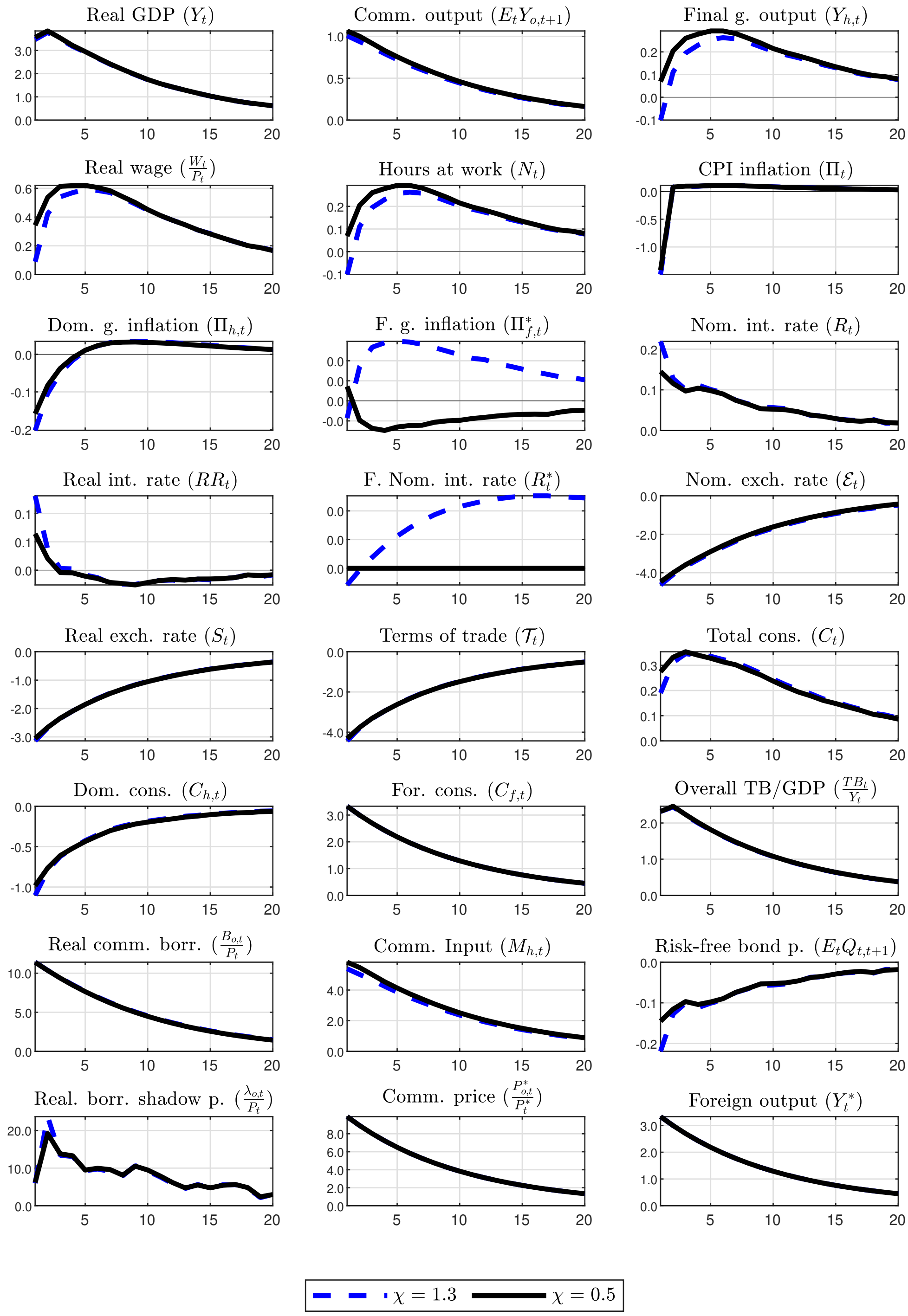
Figure A.2.1: Sub-optimal Taylor-type rule specifications





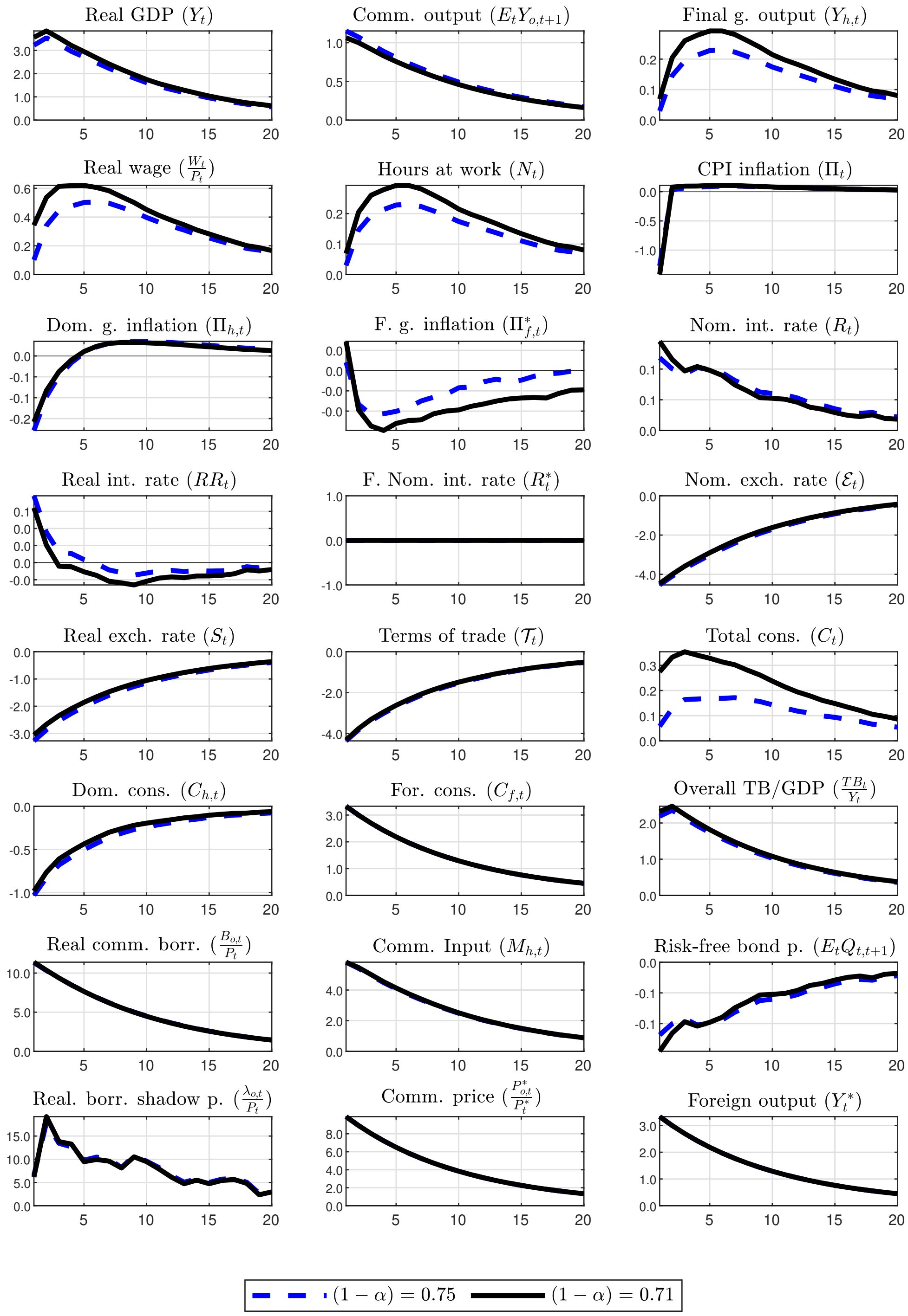
Note. The importance of not responding to deviations of Y_t (real gross domestic product), $\mathcal{E}_t$ (level of the nominal exchange rate, NER) and $\Delta\mathcal{E}_t$ (appreciation/depreciation of the NER). C. cost = compensating cost; TR = Taylor rule. The conditional compensating cost Ω^C, as defined in (2.26), indicates the fraction of consumption required to equate the conditional welfare under the baseline policy regime ($\mathscr{W}_0^{C,b}$) to the one achieved under another policy rule ($\mathscr{W}_0^{C,o}$). A negative value implies inferior welfare with respect to the (theoretical and optimal) Ramsey policy. As a result, evaluated rules with negative welfare values are sup-optimal. Coefficients that do not appear in the Taylor-type rule specification (written in the plot legend) are set to zero. They exactly follow the specifications as indicated in Table (2.1) which shows the optimized Taylor-type rules to a correlated CPS and WAS scenario.

Figure A.2.2: IRFs to a correlated CPS & WAS scenario under the optimal (Ramsey) policy (in %)



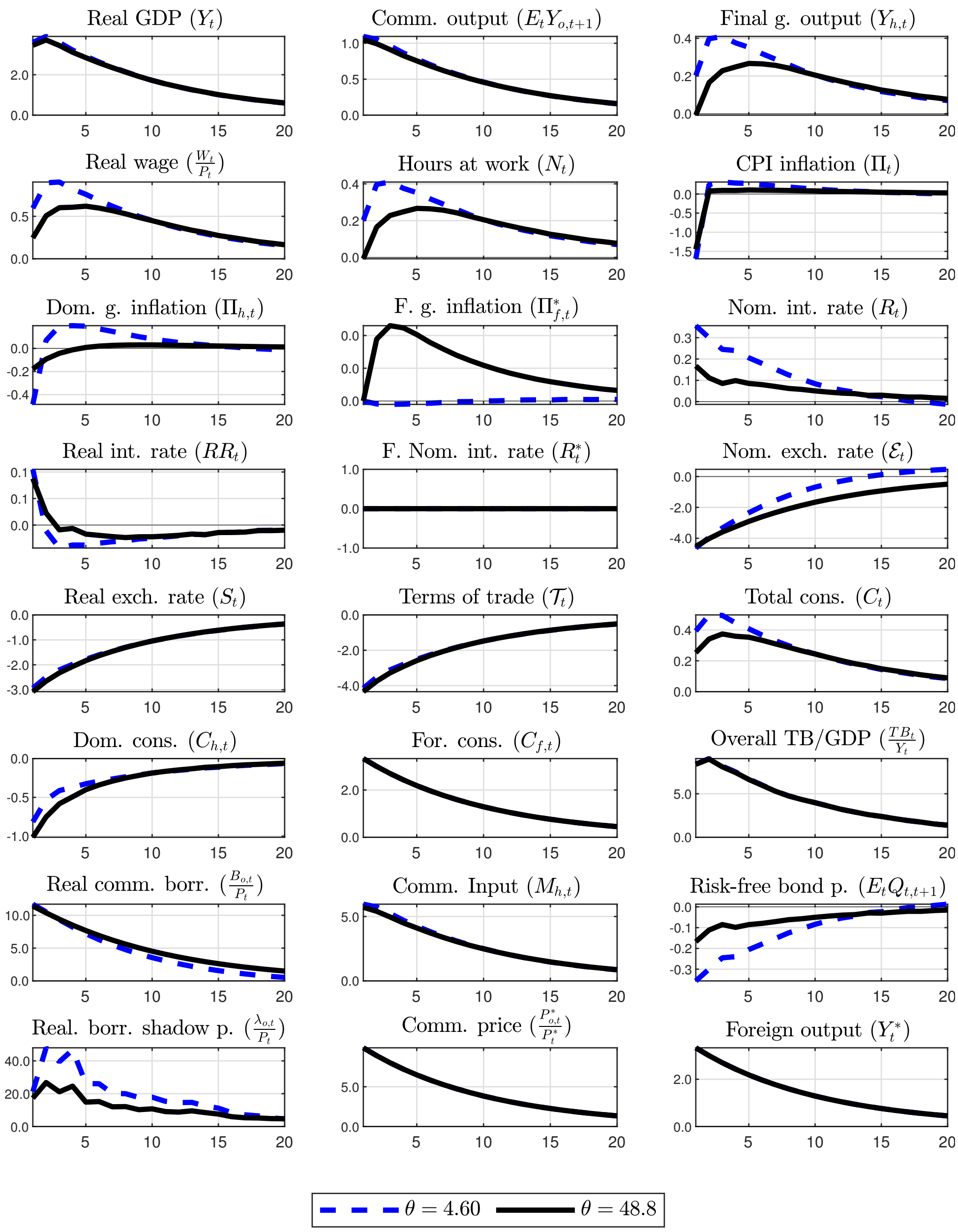
Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock and 3.33% positive world activity shock. The correlation between both shocks is set to 0.99. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. An appreciation corresponds to a drop in the nominal or real exchange rates.

Figure A.2.3: IRFs to a correlated CPS & WAS scenario under the optimal (Ramsey) policy (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock and 3.33% positive world activity shock. The correlation between both shocks is set to 0.99. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. An appreciation corresponds to a drop in the nominal or real exchange rates.

Figure A.2.4: IRFs to a correlated CPS & WAS scenario under the optimal (Ramsey) policy (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock and 3.33% positive world activity shock. The correlation between both shocks is set to 0.99. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. An appreciation corresponds to a drop in the nominal or real exchange rates.

2.1.5 Commodity price shock scenario: details

Table A.2.1: Optimized monetary policy rules to a CPS scenario

Panel (a): Welfare evaluation

Regime (policy rule)	C. Welfare $\mathscr{W}_0^C$	C. C. cost Ω^C (%)	U. Welfare $\mathscr{W}_0^U$	U. C. cost Ω^U (%)	Optimized parameters α_R	α_Π	α_{Π_h}	α_Y	$\alpha_\mathcal{E}$	$\alpha_{\Delta\mathcal{E}}$
Ramsey	-42.029	0.000	-42.053	0.000	–	–	–	–	–	–
Strict CPI (Π_t)	-42.204	-0.146	-42.224	-0.143	–	–	–	–	–	–
Strict domestic ($\Pi_{h,t}$)	-42.039	-0.008	-42.056	-0.003	–	–	–	–	–	–
NER ($\mathcal{E}_t$)	-43.494	-1.218	-43.539	-1.235	–	–	–	–	–	–
NER change ($\Delta\mathcal{E}_t$)	-43.494	-1.218	-43.539	-1.235	–	–	–	–	–	–
Taylor rule 1	-42.156	-0.106	-42.175	-0.102	0.0	2.9	–	0.0	0.0	–
Taylor rule 2	-42.156	-0.106	-42.175	-0.102	0.0	2.9	–	0.0	–	0.0
Taylor rule 3	-42.081	-0.043	-42.099	-0.039	0.0	–	3.1	0.0	0.0	–
Taylor rule 4	-42.081	-0.043	-42.099	-0.039	0.0	–	3.1	0.0	–	0.0

Panel (b): Second moments

Regime	Standard deviation (%) Y_t	$Y_{h,t}$	$Y_{o,t}$	C_t	Π_t	$\Pi_{h,t}$	$\Delta\mathcal{E}_t$	R_t	RR_t	N_t	$\mathscr{W}_{0,t}^C$
Ramsey	7.27	3.59	7.08	3.27	1.43	0.34	5.46	1.32	0.92	0.93	0.60
	[0.92]	[0.38]	[0.65]	[0.34]	[0.10]	[0.04]	[0.37]	[0.13]	[0.09]	[0.14]	[0.07]
Strict CPI (Π_t)	13.11	5.10	9.47	4.77	0.00	0.66	3.38	1.01	1.01	3.37	1.06
Strict domestic ($\Pi_{h,t}$)	13.16	5.90	9.45	4.75	1.29	0.00	5.41	1.01	0.77	2.15	1.06
NER ($\mathcal{E}_t$)	13.41	5.83	9.51	5.45	2.29	2.29	0.00	1.31	1.12	5.50	1.05
NER change ($\Delta\mathcal{E}_t$)	13.41	5.83	9.51	5.45	2.29	2.29	0.00	1.31	1.12	5.50	1.05
Taylor rule 1	13.10	5.10	9.47	4.55	0.40	0.56	3.66	1.17	0.95	3.05	1.05
Taylor rule 2	13.10	5.10	9.47	4.55	0.40	0.56	3.66	1.17	0.95	3.05	1.05
Taylor rule 3	13.13	5.58	9.49	4.48	1.20	0.37	5.10	1.16	0.67	2.28	1.05
Taylor rule 4	13.13	5.58	9.49	4.48	1.20	0.37	5.10	1.16	0.67	2.28	1.05

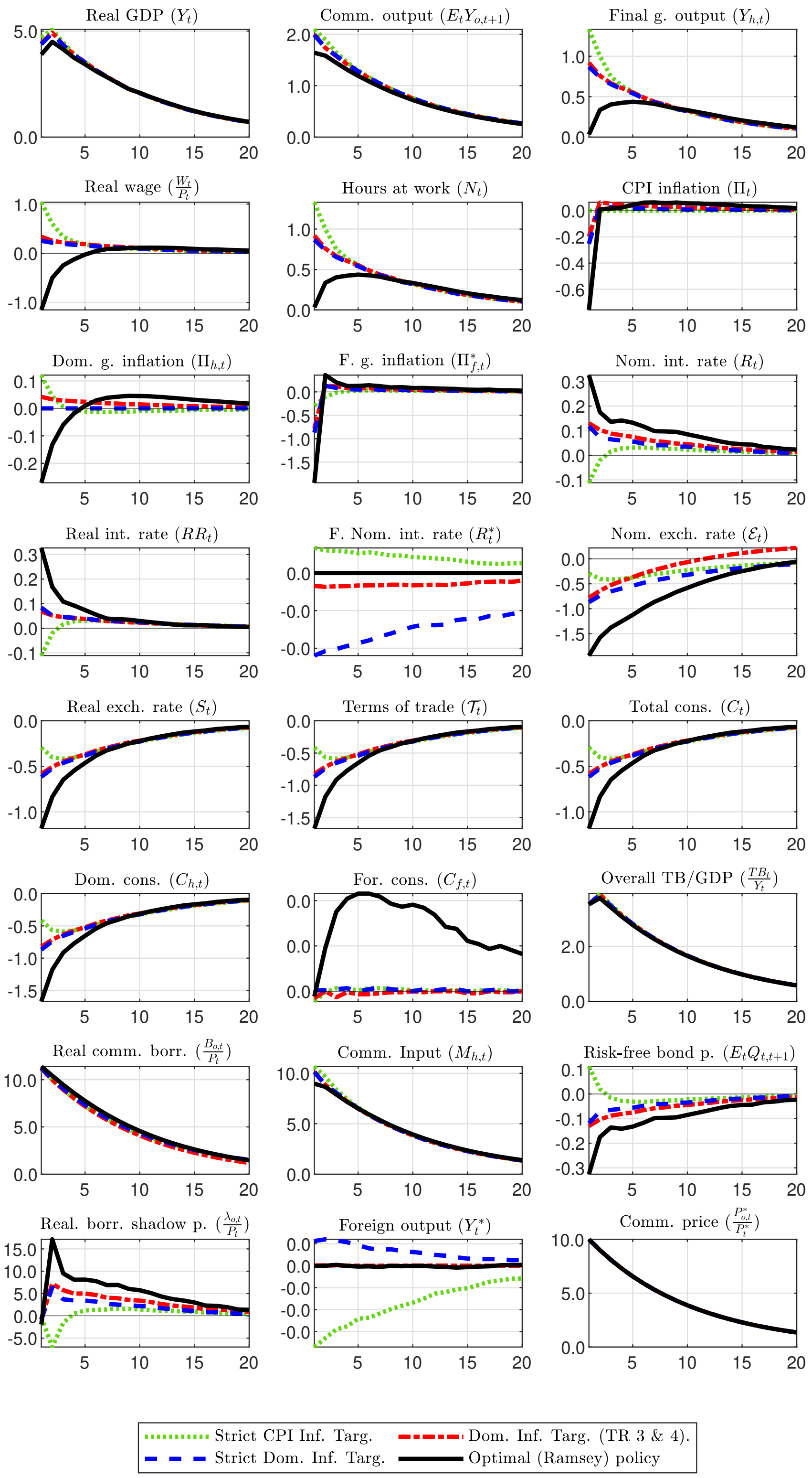
Note. CPS = commodity price shock; C. = Conditional; U. = unconditional; C. cost = compensation cost; CPI = consumer price index; NER = nominal exchange rate. Panel (a): rules are evaluated under the same steady state. A dash indicates the absence of the respective parameter in the specified rule. Parameter values increase at 0.1 step within its respective grid, which is defined as $\{\alpha_R\}$ ∈[0,0.9], $\{\alpha_\Pi, \alpha_{\Pi_h}\}$ ∈[0,3.1] and $\{\alpha_Y, \alpha_\mathcal{E}, \alpha_{\Delta\mathcal{E}}\}$ ∈[0,1]. Note that the Ramsey plan is taken as the conditional or unconditional welfare baseline measure ($\mathscr{W}_0^{\{C,U\},b}$). Panel (b): standard deviations are in percentage and correspond to the percentage deviation of each variable with respect to its respective steady state. The row of numbers in brackets under the Ramsey second moments are the standard deviation of the simulation of 2000 replications for 20 periods corresponding to each variable.

Table A.2.2: Optimal (Ramsey) policy to a higher loan-to-value ratio (χ)

LR χ	C. Welfare $\mathscr{W}_0^{C,b}$	U. Welfare $\mathscr{W}_0^{U,b}$	Standard deviation (%) Y_t	$Y_{h,t}$	$Y_{o,t}$	C_t	Π_t	$\Pi_{h,t}$	$\Delta\mathcal{E}_t$	R_t	RR_t	N_t	$\mathscr{W}_{0,t}^{C,b}$
0.7	-42.03	-42.05	7.27	3.59	7.08	3.27	1.43	0.34	5.46	1.32	0.92	0.93	0.60
			[0.92]	[0.38]	[0.65]	[0.34]	[0.10]	[0.04]	[0.37]	[0.13]	[0.09]	[0.14]	[0.07]
1.3	-42.05	-42.08	7.21	3.60	7.07	3.30	1.49	0.40	5.69	1.47	1.04	0.94	0.60
			[0.91]	[0.38]	[0.65]	[0.34]	[0.11]	[0.05]	[0.39]	[0.15]	[0.11]	[0.13]	[0.07]

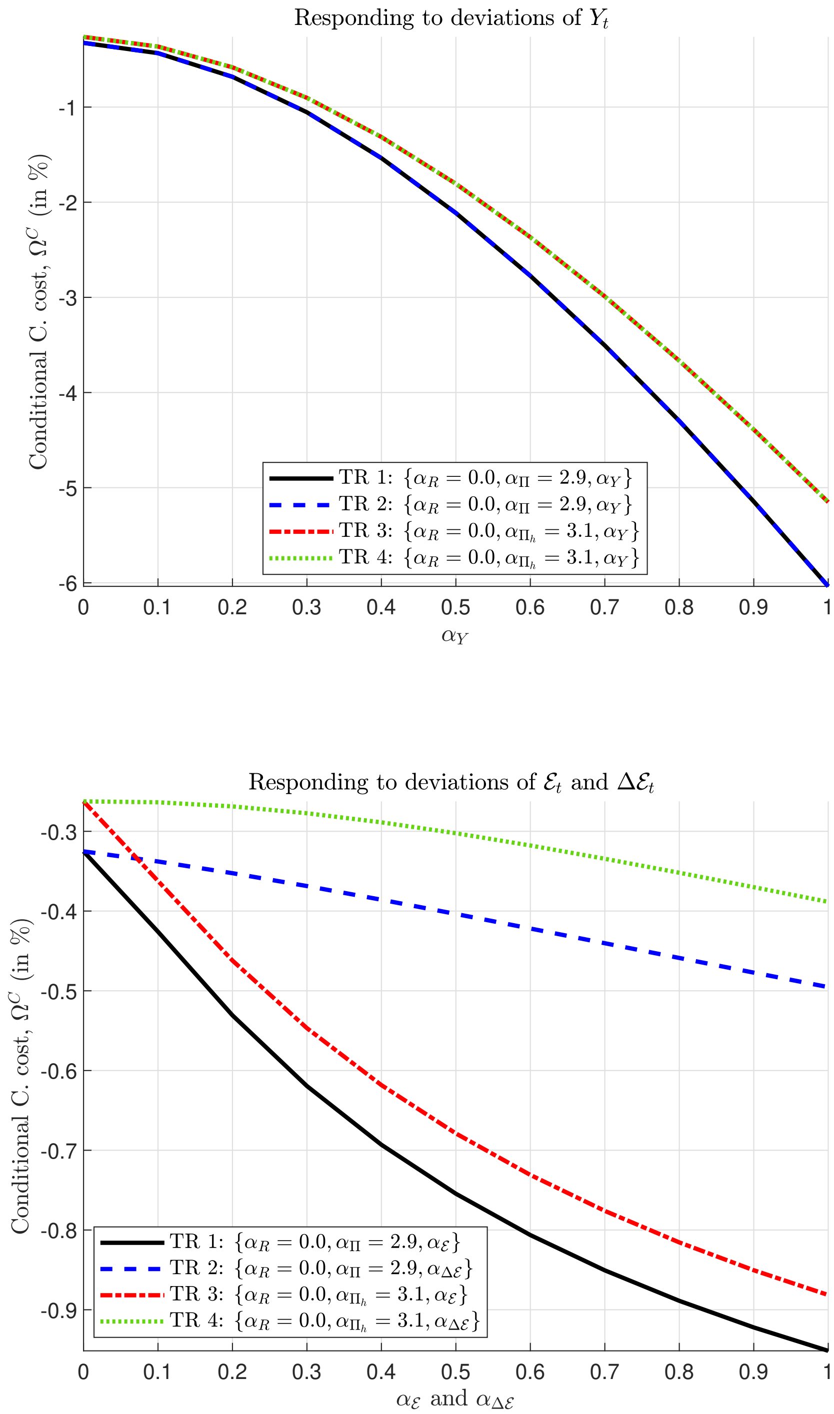
Note. LR = loan-to-value ratio (χ); C. = Conditional; U. = unconditional; $\mathscr{W}_0^{\{C,U\},b}$ = {conditional, unconditional} welfare baseline measure (b). Optimal (Ramsey) monetary policy to a 10% commodity price shock. Standard deviations are in percentage and correspond to the percentage deviation of each variable with respect to its respective steady state. The row of numbers in brackets are the standard deviation of the simulation of 2000 replications for 20 periods corresponding to each variable.

Figure A.2.5: IRFs to a CPS scenario under selected policy regimes (in %)



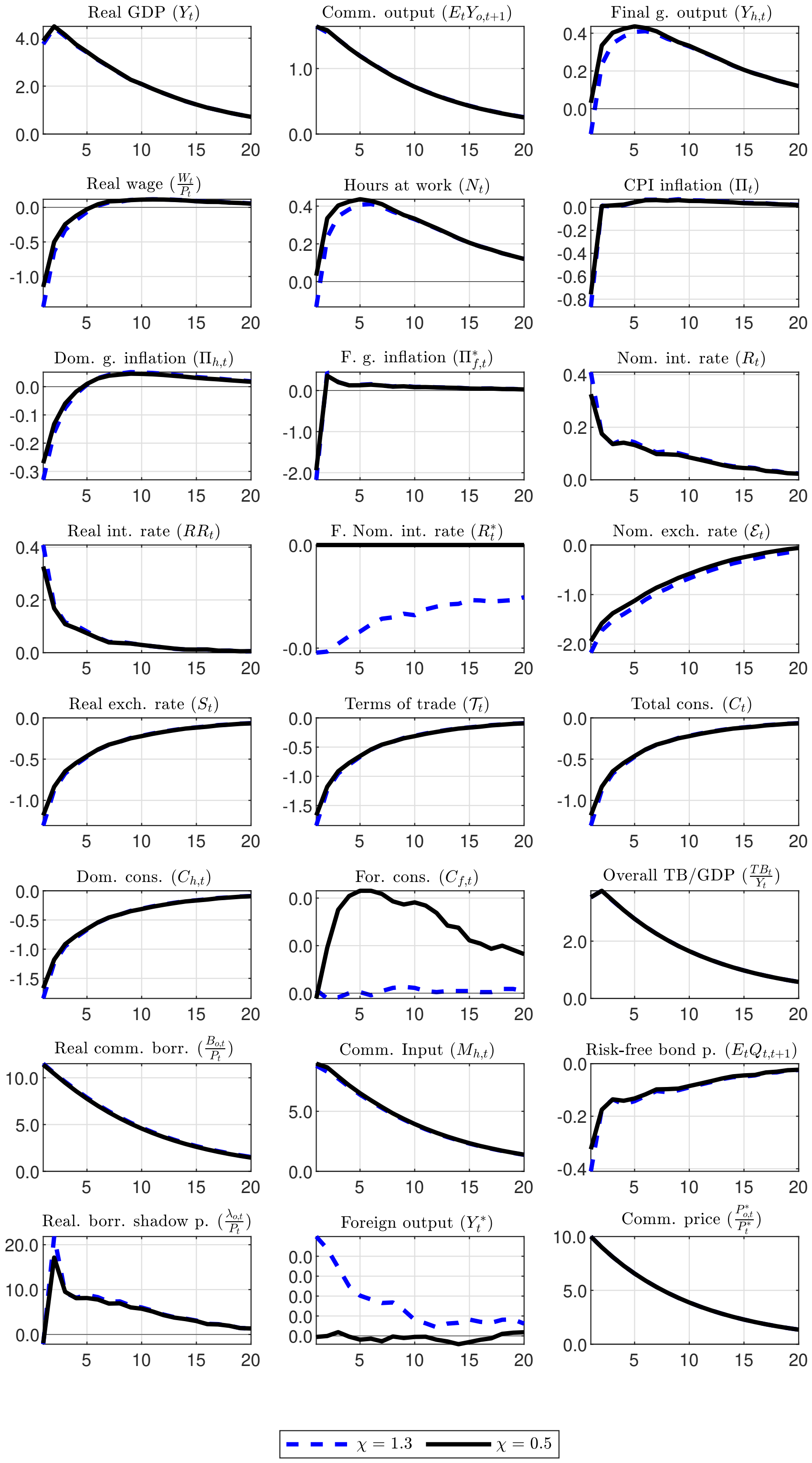
Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. An appreciation corresponds to a drop in the nominal or real exchange rates.

Figure A.2.6: Sub-optimal Taylor-type rule specifications



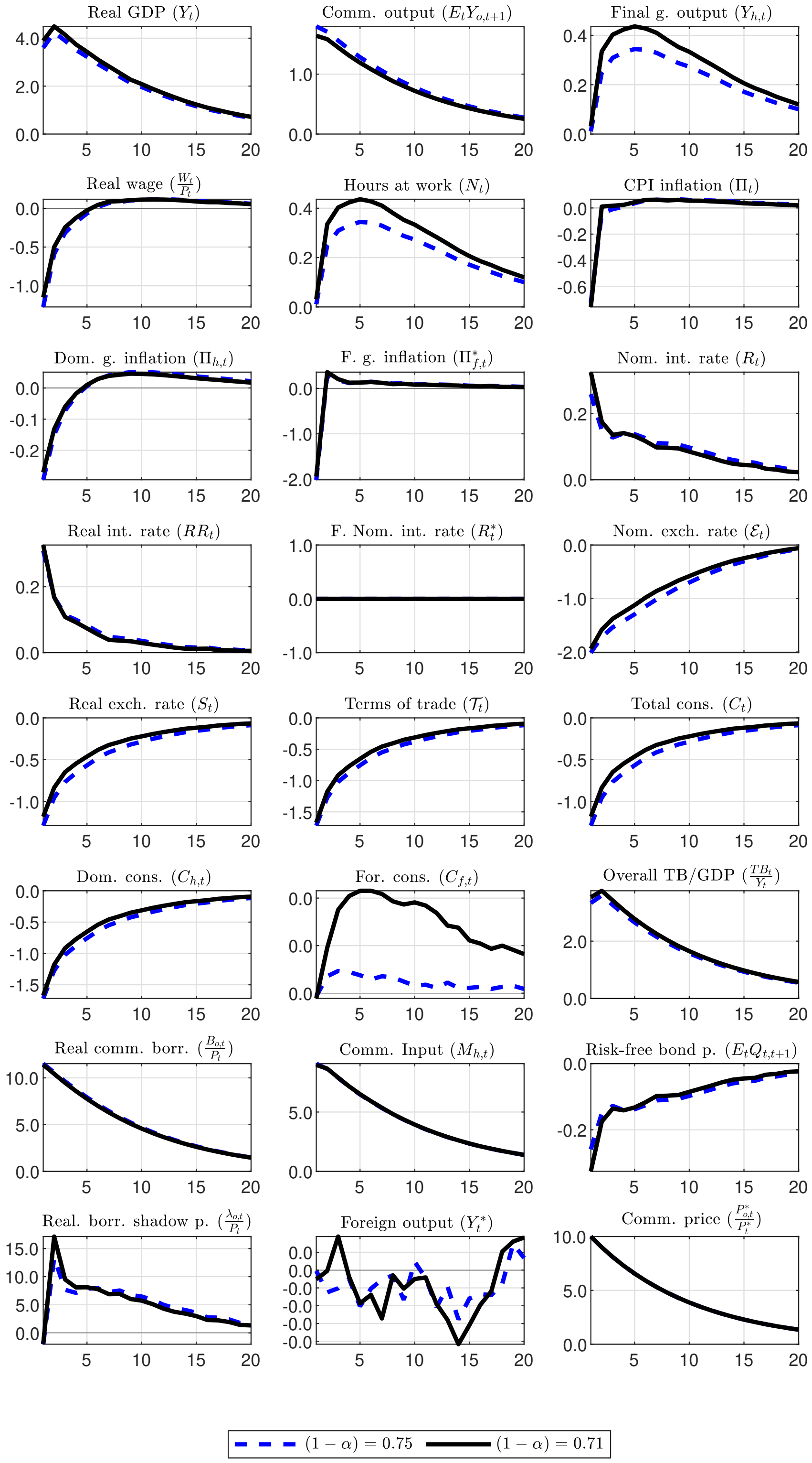
Note. The importance of not responding to deviations of Y_t (real gross domestic product), $\mathcal{E}_t$ (level of the nominal exchange rate, NER) and $\Delta\mathcal{E}_t$ (appreciation/depreciation of the NER). C. cost = compensating cost; TR = Taylor rule. The conditional compensating cost Ω^C, as defined in (2.26), indicates the fraction of consumption required to equate the conditional welfare under the baseline policy regime ($\mathscr{W}_0^{C,b}$) to the one achieved under another policy rule ($\mathscr{W}_0^{C,o}$). A negative value implies inferior welfare with respect to the (theoretical and optimal) Ramsey policy. As a result, evaluated rules with negative welfare values are sup-optimal. Coefficients that do not appear in the Taylor-type rule specification (written in the plot legend) are set to zero. They exactly follow the specifications as indicated in Table (A.2.1) which shows the optimized Taylor-type rules to a CPS scenario.

Figure A.2.7: IRFs to a CPS scenario under the optimal (Ramsey) policy (in %)



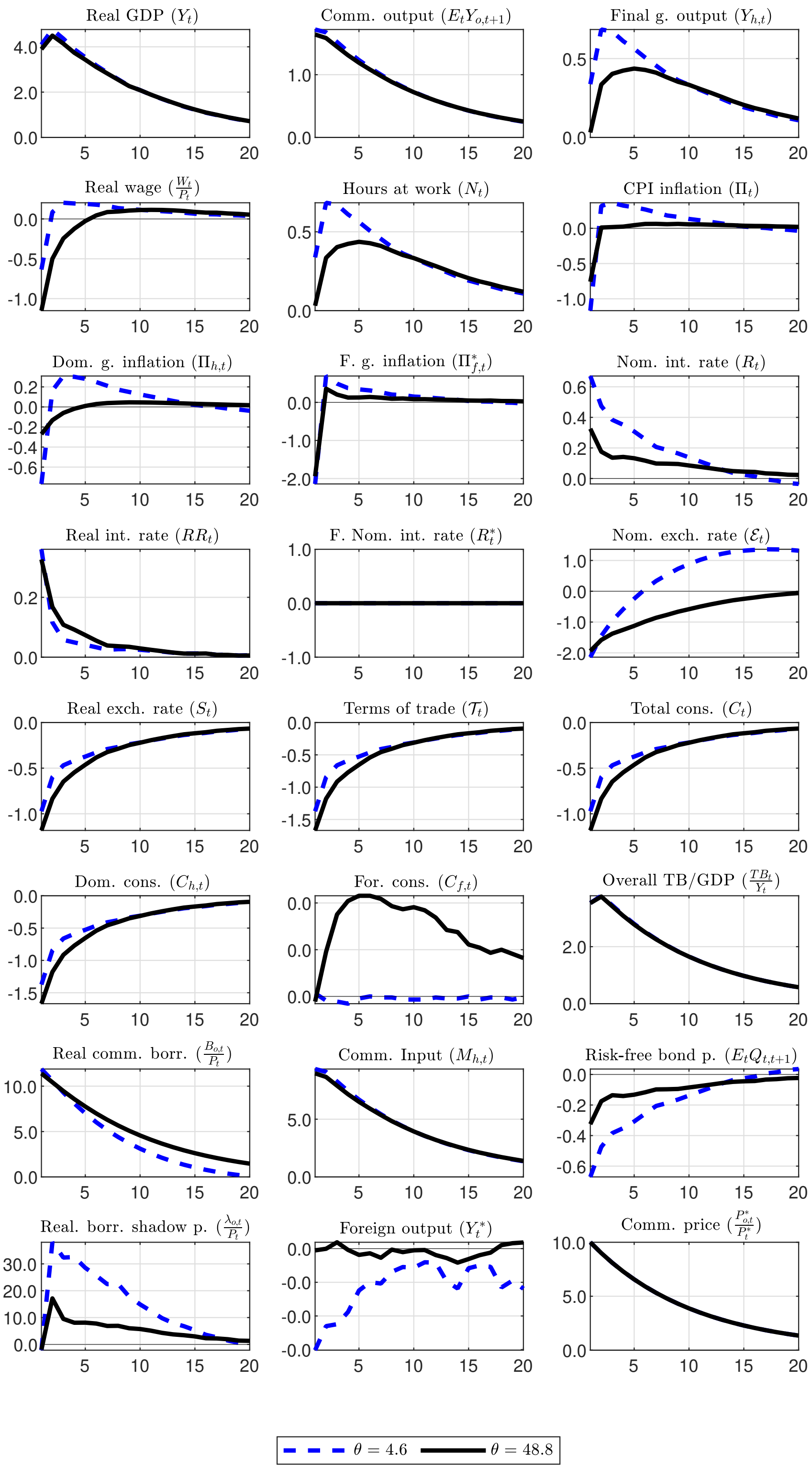
Note. The impulse–response function (IRF) plots display a 10% (positive) commodity price shock. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. An appreciation corresponds to a drop in the nominal or real exchange rates.

Figure A.2.8: IRFs to a CPS scenario under the optimal (Ramsey) policy (in %)



Note. The impulse–response function (IRF) plots display a 10% (positive) commodity price shock. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. An appreciation corresponds to a drop in the nominal or real exchange rates.

Figure A.2.9: IRFs to a CPS scenario under each policy regime (in %)



Note. The impulse–response function (IRF) plots display a 10% (positive) commodity price shock. Horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. An appreciation corresponds to a drop in the nominal or real exchange rates.

Table A.2.3: Optimal (Ramsey) policy to a higher home consumption bias $(1-\alpha)$

	C.	U.											
HCB	Welfare	Welfare	Standard deviation (%)										
$1-\alpha$	$\mathscr{W}_0^{C,b}$	$\mathscr{W}_0^{U,b}$	Y_t	$Y_{h,t}$	$Y_{o,t}$	C_t	Π_t	$\Pi_{h,t}$	$\Delta\mathcal{E}_t$	R_t	RR_t	N_t	$\mathscr{W}_{0,t}^{C,b}$
0.71	-42.03	-42.05	7.27	3.59	7.08	3.27	1.43	0.34	5.46	1.32	0.92	0.93	0.60
			[0.92]	[0.38]	[0.65]	[0.34]	[0.10]	[0.04]	[0.37]	[0.13]	[0.09]	[0.14]	[0.07]
0.75	-36.34	-36.37	6.96	3.53	7.25	3.35	1.22	0.37	5.41	1.14	0.83	0.72	0.71
			[0.88]	[0.38]	[0.67]	[0.35]	[0.08]	[0.04]	[0.36]	[0.11]	[0.08]	[0.11]	[0.08]

Note. HCB = home consumption bias $(1-\alpha)$; C. = Conditional; U. = unconditional; $\mathscr{W}_0^{\{C,U\},b}$ = {conditional, unconditional} welfare baseline measurement (b). Optimal (Ramsey) monetary policy to a 10% commodity price shock. Standard deviations are in percentage and correspond to the percentage deviation of each variable with respect to its respective steady state. The row of numbers in brackets are the standard deviation of the simulation of 2000 replications for 20 periods corresponding to each variable.

Table A.2.4: A lower price rigidity (θ)

	C.	U.											
AC	Welfare	Welfare	Standard deviation (%)										
θ	$\mathscr{W}_0^{C,b}$	$\mathscr{W}_0^{U,b}$	Y_t	$Y_{h,t}$	$Y_{o,t}$	C_t	Π_t	$\Pi_{h,t}$	$\Delta\mathcal{E}_t$	R_t	RR_t	N_t	$\mathscr{W}_{0,t}^{C,b}$
Optimal (Ramsey) policy regime													
48.8	-42.03	-42.05	7.27	3.59	7.08	3.27	1.43	0.34	5.46	1.32	0.92	0.93	0.60
			[0.92]	[0.38]	[0.65]	[0.34]	[0.10]	[0.04]	[0.37]	[0.13]	[0.09]	[0.14]	[0.07]
4.6	-42.34	-42.51	7.55	3.74	7.16	3.15	2.18	1.53	5.84	2.26	0.88	1.15	0.60
			[0.98]	[0.41]	[0.64]	[0.33]	[0.25]	[0.23]	[0.45]	[0.28]	[0.11]	[0.18]	[0.07]
Strict domestic inflation targeting regime													
48.8	-42.04	-42.06	13.16	5.90	9.45	4.75	1.29	0.00	5.41	1.01	0.77	2.15	1.06
4.6	-42.04	-42.06	13.16	5.90	9.45	4.75	1.29	0.00	5.41	1.01	0.77	2.15	1.06
Strict CPI inflation targeting regime													
48.8	-42.20	-42.22	13.11	5.10	9.47	4.77	0.00	0.66	3.38	1.01	1.01	3.37	1.06
4.6	-42.08	-42.05	13.13	5.63	9.45	4.71	0.00	1.11	4.06	0.74	0.74	2.22	1.06

Note. AC = adjustment cost parameter (θ); C. = Conditional; U. = unconditional; $\mathscr{W}_0^{\{C,U\},b}$ = {conditional, unconditional} welfare baseline measure (b). Optimal (Ramsey) monetary policy to a 10% commodity price shock. Standard deviations are in percentage and correspond to the percentage deviation of each variable with respect to its respective steady state. The row of numbers in brackets are the standard deviation of the simulation of 2000 replications for 20 periods corresponding to each variable.

2.1.6 Supplementary material

Supplementary material (the online appendix) associated with this article can be found, in the online version, at (click here).

3.1 Appendix

3.1.1 Policy rules: additional details

Welfare measurements

The associated welfare measurement under the optimal commitment policy is given by

$$W^c(p^*_{c,t}, x^c_{t-1}) = -\frac{\Omega}{2}\omega^2\Big\{(a_\pi^2 + \lambda_x a_x^2)[\frac{1}{1-\beta\rho^2}(p^*_{c,t})^2 + \beta\sigma_\epsilon^2\frac{1}{1-\beta}\frac{1}{1-\rho^2}]$$

$$+(b_\pi^2 + \lambda_x b_x^2)\frac{1}{1-\beta b_x^2}[(\omega a_x)^2\rho^2\frac{1}{1-b_x^{-2}\rho^2}(p^*_{c,t})^2 + (\omega a_x)^2\sigma_\epsilon^2\frac{1}{1-b_x^2}\frac{1}{1-\rho^2}]\Big\}$$

$$-\frac{\Omega}{2}\omega^2\frac{(b_\pi^2 + \lambda_x b_x^2)}{1-\beta b_x^2}b_x^2(x^c_{h,t-1})^2. \tag{A.3.1}$$

The associated welfare measurement under the optimal discretionary policy is defined as

$$W^d(p^*_{c,t}) = -\frac{\frac{\Omega}{2}\omega^2(c_\pi^2 + \lambda_x c_x^2)}{1-\beta\rho^2}\big[(p^*_{c,t})^2 + \frac{\beta\sigma_\epsilon^2}{1-\beta}\frac{1-\beta\rho^2}{1-\rho^2}\big]. \tag{A.3.2}$$

Unconditional variances

Commodity price shock,

$$\sigma^2_{p^*_c} = \frac{\sigma_\epsilon^2}{1-\rho^2_{p^*_{c,t}}}. \tag{A.3.3}$$

Domestic output gap under the optimal commitment policy,

$$(\sigma_x^c)^2 = \frac{(\omega a_x)^2\sigma^2_{p^*_c}}{1-b_x^2}. \tag{A.3.4}$$

Domestic inflation under the optimal commitment policy ,

$$(\sigma_\pi^c)^2 = \frac{(\omega a_\pi)^2\sigma^2_{p^*_c}}{1-b_\pi^2}. \tag{A.3.5}$$

Domestic output gap under the optimal discretionary policy,

$$(\sigma_x^d)^2 = (\omega c_x)^2\sigma^2_{p^*_c}. \tag{A.3.6}$$

Domestic inflation under the optimal discretionary policy,

$$(\sigma_\pi^d)^2 = (\omega c_\pi)^2 \sigma_{p_c^*}^2. \tag{A.3.7}$$

3.1.2 Numerical algorithm: details

Given the state-space representation indicated in subsubsection 3.2.3, one can calculate $\hat{W}^d(p_{c,t}^*)$ as follows.

As of equations (3.4) and (3.9), one may write the state-space representation,

$$(1+\frac{\xi^2}{\lambda_x})\pi_h(p_{c,i}^*) = \beta \sum_j p(p_{c,j}^*|p_{c,i}^*)\pi_h(p_{c,j}^*) + \omega p_{c,i}^*.$$

Equivalently, in matrix notation,

$$\begin{bmatrix} \frac{1}{\omega}[1+\frac{\xi^2}{\lambda_x} - \beta p(p_{c,1}^*|p_{c,1}^*)] & -\frac{\beta}{\omega}p(p_{c,2}^*|p_{c,1}^*) & \cdots & -\frac{\beta}{\omega}p(p_{c,n_{p_c^*}}^*|p_{c,1}^*) \\ -\frac{\beta}{\omega}p(p_{c,1}^*|p_{c,2}^*) & \frac{1}{\omega}[1+\frac{\xi^2}{\lambda_x} - \beta p(p_{c,2}^*|p_{c,2}^*)] & \cdots & -\frac{\beta}{\omega}p(p_{c,n_{p_c^*}}^*|p_{c,2}^*) \\ \vdots & \vdots & \ddots & \vdots \\ -\frac{\beta}{\omega}p(p_{c,1}^*|p_{c,n_{p_c^*}}^*) & -\frac{\beta}{\omega}p(p_{c,2}^*|p_{c,n_{p_c^*}}^*) & \cdots & \frac{1}{\omega}[1+\frac{\xi^2}{\lambda_x} - \beta p(p_{c,n_{p_c^*}}^*|p_{c,n_{p_c^*}}^*)] \end{bmatrix}$$
$$\begin{bmatrix} \pi_h(p_{c,1}^*) \\ \pi_h(p_{c,2}^*) \\ \vdots \\ \pi_h(p_{c,n_{p_c^*}}^*) \end{bmatrix} = \begin{bmatrix} p_{c,2}^* \\ p_{c,2}^* \\ \vdots \\ p_{c,n_{p_c^*}}^* \end{bmatrix},$$

where each grid for the shock makes possible to solve for $\pi_h(p_{c,i}^*)$. Subsequently, once $\pi_h(p_{c,i}^*)$ is known, substituting (3.9) into (3.5) one can solve for $\hat{W}^d(p_{c,i}^*)$. In recursive terms,

$$\hat{W}^d(p_{c,i}^*) = -\frac{\Omega}{2}(1+\frac{\xi^2}{\lambda_x})[\pi_h(p_{c,i}^*)]^2 + \beta \sum_j p(p_{c,j}^*|p_{c,i}^*)\hat{W}^d(p_{c,j}^*).$$

The numerical algorithm follows the same steps as Sunakawa (2015). Next points describe the algorithm steps.

1. Initial guess values for functions $\hat{W}^{(0)}(u)$ and $\pi_h^{(0)}(u)$ are set according to each grid point on $P \times X$ of the space $u = (p_c^*, x_{h,-1})$.

2. For every grid point u, the equations for $(W^{i,u}, \pi_h^{i,u}, x_h^{i,u}, z^{i,u})$ are solved, given the functions $W^{(i-1)}(p_c^{*\prime}, x_h)$ and $\pi_h^{i-1}(p_c^{*\prime}, x_h)$.

3. Set the new functions as $W^{(i)}(u) = \{W^{i,u}\}_{u\in P\times X}$ and $\pi_h^{(i)}(u) = \{\pi_h^{i,u}\}_{u\in P\times X}$.

4. Iterate steps 2 and 3 until the functions $W^{(i)}(u)$ and $\pi_h^{(i)}(u)$ converge at each grid point.

The two relevant cases for the sustainability constraint are that it may bind or not.

In case the sustainability constraint binds, $z^{i,u} = 1$. Solve
$W^{i,u} = -\frac{\Omega}{2}([\pi_h^{i,u}]^2 + \lambda_x[x_h^{i,u}]^2) + \beta \sum_{u'} p(u'|u)W^{(i-1)}(u', x_h^{i,u})$,
$x_h^{i,u} = -\frac{\xi}{\lambda_x}\pi_h^{i,u} + x_{h,-1}$,
$\pi_h^{i,u} = \xi x_h^{i,u} + \beta \sum_{p_c^{*\prime}} p(p_c^{*\prime}|p_c^*)\pi_h^{(i-1)} + \omega p_c^*$,
for the values of $(x_h^{i,u}, \pi_h^{i,u}, W^{i,u})$.

In case the sustainability constraint does not bind, $z^{i,u} \in (0,1)$ and $W^{i,u} = \tilde{W}^d(p_c^*)$. Solve
$\tilde{W}^d(p_c^*) = -\frac{\Omega}{2}([\pi_h^{i,u}]^2 + \lambda_x[x_h^{i,u}]^2) + \beta \sum_{u'} p(u'|u)W^{(i-1)}(u', x_h^{i,u})$,
$x_h^{i,u} = -\frac{\xi}{\lambda_x}\pi_h^{i,u} + z^{i,u}x_{h,-1}$,
$\pi_h^{i,u} = \xi x_h^{i,u} + \beta \sum_{p_c^{*\prime}} p(p_c^{*\prime}|p_c^*)\pi_h^{(i-1)} + \omega p_c^*$,
for the values of $(x_h^{i,u}, \pi_h^{i,u}, z^{i,u})$.

Then, as $x_h^{i,u}$ may not be on the grid point, these functions are approximated using a spline interpolation for those points of X, while an outerpolation, for those outside of X. For conditional expectations, cubic splines are used. So that, $h_{w,i}(x_h) = \sum_{p_{c,j}^*} p(p_{c,j}^*|p_{c,i}^*)W(p_{c,j}^*, x_h)$ and $h_{\pi_h,i}(x_h) = \sum_{p_{c,j}^*} p(p_{c,j}^*|p_{c,i}^*)\pi_h(p_{c,j}^*, x_h)$, for each point of the grid $(i = 1, ..., n_{p_c^*})$.

Error approximation

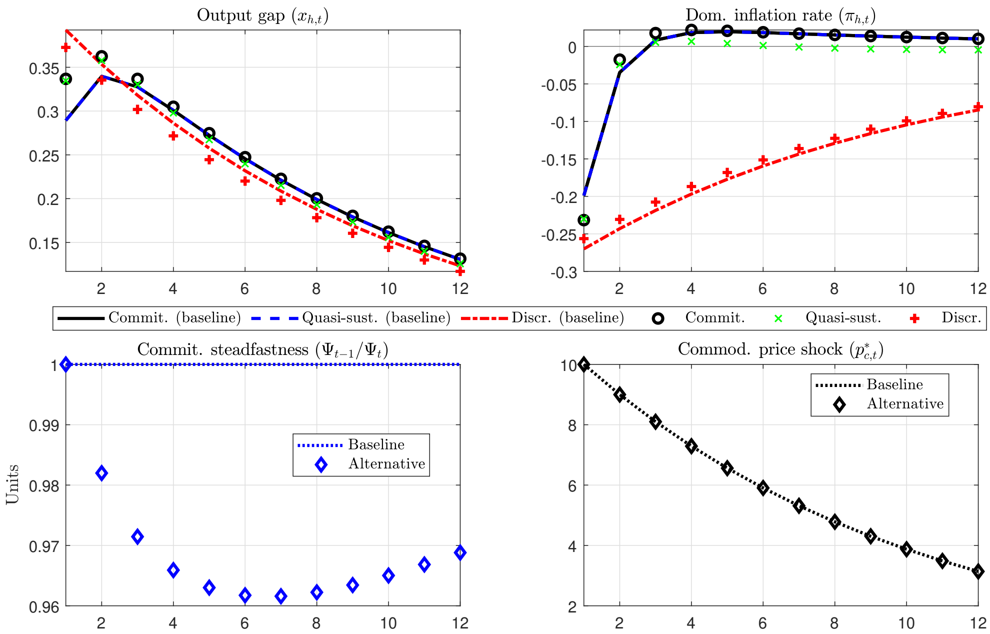
Error computations are effectuated using the residual function specification,

$$R(\tilde{u}) = -W(\tilde{u}) - ([\pi_h(\tilde{u})]^2 + \lambda_x[x_h(\tilde{u})]^2) + \beta h_{w,i}(x_h(\tilde{u})),$$

where $\tilde{u} \in \tilde{X} \times P$ is a grid with a larger number of points, in comparison to the ones used for result computations.

As in Sunakawa (2015), the total number of grids are 201. They are used to compare $\tilde{X}$ against X, which is obtained using 15 grids. To evaluate $W(\tilde{u})$, $\pi_h(\tilde{u})$ and $x_h(\tilde{u})$, a linear interpolation is used. Moreover, absolute and relative errors are also computed as $e^{abs} = \|R(\tilde{u})\|_\infty$ and $e^{abs} = \|R(\tilde{u})/W(\tilde{u})\|_\infty$. Note that $R(u) = 0$ holds for $u \in X \times P$. Details for the calculated errors are displayed in Table A.3.3.

Figure A.3.1: Varying the discount factor: $\beta = \{0.9963, 0.6\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

3.1.3 Results: additional details

Table A.3.1: Simulated standard deviations (in %)

Order	Model scenario	$\pi_{h,t}^{\{s,c\}}$	$\pi_{h,t}^{d}$	$x_{h,t}^{\{s,c\}}$	$x_{h,t}^{d}$	$\Delta e_t^{\{s,c\}}$	Δe_t^{d}	$\pi_t^{\{s,c\}}$	π_t^{d}	$i_t^{\{s,c\}}$	i_t^{d}	$r_t^{\{s,c\}}$	r_t^{d}	$s_t^{\{s,c\}}$	s_t^{d}	$p_{c,t}^{*}$
1	Baseline ($\chi = 0.5$)	***0.22	0.63	*0.91	0.92	2.34	2.31	6.25	6.14	5.39	5.48	2.35	2.35	5.19	5.26	23.46
2	$\chi = \{0.5, 0.9\}$	***0.04	0.13	*0.18	0.18	2.97	2.96	7.92	7.90	6.60	6.62	2.98	2.98	6.57	6.58	23.47
3	$\chi = \{0.5, 1.5\}$	***0.22	0.63	*0.91	0.92	3.91	3.95	10.44	10.59	8.48	8.41	3.92	3.92	8.63	8.56	23.45
4	$\chi = \{0.5, 2\}$	***0.43	1.27	*1.81	1.84	4.70	4.78	12.55	12.87	10.04	9.94	4.70	4.70	10.32	10.18	23.39
5	$s_{y_c} = \{0.2, 0.3\}$	***0.22	0.63	*0.91	0.92	2.34	2.31	6.24	6.14	5.38	5.47	2.35	2.35	5.18	5.25	23.42
6	$s_m = \{0.15, 0.30\}$	***0.35	1.03	*1.45	1.47	3.72	3.67	9.91	9.74	8.63	8.78	3.73	3.73	8.24	8.33	23.44
7	$1 - \theta = \{0.25, 0.40\}$	***0.26	0.66	0.94	0.95	2.34	2.31	6.24	6.13	5.41	5.49	2.35	2.35	5.19	5.26	23.44
8	$DM = \{1.2, 1.3\}$	***0.28	0.86	**0.89	0.90	2.34	2.30	6.24	6.11	5.38	5.49	2.35	2.35	5.19	5.28	23.42
9	$\rho_{p_c^*} = \{0.9, 0.0\}$	***0.19	0.19	***0.23	0.27	3.10	3.09	8.24	8.21	2.64	2.76	3.13	3.13	2.22	2.22	10.06
10	$\sigma_{p_c^*} = \{0.1, 0.5\}$	***1.08	3.17	*4.54	4.61	11.71	11.56	31.22	30.69	26.94	27.39	11.75	11.74	25.95	26.31	117.27
11	$\beta = \{0.9963, 0.9\}$	***0.23	0.62	***0.92	0.90	2.34	2.31	6.25	6.14	5.39	5.46	2.35	2.35	5.18	5.25	23.42
12	$\phi = \{3, 1\}$	***0.38	1.25	***1.75	1.76	2.56	2.52	6.84	6.68	6.08	6.29	2.57	2.57	5.68	5.82	23.40
13	$\beta = \{0.9963, 0.6\}$	***0.21	0.60	***0.93	0.87	2.34	2.31	6.23	6.14	5.40	5.45	2.35	2.35	5.18	5.24	23.39

Note. Simulation results for each policy rule are obtained using the same pseudo-random numbers to perform 2000 replications for 1100 initial periods (10% of the initial periods are discarded to avoid initial value effects). The probability of binding the sustainability constraint is nil for each one of the first twelve scenarios, $Pr(z < 1) = 0.00$; although positive and equal to 79.6% for the last scenario. Superscript s = optimal quasi-sustainable policy; Superscript c = optimal commitment policy; Superscript d = optimal discretionary policy. β = subjective discount factor; χ = elasticity borrowing limit to commodity price (financial channel parameter); DM = desired markup; $\rho_{p_c^*}$ = auto-correlation parameter of the foreign commodity price shock; $\sigma_{p_c^*}$ = standard deviation parameter of the foreign commodity price shock; s_m = share of inputs used for commodity production goods; $1 - \theta$ = Calvo price re-set probability; s_{y_c} = Share of the comm. producing sector to GDP; ϕ = Inverse Frisch elasticity rate. Statistical significance for a Two-sample F-test of equal variances denoted as: * $p < 0.1$,** $p < 0.05$,*** $p < 0.01$.

Table A.3.2: Simulated correlation matrices (in %)

Variables	$\pi^{\{s,c\}}_{h,t}$	$x^{\{s,c\}}_{h,t}$	$\pi^{d}_{h,t}$	$x^{d}_{h,t}$	$p^{*}_{c,t}$
$\chi = 0.5$, $\omega = -0.01$ (baseline)					
$\pi^{\{s,c\}}_{h,t}$	100.00	-18.48	31.40	-31.40	-30.83
$x^{\{s,c\}}_{h,t}$	-18.48	100.00	-99.11	99.11	87.47
$\pi^{d}_{h,t}$	31.40	-99.11	100.00	-100.00	-88.67
$x^{d}_{h,t}$	-31.40	99.11	-100.00	100.00	88.67
$p^{*}_{c,t}$	-30.83	87.47	-88.67	88.67	100.00
$\chi = 0.9$, $\omega = -0.003$					
$\pi^{\{s,c\}}_{h,t}$	100.00	-17.16	29.27	-29.27	-27.00
$x^{\{s,c\}}_{h,t}$	-17.16	100.00	-99.23	99.23	89.20
$\pi^{d}_{h,t}$	29.27	-99.23	100.00	-100.00	-89.98
$x^{d}_{h,t}$	-29.27	99.23	-100.00	100.00	89.98
$p^{*}_{c,t}$	-27.00	89.20	-89.98	89.98	100.00
$\chi = 1.5$, $\omega = 0.01$					
$\pi^{\{s,c\}}_{h,t}$	100.00	-17.56	30.37	-30.37	26.24
$x^{\{s,c\}}_{h,t}$	-17.56	100.00	-99.13	99.13	-87.80
$\pi^{d}_{h,t}$	30.37	-99.13	100.00	-100.00	88.48
$x^{d}_{h,t}$	-30.37	99.13	-100.00	100.00	-88.48
$p^{*}_{c,t}$	26.24	-87.80	88.48	-88.48	100.00
$\chi = 2$, $\omega = 0.0273$					
$\pi^{\{s,c\}}_{h,t}$	100.00	-17.12	29.06	-29.06	27.23
$x^{\{s,c\}}_{h,t}$	-17.12	100.00	-99.34	99.34	-89.39
$\pi^{d}_{h,t}$	29.06	-99.25	100.00	-100.00	90.20
$x^{d}_{h,t}$	-29.06	99.25	-100.00	100.00	-90.20
$p^{*}_{c,t}$	27.23	-89.39	90.20	-90.20	100.00

Note. Simulation results for each policy rule are obtained using the same pseudo-random numbers to perform 2000 replications for 1100 initial periods (10% of the initial periods are discarded to avoid initial value effects). Superscript s = optimal quasi-sustainable policy; Superscript c = optimal commitment policy; Superscript d = optimal discretionary policy.

3.2 Supplementary material

3.2.1 Other predictions of the DMT model

Varying the financial channel: elastic elasticities

According to the structure of DMT's model (subsection 3.2.1) and the NKPC (equation (3.4)), the parameter ω depends on the value of the financial channel parameter χ (equation (3.3)). Then, if it is assumed that the elasticity that measures borrowing conditions for the representa-

Table A.3.3: Errors summary for the optimal quasi-sustainable monetary policy (in %)

Order	Model scenario	Absolute			Relative		
		$W(\tilde{u})$	$\pi_{h,t}(\tilde{u})$	$x_{h,t}(\tilde{u})$	$W(\tilde{u})$	$\pi_{h,t}(\tilde{u})$	$x_{h,t}(\tilde{u})$
1	Baseline ($\chi = 0.5$)	9.94E-04	7.59E-16	2.78E-15	4.21E-02	7.55E-16	2.71E-15
2	$\chi = \{0.5, 0.9\}$	8.19E-04	1.39E-16	3.52E-16	5.62E+00	1.39E-16	3.50E-16
3	$\chi = \{0.5, 1.5\}$	9.94E-04	7.37E-16	2.08E-15	4.21E-02	7.33E-16	2.04E-15
4	$\chi = \{0.5, 2\}$	9.93E-04	1.47E-15	4.16E-15	9.68E-03	1.46E-15	3.99E-15
5	$s_{y_c} = \{0.2, 0.3\}$	9.94E-04	7.59E-16	2.78E-15	4.21E-02	7.55E-16	2.71E-15
6	$s_m = \{0.15, 0.30\}$	9.93E-04	1.21E-15	3.47E-15	1.95E-02	1.20E-15	3.35E-15
7	$1 - \theta = \{0.25, 0.40\}$	9.96E-04	1.83E-15	2.78E-15	4.00E-02	1.82E-15	2.69E-15
8	$DM = \{1.2, 1.3\}$	9.93E-04	6.94E-16	2.08E-15	4.30E-02	6.89E-16	2.08E-15
9	$\rho_{p_c^*} = \{0.9, 0.0\}$	9.82E-04	1.88E-11	6.94E-16	1.25E+01	1.88E-11	6.88E-16
10	$\sigma_{p_c^*} = \{0.1, 0.5\}$	1.02E-02	3.90E-15	1.11E-14	1.25E-02	3.76E-15	1.02E-14
11	$\beta = \{0.9963, 0.9\}$	2.62E-04	2.06E-05	3.07E-02	3.41E-01	2.06E-05	3.05E-02
12	$\phi = \{3, 1\}$	9.95E-04	7.81E-16	4.16E-15	2.04E-02	7.68E-16	4.04E-15
13	$\beta = \{0.9963, 0.6\}$	2.71E-04	6.41E-04	8.20E-02	2.68E+00	6.38E-04	8.18E-02

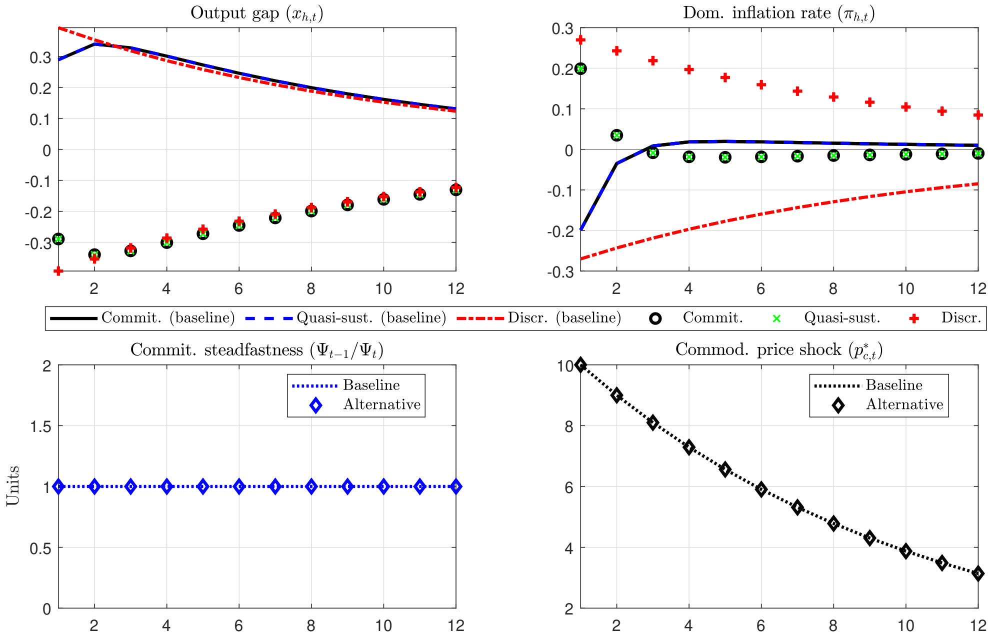
Note. $\tilde{u}$ = state space defined as of the simulated commodity price shock ($\tilde{P_c^*}$) and the lagged output gap ($\tilde{X}$), $\tilde{u} \in \tilde{X} \times P_c^*$. β = subjective discount factor; χ = elasticity borrowing limit to commodity price (financial channel parameter); DM = desired markup; $\rho_{p_c^*}$ = auto-correlation parameter of the foreign commodity price shock; $\sigma_{p_c^*}$ = standard deviation parameter of the foreign commodity price shock; s_m = share of inputs used for commodity production goods; $1-\theta$ = Calvo price re-set probability; s_{y_c} = Share of the comm. producing sector to GDP; ϕ = Inverse Frisch elasticity rate.

tive commodity-producing firm with respect to international commodity price fluctuations is $\chi = 1.5 > 1$, the parameter ω in the NKPC is $\omega = 0.01 > 0$.

Under the former alternative calibration, there is a symmetric variation in the borrowing elasticity parameter with respect to the unity, $\chi = \{0.5, 1.5\}$. And the respective responses of the domestic inflation and the output gap turn out to be symmetric under the same 10% CPS and the optimal policies (Figure B.3.2). Subsequently, –at least under the set of assumptions incorporated in this version of DMT's model– their model predicts that when commodity-producing firms can access borrowings that are elastic (or favorable) to international commodity prices condition, a CPS can rise the domestic inflation rate. In such a case, it can be said that the answer of the domestic inflation rate to a CPS is qualitatively analogous to that resulting from a standard cost-push shock or a markup shock, as accounted in the literature. As a result, one observes an inflationary process, an economic decline and the usual policymaker's trade-off (where domestic inflation rises while the output gap declines).

However, in contrast to the former argument, when borrowing conditions are unfavorable with respect to commodity prices evolution (the inelastic elasticity as in the baseline calibration: $\chi = 0.5 < 1$, $\omega = -0.01 < 0$),

Figure B.3.2: Varying the financial channel: $\chi = \{0.5, 1.5\}$, $\omega = \{-0.01, 0.01\}$ (in %)



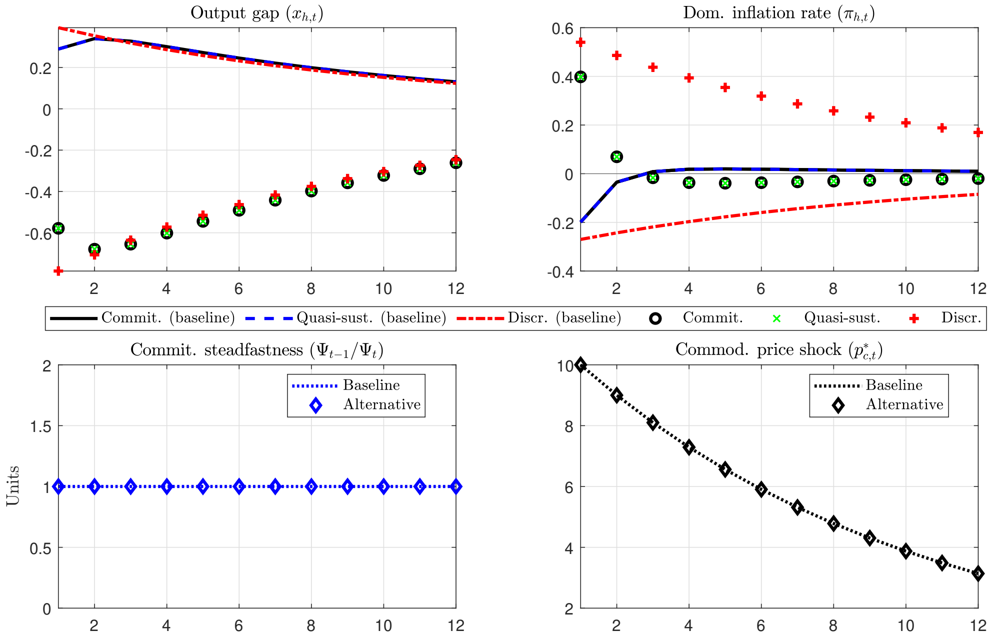
Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

the CPS makes the domestic inflation and the output gap to display responses that are consistent with model estimates (see Bergholt et al., 2019).[19] Namely, while a CPS hits the economy, there is a deflationary process and an economic boom that reverse over time. Accordingly, the CPS is positively correlated with the output gap, while negatively correlated with the domestic inflation (Table A.3.2).

On the other side, comparing the baseline calibration against another alternative value for the borrowing elasticity, $\chi = \{0.5, 2\}$, $\omega = \{-0.01, 0.03\}$, it can be noticed that the more elastic commodity firm borrowings become with respect to international commodity prices conditions, the higher the volatilities for the domestic inflation and the output gap are (Figure B.3.3). The same claim holds for the real and nominal exchange rates volatilities. In the case of the symmetrical values for the parameter $\chi = \{0.5, 1.5\}$, volatilities of the macroeconomic variables are equal (Table A.3.1).

[19]Note that the predictions of Báez's (2022) model are in line with these stylized facts, even if the financial channel parameter of its endogenous income-based borrowing constraint (in the commodity sector) is above the unity (but always positive).

Figure B.3.3: Varying the financial channel: $\chi = \{0.5, 2\}$, $\omega = \{-0.01, 0.03\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

Varying the commodity sector share to GDP

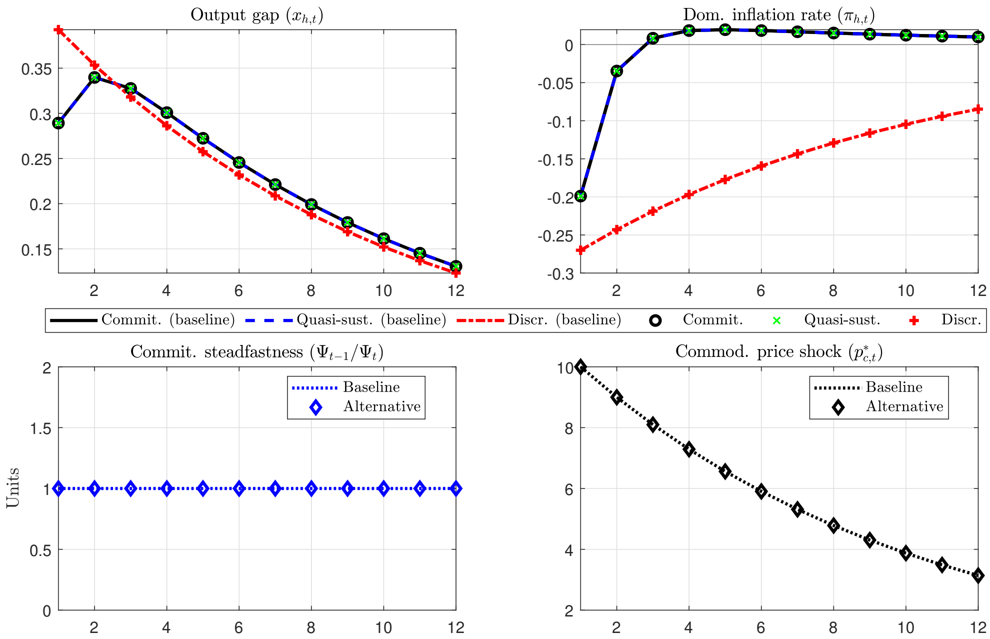
According to the prediction of DMT's model, varying the commodity sector share with respect to the gross domestic product (GDP) of the economy turns out not to be significant. This relevancy is in contrast to the key monetary policy implications derived from the case of a variation in the commodity inputs share of the economy (as it is seen in subsubsection 3.3.2 of the paper).

In particular, varying the commodity sector share with respect to the GDP (s_m) from 20% to 30%, does not changes either the dynamics of the economy or its steady state (Figure B.3.4). As it can be appreciated, what matters under the DMT's model framework is the share of commodity inputs produced in the domestic economy (s_m).

Varying other parameters of DMT's model

The following simulations show variations of some selected parameters of the DMT model.

Figure B.3.4: Higher commodity sector share to GDP: $s_{y_c} = \{0.2, 0.3\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

The common result is that the sustainability constraint never binds (under the alternative calibrations), making the optimal commitment policy consistent with the optimal quasi-sustainable policy, and leaving the optimal discretionary policy as the worst welfare policy outcome. Moreover, all the results are symmetric. That is to say, each vice versa case of each simulation presented is true and provides the same opposite result.

Varying the price rigidity

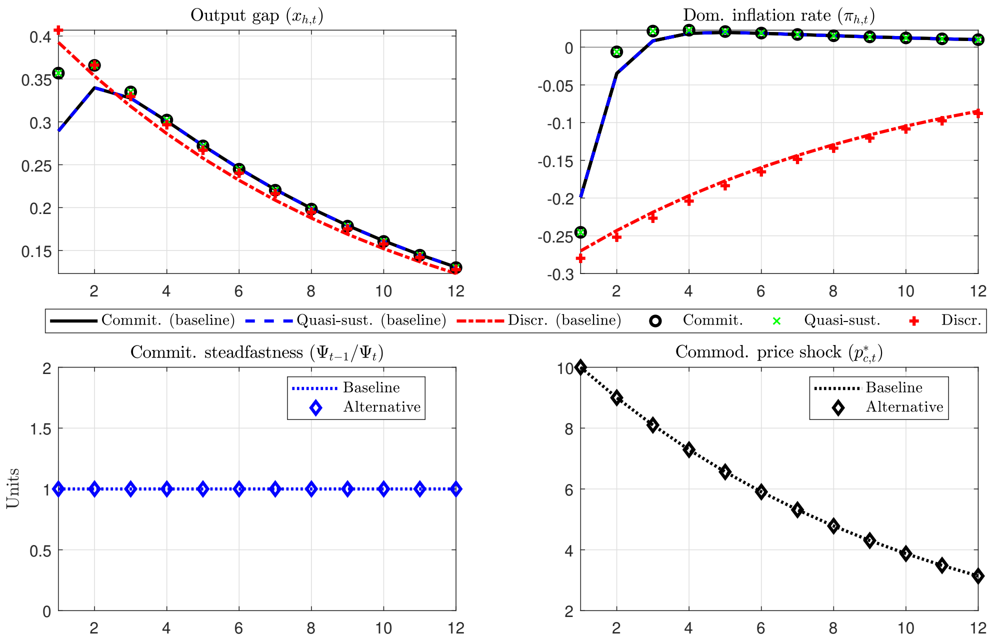
The more flexible prices are in the economy, the larger the responses of the domestic inflation rate and the output gap to the CPS (Figure B.3.5).

The Calvo parameter $1 - \theta$ varies from 25% (baseline calibration) to 40% (alternative calibration) in the probability that firms re-adjust their prices per quarter.

Varying the desired markup price

The higher the markup price, the higher effects over the domestic inflation, but the lower over the output gap (Figure B.3.6).

Figure B.3.5: Lower price rigidity: $1 - \theta = \{0.25, 0.40\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

It is assumed that the desired markup price parameter varies from 20% (baseline calibration) to 30% (alternative calibration).

Amplifying the shock

Independently of the CPS size, the optimal quasi-sustainable policy is always consistent with the optimal sustainable policy. Then, it can be stated that the higher the shock, the higher the responses from the output gap and the domestic inflation rate (Figure B.3.7).

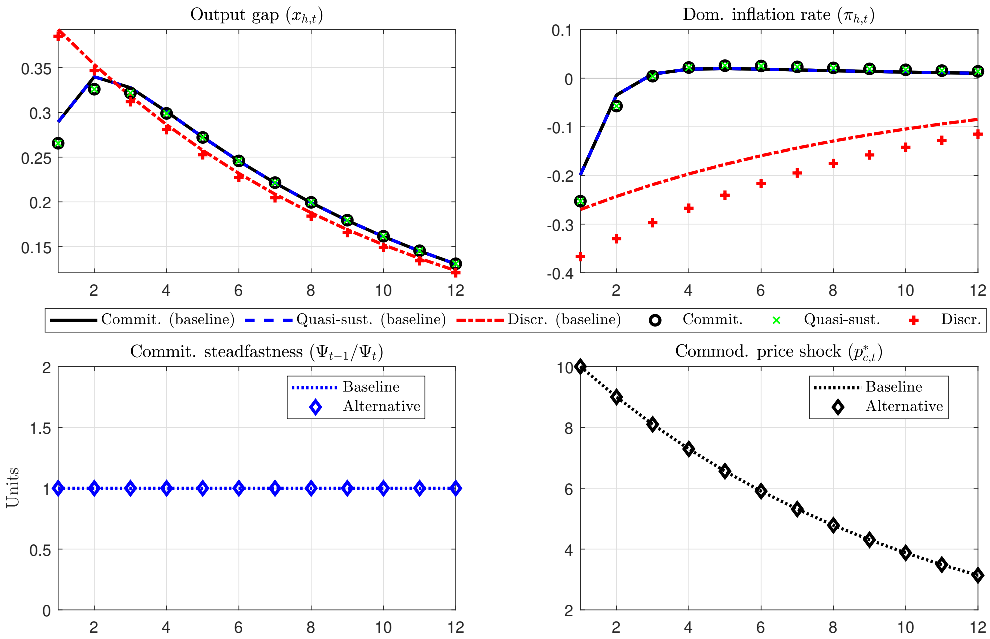
In this particular case, note that despite the considerable variation in the size of the shock (five times: from 10% to 50% increase in the parameter $\sigma_{p^*_{c,t}}$), still the sustainability constraint does not bind. Subsequently, the commitment steadfastness is full.

Varying the inverse Frisch elasticity rate

The lower the elasticity to wages, the higher the response from the domestic output is, but the lower in the case of the domestic inflation (Figure B.3.8).

In the simulation it is assumed that the inverse Frisch elasticity rate (ϕ)

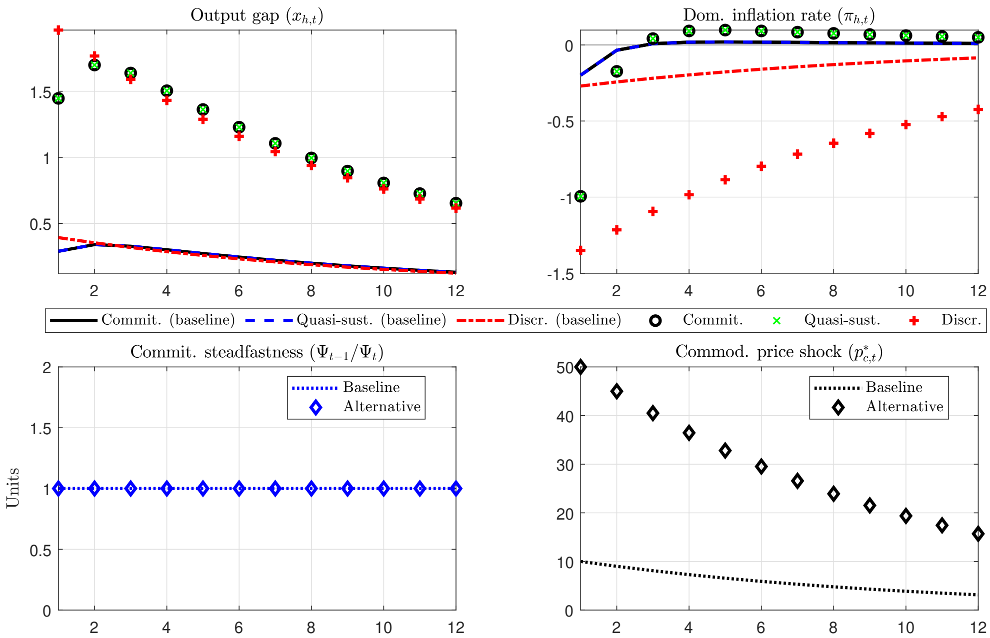
Figure B.3.6: Varying the desired markup price: $DM = \{1.2, 1.3\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

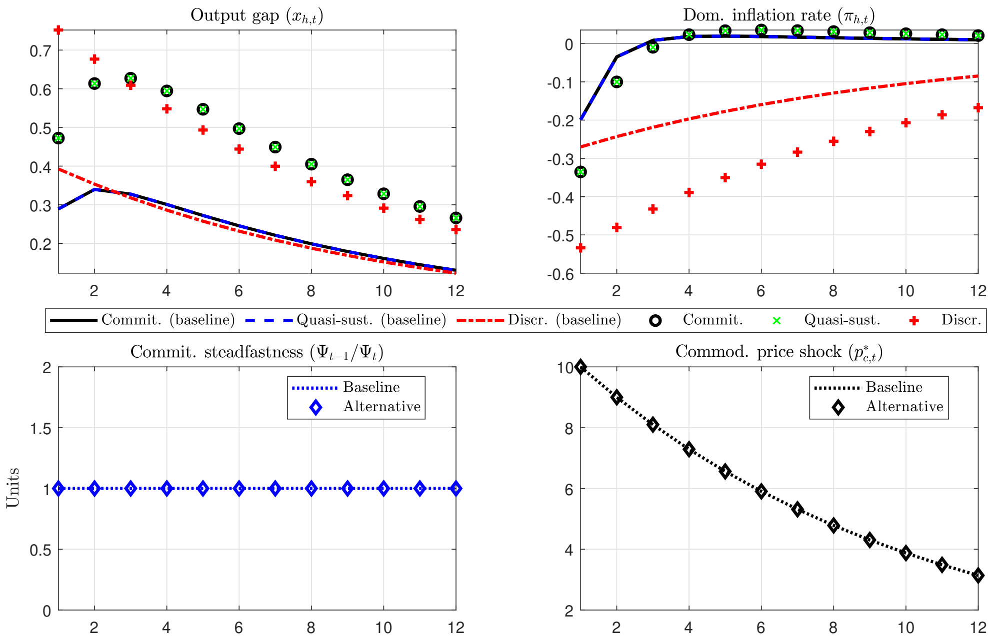
drops from 3 to 1. Therefore, as a result of a lower sensitivity in the hours at work with respect to real wages, the amount of work increases with the economic boom (measured by the domestic output gap). Note that the domestic inflation rate displays a deeper drop because marginal costs are lower under the alternative scenario (or alternative calibration).

Figure B.3.7: Amplifying the shock: $\sigma_{p^*_{c,t}} = \{0.1, 0.5\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

Figure B.3.8: Varying the inverse Frisch elasticity rate: $\phi = \{3, 1\}$ (in %)



Note. The impulse–response function (IRF) plots display a 10% positive commodity price shock. The shock is equivalent to a one standard deviation percentage from its respective steady state. Unless it is exclusively specified, horizontal and vertical axes indicate quarters and percentage deviation from the steady state, respectively. The solid, dashed and dash-dotted lines are variable responses under the baseline calibration values (or baseline scenario). While the circle, cross and plus signs are variable responses under the alternative calibration values (or alternative scenario).

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