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Optimal Monetary Policy in a Small Open Economy Under Segmented Asset Markets and Sticky Prices

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Optimal Monetary Policy in a Small Open Economy under Segmented Asset Markets and Sticky Prices

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Abstract

This paper studies optimal monetary policy in a two-sector small open economy model under segmented asset markets and sticky prices. We solve the Ramsey problem under full commitment, and characterize the optimal monetary policy in a calibrated version of the model. The findings of the paper are threefold. First, the Ramsey solution mimics the allocations under flexible prices. Second, under the optimal policy the volatility of non-tradable inflation is close to zero. Third, stabilizing nontradable inflation is optimal regardless of the financial structure of the small open economy. Even for a moderate degree of price stickiness, implementing a monetary policy that mitigates asset market segmentation is highly distortionary. This last result suggests that policymakers should resort to other policy instruments in order to correct financial imperfections.

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1 Introduction

In the last two decades has emerged a strong consensus about the importance of achieving a low and stable inflation rate as the main goal of monetary policy. Figure 1 illustrates this point and shows how inflation has converged to single digit rates during the last 10 years in both emerging and industrialized economies. Nevertheless, the environment in which monetary policy is implemented differs significantly across economies. In particular, most emerging countries exhibit underdeveloped financial markets that prevent efficient consumption and saving decisions. Figure 2 compares the ratio of M3 and private credit to GDP in developing and developed countries. This measure of financial depth indicates that households and firms in developing countries have limited access to financial instruments in order to carry out efficient intertemporal decisions.

If we consider relevant the consequences of financial imperfections, then there is potential role of monetary policy to correct these distortions in emerging economies[2]. For instance, if households cannot smooth consumption over time, one possible way to correct this distortion is to implement a monetary policy that increases consumption in bad states of nature and reduces it in good states. Such a policy may improve the intertemporal allocation of households with limited access to financial markets. However, this policy does not come for free. A stable consumption profile can be achieved at the cost of inducing some inflation volatility, which in turn is distortionary. In this context it is not clear what the policy recommendation for an emerging economy is: To what extent is price stability an optimal policy criterion? Is there a role for monetary policy to correct financial imperfections? In this paper we consider these questions in the framework of a dynamic stochastic general equilibrium model.

In the model economy there are two sectors: tradable and non-tradable. The firms in the tradable sector are perfectly competitive and can adjust their prices freely. On the other hand, firms in the non-tradable sector are monopolistically competitive and display

[2]Several papers study the role of monetary policy in models with financial frictions. Céspedes et al. (2004) and Gertler et al. (2003) discuss whether it is optimal for the monetary authority to stabilize the exchange rate in order to insure firms that have liabilities denominated in foreign currency. Both authors find that a fixed exchange rate is a suboptimal policy that exacerbates the negative effects of an external shock. Caballero and Krishnamurthy (2003), in a different framework, study how monetary policy should be designed in order to provide insurance incentives to households and firms against "sudden stops" (i.e. sudden capital outflows from emerging market economies). They propose a monetary regime in which the private sector may have an incentive to accumulate foreign assets to better deal with sudden stops.

price stickiness[3]. Sticky prices are modeled as a quadratic adjustment cost for firms à la Rotemberg (1982)[4]. This cost generates real effects from monetary policy. We model financial imperfections in emerging countries as an asset market segmentation problem. In this environment, only a fraction of the population has access to financial markets. Households excluded from financial markets can only save through the accumulation of real money balances. Even though this assumption cannot capture all types of financial imperfections present in emerging countries, it is a tractable way to model the lack of financial assets for a large segment of the population[5].

We follow Ramsey (1927) and Lucas and Stokey (1983) in characterizing the optimal monetary policy. In this approach, the Ramsey planner chooses an allocation that maximizes the household's welfare subject to the resource constraints of the economy and additional constraints that capture the equilibrium reactions by firms and households to monetary policy[6]. In addition, we assume that the monetary authority implements the policy under full commitment. This implies that monetary policy is credible, and prevents any inflation-bias outcome.

The conclusions of the paper are threefold. First, the allocation under the optimal policy is quantitatively similar to the one in an economy with flexible prices. This result shows that the Ramsey policy is successful in minimizing the impact of nominal distortions in the economy. Second, under the optimal policy the volatility of non-tradable inflation is close to zero. To implement this policy prescription the Ramsey planner faces a trade-off to correct all distortions in the model. In the case of sticky prices, the goal of an optimal monetary policy is to reproduce the flexible price equilibrium. This outcome is possible with a monetary policy that stabilizes the price level[7]. Such policy allows stable markups which ensures a flexible-price allocation. On the other hand, under seg-

[3] This assumption captures the fact that the non-tradable sector displays a higher degree of price stickiness compared to the tradable sector. See Burstein et al. (2003).

[4] Rotemberg (1982) mentions two reasons why price changes might be costly. First, there is the physical cost of changing posted prices (menu costs). Second, the costs are related to the negative effects on reputation when firms frequently change their prices.

[5] Campbell and Mankiw (1991) show empirical evidence that around 50 percent of households in the United States base their consumption decisions on current income, which is consistent with the hypothesis of segmented asset markets. For emerging economies, where financial markets are underdeveloped, it is reasonable to assume that asset market segmentation is at least as severe as in the United States.

[6] This is the primal approach of the Ramsey problem.

[7] Complete stabilization of the price of non-tradable goods eliminates the distortion associated with sticky prices. Woodford (2002) shows that in a model economy with sticky prices, price stability is the welfare-maximizing policy. Goodfriend and King (2001) also find that price stability is the optimal policy. They call this a *neutral* policy, since it keeps output at the potential level, defined as the outcome of an imperfectly competitive real business cycle model.

mented asset markets the goal of monetary policy is to improve the risk-sharing between agents. That is, the intertemporal marginal rate of substitution of households excluded from financial markets should be as close as possible to the one from agents with access to financial markets. However, a policy designed to improve risk-sharing is not compatible with price stability. In order to improve the intertemporal allocation of households it is necessary to stabilize their consumption path and allow some variation in the price level, which is distortionary under sticky prices. When we calibrate the model economy for plausible values of asset market segmentation and price stickiness, we find that the tension existing to correct these distortions is resolved in favor of undoing the effects of price stickiness.

Third, we find that achieving low non-tradable inflation volatility is optimal for any degree of asset market segmentation. When we conduct a sensitivity analysis for different assumptions of asset market segmentation, the prescription of bringing inflation volatility close to zero remains optimal. This suggests that correcting asset market segmentation with monetary instruments, even under extreme assumptions of segmentation, is highly distortionary.

This paper is related to several studies about optimal monetary policy. In a closed economy with flexible prices and perfect competition, Lucas and Stokey (1983), Chari et al. (1991) and Chari and Kehoe (1999) followed the Ramsey approach and show that the optimal monetary policy is to set the nominal interest rate to zero (i.e. Friedman's rule). More recently, Khan et al.(2003), Schmitt-Grohé and Uribe (2004), and Siu (2004) study the problem of optimal monetary policy in models with monopolistic competition and sticky prices and find that the Ramsey prescription is to reduce inflation volatility close to zero.

In an open economy setting, there is an extensive literature about optimal monetary policy. However, the Ramsey approach has not been as broadly used as in closed economy models[8]. For the case of a small open economy model with sticky prices, Galí and Monacelli (2005) find a similar prescription to closed economy models since the optimal policy fully stabilizes the domestic price level. On the other hand, Lahiri et al. (2006) characterize the optimal policy in a small open economy with flexible prices and segmented asset markets. In their model, the optimal monetary policy induces high inflation volatility in order to provide insurance to agents excluded from asset markets.

[8] Schmitt-Grohé and Uribe (2003b) solve the Ramsey problem for a small open economy in a flexible price environment. Faia and Monacelli (2004) follow the same approach in a two-country model with sticky prices and monopolistic competition.

The goal of this paper is to characterize the interaction between sticky prices and asset market segmentation in the design of the optimal monetary policy in a small open economy. In principle, both frictions are present in developing countries, and it is not evident how a monetary policy should deal simultaneously with these distortions[9]. As opposed to most of the open economy macroeconomics literature, we solve the Ramsey problem to characterize the optimal monetary policy in this environment. This approach makes it possible to analyze from a general equilibrium perspective how monetary policy should be implemented to correct multiple distortions in an economy.

The remainder of this paper is organized as follows. Section 2 presents the small open economy model. Section 3 describes the Ramsey problem under full commitment. Section 4 analyzes the dynamics under the optimal monetary policy. Section 5 concludes.

2 Model

In this section we describe a simple infinite-horizon production economy with sticky prices and segmented asset markets. In the economy there are two types of households: traders and non-traders. The former type of agent has access to financial markets while the latter one does not participate in them. The non-traders can only save through the accumulation of real money balances. To simplify the model, we suppose that the fraction of households participating in the financial markets is fixed over time.

The production side of the model has two sectors: tradable and non-tradable. The tradable good sector exhibits flexible prices and takes international prices as given. In contrast, the non-tradable sector displays monopolistic competition and sticky prices, which are modeled as a quadratic adjustment cost à la Rotemberg. The introduction of money in this model is motivated as a device to reduce household transaction costs. The fiscal policy is characterized by a balanced budget and government expenditure is financed with lump sum taxes levied on both types of households. Money injections are engineered in financial markets, so traders are the only ones who absorb them. The model has three types of exogenous fluctuations: productivity shocks in the tradable and non-tradable sectors and government expenditure shocks.

[9] Lahiri et. al. (2004) pose a question similar to the one in this paper: "The fact that most of the literature on the choice of exchange rate regimes and monetary policy rules relies on sticky prices models raises a fundamental (though seldom asked) question: are sticky prices (i.e. frictions in goods markets) more relevant in emerging markets than frictions in asset markets?"

2.1 Households

The households decide a sequence of tradable and non-tradable consumption and labor supply with the objective to maximize their expected present value utility:

$$U(i) = \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t^T(i), c_t^N(i), l_t(i)) \right] (i = tr, nt)$$

where c_t^T, c_t^N, and l_t denote tradable consumption, non-tradable consumption, and labor supply, respectively. β is a subjective discount factor and $\mathbb{E}_0$ denotes the expectation operator conditional on the information in period 0. The index $i = tr$ stands for allocations for trader households while $i = nt$ is for non-trader households. We assume the two types of households share the same preferences.

The role of money is to facilitate consumption purchases. In particular, we assume that consumption of both types of goods is subject to a proportional transaction cost, $s(v_t(i))$, that depends on the money velocity:

$$v_t(i) = \frac{p_t^T c_t^T(i) + p_t^N c_t^N(i)}{M_t(i)}$$

where p^T and p^N are the prices of tradable and non-tradable goods, respectively, and $M_t(i)$ is the nominal money holdings of type i household.

2.1.1 Traders

The fraction of traders in the economy is denoted by λ. Traders have access to two types of financial assets: a domestic one-period contingent bond and an international one-period non-contingent bond. The domestic bond delivers one unit of domestic currency in the next period in some particular state. The international bond delivers one unit of foreign currency in the next period in each state of nature. Consequently, the trader's budget constraint is described by:

$$\begin{aligned} &(1 + s(v_t(tr)))(p_t^T c_t^T(tr) + p_t^N c_t^N(tr)) + \mathbb{E}_t[q_{t,t+1} d_{t+1}(tr)] \\ &+ e_t b_t^*(tr) + M_t(tr) = W_t l_t(tr) + d_t(tr) + e_t R_{t-1}^* b_{t-1}^*(tr) \\ &+ M_{t-1}(tr) + \frac{\Pi_t}{\lambda} + \frac{X_t}{\lambda} - T_t \end{aligned} \quad (1)$$

On the left-hand side of equation (1) we include household's expenditure. The first term is the expenditure on tradable and non-tradable consumption goods including transaction costs. The second is the expenditure on domestic contingent bonds. $d_{t+1}(tr)$ is the units of these bonds bought by the trader and $q_{t,t+1}$ is the period t price of these securities normalized by the probability of the occurrence of each state of nature. The trader also buys $b_t^*(tr)$ units of international non-contingent bonds where e_t denotes the nominal exchange rate. The fourth term is the money holdings that the trader chooses to carry over from t to $t+1$. On the right-hand side of the equation we include the sources of income. The first term is labor income. W_t is the nominal wage rate and $l_t(tr)$ is the amount of labor supplied. $d_t(tr)$ is the quantity of contingent bonds held by the trader from the previous period that pays at the state in current period t. The third term is the return on the non-contingent international bond holding where R_{t-1}^* is the gross interest rate on this bond in terms of foreign currency. $M_{t-1}(tr)$ is the money holdings from the last period and Π_t is the nominal profits from firms[10]. X_t is the per capita money injections which are carried out in the financial markets and for this reason, are only absorbed by traders. Due to the fact that the size of traders in the economy is λ, Π/λ and X/λ are the dividends and money injections per trader. T is the lump sum tax which is designed to finance government expenditures and is the same across all type of households.

The problem for the traders is to maximize their utility subject to their budget constraint, initial asset holdings $(M_{-1}(tr), d_0(tr), b_0^*(tr))$, and borrowing constraints $d_t(tr) \geqslant -\overline{d}$ and $b_t^*(tr) \geqslant -\overline{b}$[11]. The following are the first-order conditions for their problem:

$$\frac{u_{c^T,t}(tr)}{u_{c^N,t}(tr)} = \frac{p_t^T}{p_t^N} \tag{2}$$

$$-\frac{u_{l,t}(tr)}{u_{c^T,t}(tr)} = \frac{W_t}{p_t^T h(v_t(tr))} \tag{3}$$

$$\frac{u_{c^N,t}(tr)}{p_t^N h(v_t(tr))}\left(1 - s'(v_t(tr))(v_t(tr))^2\right) = \beta \mathbb{E}_t \left[\frac{u_{c^N,t+1}(tr)}{p_{t+1}^N h(v_{t+1}(tr))}\right] \tag{4}$$

$$\frac{u_{c^T,t}(tr)e_t}{p_t^T h(v_t(tr))} = \beta R_t^* \mathbb{E}_t \left[\frac{u_{c^T,t+1}(tr)e_{t+1}}{p_{t+1}^T h(v_{t+1}(tr))}\right] \tag{5}$$

$$q_{t,t+1} = \beta \frac{u_{c^N,t+1}(tr)}{u_{c^N,t}(tr)} \frac{p_t^N h(v_t(tr))}{p_{t+1}^N h(v_{t+1}((tr))} \tag{6}$$

where

[10] Since traders participate in financial markets we assume that only them own shares, and hence receive all the profits.

[11] For large positive numbers $\overline{d}$ and $\overline{b}$, these borrowing constraints prevent Ponzi schemes.

$$h(v_t(tr)) = 1 + s(v_t(tr)) + s'(v_t(tr))v_t(tr)$$

Equation (2) determines the relative demand of tradable and non-tradable goods by the traders as a function of the relative price of tradable goods (p^T/p^N). The traders' labor supply is specified by (3) which equates the marginal rate of substitution between leisure and tradable consumption with the real wage in terms of tradable goods. Since the transaction cost affects the effective price of consumption goods, it introduces a wedge ($h(v_t(tr))$ in the labor supply decision[12].

Equations (4), (5), and (6) define indirectly a money demand function, an interest parity condition, and the market nominal interest rate. To interpret them clearly, we have to manipulate the equations. First, recall that the gross nominal interest can be written as:

$$R_t = (\mathbb{E}_t[q_{t,t+1}])^{-1}$$

Combining this last expression with (4) implies $R_t(1 - s'(v_t(tr))(v_t(tr))^2) = 1$. Using the definition of velocity and writing $p^T c_t^T(tr) + p_t^N c_t^N(tr)$ as $p_t c_t(tr)$ we obtain[13]:

$$\frac{M_t(tr)}{p_t} = \frac{c_t(tr)}{G^{-1}(\frac{R_t - 1}{R_t})}$$

where $G(\cdot)$ is defined as $G(v) = s'(v)v^2$. Also, combining the expression of the gross nominal interest rate with (5) we get an interest parity condition:

$$\frac{R_t}{R_t^*} = \mathbb{E}_t\left[\frac{e_{t+1}}{e_t}\right] + R_t \text{cov}\left(q_{t,t+1}, \frac{e_{t+1}}{e_t}\right)$$

2.1.2 Non-traders

The size of non-trader households in the economy is $(1 - \lambda)$. This type of household does not have access to financial markets and can only use money to transfer resources across time. They receive the same nominal wage rate W_t, and pay the same lump sum taxes T_t as traders. These elements imply the following budget constraint:

[12] The term $(h(v_t(tr))$ is standard in models with transaction costs. This wedge can be interpreted as an implicit consumption tax.

[13] In this case p_t denotes the aggregate price level and $c_t(tr)$ is the composite consumption of traders.

$$(1+s(v_t(nt)))(p_t^T c_t^T(nt) + p_t^N c_t^N(nt)) + M_t(nt) = \\ W_t l_t(nt) + M_{t-1}(nt) - T_t \tag{7}$$

The first-order conditions obtained by maximizing the non-traders utility function subject to their budget constraint are:

$$\frac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)} = \frac{p_t^T}{p_t^N} \tag{8}$$

$$-\frac{u_{l,t}(nt)}{u_{c^T,t}(nt)} = \frac{W_t}{p_t^T h(v_t(nt))} \tag{9}$$

where:

$$h(v_t(nt)) = 1 + s(v_t(nt)) + s'(v_t(nt))v_t(nt)$$

$$\frac{u_{c^N,t}(nt)}{p_t^N h(v_t(nt))}\left(1 - s'(v_t(nt))(v_t(nt))^2\right) = \beta \mathbb{E}_t \left[\frac{u_{c^N,t+1}(nt)}{p_{t+1}^N h(v_{t+1}(nt))}\right] \tag{10}$$

Equations (8), (9), and (10) are equivalent to the equations (2), (3), and (4) derived for the traders. Specifically, (8) determines the relative consumption of tradable vis-à-vis non-tradable goods for the non-traders as a function of the relative price of tradable goods. Labor supply is defined by (9) and the implicit money demand by (10). However, since these households do not participate in the asset markets, the implicit money demand does not depend on the nominal interest rate[14].

2.2 Firms in the Tradable Sector

Firms in the tradable sector behave competitively and have a constant returns to scale technology that uses labor and non-tradable inputs. In particular, the production of tradable goods y^T is described by:

$$y_t^T = z_t^T f^T(l_t^T, N_t) \tag{11}$$

where l_t^T and N_t are the amount of labor and non-tradable inputs, respectively, and z_t^T denotes an exogenous productivity shock in the sector. Profit maximization determines the labor and non-tradable inputs demand functions:

[14] This is is due to the fact that in the absence of asset markets, the intertemporal marginal rate of substitution is no longer linked to the nominal interest rate.

$$W_t = z_t^T p_t^T f_{l^T,t}^T \tag{12}$$

$$p_t^N = z_t^T p_t^T f_{N,t}^T \tag{13}$$

2.3 Firms in the Non-tradable Sector

There are two types of firms in the non-tradable sector: retailers and intermediate good producers. The retailers use labor to produce a differentiated good. The intermediate producers combine these differentiated goods to produce a final non-tradable output that is consumed by households and used as an input by firms in the tradable sector.

2.3.1 Retailers

Retailers produce y_t^N units of non-tradable final goods according to a constant elasticity of substitution aggregator of a continuum of non-tradable intermediate goods indexed along the unit interval $j \in [0, 1]$:

$$y_t^N = \left[\int_0^{\infty} y_t^N(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{14}$$

The first-order condition of the profit-maximization problem leads to intermediate input demands:

$$y_t^N(j) = y_t^N \left[\frac{p_t^N(j)}{p_t^N} \right]^{-\varepsilon} \tag{15}$$

where $p_t^N = \left[\int_0^1 p_t^N(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}}$ is the aggregate price level of non-tradable goods.

2.3.2 Intermediate Good Producers

Producers of non-tradable intermediate inputs are assumed to be monopolistic competitors and face a cost of adjusting their prices. In particular, we follow Rotemberg (1982) and consider quadratic costs of price adjustment for each intermediate good producer j:

$$\frac{\kappa}{2} \left(\frac{p_t^N(j)}{p_{t-1}^N(j)} - 1 \right)^2$$

These costs are expressed in terms of the non-tradable final good. The parameter κ measures the degree of price stickiness in the non-tradable sector. The higher κ is, the more sluggish is the adjustment of nominal prices in this sector. The production technology is given by:

$$y_t^N(j) = z_t^N l_t^N(j)$$

where $l_t^N(j)$ is the labor utilized by the intermediate producer and z_t^N an exogenous productivity shock in the sector. The intermediate producer of variety j will choose a sequence of prices to maximize the expected present value of profits given the demand function (15), the production function, the wage rate W_t, the initial price p_{-1}^N[15] and productivity shock z_t^N:

$$\max_{\{p_t^N(j)\}_{t=0}^{\infty}} \mathbb{E}_0 \left[\sum_{t=0}^{\infty} q_{0,t} \left(p_t^N(j) y_t^N(j) - W_t l_t^N(j) - p_t^N \frac{\kappa}{2} \left(\frac{p_t^N(j)}{p_{t-1}^N(j)} - 1 \right)^2 \right) \right] \tag{16}$$

where $q_{0,t}$ is the price of a nominal contingent security in period 0 that delivers one unit of domestic currency in period t in some particular state normalized by the probability of occurrence. The prices of the securities can be constructed recursively by initially using the one period contingent bonds which are priced by the traders ($q_{0,t} = q_{t-1,t} q_{0,t-1}$). Considering a symmetric equilibrium in which $p_t^N = p_t^N(j)$, $l_t^N = l_t^N(j)$ for all $j \in [0,1]$, we obtain an expectation-augmented Phillips curve from the first-order condition of the profit maximization problem:

$$\pi_t^N(\pi_t^N - 1) = \mathbb{E}_t[q_{t,t+1}(\pi_{t+1}^N)^2(\pi_{t+1}^N - 1)] - \frac{\varepsilon}{\kappa} z_t^N l_t^N [\frac{\varepsilon - 1}{\varepsilon} - mc_t]$$

where $\pi_t^N = p_t^N / p_{t-1}^N$ is the gross inflation rate of non-tradable goods and mc_t denotes the real marginal cost of producing non-tradable intermediate goods. Due to the fact that intermediate good producers have a constant returns to scale technology, their marginal cost is the same for all of them. The marginal cost is then given by:

$$mc_t = \frac{W_t}{p_t^N z_t^N} \tag{17}$$

Finally, for the symmetric equilibrium we can write total final production in this sector as $y_t^N = z_t^N l_t^N$.

[15] For simplicity we will assume that the initial prices of all intermediate producers are equal, that is $p_{-1}^N(j) = p_{-1}^N$.

2.4 Government

The government issues currency (M_t^s) according to the law of motion:

$$M_t^s = M_{t-1}^s + X_t \tag{18}$$

where X_t denotes per capita money injections.

In the fiscal sector, the government levies a lump sum tax T_t from both types of households to finance government expenditure g_t^N[16]. We abstract from marginal tax rates, and preclude the possibility of financing fiscal deficits issuing debt. Hence, the consolidated budget constraint of the government is given by:

$$M_t^s = M_{t-1}^s + p_t^N g_t^N + X_t - T_t \tag{19}$$

2.5 International Transactions

Regarding trade integration we assume that the law of one price holds for tradable goods:

$$p_t^T = e_t p_t^* \tag{20}$$

Without loss of generality, we will assume that the foreign price p_t^* remains constant and equal to one.

As is common in small open economy models, we introduce a friction in the international financial markets in order to induce stationarity of international bonds[17]. In particular, we introduce an upward-sloping supply of funds. With this friction, the international interested rate faced by the country (R_t^*) is increasing function of net foreign assets (B_t^*). The functional form we assume for the supply of funds is:

[16] We assume that all fiscal expenditure is denominated in non-tradable goods. In simulations not reported here we found that introducing tradable government expenditure does not change the main conclusions of the paper.

[17] In a standard small open economy model the international interest rate is given and international bonds follow a unit root process. A non-stationary variable is problematic when the model is solved with a local method, as it is the case in this paper. A unit root implies that deviations from the steady state are permanent, while local methods are accurate only for small deviations around the steady state. Consequently, local methods are unreliable in the standard small open economy model. To overcome this problem, Schmitt-Grohé and Uribe (2003a) propose four different methods to induce stationarity in the international bonds. In our model we adopt one of these methods which consists in imposing and upward-sloping supply of funds.

$$R_t^* = R^* \left[\frac{B_t^*}{B^*} \right]^\nu \tag{21}$$

Where R^* and B^* are the steady values of the international interest rate and net foreign assets, respectively, and ν is the elasticity of the supply of funds schedule.

2.6 Market Clearing Conditions

In each period markets clear for tradable and non-tradable goods, labor, money, domestic and foreign bonds. The market clearing condition for the labor market is:

$$\lambda l_t(tr) + (1-\lambda) l_t(nt) = l_t^T + l_t^N \tag{22}$$

We will assume that transaction costs are deadweight losses in the non-tradable sector. Also, recalling that N_t is the non-tradable input in the tradable sector and $\kappa(\pi_t^N - 1)^2/2$ is the amount of resources used in adjusting prices in that sector, we obtain the equilibrium condition for non-tradable goods:

$$\begin{aligned} &\lambda c_t^N(tr) + (1-\lambda) c_t^N(nt) + \lambda s(v_t(tr)) \left[c_t^N(tr) + \frac{p_t^T}{p_t^N} c_t^T(tr) \right] \\ &+(1-\lambda) s(v_t(nt)) \left[c_t^N(nt) + \frac{p_t^T}{p_t^N} c_t^T(nt) \right] + N_t \\ &+g_t^N + \frac{\kappa}{2} \left(\pi_t^N - 1 \right)^2 = y_t^N \end{aligned} \tag{23}$$

The market clearing condition in the tradable sector can be expressed as:

$$\lambda c_t^T(tr) + (1-\lambda) c_t^T(nt) + B_t^* \frac{e_t}{p_t^T} = y_t^T + R_{t-1}^* B_{t-1}^* \frac{e_t}{p_t^T} \tag{24}$$

where B_t^* stands for the aggregate net foreign assets. Since traders are the only agents that participate in international financial markets, the following equivalence holds:

$$B_t^* = \lambda b_t^*(tr) \tag{25}$$

Because trader households are identical, in equilibrium there is no borrowing or lending in domestic contingent bonds. This implies:

$$d_t(tr) = 0 \tag{26}$$

Finally, the equilibrium condition in the money market is given by:

$$M_t^s = \lambda M_t(tr) + (1-\lambda)M_t(nt) \tag{27}$$

2.7 Equilibrium

An equilibrium for this economy is a set of (i) Prices: $\{e_t,\, p_t^T,\, p_t^N,\, q_{t,t+1},\, W_t,\, R_t^*,\, mc_t\}$, and (ii) Allocations: $\{c_t^T(tr),\, c_t^N(tr),\, c_t^T(nt),\, c_t^N(nt),\, b_t^*(tr),\, B_t^*,\, d_t,\, M_t(tr),\, M_t(nt),\, M_t^s,$ $l_t(tr),\, l_t(nt),\, l_t^T,\, l_t^N,\, N_t,\, y_t^T,\, y_t^N\}$; such that (2) - (13) and (17)-(27) hold, given policies $\{X_t, T_t\}$, exogenous process $\left\{z_t^T, z_t^N, g_t^N\right\}$, and initial conditions $(M_{-1}(tr),\, M_{-1}(nt),$ $b_{-1}^*(tr),\, p_{-1}^N)$.

3 Ramsey Problem

In this section we characterize the optimal monetary policy in the small open economy model. Our analysis is in the tradition of Ramsey (1927) and draws heavily on modern literature of optimal policy in dynamic economies. In particular, our methodology is built on the work of Khan et al. (2003) and Schmitt-Grohé and Uribe (2004), whom adapt the approach of Stokey and Lucas (1983) to include monopolistic competition and sticky prices. Unlike these papers, we consider a small open economy with an additional friction: asset market segmentation.

We solve the Ramsey problem with the primal approach, where prices and policy instruments of the model economy are recast in terms of allocations. In addition, the optimal allocations are derived considering the case of monetary policy with full commitment. The objective of the monetary authority is to achieve an allocation that yields the maximum weighted utility of households. In particular, the Ramsey problem consists of choosing a sequence of plans $\{c_t^T(tr),\, c_t^N(tr),\, l_t(tr),\, v_t(tr),\, c_t^T(nt),\, c_t^N(nt),\, l_t(nt),\, l_t^T,\, N_t,$ $\pi_t^N,\, B_t^*\}$ to maximize the following welfare criterion:

$$\mathbb{E}_0[\sum_{t=0}^{\infty}\beta^t(\lambda u(c_t^T(tr), c_t^N(tr), l_t(tr)) + (1-\lambda)u(c_t^T(nt), c_t^N(nt), l_t(nt)))]$$

subject to the set of the competitive equilibrium conditions. In order to make the Ramsey problem tractable, we rewrite the equilibrium conditions described in the previous section into a compact set of constraints. First, combining (2) and (8) with (13) we get expressions that relate the marginal rate of substitution between non-tradable and tradable consumption for both types of households with the marginal productivity of non-tradable inputs in the tradable sector:

$$z_t^T f_N^T(l_t^T, N_t) = \frac{u_{c^N,t}(tr)}{u_{c^T,t}(tr)} \tag{28}$$

$$z_t^T f_N^T(l_t^T, N_t) = \frac{u_{c^N,t}(nt)}{u_{c^T,t}(nt)} \tag{29}$$

Likewise, we obtain equations that link the marginal rate of substitution between leisure and tradable consumption for households with the marginal productivity of labor in the tradable sector. This can be done using (3), (9), and (12):

$$z_t^T f_l^T(l_t^T, N_t) = -\frac{u_{l,t}(tr)h(v_t(tr))}{u_{c^T,t}(tr)} \tag{30}$$

$$z_t^T f_l^T(l_t^T, N_t) = -\frac{u_{l,t}(nt)h(v_t(nt))}{u_{c^T,t}(nt)} \tag{31}$$

Replacing the definition of non-tradable inflation ($\pi_t^N = p_t^N/p_{t-1}^N$) in (4) and (10) we obtain:

$$\frac{u_{c^N,t}(tr)}{h(v_t(tr))}\left(1 - s'(v_t(tr))(v_t(tr))^2\right) = \beta \mathbb{E}_t\left[\frac{u_{c^N,t+1}(tr)}{\pi_{t+1}^N h(v_{t+1}(tr))}\right] \tag{32}$$

$$\frac{u_{c^N,t}(nt)}{h(v_t(nt))}\left(1 - s'(v_t(nt))(v_t(nt))^2\right) = \beta \mathbb{E}_t\left[\frac{u_{c^N,t+1}(nt)}{\pi_{t+1}^N h(v_{t+1}(nt))}\right] \tag{33}$$

Also, using (5), (20), and (21) we can derive an expectational equation governing the portfolio decisions over foreign debt:

$$\frac{u_{c^T,t}(tr)}{h(v_t(tr))} = \beta R^* \left[\frac{B_t^*}{B^*}\right]^{\nu} \mathbb{E}_t\left[\frac{u_{c^T,t+1}(tr)}{h(v_{t+1}(tr))}\right] \tag{34}$$

The Phillips curve derived in (17) can be rearranged to eliminate $q_{t,t+1}$ and mc_t. We do so using (3), (6) and (17):

$$\frac{u_{c^N,t}(tr)}{h(v_t(tr))}\pi_t^N(\pi_t^N - 1) = \beta\mathbb{E}_t[\frac{u_{c^N,t+1}(tr)}{h(v_{t+1}(tr))}\pi_{t+1}^N(\pi_{t+1}^N - 1)]$$
$$-\frac{\varepsilon - 1}{\kappa}\left[\frac{\varepsilon}{\varepsilon - 1}u_{l,t}(tr) + \frac{u_{c^N,t}(tr)}{h(v_t(tr))}z_t^N\right]\left[\lambda l_t(tr) + (1-\lambda)l_t(nt) - l_t^T\right] \tag{35}$$

In the market-clearing condition for the non-tradable sector (23) we can substitute the definition of the relative price of tradable goods using (2) and (8). Also, combining (11) and (22), we can express total non-tradable production as a function of the total labor supplied and the labor used in the tradable sector. After these replacements, the resource constraint of non-tradable goods is given by:

$$\lambda c_t^N(tr) + (1-\lambda)c_t^N(nt) + g_t^N + N_t + \lambda s(v_t(tr))[c_t^N(tr) + \frac{u_{c^T,t}(tr)}{u_{c^N,t}(tr)}c_t^T(tr)]$$
$$+\tfrac{\kappa}{2}\left(\pi_t^N - 1\right)^2 + (1-\lambda)s(v_t(nt))[c_t^N(nt) + \frac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)}c_t^T(nt)] \tag{36}$$
$$= z_t^N\left[\lambda l_t(tr) + (1-\lambda)l_t(nt) - l_t^T\right]$$

Using the law of one price in the tradable sector (20), we can rewrite the market-clearing condition for tradable goods as:

$$\lambda c_t^T(tr) + (1-\lambda)c_t^T(nt) + B_t^* = z_t^T f^T(l_t^T, N_t) + R^*\left[\frac{B_{t-1}^*}{B^*}\right]^{\nu} B_{t-1}^* \tag{37}$$

Since we have two types of households, we need to keep track of one of the household's budget constraint. We use the budget constraint of the non-traders (7). We normalize it in terms of non-tradable goods and using (8), the definition of velocity of non-traders, and the fact that in equilibrium $T_t = p_t^N g_t^N$, we obtain:

$$(1 + s(v_t(nt)) + \frac{1}{v_t(nt)})[c_t^N(nt) + \frac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)}c_t^T(nt)] + g_t^N$$
$$= -\frac{u_{l,t}(nt)h(v_t(nt))}{u_{c^N,t}(nt)}l_t(nt) + \left[c_{t-1}^N(nt) + \frac{u_{c^T,t-1}(nt)}{u_{c^N,t-1}(nt)}c_{t-1}^T(nt)\right]\frac{1}{v_{t-1}(nt)\pi_t^N} \tag{38}$$

The previous constraints can be classified in three groups. Constraints (28), (29), (30), (31), and (36) are intratemporal conditions in the sense that they include only variables dated at t. Constraints (37) and (38) are predetermined equations since they include variables dated at t and $t-1$. Finally, constraints (32), (33), (34), and (35) are expectational equations, that is, they contain expectations of variables at $t+1$ based on information at t. This last group of expectational equations pose a challenge to the solution of the Ramsey problem. Since these constraints do not have the standard recursive structure[18], the Bellman equation fails to hold. We reformulate the problem to a recursive one using the framework developed by Marcet and Marimon (1998). With their approach we recast the Ramsey problem into a recursive formulation introducing new states variables. In our monetary problem, these variables are the Lagrange multipliers associated with the expectational equations (32)-(35). In Appendix A we show how to reexpress the Lagrangian associated with the Ramsey problem into a recursive *saddle point functional equation*.

Notice that in our analysis we abstract from the optimal policy problem at time 0. Implicitly, we assume that the government has been conducting the optimal policy for a long period of time. This type of policy implementation has been referred by Woodford (2003) as "optimal from a timeless perspective."

4 Dynamics under the Optimal Policy

In this section, we show the numerical results of the model. First, we explain the calibration strategy for the model economy. Then we describe the dynamics of the optimal monetary policy in a simplified model that only considers sticky prices. This version of the model will help to understand the role of monetary policy in a small open economy with nominal rigidities. Then we characterize the optimal monetary policy in the full-blown model that also includes segmented asset markets. The model is solved using the second-order approximation algorithm developed by Schmitt-Grohé and Uribe (2004). As shown by Kim and Kim (2003), a conventional first-order approximation may present problems to correctly measure the welfare of households, which is a crucial element in the implementation of an optimal policy problem.

4.1 Calibration

We calibrate the parameters of the model to match the features of an emerging small open economy. We consider Chile as a prototype case of a small open economy with

[18] In recursive problems only past variables can affect current actions. This Ramsey problem has a non-recursive structure since in the expectational equations current variables depend on the expected value of future variables.

a credible monetary policy, so most of the parameters are calibrated according to this emerging country. In the model the time unit is one quarter. We adopt a logarithmic utility function:

$$u(c,l) = \ln c + \psi \log(1-l) \tag{39}$$

and a C.E.S. function for the composite consumption good:

$$c = \left[\theta(c^T)^\mu + (1-\theta)(c^N)^\mu\right]^{\frac{1}{\mu}} \tag{40}$$

We choose a preference weight on leisure consistent with a steady state labor supply of 0.22. For the intratemporal elasticity of substitution $1/(1-\mu)$ we rely on the estimation of Gonzales-Rozada and Neumeyer (2003) and set its value to 0.5. The preference weight θ is chosen to match the share of tradable goods in the Chilean CPI.

We specify a C.E.S. production function for the firms in the tradable sector:

$$y_t^T = z_t^T(\alpha_T(l_t^T)^{1-\phi} + (1-\alpha_T)(N_t)^{1-\phi})^{\frac{1}{1-\phi}} \tag{41}$$

We set the labor weight in the production function to $\alpha_T = 0.4$. This parameter value is taken from Guajardo (2003) and is consistent with the labor share of the tradable sector in Chile. For the elasticity of substitution between labor and the intermediate non-tradable input there are no estimates for the Chilean economy. We assume $\phi = 1.5$, which is the value generally used in the international business cycle literature for the elasticity of substitution between domestic and foreign inputs in the production function[19]. Based on Bergoeing and Piguillem (2003) we set $\varepsilon = 6$, which implies a steady state markup of 20 percent.

We assume the same transaction costs specification as Schmitt-Grohé and Uribe (2004):

$$s(v) = \omega v + \frac{\xi}{v} - 2\sqrt{\xi\omega} \tag{42}$$

One particular feature of this transaction technology is that it exhibits a satiation point of real money balances. This is necessary in order to obtain well-defined money demand at a zero nominal interest rate (i.e. the Friedman rule). With a zero nominal interest rate, transaction costs are nil and the equilibrium consumption velocity is equal to $\overline{v} = \sqrt{\xi/\omega}$. To calibrate the parameters of the transaction costs technology, we

[19] See Chari et al. (2002).

estimate an aggregate demand for real money balances based on this specification of the transaction costs[20]:

$$v_t^2 = \frac{\xi}{\omega} + \frac{1}{\omega}\frac{R_t - 1}{R_t} \tag{43}$$

For consumption velocity we use the ratio of nominal private consumption to M1. For the estimation, we consider the nominal interest rate on deposits between 90 days and one year. The OLS parameter estimates of equation (43) are $\omega = 0.06$ and $\xi = 0.17$[21].

To calibrate the quadratic adjustment cost of prices we follow Galí and Gertler (1999) and estimate the log-linearized version of the expectational augmented Phillips curve:

$$\widehat{\pi}_t^N = \beta E_t[\widehat{\pi}_{t+1}^N] + \frac{(\varepsilon - 1)h}{\kappa}\widehat{mc}_t \tag{44}$$

where $\widehat{x}_t$ denotes the log-linearization of variable x_t. This equation resembles the new Phillips curve derived under Calvo's staggered price setting assumptions. We estimate the reduced form of equation (44) using the Generalized Method of Moments[22]. The estimator of the marginal costs coefficient, $\frac{(\varepsilon-1)h}{\kappa}$, is equal to 0.084. Given the steady state labor supply and the elasticity between differentiated goods, the implied coefficient for the quadratic cost adjustment is 13.16. This coefficient is consistent with a price stickiness of 4 quarters in Calvo's model. This estimate is somewhat higher than the 3 quarters price stickiness observed in the United States (Sbordone, 2002). Nevertheless, we carry out a sensitivity analysis to evaluate the robustness of the simulation to different assumptions about price stickiness.

We do not have an estimate of the fraction of the population that is excluded from asset markets in Chile. Using data from the Survey of Consumer Finance, Mulligan and Sala-i-Martin (2000) show that in 1989, 59 percent of U.S. households did not invest in interest-bearing assets. This amount of asset market segmentation for a developed economy suggests that in emerging market economies, where financial markets are less developed, this friction may be more severe. In the baseline calibration we assume 50 percent of asset market segmentation. Also, we conduct a sensitivity analysis to ana-

[20] Since it is not possible to obtain empirical estimates of these parameters for each type of agent, we estimate an aggregate demand for money and assume it holds for both types of agents.

[21] The estimated equation is $v_t^2 = 2.68 + 15.64(R_t - 1)/R_t$. The t-statistics for the first and second coefficient are 20.82 and 15.72, respectively. The coefficient of determination is 0.82.

[22] We estimate the equation with GMM for the sample period 1990:1 - 2002:4. Instruments used include four lags of non-tradable inflation, wage inflation, real marginal costs, and the non-tradable output gap.

lyze how numerical results may change in response to different degrees of asset market segmentation.

For financial transactions with the rest of the world we follow Schmitt-Grohé and Uribe (2001) and assume a highly elastic supply of funds setting $\nu = 0.00001$. We assume a low value of ν since the only purpose of the upward-sloping supply of funds is to induce stationarity in the model and not to capture the behavior of the risk premium in the economy. This implies that the allocations will be approximately the same with or without the supply of funds. The steady state of net foreign assets B_t^* is consistent with a ratio of net exports to GDP of 2.3 percent, and the discount factor β is equal to inverse of the gross foreign interest rate R^* at the steady state. The parameter values are summarized in table 1.

Table 1: Parameter values for the Chilean Economy

Description	**Symbol**	**Value**
Discount Factor	β	0.99
Tradable weight in consumption	θ	0.07
Intratemporal Elasticity of Substitution	$\frac{1}{1-\mu}$	0.50
Parameter Transaction Cost Function	ω	0.06
Parameter Transaction Cost Function	ξ	0.17
Markup	$\frac{\varepsilon}{\varepsilon-1}$	1.20
Price adjustment cost	κ	13.16
Labor share in the tradable sector	α_T	0.40
Elasticity of substitution for tradable firms	ϕ	1.5
Foreign interest rate elasticity	ν	10^{-5}
Asset Market Segmentation	λ	0.5

We assume that the exogenous processes in the model economy follow an AR(1) process. The estimated processes are the following (standard errors in parentheses)[23]:

$$z_t^T = \underset{(0.11)}{0.65} z_{t-1}^T + \epsilon_t^T,\ \ \epsilon_t^T \sim N(0, \sigma_T^2), \sigma_T = 0.027 \tag{45}$$

$$z_t^N = \underset{(0.08)}{0.84} z_{t-1}^N + \epsilon_t^N,\ \ \ \epsilon_t^N \sim N(0, \sigma_N^2),\ \ \sigma_N = 0.021 \tag{46}$$

$$g_t^N = \underset{(0.10)}{0.76} g_{t-1}^N + \epsilon_t^G,\ \ \ \epsilon_t^G \sim N(0, \sigma_G^2),\ \ \sigma_G = 0.026 \tag{47}$$

4.2 Optimal Monetary Policy in a Model with Sticky Prices

In this section we characterize the optimal policy problem in a small open economy with sticky prices. We consider a version of the model laid out in section 2 in which $\lambda = 1$, that is, all agents in the economy have access to international and domestic bonds and hence there is no asset market segmentation. We compare the allocations under the Ramsey policy with a benchmark two-sector real model with monopolistic competition which is described in Appendix B[24]. The comparison between models allows us to quantify to which extent the Ramsey policy is able to mitigate the distortions associated with sticky prices and monetary transaction costs. In the extreme case, if the optimal policy is successful to eliminate all nominal frictions, then the Ramsey allocations will coincide exactly with the ones from the real model. Given the parametrization in section 4.1, we find quantitatively small deviations of the Ramsey solution from the benchmark model, which indicates that the optimal policy is capable to reproduce to a great extent the flexible-price equilibrium.

In order to draw a clear policy prescription we also investigate if the Ramsey policy can be implemented with a simple monetary policy rule. This comparison is useful since, in principle, a simple rule can be followed by a central bank. We find that in response to any shock in the model, the Ramsey policy provides an allocation quantitatively similar to the outcome under the non-tradable inflation targeting rule[25]. Below we describe the

[23] All the variables are expressed in logarithms.

[24] We could also compare the Ramsey allocation with a model with perfect competition to measure the deviations with respect to the first best. However, Goodfriend and King (1997) show that monetary policy has limited impact to modify the steady state markup in order to achieve the first best allocation. In that sense, the relevant benchmark model is one with monopolistic competition.

[25] In the previous version of the paper we compared the Ramsey solution with additional rules such as exchange rate peg and money peg. We found large deviations in the allocations between these rules and the optimal policy. In this version we focus only on the non-tradable inflation targeting rule, since it achieves the closest allocation to the optimal policy.

dynamics of the Ramsey policy in response to productivity shocks in the tradable and non-tradable sector[26].

Figures 3 and 4 show the impulse responses of the Ramsey solution to a one percent increase in tradable-sector productivity. In figure 3 we can notice that the dynamics under the optimal policy replicate almost identically the one observed for the real model in terms of output, labor supply, markups and real exchange rate. This result shows that the Ramsey policy is able to mimic the allocation under flexible prices. Since in New Keynesian models potential output is defined as the one prevalent under flexible prices, the Ramsey policy derived in this case achieves an output gap close to zero. Notice in panel 2 of figure 3 that in response to an increase in tradable productivity the interest rate increases by slightly more than 100 basis points, which implies a countercyclical monetary policy.

They key reason why the optimal policy response is countercyclical is to mitigate the effects of price stickiness in the non-tradable sector. The tradable productivity shock bids up wage in the non-tradable sector generating a shift in marginal costs. With price stickiness, the increase in the marginal cost will also increase the real marginal cost and reduce the markup. In order to restore the flexible price equilibrium in which markups are constant, the optimal response of the monetary authority is to contract the money supply which reduces the aggregate demand. This countercyclical monetary policy offsets the reduction in markups, and hence limits the misallocation of resources in the non-tradable sector. In panel 8 we can see that the optimal policy largely stabilizes the markup, achieving an allocation similar to the benchmark model.

In figure 4 we compare the Ramsey policy with the monetary policy rule of non-tradable inflation targeting. Formally, this rule is defined as $\pi_t^N = \overline{\pi}$. To properly compare the allocations of the two models, we set the inflation target $\overline{\pi}$ equal to the steady state inflation rate in the Ramsey problem[27]. In all panels we can see that it is possible to mimic very closely the Ramsey allocations with the non-tradable inflation targeting rule. In panel 2 we can appreciate that compared to the monetary rule, the optimal policy smooths the response of the nominal interest rate. The main reason behind the interest rate smoothing behavior is the presence of monetary transaction costs. The Ramsey planner has to weigh the effects of monetary transaction costs and

[26] We find that a limited impact of government expenditure shocks to the economy as in Goodfriend and King (2001) due to the assumption of a highly elastic supply of funds. This assumption allows agents to insure against the wealth effects of government expenditure. Given the reduced scope of fiscal policy in the model, we do not present the impulse response function of government expenditure shocks.

[27] In the steady state the Ramsey policy generates an annual deflation rate of 0.05 percent.

sticky prices on household's welfare. The first distortion can be corrected implementing the Friedman rule, while the second one stabilizing the non-tradable inflation rate. Given the baseline calibration, we find that the Ramsey policy can be approximated with a non-tradable inflation targeting rule. This result indicates that the impact of sticky prices on the household's welfare is much higher than the impact of monetary transaction costs, otherwise we would see an optimal policy close to the Friedman rule. Nevertheless, the impact of monetary transaction costs is not trivial. The Ramsey planner mitigates the transaction costs stabilizing the nominal interest rate as much as possible. In panel 5 we can observe that the policy of interest rate smoothing induces a small departure of the markup from the flexible price equilibrium.

Regarding the real exchange rate dynamics, figure 3 and 4 shows a real appreciation of 1 percent in response to a 1 percent increase in the productivity of the tradable sector. This response is consistent with the Balassa-Samuelson effect. A higher productivity in the tradable sector bids up the wages in the whole economy, generating an increase in real marginal costs in the non-tradable sector. As a consequence of this shift in the real marginal costs there is an increase in the relative price of non-tradable goods, which implies an appreciation of the real exchange rate. With sticky prices a specific monetary policy can influence how the real exchange adjusts. The appreciation of the real exchange rate can be achieved either with an increase in the price of non-tradable goods or with an appreciation of the nominal exchange rate. In panel 3 of figure 4 we can appreciate that under the optimal policy the non-tradable inflation rate is largely stabilized, and hence the nominal exchange rate absorbs most of the real shock. This outcome of the optimal policy is consistent with Friedman's argument in favor of a flexible exchange rate regime[28]. Fluctuations in the nominal exchange rate provide a better insulation from shocks since it allows a quick adjustment in relative prices. An alternative policy rule would entail fluctuations of the non-tradable price and would involve a loss of non-tradable resources which is welfare reducing.

Figures 5 and 6 presents the impulse response functions of the Ramsey solution to an increase in the productivity in the non-tradable sector. In these figures we compare the results of the Ramsey policy with the benchmark real model and a monetary model with an inflation targeting rule. We also find for this case that the Ramsey policy provides an allocation close to the one under flexible prices, and that the non-tradable inflation targeting rule closely resembles the Ramsey policy. However, there are two main differences with respect to the dynamics under tradable productivity shocks. First, the monetary policy is procyciclical. The procyclicality can be explained by the response of

[28]See Friedman (1953).

markups to an increase in the productivity of the non-tradable sector. Higher productivity implies a reduction of nominal marginal costs, and under sticky prices this will reduce the real marginal cost and will increase in the markup. A procyclical monetary policy expands the aggregate demand and stabilizes the marginal cost and the markup. This stabilization of the markup eliminates the incentives of the firms to change prices, and prevents a loss of resources in the non-tradable sector. Second, there is an depreciation of the real exchange rate. The intuition for this response of the real exchange rate is the same as before. A raise in productivity increases the demand for labor, nominal wages and the marginal costs in the tradable sector. This raise in the marginal cost will increase the relative price of tradable goods and generate a real depreciation of the exchange rate. To prevent the welfare costs of non-tradable price fluctuations the Ramsey planner stabilizes the inflation in the non-tradable sector an allows a depreciation of the nominal exchange rate.

Finally, we conduct a sensitivity analysis for different assumptions of price stickiness. In figure 7 we plot the standard deviation of non-tradable inflation for different values of κ. We find that under the Ramsey policy the non-tradable inflation volatility is close to zero for a wide range of parameter values of price stickiness. Even if we assume a degree of price stickiness several times lower than the empirical estimates for the Chilean economy, it is optimal to achieve a stable path for the price of non-tradable goods. As we decrease the parameter κ, the welfare costs of price stickiness become less relevant therefore the optimal policy is redirected to attenuate the negative effects of monetary transaction costs. Figure 8 shows that as we reduce the price rigidity in the economy the optimal policy stabilizes the volatility of the nominal interest rate in order to mitigate the distortions of monetary transactions costs. As we approach to the case of flexible prices, the optimal policy turns to be similar to the Friedman rule, which completely eliminates money distortions.

4.3 Optimal Monetary Policy in a Model with Sticky Prices and Asset Market Segmentation

In this section we characterize the Ramsey policy in the full-blown model with sticky prices and asset market segmentation. We carry out the same analysis as before and compare the allocations of the optimal policy with the ones of the benchmark real model and the monetary model with a non-tradable inflation targeting rule. The results obtained previously for the optimal policy under price rigidities are robust to the introduction of asset market segmentation. First, the Ramsey allocation is quantitatively close to the benchmark real model in the presence of asset market segmentation and sticky prices. Second, the optimal policy can be approximated by the inflation targeting rule.

It is surprising that in spite of the potential welfare costs of asset market segmentation we find no substantial changes in the properties of the Ramsey policy. This result reveals that monetary policy is an inefficient tool to correct the problem of segmented asset markets in the presence of price stickiness. This outcome reflects that correcting sticky prices provides a higher welfare compared to correcting asset market segmentation. In an economy with segmented asset markets one goal of optimal monetary policy is to achieve full risk-sharing, allowing non-traders to have the same intertemporal marginal rate of substitution of traders. However in order to correct this financial distortion, monetary policy has to deviate from the flexible-price allocation which results in even a greater welfare cost than the one generated by asset market segmentation. In figures 9 to 12 we discuss in more detail the intuition of this result.

Figures 9 and 10 present the dynamics of the Ramsey policy for a tradable productivity shock. The dynamics of the aggregate variables are broadly similar to the model economy with sticky prices. However, there is a significant divergence in the allocations for each type of agent. The difference between traders and non-traders can be explained by the incidence of wealth effects. In the case of traders, the allocations will be affected mainly by the substitution effects since the wealth effects will be absorbed by the rest of the world through the net foreign assets. On the other hand, non-traders cannot access to international bonds and their allocations will respond both to the substitution and wealth effects. We observe in panels 5 and 6 of figure 9 the difference in the dynamics of non-tradable consumption for traders and non-traders. In response to a productivity shock traders reduce their non-tradable consumption. Since there is an appreciation of the real exchange rate, the non-tradable goods turn relatively more expensive compared to the tradable goods, therefore the substitution effect induces this contraction in non-tradable goods. On the other hand, non-traders have a stable path of non-tradable consumption. Since non-traders face both a substitution and a wealth effects, the reduction of non-tradable consumption due to the substitution effect is fully compensated by the increase wealth due to a raise in productivity in the tradable sector.

In figure 9 we can also appreciate that the consumption of tradable and non-tradable goods, for each type of agent, tend to move together. These dynamics are generated by the calibration of the intratemporal elasticity of substitution, which generates a high complementary between tradable and non-tradable goods. On the other hand, the response of labor supply will also depend in the access to international financial markets. A increase in productivity will raise real wages which generates a substitution and wealth effect. Given that the traders have access to foreign bonds, they will be affected mainly by the substitution effect so the increase in real wage will induce a higher labor effort. Since the non-traders are excluded from financial markets, both the substitution and wealth effect will affect them. However, both effects cancel out so the labor supply for non-traders remains relatively stable.

In figure 10 we can observe that the Ramsey policy can be approximated by the non-tradable inflation targeting rule. In similar way to the economy with only sticky prices, the Ramsey planners tends to smooth the nominal interest rate and to stabilize the markup. In panel 6 of figure 10 we observe one key margin that is being distorted with asset market segmentation: the intertemporal marginal rate of substitution (IMRS) of non-traders. If non-traders could suddenly have access to international financial markets, then their IMRS should be equal to the inverse of the foreign interest rate, i.e. a condition similar to (5) should hold for non-traders. Since we are assuming a highly elastic supply of funds, the IMRS of non-traders should be constant under no asset market segmentation. In panel 6 we observe that the IMRS is far from being constant, however the Ramsey policy marginally reduces it compared to the non-tradable inflation targeting rule.

Figures 11 and 12 present the dynamics in response to a productivity shock in the non-tradable sector. In this case we obtain similar results as before: The Ramsey policy achieves and allocation close to the flexible price equilibrium and the optimal policy can be approximated by a non-tradable inflation targeting rule. As opposed to the shock in the tradable sector, in this case we observe a depreciation of the real exchange rate. In response to the productivity shock the IMRS also deviates from the efficiency condition, but to a lower extent than in the case of the non-tradable shock. In panel 6 of figure 12 we can appreciate that the Ramsey policy stabilizes the IMRS compared to the non-tradable inflation targeting rule, with the objective of minimizing the negative effects of asset market segmentation.

In figures 13 and 14 we show a sensitivity analysis of the optimal policy for different values of price stickiness and asset market segmentation. In figure 13 we plot the standard deviation of non-tradable inflation, and find a robust case for stabilizing the non-tradable inflation rate. Given the baseline calibration for price stickiness, stabilizing non-tradable inflation is optimal regardless of the degree of asset market segmentation. Despite the fact that financial markets are incomplete for a fraction of the households, the social planner does not sacrifice the goal of price stability in order to provide insurance for the non-traders. This result suggests that welfare costs associated with sticky prices are substantially larger than those generated by asset market segmentation and monetary transactions. Only for very small values of κ is optimal to induce some inflation volatility. In figure 14 we show a similar sensitivity analysis but with the standard deviation of the nominal interest rate. There are two important properties shown in this figure. First, for any level of asset market segmentation, as we reduce the amount of price stickiness the optimal policy stabilizes the nominal interest rate in order to correct monetary distortions. Second, for any level of price stickiness, as we increase the magnitude of asset market segmentation the volatility of the nominal interest rate is higher. This is explained by the fact that the price of domestic bonds, which defines the nominal interest rate, is exclusively determined by the transactions of traders. As we increase the degree of asset market segmentation, a smaller amount of traders will absorb the monetary injections inducing a higher volatility of asset prices and the nominal interest rate.

Finally, figure 15 shows a sensitivity analysis of the weights in the social welfare function. Throughout the paper we have assumed a Ramsey planner that weights the welfare of the society according to the population size of the agents. In this setting there is trade-off between smoothing the consumption path of non-traders and stabilizing the non-tradable inflation rate. For the baseline calibration we find a strong case for stabilizing the non-tradable inflation rate for any level of asset market segmentation. Now we evaluate to which extent this result holds if we consider an alternative planner that assigns more importance to the welfare of non-traders[29]. A higher weight of non-traders in the social welfare function will increase the relevance of consumption smoothing since this type of agent cannot participate in the financial markets. In figure 15 we can appreciate that as the Ramsey planner gives more importance to the non-traders there is an increase in the volatility of the inflation rate and the nominal interest. Since the role of consumption smoothing turns more relevant, the monetary authority has to engage in an active monetary policy in favor of non-traders which generates more inflation volatility. What is striking from this result is that as we depart from the population weights in the social welfare function, the inflation volatility increases at a relatively slow rate. Even if there is a substantial change in the welfare weights, the volatility of inflation is largely below the one observed under the assumption of flexible prices.

[29] Recall that λ is the population size of traders in the economy. We define "λ-Ramsey Planner", the weight of traders in the welfare objective function of the Ramsey planner. Notice that in the sensitivity analysis we change the parameter "λ- Ramsey Planner" but holding λ constant.

5 Concluding Remarks

In this paper we characterize the optimal monetary policy for a small open economy with sticky prices and asset market segmentation. Following the Ramsey approach, we find that in this environment the optimal policy features a volatility of non-tradable inflation close to zero. This policy stabilizes the markups, reduces the incentives of non-tradable firms to change prices, and provides an allocation quantitatively similar to the one under flexible prices. Even though a tension exists to undo all distortions present in the model economy, the optimal policy prioritizes the elimination of sticky prices over other goals. This result reveals that using monetary instruments to correct financial frictions, such as asset market segmentation, is highly distortionary in an environment with sticky prices.

This paper has two important implications for policymakers. First, the optimal monetary policy should target an appropriate price index. Despite the fact that conventional wisdom among policymakers suggests as optimal stabilizing the inflation rate of the consumer price index, this policy could be distortionary. The optimal policy should target only the subset of prices that display stickiness. The empirical evidence shows that the non-tradable sector exhibits more price stickiness than the tradable sector, so stabilizing a price index that puts more weight on the non-tradable sector is welfare-improving.

Second, stabilizing non-tradable inflation is optimal regardless of the financial structure of the economy. This result is crucial for developing countries, which have shallow financial markets. Even if underdeveloped financial markets increase the volatility of consumption, and hence the welfare cost of business cycle fluctuations, it is not optimal to correct this distortion with monetary policy. A monetary policy aimed at smoothing consumption is highly distortionary since it implies variations in the non-tradable price, fluctuations in the markups, and hence a misallocation of resources. One should interpret this result with caution. The fact that correcting asset market segmentation by monetary means is welfare-reducing does not imply that financial imperfections should be disregarded by policymakers. As an alternative, we may also think of the possibility of designing an appropriate fiscal policy to achieve a better intertemporal allocation. The benefits of using fiscal instruments to cope with asset market segmentation is an important issue that can be analyzed in the Ramsey policy framework as well.

This paper can be extended in several dimensions. In addition to asset market segmentation, we may include additional real and nominal frictions in the model in order to match the main features of the data. This approach has been followed by Schmitt-Grohé and Uribe (2005). They evaluate optimal fiscal and monetary policies in a model that reproduce the dynamics of the U.S. business cycle, and find a strong case for stabilizing the inflation rate. A similar exercise could be done to evaluate the robustness of our results in a more realistic setup. Another extension could be to model the lack of financial development in emerging economies introducing agents with borrowing constraints as in Monaccelli (2006). In that environment, Monacelli also finds a strong case for price stability even though inflation has redistributive effects from savers to borrowers. We can adapt this financial friction to the case of many emerging economies which have debt denominated in foreign currency. In this context it would be interesting to evaluate the role of the nominal exchange rate in redistributing resources across agents.

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Appendix A: Lagrangian of the Ramsey Problem

In this appendix we describe the Lagrangian associated with the Ramsey problem in section 3. To simplify the arguments of the optimization problem we define the following vectors: $d_t = [c_t^T(tr),\, c_t^N(tr),\, l_t(tr),\, v_t(tr),\, c_t^T(nt),\, c_t^N(nt),\, l_t(nt),\, v_t(nt),\, l_t^T,\, N_t,\, B_t^*,\, \pi_t^N]'$ and $\mu_t = [\mu_{1,t}, \ldots, \mu_{11,t}]'$, where μ_1 - μ_{11} are the Lagrange multipliers associated with the constraints (28) - (38). Then the Lagrangian can be written as:

$$\min_{\{\mu_t\}_{t=0}^{\infty}} \max_{\{d_t\}_{t=0}^{\infty}} \mathbb{E}_0 \{ \sum_{t=0}^{\infty} \beta^t [\lambda u(c_t^T(tr), c_t^N(tr), l_t(tr)) + (1-\lambda) u(c_t^T(nt), c_t^N(nt), l_t(nt))$$

$$+\mu_{1,t}\left(z_t^T f_N^T(l_t^T, N_t) - \frac{u_{c^N,t}(tr)}{u_{c^T,t}(tr)}\right) + \mu_{2,t}\left(z_t^T f_N^T(l_t^T, N_t) - \frac{u_{c^N,t}(nt)}{u_{c^T,t}(nt)}\right)$$

$$+\mu_{3,t}\left(z_t^T f_l^T(l_t^T, N_t) + \frac{u_{l,t}(tr) h(v_t(tr))}{u_{c^T,t}(tr)}\right)$$

$$+\mu_{4,t}\left(z_t^T f_l^T(l_t^T, N_t) + \frac{u_{l,t}(nt) h(v_t(nt))}{u_{c^T,t}(nt)}\right)$$

$$+\mu_{5,t}\left(\frac{u_{c^N,t}(tr)}{h(v_t(tr))}(1 - s'(v_t(tr))(v_t(tr))^2) - \beta \mathbb{E}_t\left[\frac{u_{c^N,t+1}(tr)}{\pi_{t+1}^N h(v_{t+1}(tr))}\right]\right)$$

$$+\mu_{6,t}\left(\frac{u_{c^N,t}(nt)}{h(v_t(nt))}(1 - s'(v_t(nt))(v_t(nt))^2) - \beta \mathbb{E}_t\left[\frac{u_{c^N,t+1}(nt)}{\pi_{t+1}^N h(v_{t+1}(nt))}\right]\right)$$

$$+\mu_{7,t}\left(\frac{u_{c^T,t}(tr)}{h(v_t(tr))} - \beta R^* \left[\frac{B_t^*}{B^*}\right]^{\nu} \mathbb{E}_t\left[\frac{u_{c^T,t+1}(tr)}{h(v_{t+1}(tr))}\right]\right)$$

$$+\mu_{8,t}\left(\begin{array}{l} \dfrac{u_{c^N,t}(tr)}{h(v_t(tr))}\pi_t^N(\pi_t^N - 1) - \beta \mathbb{E}_t\left[\dfrac{u_{c^N,t+1}(tr)}{h(v_{t+1}(tr))}\pi_{t+1}^N(\pi_{t+1}^N - 1)\right] \\ \\ +\dfrac{\varepsilon - 1}{\kappa}\left[\dfrac{\varepsilon}{\varepsilon - 1}u_{l,t}(tr) + \dfrac{u_{c^N,t}(tr)}{h(v_t(tr))}z_t^N\right]\left[\lambda l_t(tr) + (1-\lambda) l_t(nt) - l_t^T\right] \end{array}\right)$$

$$+\mu_{9,t}\left(\begin{array}{l} z_t^N\left[\lambda l_t(tr) + (1-\lambda) l_t(nt) - l_t^T\right] - \lambda c_t^N(tr) - (1-\lambda) c_t^N(nt) \\ \\ -\lambda s(v_t(tr))\left[c_t^N(tr) + \dfrac{u_{c^T,t}(tr)}{u_{c^N,t}(tr)}c_t^T(tr)\right] - g_t^N - N_t \\ \\ -(1-\lambda) s(v_t(nt))\left[c_t^N(nt) + \dfrac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)}c_t^T(nt)\right] - \dfrac{\kappa}{2}(\pi_t^N - 1)^2 \end{array}\right)$$

$$+\mu_{10,t}\left(z_t^T f^T(l_t^T, N_t) + R^* \left[\frac{B_{t-1}^*}{B^*}\right]^{\nu} B_{t-1}^* - B_t^* - \lambda c_t^T(tr) - (1-\lambda) c_t^T(nt)\right)$$

$$+\mu_{11,t}\begin{pmatrix} -\frac{u_{l,t}(nt)h(v_t(nt))}{u_{c^N,t}(nt)}l_t(nt)+S-g_t^N \\ \\ +\left[c_{t-1}^N(nt)+\frac{u_{c^T,t-1}(nt)}{u_{c^N,t-1}(nt)}c_{t-1}^T(nt)\right]\frac{1}{v_{t-1}(nt)\pi_t^N} \\ \\ -\left[c_t^N(nt)+\frac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)}c_t^T(nt)\right]\left(1+s(v_t(nt))+\frac{1}{v_t(nt)}\right)\end{pmatrix}]\}$$

given B^*_{-1},$c^T_{-1}(nt)$, $c^N_{-1}(nt)$, and $v_{-1}(nt)$.

Remark 1. Let g^1, g^2 : domain$(d_t) \to \mathbb{R}$ be two functions. We have the following identity:

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\chi_t(g^1(d_t)+\beta\mathbb{E}_t[g^2(d_{t+1})])\right]=\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\mathbb{E}_t(\chi_t g^1(d_t)+\chi_{t-1}g^2(d_t))\right]$$

This can easily be proved by rearranging the terms and using the law of iterated expectations. We apply this remark to the Lagrangian above to rewrite:

$$\begin{aligned}\min_{\{\mu_t\}_{t=0}^{\infty}}\max_{\{d_t\}_{t=0}^{\infty}}\ &\mathbb{E}_0\{\sum_{t=0}^{\infty}\beta^t\mathbb{E}_t[\lambda u(c_t^T(tr),c_t^N(tr),l_t(tr))+(1-\lambda)u(c_t^T(nt),c_t^N(nt),l_t(nt))\\
&+\mu_{1,t}\left(z_t^T f_N^T(l_t^T,N_t)-\frac{u_{c^N,t}(tr)}{u_{c^T,t}(tr)}\right)+\mu_{2,t}\left(z_t^T f_N^T(l_t^T,N_t)-\frac{u_{c^N,t}(nt)}{u_{c^T,t}(nt)}\right)\\
&+\mu_{3,t}\left(z_t^T f_l^T(l_t^T,N_t)+\frac{u_{l,t}(tr)h(v_t(tr))}{u_{c^T,t}(tr)}\right)\\
&+\mu_{4,t}\left(z_t^T f_l^T(l_t^T,N_t)+\frac{u_{l,t}(nt)h(v_t(nt))}{u_{c^T,t}(nt)}\right)\\
&+\frac{u_{c^N,t}(tr)}{h(v_t(tr))}\left[(1-s'(v_t(tr))(v_t(tr))^2)\mu_{5,t}-\frac{1}{\pi_t^N}\mu_{5,t-1}\right]\\
&+\frac{u_{c^N,t}(nt)}{h(v_t(nt))}\left[(1-s'(v_t(nt))(v_t(nt))^2)\mu_{6,t}-\frac{1}{\pi_t^N}\mu_{6,t-1}\right]\\
&+\frac{u_{c^T,t}(tr)}{h(v_t(tr))}\left[\mu_{7,t}-R^*\left[\frac{B_{t-1}^*}{B^*}\right]^{\nu}\mu_{7,t-1}\right]\\
&+\frac{u_{c^N,t}(tr)}{h(v_t(tr))}\pi_t^N(\pi_t^N-1)\left[\mu_{8,t}-\mu_{8,t-1}\right]\end{aligned}$$

$$+\mu_{8,t}\left(\frac{\varepsilon-1}{\kappa}\left[\frac{\varepsilon}{\varepsilon-1}u_{l,t}(tr)+\frac{u_{c^N,t}(tr)}{h(v_t(tr))}z_t^N\right]\left[\lambda l_t(tr)+(1-\lambda)l_t(nt)-l_t^T\right]\right)$$

$$+\mu_{9,t}\left(\begin{array}{l} z_t^N\left[\lambda l_t(tr)+(1-\lambda)l_t(nt)-l_t^T\right]-\lambda c_t^N(tr)-(1-\lambda)c_t^N(nt) \\ \\ -\lambda s(v_t(tr))\left[c_t^N(tr)+\dfrac{u_{c^T,t}(tr)}{u_{c^N,t}(tr)}c_t^T(tr)\right]-g_t^N-N_t \\ \\ -(1-\lambda)s(v_t(nt))\left[c_t^N(nt)+\dfrac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)}c_t^T(nt)\right]-\dfrac{\kappa}{2}(\pi_t^N-1)^2 \end{array}\right)$$

$$+\mu_{10,t}\left(z_t^T f^T(l_t^t,N_t)+R^*\left[\frac{B_{t-1}^*}{B^*}\right]^{\nu}B_{t-1}^*-B_t^*-\lambda c_t^T(tr)-(1-\lambda)c_t^T(nt)\right)$$

$$+\mu_{11,t}\left(\begin{array}{l} -\dfrac{u_{l,t}(nt)h(v_t(nt))}{u_{c^N,t}(nt)}l_t(nt)-g_t^N \\ \\ +\left[c_{t-1}^N(nt)+\dfrac{u_{c^T,t-1}(nt)}{u_{c^N,t-1}(nt)}c_{t-1}^T(nt)\right]\dfrac{1}{v_{t-1}(nt)\pi_t^N} \\ \\ -\left[c_t^N(nt)+\dfrac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)}c_t^T(nt)\right]\left(1+s(v_t(nt))+\dfrac{1}{v_t(nt)}\right) \end{array}\right)]\}$$

given B_{-1}^*,$c_{-1}^T(nt)$, $c_{-1}^N(nt)$, $v_{-1}(nt)$, and $\mu_{5,-1}=\mu_{6,-1}=\mu_{7,-1}=\mu_{8,-1}=0$.

To see the inclusion of μ_5 - μ_8 as state variables in the characterization of the optimal policy, we follow the framework of Marcet and Marimon (1998), expressing this Lagrangian as a *saddle point function equation*:

$$W(d_{t-1}^x,\mu_{t-1}^x,z_t)=$$

$$\min_{\mu_t}\max_{d_t}\{\lambda u(c_t^T(tr),c_t^N(tr),l_t(tr))+(1-\lambda)u(c_t^T(nt),c_t^N(nt),l_t(nt))$$

$$+\mu_{1,t}\left(z_t^T f_N^T(l_t^T,N_t)-\frac{u_{c^N,t}(tr)}{u_{c^T,t}(tr)}\right)+\mu_{2,t}\left(z_t^T f_N^T(l_t^T,N_t)-\frac{u_{c^N,t}(nt)}{u_{c^T,t}(nt)}\right)$$

$$+\mu_{3,t}\left(z_t^T f_l^T(l_t^T,N_t)+\frac{u_{l,t}(tr)h(v_t(tr))}{u_{c^T,t}(tr)}\right)$$

$$+\mu_{4,t}\left(z_t^T f_l^T(l_t^T,N_t)+\frac{u_{l,t}(nt)h(v_t(nt))}{u_{c^T,t}(nt)}\right)$$

$$+\frac{u_{c^N,t}(tr)}{h(v_t(tr))}\left[(1-s'(v_t(tr))(v_t(tr))^2)\mu_{5,t}-\frac{1}{\pi_t^N}\mu_{5,t-1}\right]$$

$$
\begin{aligned}
&+\frac{u_{c^N,t}(nt)}{h(v_t(nt))}\left[(1-s'(v_t(nt))(v_t(nt))^2)\mu_{6,t}-\frac{1}{\pi_t^N}\mu_{6,t-1}\right]\\
&+\frac{u_{c^T,t}(tr)}{h(v_t(tr))}\left[\mu_{7,t}-R^*\left[\frac{B^*_{t-1}}{B^*}\right]^{\nu}\mu_{7,t-1}\right]\\
&+\frac{u_{c^N,t}(tr)}{h(v_t(tr))}\pi_t^N(\pi_t^N-1)\left[\mu_{8,t}-\mu_{8,t-1}\right]\\
&+\mu_{8,t}\left(\frac{\varepsilon-1}{\kappa}\left[\frac{\varepsilon}{\varepsilon-1}u_{l,t}(tr)+\frac{u_{c^N,t}(tr)}{h(v_t(tr))}z_t^N\right]\left[\lambda l_t(tr)+(1-\lambda)l_t(nt)-l_t^T\right]\right)\\
&+\mu_{9,t}\left(\begin{array}{l}
z_t^N\left[\lambda l_t(tr)+(1-\lambda)l_t(nt)-l_t^T\right]-\lambda c_t^N(tr)-(1-\lambda)c_t^N(nt)\\
\\
-\lambda s(v_t(tr))\left[c_t^N(tr)+\dfrac{u_{c^T,t}(tr)}{u_{c^N,t}(tr)}c_t^T(tr)\right]-g_t^N-N_t\\
\\
-(1-\lambda)s(v_t(nt))\left[c_t^N(nt)+\dfrac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)}c_t^T(nt)\right]-\dfrac{\kappa}{2}(\pi_t^N-1)^2
\end{array}\right)\\
&+\mu_{10,t}\left(z_t^T f^T(l_t^t,N_t)+R^*\left[\frac{B^*_{t-1}}{B^*}\right]^{\nu}B^*_{t-1}-B^*_t-\lambda c_t^T(tr)-(1-\lambda)c_t^T(nt)\right)\\
&+\mu_{11,t}\left(\begin{array}{l}
-\dfrac{u_{l,t}(nt)h(v_t(nt))}{u_{c^N,t}(nt)}l_t(nt)+S-g_t^N\\
\\
+\left[c_{t-1}^N(nt)+\dfrac{u_{c^T,t-1}(nt)}{u_{c^N,t-1}(nt)}c_{t-1}^T(nt)\right]\dfrac{1}{v_{t-1}(nt)\pi_t^N}\\
\\
-\left[c_t^N(nt)+\dfrac{u_{c^T,t}(nt)}{u_{c^N,t}(nt)}c_t^T(nt)\right]\left(1+s(v_t(nt))+\dfrac{1}{v_t(nt)}\right)
\end{array}\right)\\
&+\beta\mathbb{E}_t\left[W(d_t^x,\mu_t^x,z_{t+1})|z_t\right]\}
\end{aligned}
$$

where $W(\cdot)$ is the value function, $d_t^x=[B_t^*,\, c_t^T(nt),\, c_t^N(nt),\, v_t(nt)]'$, $\mu_t^x=[\mu_{5,t},\, \mu_{6,t},\, \mu_{7,t},\, \mu_{8,t}]'$, and $z_t=[z_t^T,\, z_t^N,\, g_t^N]'$. Additionally, in the text we collect the first two vectors in $x_t=[d_t^x,\, \mu_t^x]$ and the rest of the endogenous variables in vector y_t.

Appendix B: Benchmark Two-sector Real Model

This appendix shows the equilibrium conditions of the benchmark two-sector real model. We consider a similar model to the one in the main text, but featuring monopolistic competition and segmented asset markets as the main frictions. We abstract from sticky prices and monetary transaction costs. The equilibrium conditions of the model are given by:

$$\frac{u_{c^N,t}(tr)}{u_{c^T,t}(tr)} = p_t \tag{1}$$

$$-\frac{u_{l,t}(tr)}{u_{c^T,t}(tr)} = w_t \tag{2}$$

$$u_{c^T,t}(tr) = \beta R_t^* \mathbb{E}_t \left[u_{c^T,t+1}(tr) \right] \tag{3}$$

$$\frac{u_{c^N,t}(nt)}{u_{c^T,t}(nt)} = p_t \tag{4}$$

$$-\frac{u_{l,t}(nt)}{u_{c^T,t}(nt)} = w_t \tag{5}$$

$$z_t^T f_{l^T,t}^T = w_t \tag{6}$$

$$z_t^T f_{N,t}^T = p_t \tag{7}$$

$$p_t \left(\frac{\varepsilon - 1}{\varepsilon} \right) z_t^N = w_t \tag{8}$$

$$g_t^N = T_t \tag{9}$$

$$R_t^* = R^* \left[\frac{B_t^*}{B^*} \right]^\nu \tag{10}$$

$$\lambda l_t(tr) + (1-\lambda) l_t(nt) = l_t^T + l_t^N \tag{11}$$

$$\lambda c_t^N(tr) + (1-\lambda) c_t^N(nt) + N_t + g_t^N = y_t^N \tag{12}$$

$$\lambda c_t^T(tr) + (1-\lambda)c_t^T(nt) + B_t^* = y_t^T + R_{t-1}^* B_{t-1}^* \tag{13}$$

$$c_t^T(nt) + p_t c_t^N(nt) = w_t l_t(nt) - T_t \tag{14}$$

Equations (1), (2), and (3) are the first-order conditions for traders. (1) determines the allocation between tradable and non-tradable goods, (2) the labor supply, and (3) the consumption-saving decision. Equations (4) and (5) are the first-order conditions for non-traders. (4) determines the allocation between tradable and non-tradable goods, and (5) the labor supply. Equations (6), (7), and (8) are the demand functions for labor and non-tradable intermediate input for tradable and non-tradable firms. Equations (9) and (10) are the government budget constraint and the upward-sloping supply of funds. Finally, equations (11), (12), and (13) are the market clearing conditions and (14) defines the budget constraint for non-traders. In this model p_t is the relative price of non-tradable goods, and w_t is the real wage in terms of tradable goods.

An equilibrium for this economy is a set of (i) Prices: $\{p_t,\ w_t,\ R_t^*\}$, and (ii) Allocations: $\{c_t^T(tr),\ c_t^N(tr),\ c_t^T(nt),\ c_t^N(nt),\ B_t^*(tr),\ l_t(tr),\ l_t(nt),\ l_t^T,\ l_t^N,\ N_t,\ y_t^T,\ y_t^N\}$; such that (1) - (14) hold, given a policy $\{T_t\}$, exogenous process $\left\{z_t^T, z_t^N, g_t^N\right\}$, and initial an condition (B_{-1}^*).

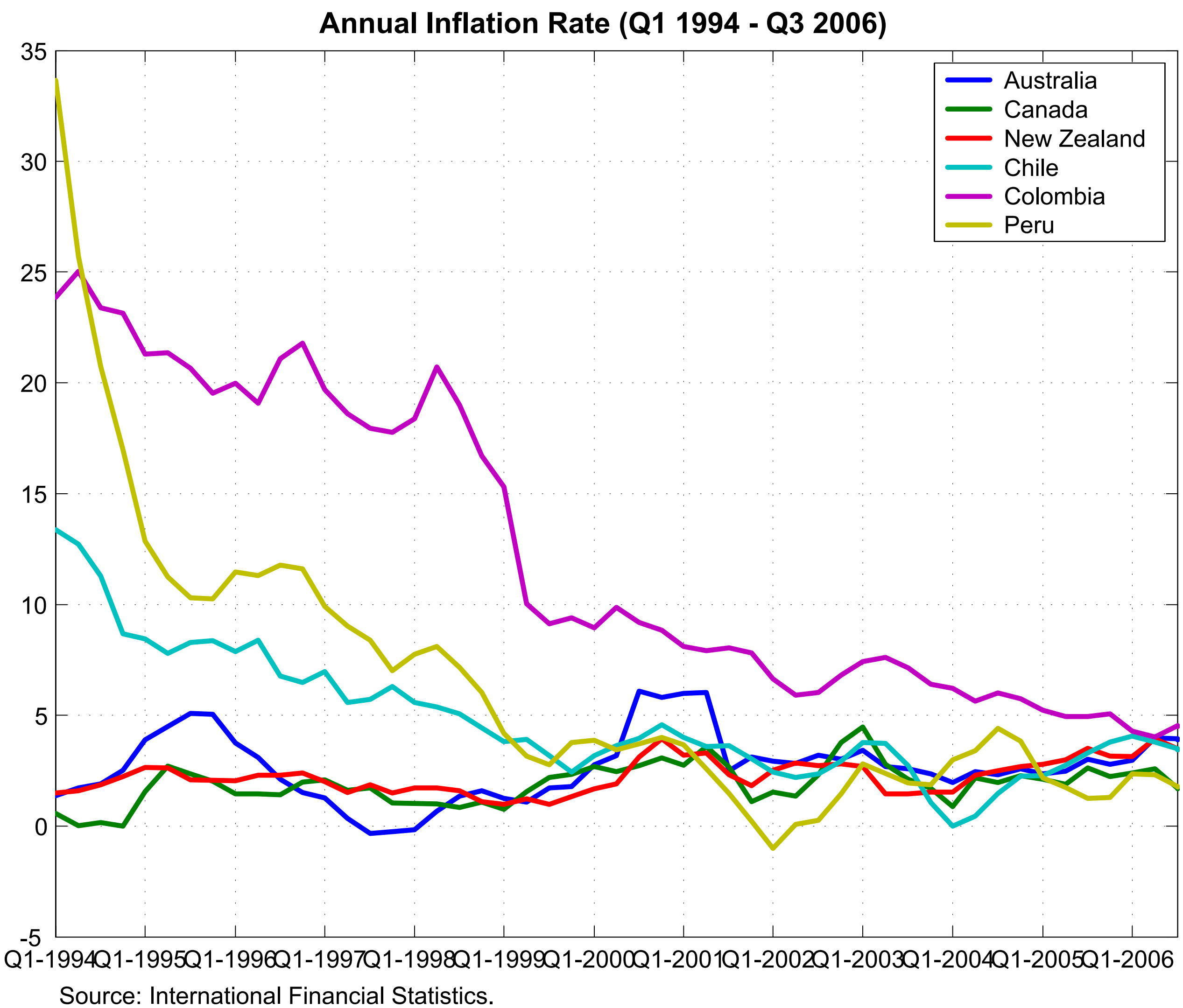

Figure 1: Annual inflation rate in a emerging and developed economies.

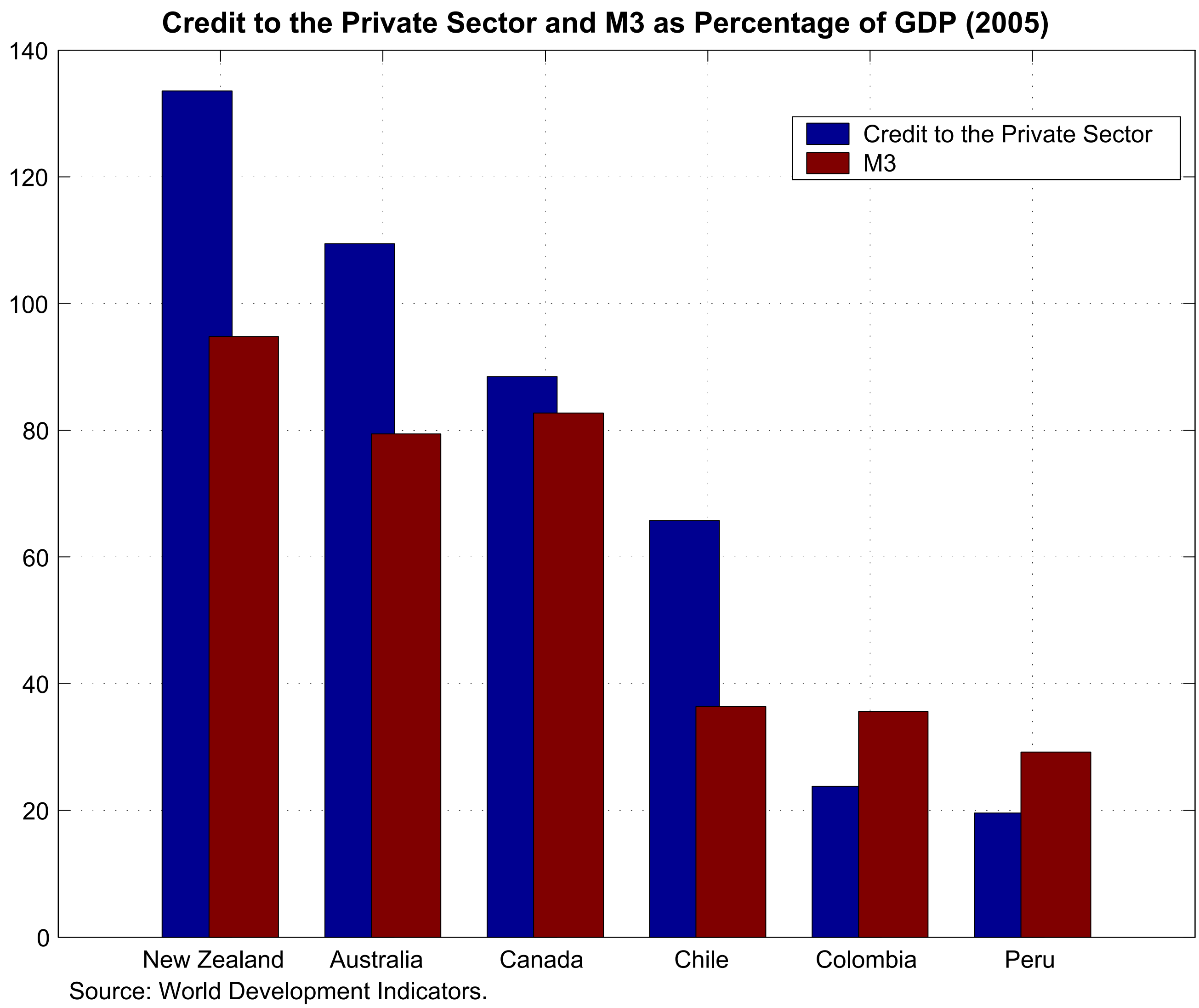

Figure 2: Financial structure in emerging and developed economies.

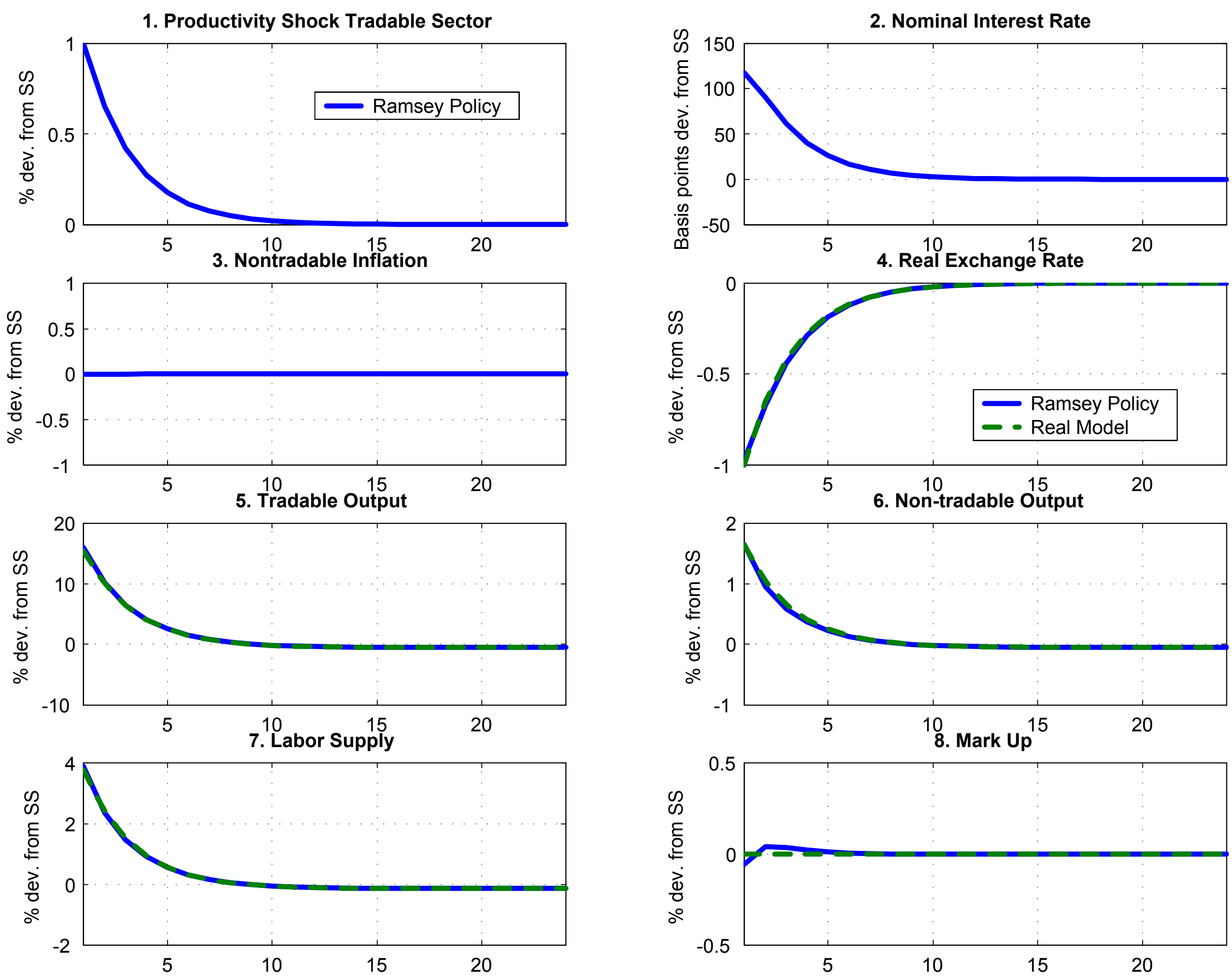

Figure 3: Impulse Responses to a Productivity Shock in the Tradable Sector. Model with Sticky Prices.

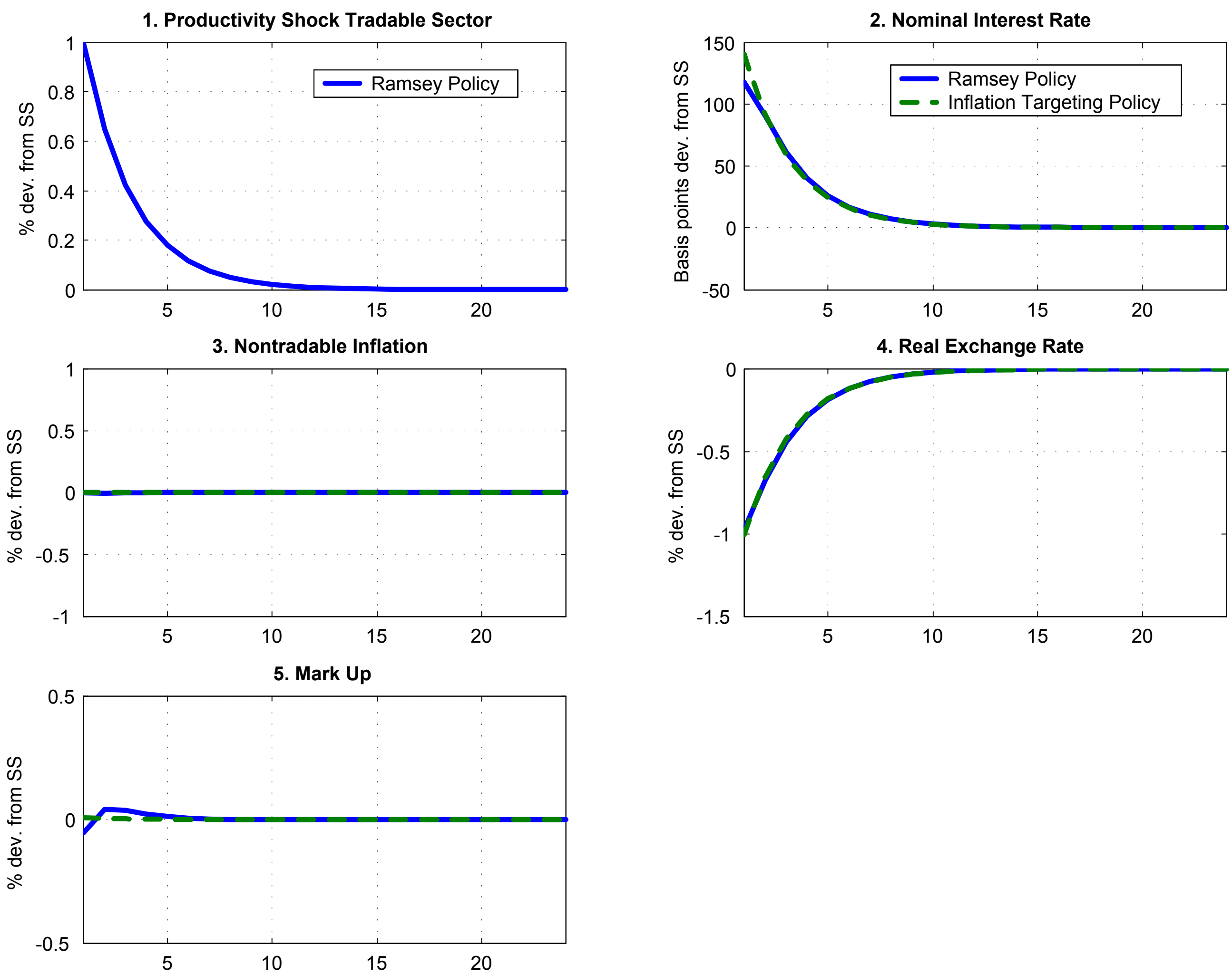

Figure 4: Impulse Responses to a Productivity Shock in the Tradable Sector. Model with Sticky Prices (cont.)

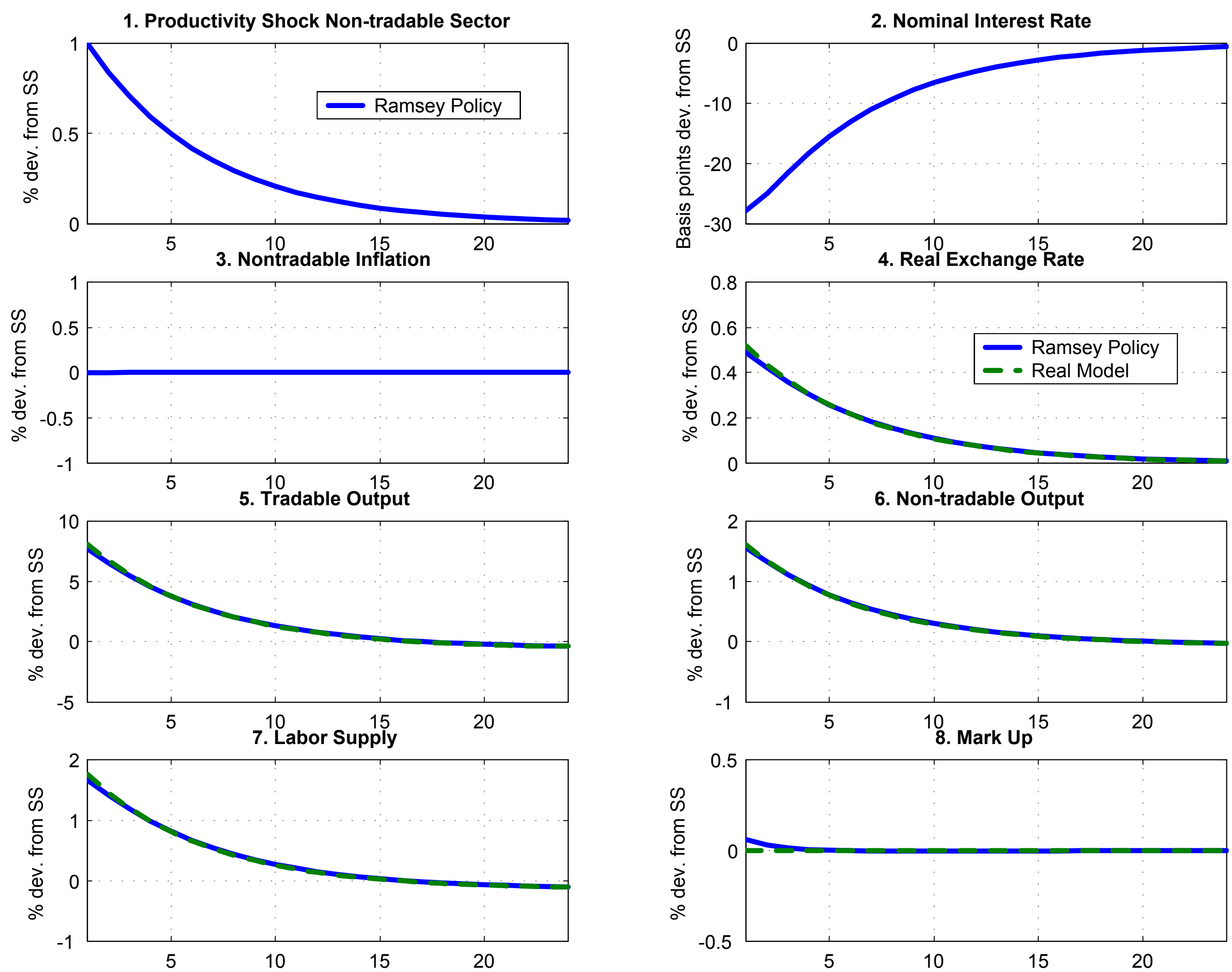

Figure 5: Impulse Responses to a Productivity Shock in the Non-tradable Sector. Model with Sticky Prices.

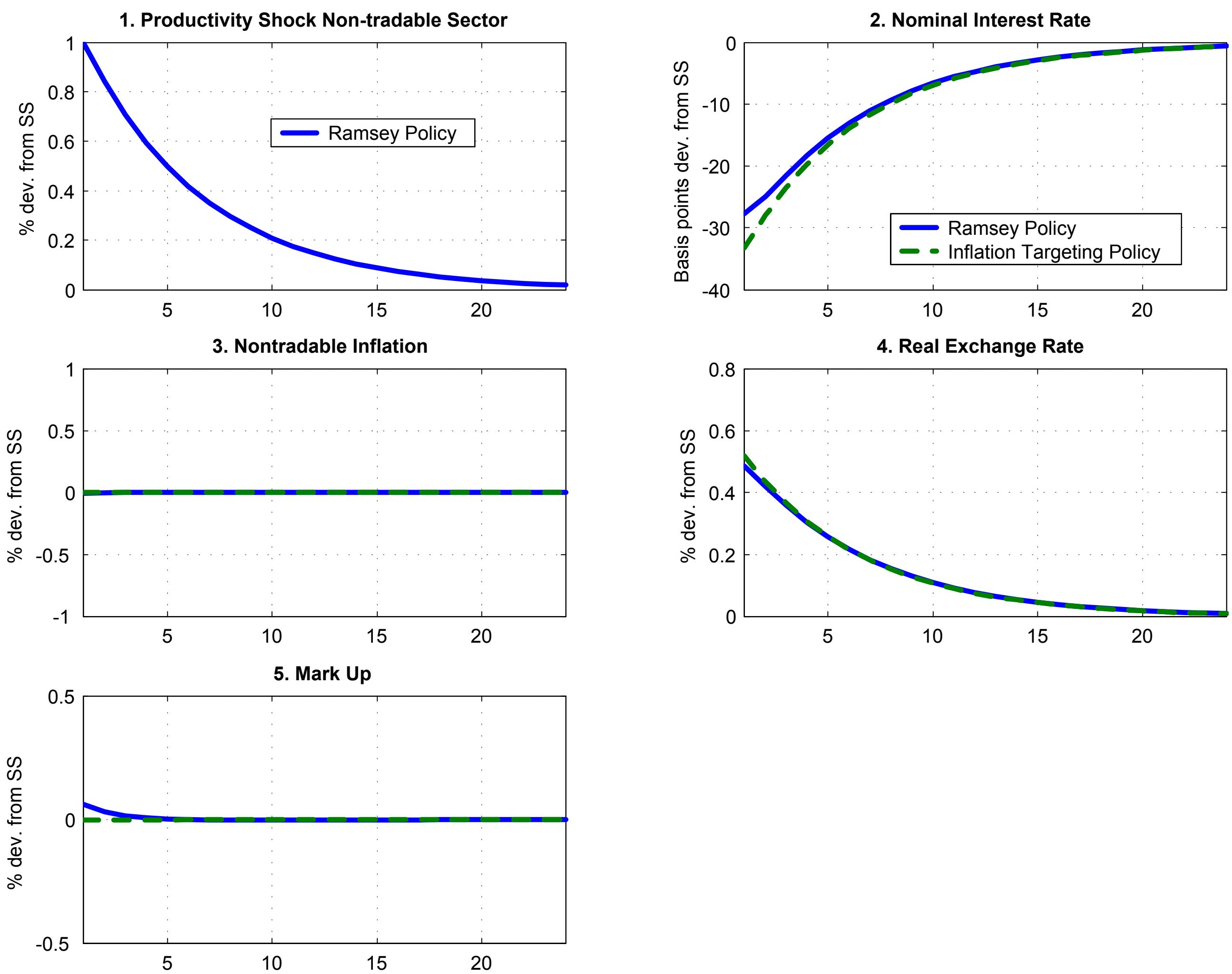

Figure 6: Impulse Responses to a Productivity Shock in the Non-tradable Sector. Model with Sticky Prices (cont.)

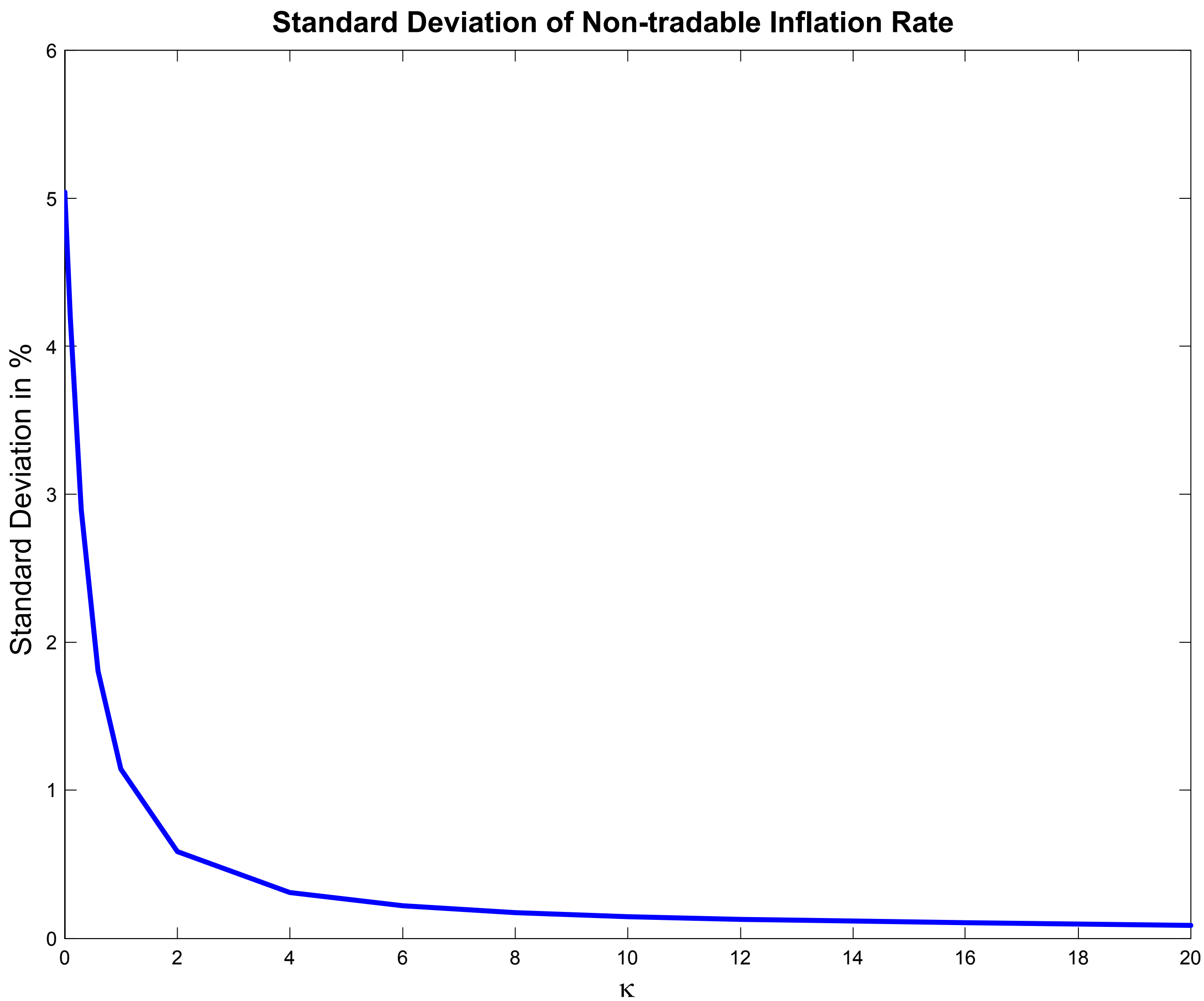

Figure 7: Sensitivity Analysis of Non-tradadable Inflation Rate

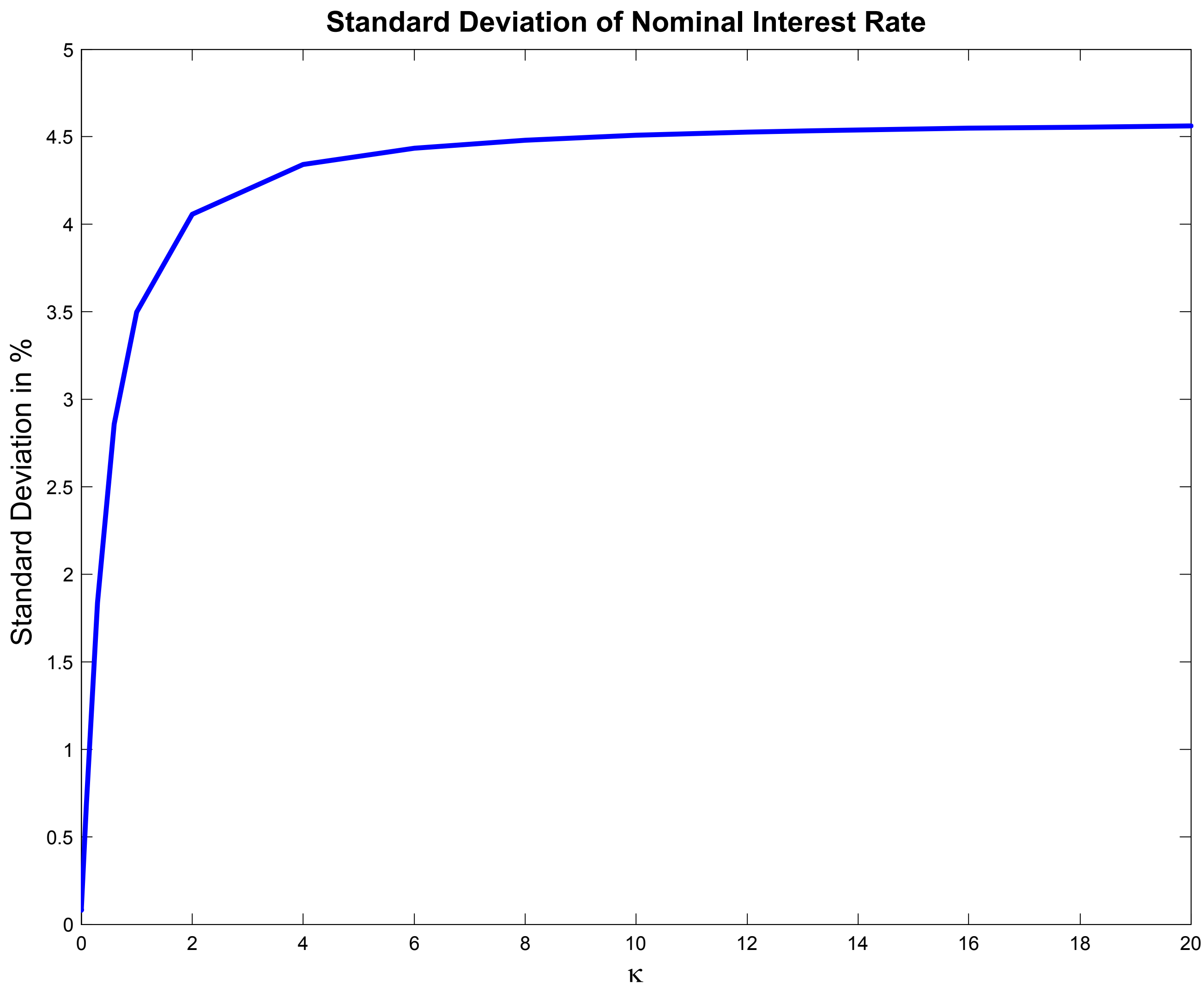

Figure 8: Sensitivity Analysis of Nominal Interest Rate

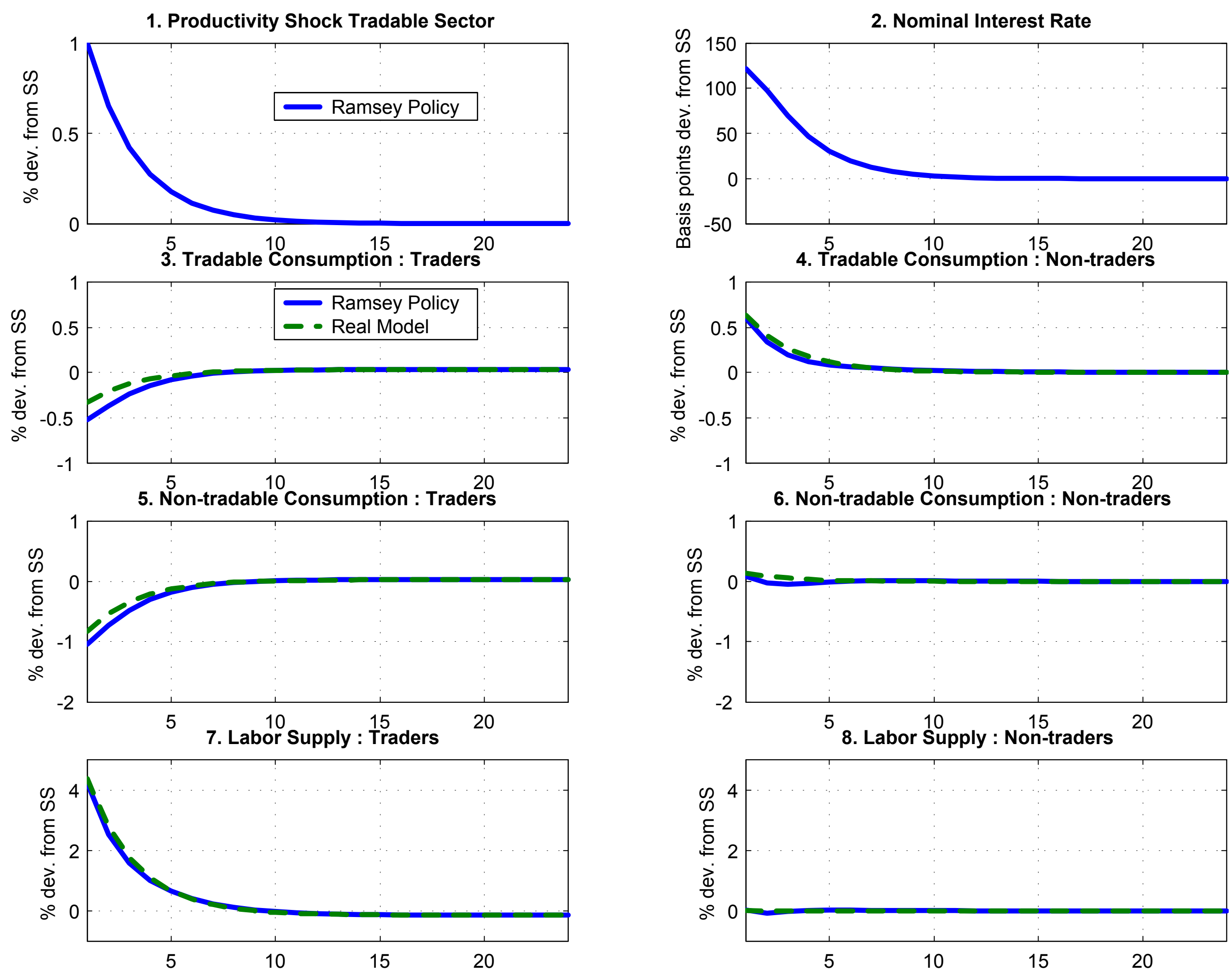

Figure 9: Impulse Responses to a Productivity Shock in the Tradable Sector. Model with Sticky Prices and Asset Market Segmentation.

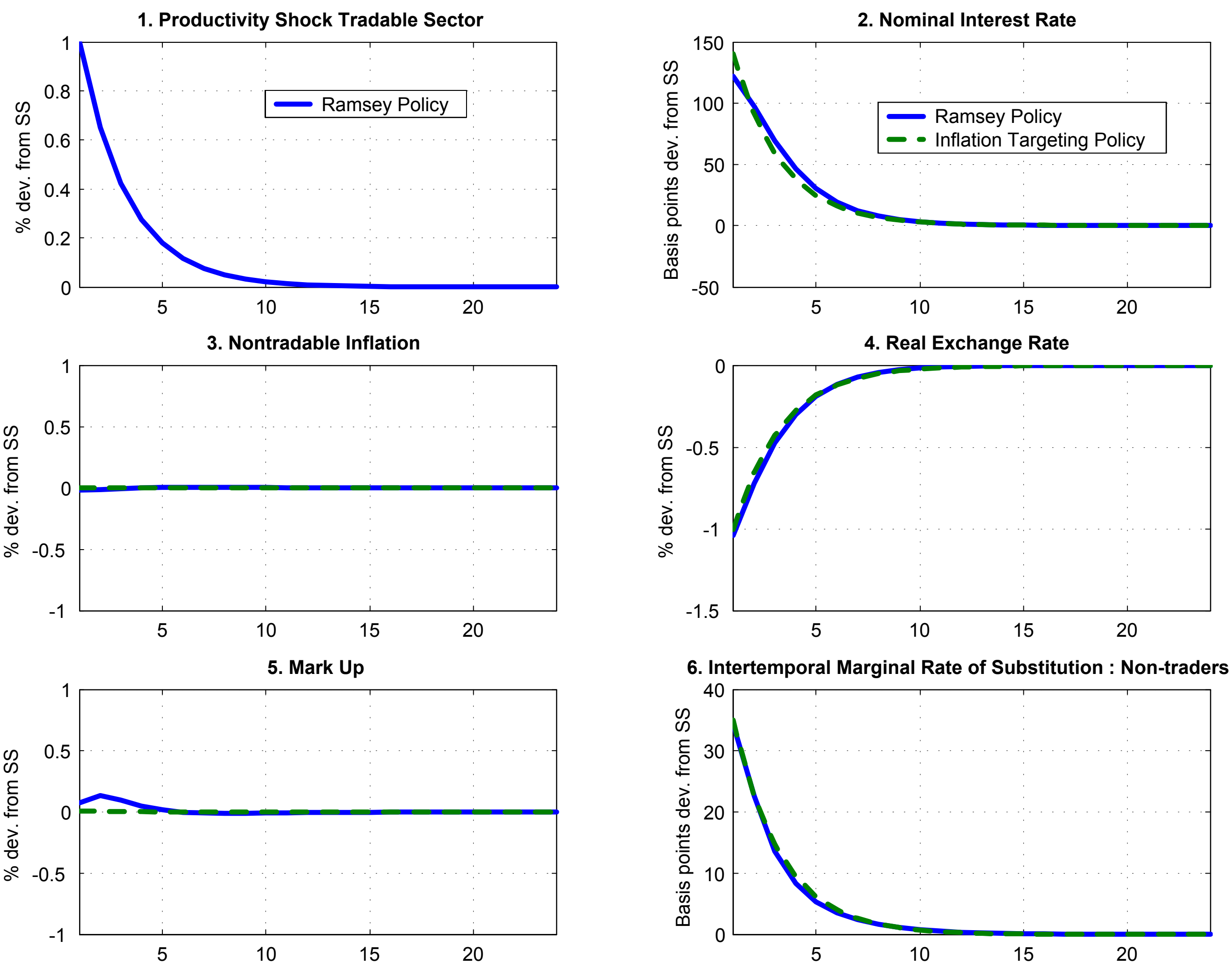

Figure 10: Impulse Responses to a Productivity Shock in the Tradable Sector. Model with Sticky Prices and Asset Market Segmentation (cont.)

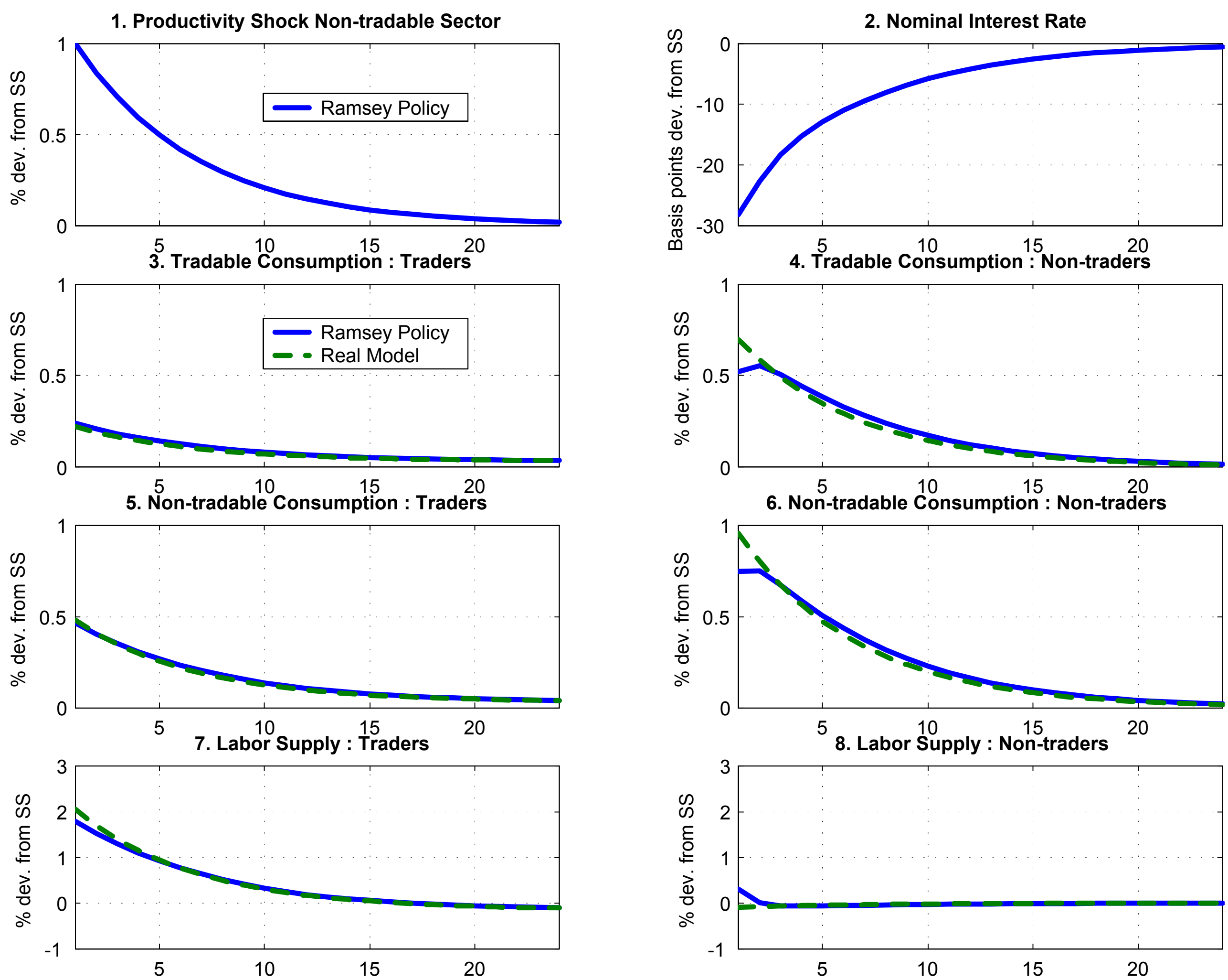

Figure 11: Impulse Responses to a Productivity Shock in the Non-tradable Sector. Model with Sticky Prices and Asset Market Segmentation.

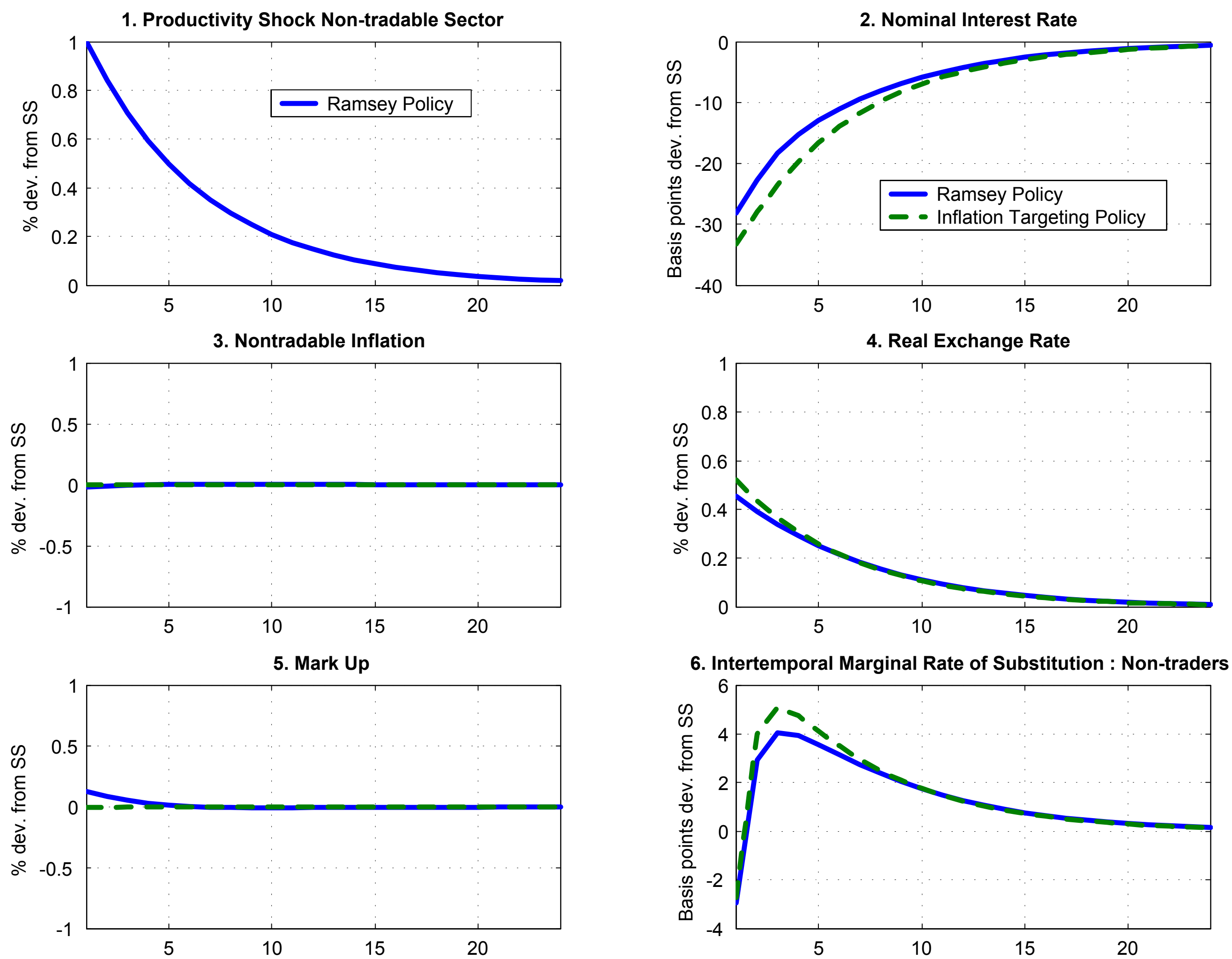

Figure 12: Impulse Responses to a Productivity Shock in the Tradable Sector. Model with Sticky Prices and Asset Market Segmentation (cont.)

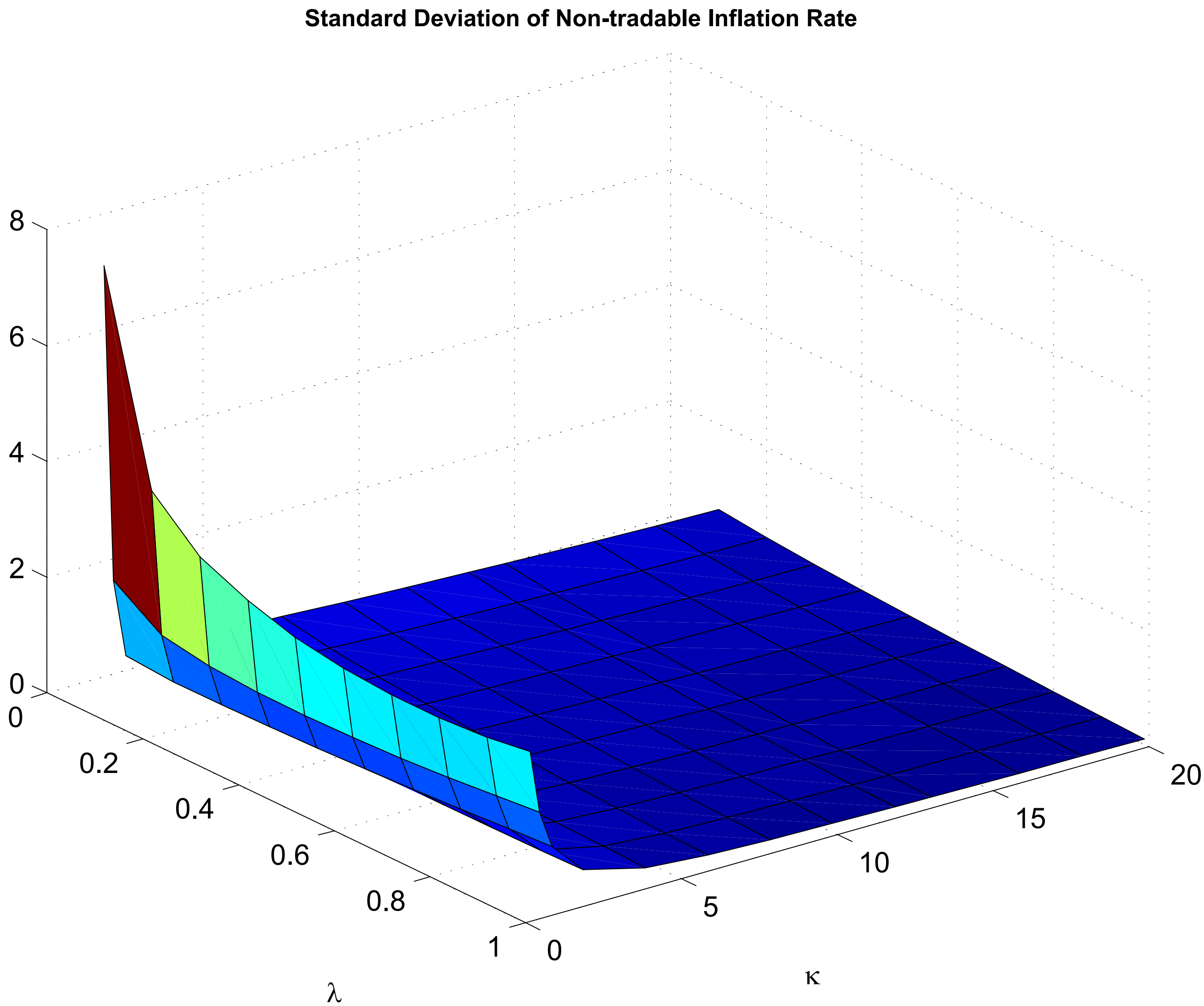

Figure 13: Sensitivity Analysis of Non-tradadable Inflation Rate

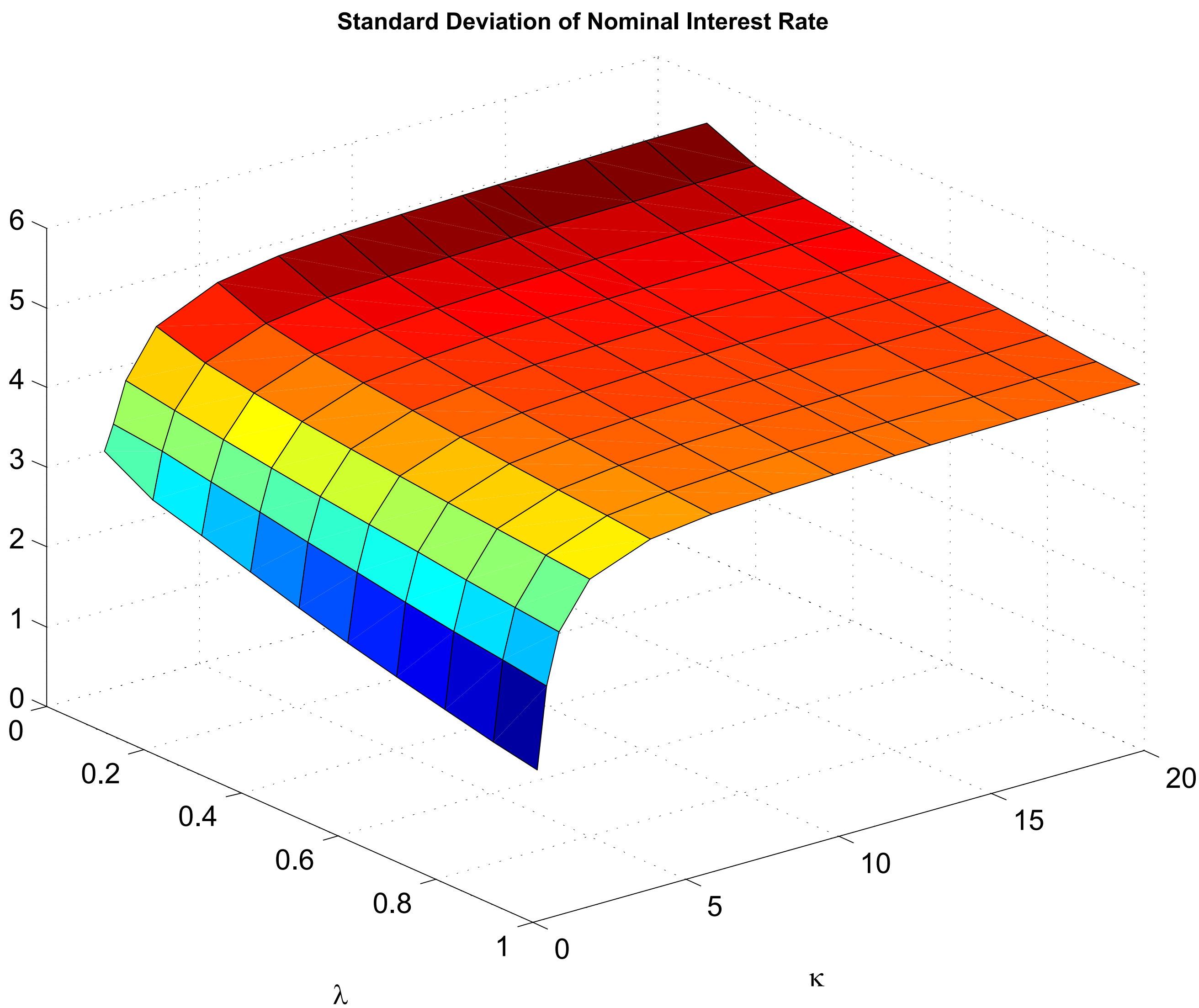

Figure 14: Sensitivity Analysis of Nominal Interest Rate

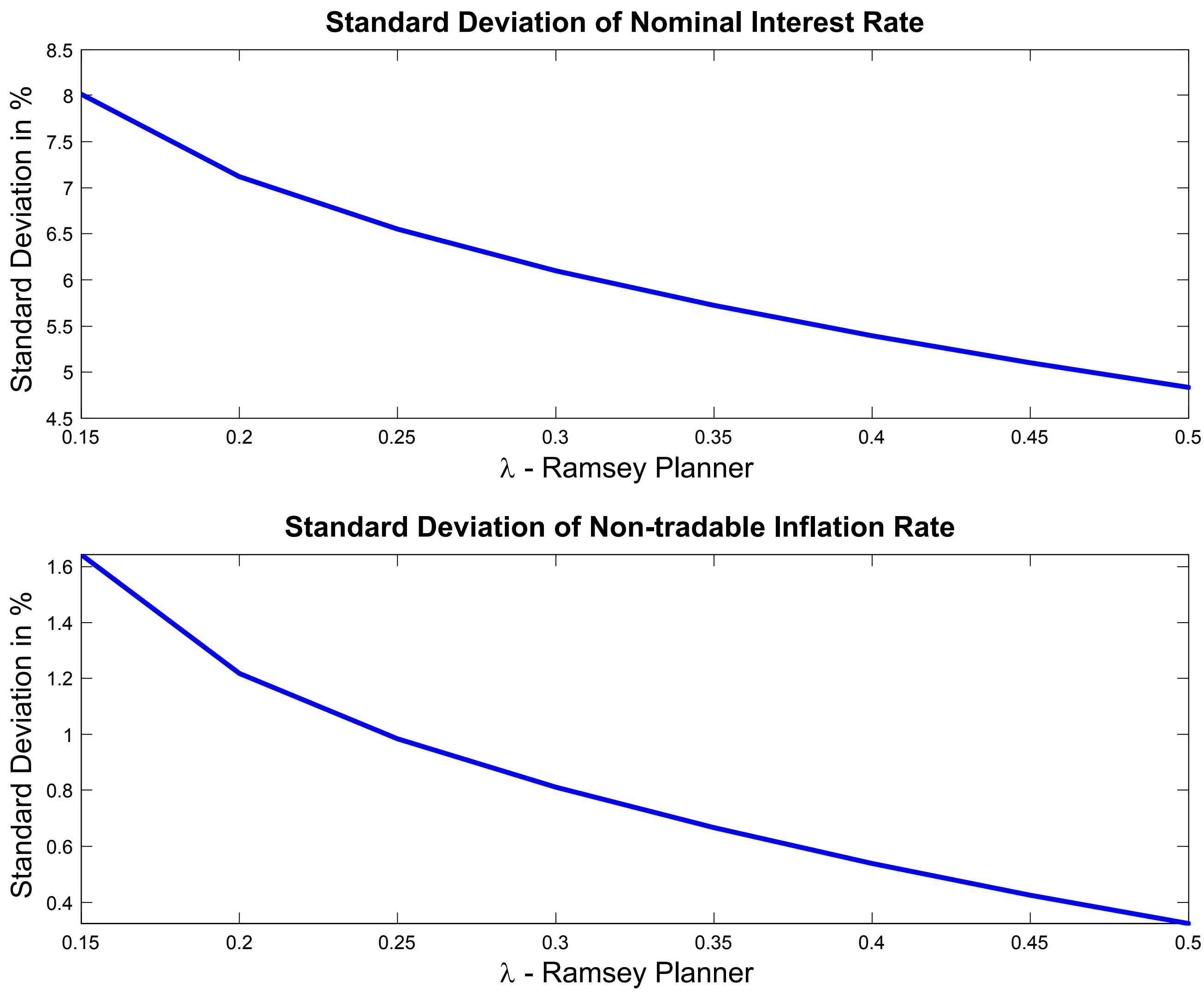

Figure 15: Sensitivity Analysis of Nominal Interest Rate and Non-tradable Inflation Rate