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Optimal Monetary Policy under Sudden Stops

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Abstract

Emerging market economies often face sudden stops in capital inflows or reduced access to the international capital market, a development that can cause serious disruptions in economic activity. This paper analyzes what monetary policy can accomplish in such an event. Optimal monetary policy exploits export revenues to minimize the impact on the domestic economy. However, this approach will not completely insulate the economy from some contraction. Domestic currency depreciation combined with high interest rates is needed to achieve this result. The paper shows that the arrival of the sudden stop further aggravates the time inconsistency problem. Optimal policy is fairly well approximated by a flexible targeting rule, which stabilizes a basket composed of domestic price inflation, exchange rate, and output. For some parameterizations, the best rule can be specified as an interest rate rule that responds to the natural interest rate, inflation, output, and exchange rate depreciation. We further show that from a welfare perspective, the desirability of a fixed exchange rate regime depends on the economic environment.

Key words: sudden stops, monetary policy, emerging markets, financial crises

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1 Introduction

Emerging market economies are typically characterized as unstable environments subject to a variety of shocks that either do not affect the more developed countries or that are magnified due to lack of credibility of these economies. Caballero (2001) documents some of these issues and reaches the important conclusion that many of the problems of these economies are related to the recurrent loss of access to the international capital markets. Some of the episodes can go as far as to lead to an outbreak of sudden and sharp reversals in the financial account, the sort of which are described as "sudden stops" of capital inflows in the literature, following Calvo (1998).

These shocks affect the production capacity of the economy by restricting the sources for financing investment and imported inputs and thus increasing costs. The subsequent adjustment requires a reversal of the current account usually accompanied by a contraction in economic activity as a corollary of the increased cost of borrowing.[1] The reduction in capital inflows also puts significant pressure on the exchange rate leading to significant devaluations and increased interest rates in order to reduce the draining of capital. As mentioned in Fraga et al. (2003) these shocks augment the trade-offs behind the conduct of monetary policy leading to higher volatility of inflation, output and interest rates.

The literature discusses extensively what the best policy regime for emerging markets might be (e.g. Mishkin (2000) and Mishkin and Savastano (2002)). This paper contributes to this literature by conducting a normative analysis of monetary policy in response to a sudden stop shock. In particular it looks at what is the optimal policy but it also discusses how do several simple rules rank amongst themselves and in comparison to the optimal policy. Furthermore, it discusses what the optimal simple rules are under alternative parameterizations and what is their performance relative to the optimal policy (which is not constrained

[1] Calvo and Reinhart (2000) documents very well the dimension of these shocks and their consequences to the economy.

to be a simple rule).

Following the framework proposed in Cúrdia (2007), the economy is subject to shocks in foreigners' perceptions about the performance of the economy. These shocks lead to increases in the required risk premium demanded from domestic borrowers. This is modeled using a modified version of the financial accelerator initially proposed by Bernanke et al. (1999) and applied to an open economy by Gertler et al. (2003). The sudden stop is therefore considered to be exogenous to the economy and is unexpected, similarly to most of the literature on the subject.

In the event of a sudden stop the resulting contraction in the financial account must be matched with an increase in the current account. This can be achieved in two ways: an increase in export revenues and/or a reduction in import expenditures. Optimal policy uses both. A common feature, across most parameterizations of the model, is that optimal monetary policy implies a depreciation of the domestic currency together with increased interest rates. The timing of the two can vary depending on the parameter configuration. In all parameterizations optimal policy implies a real depreciation of the currency. In most of the scenarios considered this is implemented through a nominal depreciation. In the baseline scenario the interest rates are kept low initially, when the shock arrives, but increase significantly afterwards.

The optimal policy just described implies that the interest rate increase imposes some adjustment on the part of the domestic economy towards less borrowing and consumption (of both domestic and foreign goods) and the real depreciation leads to increased export revenues and fewer imports. Therefore the current account adjusts through both imports and exports. This contrasts with the case of a fixed exchange rate system in which the real exchange rate is not allowed to adjust as quickly forcing more of the adjustment on the demand side of the domestic economy and imposing a stronger recession, that in this setting is also welfare reducing.

Optimal policy does not close the output gap as suggested in Hevia (2006) precisely because of the two distortions affecting the economy: monopolistic competition and the imperfect capital market. In order to oppose the two interferences Hevia (2006) finds that a labor tax should be used to eliminate the distortions from monopolistic competition and a capital tax to reduce the distortions from the imperfect capital market. Here none of those are present, leading to a negative output gap on impact, followed by a positive and persistent output gap.

The optimal path of the interest rate compares to the results of Braggion et al. (2005). These authors consider an economy that in normal circumstances has no credit constraints but is subject to the sudden imposition of collateral constraints limiting the availability of credit. Optimal policy under their calibration implies an increase of the interest rate on impact and subsequent gradual reduction, converging in the long run to levels below those verified before the arrival of the shock. In this paper the interest rate also increases (if not on impact at least one period afterwards) and also has a gradual fall. However it will not settle on levels below the initial steady state. The reason for these different results is that Braggion et al. (2005) assumes a permanent shock while here the shock is expected to eventually fade away. Interestingly the interest rate does converge to the steady state level from below, implying that after the initial increase the interest rate will stay for some time at levels just below the steady state ones.

We also analyze the extent to which the sudden stop affects the time inconsistency pressures on policy. For this purpose, we can compare the "timeless perspective" optimal policy with the policy implied by a new commitment when the sudden stop arrives, also labeled Ramsey optimal policy. The timeless perspective optimal policy is time-consistent in that the response to an unexpected shock is the same regardless of the time period considered, while the Ramsey policy is not as it ignores the expectations of agents formed in periods prior to the commitment period. The analysis shows that the Ramsey policy exploits the export revenues channel even further and delays the contraction in the domestic economy by one period. It achieves this through a larger devaluation and keeping initial interest rates lower. However, if nominal rigidities in the export sector are not present then the cost of using the devaluation channel increases because it translates into stronger cost pressures in the domestic retail sector and thus the Ramsey policy follows a path more consistent to the optimal path under "timeless perspective."

A comparison of simple rules shows that, from a welfare perspective, a peg is not the most desirable regime in the benchmark parameterization. In this case the peg is actually the worst of the simple rules considered. However, for parameterizations featuring low nominal rigidities or high elasticity of foreign demand, the fixed exchange rate regime performs better, suggesting that the peg should not be eliminated from the list of possible monetary policy strategies to consider when addressing a sudden stop event. This is an important outcome because it shows that whether a fixed exchange rate regime is a good policy depends on the economic environment (or in the model, on the parameterization).

The class of rules considered include two broad types. The first consists of interest rate rules resembling the Taylor rule proposed in Taylor (1993), augmented to include some reaction to the exchange rate, the natural real interest rate and/or the natural output gap. The second group consists of targeting rules aimed at stabilizing inflation but also output (or the output gap) and the exchange rate. A general result is that, within the class of rules considered, none manages to strictly implement the optimal policy. However a targeting rule aimed at stabilizing at the same time domestic price inflation, the exchange rate and output is almost always the best simple rule and can get very close to the optimal policy. The weights on stabilizing the three components of the basket vary depending on the parameter configuration. In the baseline calibration the weight on inflation far outweights the other two, with the exchange rate receiving very small weight.

It is also important to note that for some parameterizations, including the baseline one, the optimal policy is also very closely approximated, or even better so, by an interest rate rule responding to the natural interest rate, inflation, output deviations from steady state and the exchange rate depreciation. It is important to notice that excluding the natural rate of interest reduces the performance of the rule. For other specifications, including the one with low elasticity of foreign demand this rule is still the best but the optimal coefficients on inflation, output and exchange rate diverge to infinity making it impossible to implement strictly so. The limiting case (as coefficients diverge to infinity) is the targeting rule described above.

If one takes into account possible implementability issues like the informational requirements of a rule based on the natural interest rate or the fact that a targeting rule is an intermediate target but does not give an exact prescription for the interest rate, we show that, provided that it is aggressive enough, a simple interest rate rule responding to inflation, output and the exchange rate can get fairly close to the optimal policy.

In the baseline calibration the best interest rate rule can close up to 95% of the welfare gap between the basic CPI Taylor rule and the optimal policy. In the case with low elasticity of foreign demand or with no nominal rigidities in export prices, the best rule closes up to 85% of the welfare gap of the basic CPI Taylor rule. Furthermore, visual inspection of plots of impulse responses of different variables to the sudden stop shock show that the best rules imply paths for the variables that closely resemble those under the optimal policy, especially so for real variables. These results imply that even though the best simple rules are different from the optimal policy in a strict sense, they still get very close to implement it.

Many authors suggest inflation targeting for emerging markets – some examples are Mishkin and Savastano (2002), Caballero and Krishnamurthy (2005) and Fraga et al. (2003). Several emerging markets have successfully implemented inflation targeting frameworks (e.g. Chile and Brazil). The results presented here might be interpreted as providing some theoretical foundation suggesting that such regimes might be good policy frameworks for emerging markets also when it comes to coping with sudden stops. It is true that in the present paper we analyzed only the response to a sudden stop shock and in reality many different types of shocks can occur. However the best rules are not very different from the usual prescriptions in response to other shocks – e.g. Cúrdia and Woodford (2008) shows that a simple inflation targeting rule is robust across a variety of shocks in the presence of credit frictions, even though they consider only a closed economy framework.

This is not the only paper that looks at how alternative policy regimes cope with shocks to the credit conditions of an emerging market. The literature is actually fairly rich in such exercises. A short list of the ones more closely related are Gertler et al. (2003), Céspedes et al. (2004), Cook (2004), Devereux et al. (2006) and Cúrdia (2007). Most of these focus on a stabilization perspective. Devereux et al. (2006) is the only one which ranks the alternatives according to welfare. Cook (2004) is the only reference in which economic conditions might suggest that a peg is the best regime, while all others show that flexible exchange rates (combined with some rule in which interest rates react to inflation and output) perform better. However none of the exercises makes an explicit comparison to the optimal policy. Furthermore none of the above consider targeting rules (except to the extent that a peg is itself a very particular targeting rule). Therefore this paper presents a more comprehensive analysis of optimal monetary policy in a consistent framework. It is especially noteworthy the ability of this framework in studying under which environments does the fixed exchange rate regime perform better or worse.

The remainder of the paper is organized as follows. Section 2 presents the model in detail. Section 3 discusses the optimal monetary policy and compares it to the flexible price equilibrium. This is followed by an analysis of how different simple rules perform, in section 4. Section 5 concludes.

2 The model

The model follows very closely Cúrdia (2007). The main distinction is that here there is pricing to market and local currency pricing.[2] The domestic economy is populated by a representative household, firms and the monetary authority. The households consume, provide labor for the production of the domestic good and are the owners of the firms of the economy. The domestic good is produced in a perfectly competitive wholesale market. Retail firms purchase the domestic good from the wholesale firms, convert it into their own varieties, and operate in a monopolistic competition environment setting prices, which are sticky a la Calvo. Each retail firm will sell its variety of the domestic goods to both the domestic and foreign households. However they will set prices differently in the two markets. Furthermore they will set prices in the local currency where the goods are sold. The foreigners fulfill various roles: they sell inputs and lend money to the wholesale firms, they sell a final good to the domestic households and they purchase the domestic good. The remainder of this section describes in detail the model.[3]

2.1 Households

The representative household derives utility from consumption and disutility from labor, according to

$$\sum_{t=0}^{\infty} \beta^t U\left(C_t, L_t\right), \tag{2.1}$$

where C_t refers to consumption, L_t is labor, and

$$U\left(C_t, L_t\right) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\psi}}{1+\psi}. \tag{2.2}$$

[2] This change does not change the broad picture of the economic dynamics even if some of the transmission effects operate in a slightly different way.

[3] For easier reading of the paper appendix A shows tables listing all the variables (Table 1) and parameters (Table 2) of the model.

The budget is spent in consumption (with P_t denoting the consumption price index, CPI) and investment in domestic assets, D_t, which pay a gross return rate of R_t. The domestic assets exist in zero net supply so that, in equilibrium, $D_t = 0$ at all times. The sources of income are the wage collected, W_t, profits from wholesalers, $\pi_{w,t}$, profits from the retailers, $\pi_{r,t}$,[4] and returns on domestic asset holdings:

$$P_t C_t + D_t \leq R_{t-1} D_{t-1} + W_t L_t + \pi_{w,t} + \pi_{r,t}. \tag{2.3}$$

There is a no-Ponzi games condition, so that the problem is well defined,

$$\lim_{T \to \infty} \prod_{s=0}^{T-1} R_{t+s}^{-1} D_{t+T} \geq 0.$$

The households are restricted from accessing the international capital markets and, therefore, cannot borrow or lend to foreigners. The only way households achieve some consumption smoothing is through their holdings of firms. These can use their net worth to borrow in the international capital market and give higher or lower dividends to their shareholders, the households. In spite of no direct access to foreign credit, there is still some indirect access, through firms' leverage.

The representative household maximizes (2.1) subject to (2.3). The resulting Euler equation for consumption is

$$\frac{1}{R_t} = \beta E_t \left[\frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \frac{1}{\Pi_{t+1}} \right], \tag{2.4}$$

with $\Pi_t \equiv P_t / P_{t-1}$ denoting gross inflation. Labor supply is given by

$$\frac{W_t}{P_t} = L_t^{\psi} C_t^{\sigma}, \tag{2.5}$$

[4] Profits are defined more formally as $\pi_{w,t} \equiv \int_0^1 \pi_{w,t}(j)\, dj$ and $\pi_{r,t} \equiv \int_0^1 \pi_{r,t}(j)\, dj$.

with W_t the nominal wage.

The households consumption bundle is composed by domestic and foreign goods denoted by $C_{H,t}$ and $C_{F,t}$, respectively. Preferences over the two goods are Cobb-Douglas:

$$C_t = \left(\frac{C_{H,t}}{\gamma}\right)^{\gamma}\left(\frac{C_{F,t}}{1-\gamma}\right)^{1-\gamma}, \tag{2.6}$$

The domestic good is purchased at price $P_{H,t}$. The law of one price is assumed for the imported final good, here assumed to be the same as the foreign CPI, P_t^*, which for simplicity is set to one at all times. Foreign currency denominated values are converted to domestic currency at the rate S_t. Cost minimization implies the following consumption schedules

$$C_{H,t} = \gamma \frac{P_t C_t}{P_{H,t}}, \tag{2.7}$$

$$C_{F,t} = (1-\gamma)\frac{P_t C_t}{S_t}, \tag{2.8}$$

and the CPI is given by

$$P_t = P_{H,t}^{\gamma} S_t^{1-\gamma}. \tag{2.9}$$

2.2 Wholesale firms

Wholesale firms operate as price takers in a competitive market. They hire labor, L_t, and purchase an imported input, Z_t, that is required for production but takes one period to process and be used.[5] The technology used by firm j is given by:

$$Y_t(j) = \left(\frac{L_t(j)}{\alpha}\right)^{\alpha}\left(\frac{\omega_t(j) Z_{t-1}(j)}{1-\alpha}\right)^{1-\alpha}, \tag{2.10}$$

[5] The convention is that time subscript t denotes variables known at t. Hence, Z_t is the amount of imported input that is bought in period t, but available for use in period $t+1$.

where $\omega_t(j)$ is an idiosyncratic shock to the productivity of the imported input that is i.i.d. across firms and time, with $E[\omega_t(j)] = 1$, and is assumed to have a log-normal distribution, $\log(\omega_{t+1}(j)) \sim N\left(-\frac{1}{2}\sigma_\omega^2, \sigma_\omega^2\right)$.

Given the available imported inputs, the labor demand can be expressed as

$$L_t(j) = \alpha \frac{P_{w,t} Y_t(j)}{W_t}, \tag{2.11}$$

where $P_{w,t}$ is the wholesale price of the domestic good.

Define $R_{Z,t+1}(j)$ as the gross returns from investing one domestic currency unit in the imported input:

$$R_{Z,t+1}(j) \equiv (1-\alpha) \frac{P_{w,t+1} Y_{t+1}(j)}{S_t Z_t(j)} \tag{2.12}$$

with the imported inputs purchased at the foreign price level of one.[6] Given the current assumptions for the production function, it is possible to show that we can write

$$R_{Z,t+1}(j) = \omega_{t+1}(j) R_{Z,t+1}, \tag{2.13}$$

where $R_{Z,t+1}$ is an aggregate component, common to all firms.

At the end of the period each firm has available net worth in domestic currency, $N_t(j)$. In order to finance imported inputs for the next period it borrows from foreigners the difference between the value of its net worth and the expenditures in imports. The debt to foreigners, B_t, is denominated in foreign currency, typical of emerging market economies (denominated the "original sin"). The balance sheet of the firm is given by

$$S_t B_t(j) = S_t Z_t(j) - N_t(j). \tag{2.14}$$

[6] Assuming the price of imported inputs to be the same as foreign CPI, and this to be one at all times is just for simplicity, without any loss of generality for the analysis in this paper.

Foreign lenders have misperceptions about the distribution of the imported input productivity $\omega_{t+1}(j)$. This Knightian uncertainty is represented as

$$\omega^*_{t+1}(j) = \omega_{t+1}(j)\,\kappa_t, \tag{2.15}$$

where $\omega^*_{t+1}(j)$ refers to foreigners perceptions about $\omega_{t+1}(j)$ and κ_t is the misperception factor. If $\kappa_t = 1$ then there is no misperception (the normal case); and if $\kappa_t \neq 1$ then the perceived distribution is different from the true one. During sudden stop periods, ambiguity about the distribution for the next period can be described by allowing κ_t to have support over a given interval of values, $[\kappa_{ss}, \kappa^{ss}]$. Lenders deal with the Knightian uncertainty through a max-min criterion, as in Gilboa and Schmeidler (1989), or, in other words, that in the face of uncertainty about the underlying distribution they will pick the worst case scenario. This is what can be interpreted as "ambiguity aversion" as described in Backus et al. (2004). As a consequence, in a sudden stop period, they will take the worst case scenario, κ_{ss}, as the mean of the distribution of $\omega_{t+1}(j)$, instead of one.

The sudden stop is then defined as the state in which foreign lenders face the Knightian uncertainty, a state denoted by $\mathcal{S}_t = \mathcal{U}$. The normal state, is denoted by $\mathcal{S}_t = \mathcal{N}$. Before any shock takes place the economy is in state $\mathcal{S}_t = \mathcal{N}$. A change to $\mathcal{S}_t = \mathcal{U}$ is unexpected by the agents. If a sudden stop takes place, there is a probability of reverting to the normal state, given by $\Pr[\mathcal{S}_{t+1} = \mathcal{N} | \mathcal{S}_t = \mathcal{U}] = \delta_n$. Once the economy returns to its normal state, a shift back to $\mathcal{S}_t = \mathcal{U}$ cannot occur and therefore this is a one time sudden stop.[7]

The risk free opportunity cost for the foreigners is the international interest rate, R^*, assumed to be constant. It is important to notice that all of the analysis in this paper would still apply if we instead considered more simply that the sudden stop takes the form of a shock to R^*_t, which could be interpreted simply as an increase country risk premium. The

[7] This stochastic structure is assumed purposefully to simplify the analysis, leaving extensions of the arrival and exit of the sudden stop for later research.

two approaches are entirely consistent with each other and the one followed here can be perceived as providing a deeper level of the origin of the sudden stop.

The risk free rate is not the interest rate charged to the firms on their debt, because of the uncertain productivity of the firms, implying risk for the creditors. The foreign lenders are risk neutral (once knightian uncertainty is resolved). Following Bernanke and Gertler (1989), the problem is set as one of "costly state verification." This implies that, in order to verify the realized idiosyncratic return, the lender has to pay a cost, consisting of a fraction of those returns, so that the total cost of verification, in foreign currency, is $\mu\frac{\omega_{t+1}(j)R_{Z,t+1}S_tZ_t(j)}{S_{t+1}}$. The debt contract is, then, characterized by a default threshold and a contractual interest rate. A standard debt contract is assumed, implying that the interest rate is not state contingent but the default threshold is (only when firms cannot fulfill their obligations will they default).

The default threshold, $\bar{\omega}_{t+1}(j)$, is set to the level of returns that is just enough to fulfill the debt contract obligations,

$$\frac{\bar{\omega}_{t+1}(j)\, R_{Z,t+1}S_tZ_t(j)}{S_{t+1}} = R_{B,t}(j)\, B_t(j)\,, \tag{2.16}$$

where $R_{B,t}(j)$ is the contractual rate of the loan, set in the contract written in period t, and $R_{Z,t+1}S_tZ_t(j)$ the operational profits in units of domestic currency. If the idiosyncratic shock is greater than or equal to $\bar{\omega}_{t+1}(j)$, then the firm repays the loan and collects the remainder of the profits, equal to $\omega_{t+1}(j)\, R_{Z,t+1}S_tZ_t(j) - S_{t+1}R_{B,t}(j)\, B_t(j)$. Otherwise, it declares default, foreign lenders pay the auditing cost and collect everything there is to collect, and the firm receives nothing. Because foreign lenders are risk neutral, their participation constraint takes the form of

$$\begin{aligned} R^*B_t(j) &= E_t\left[\left(1-F^*\left(\bar{\omega}_{t+1}(j)\right)\right)R_{B,t}(j)\, B_t(j)\right] \\ &\quad +(1-\mu)\, E_t\left[\int_0^{\bar{\omega}_{t+1}(j)} \omega^*\frac{R_{Z,t+1}S_tZ_t(j)}{S_{t+1}}dF^*(\omega^*)\right], \end{aligned}$$

where $F^*(\cdot)$ denotes the distribution of $\omega_{t+1}(j)$, as perceived by foreigners. Following Cúrdia (2007), the previous expression can be rewritten as

$$E_t\left[\Omega\left(\bar{\omega}_{t+1}(j);\kappa_t\right)R_{Z,t+1}\frac{S_t}{S_{t+1}}Z_t(j)\right]=R^*B_t(j)\,, \tag{2.17}$$

with

$$\begin{aligned}
\Omega(\bar{\omega};\kappa) &\equiv \kappa\left[\Gamma\left(\frac{\bar{\omega}}{\kappa}\right)-\mu G\left(\frac{\bar{\omega}}{\kappa}\right)\right], && (2.18)\\
\Gamma(\bar{\omega}) &\equiv [1-F(\bar{\omega})]\,\bar{\omega}+\int_0^{\bar{\omega}}\omega dF(\omega)\,, && (2.19)\\
G(\bar{\omega}) &\equiv \int_0^{\bar{\omega}}\omega dF(\omega)\,, && (2.20)
\end{aligned}$$

and $F(\cdot)$ denotes the actual distribution of ω_{t+1}, $\Gamma(\bar{\omega}_t)$ the fraction of the operation profits used to repay the debt and $\mu G(\bar{\omega}_t)$ the fraction used to pay for the monitoring costs. Therefore $\Omega(\bar{\omega}_{t+1};\kappa_t)$ is the fraction of the operational profits that foreign lenders perceive that they will keep for themselves after paying the auditing costs.

Firms' cash flows, distributed as dividends to the households, are defined as

$$\Pi_{w,t}(j)\equiv P_{w,t}Y\left(L_t(j),Z_{t-1}(j)\right)-W_tL_t(j)-S_tR_{B,t}(j)\,B_{t-1}(j)-N_t(j)\,,$$

or, equivalently,[8]

$$\Pi_{w,t}(j)=\omega_t(j)\,R_{Z,t}S_{t-1}Z_{t-1}(j)-S_tR_{B,t}(j)\left(Z_{t-1}(j)-\frac{N_{t-1}(j)}{S_{t-1}}\right)-N_t(j)\,.$$

Given the state contingent nature of the optimal contract, the expected cash flow of the firm is

$$E_{t-1}\Pi_{w,t}(j)=E_{t-1}\left\{\left[1-\Gamma\left(\bar{\omega}_t(j)\right)\right]R_{Z,t}S_{t-1}Z_{t-1}(j)-N_t(j)\right\}. \tag{2.21}$$

[8] Using the balance sheet equation and the assumption of constant returns to scale.

Firms maximize the discounted sum of cash flows,

$$E_0 \sum_{t=1}^{\infty} \beta^t \Lambda_t \pi_{w,t}(j),$$

subject to the participation constraint, (2.17), and the default threshold definition, (2.16), with respect to $Z_t(j)$, $\bar{\omega}_t(j)$, $R_{B,t-1}(j)$ and $N_t(j)$. The appropriate discount factor is given by $\beta^t \Lambda_t$, from the households problem, where $\Lambda_t = C_t^{-\sigma}/P_t$ is the Lagrangian multiplier of the budget constraint.

As detailed in Cúrdia (2007), all firms will take the same decisions in face of the expectations about the future. Therefore from this point onwards we can refer to the variables in aggregate terms. The aggregate level of dividends is given by

$$\Pi_{w,t} = [1 - \Gamma(\bar{\omega}_t)] R_{Z,t} S_{t-1} Z_{t-1} - N_t, \tag{2.22}$$

which is readily understood as the fraction of the operational profits that is not paid to the foreign lenders and subtracted from the net worth that is needed for financing the imported input.

The aggregate uncovered interest parity (UIP) relationship is given by

$$R_t E_t \left[\frac{C_{t+1}^{-\sigma}}{P_{t+1}} \right] = R^* E_t \left[\frac{C_{t+1}^{-\sigma}}{P_{t+1}} \frac{S_{t+1}}{S_t} \lambda_{t+1} \right], \tag{2.23}$$

which includes the risk premium term, λ_{t+1}, due to the fact that households have access to the international capital market only through leveraged firms, which might default on their debt. The risk premium term is given, in equilibrium, by

$$\lambda_t = \frac{\Gamma'(\bar{\omega}_t)}{E_{t-1}[\Omega'(\bar{\omega}_t; \kappa_{t-1})]}. \tag{2.24}$$

The aggregate operational profit of firms will, in equilibrium, be enough to pay a premium on the foreign risk free interest rate,

$$E_t\left[\frac{C_{t+1}^{-\sigma}}{P_{t+1}}\left[1-\Gamma\left(\bar{\omega}_{t+1}\right)\right]R_{Z,t+1}\right]=\left(1-b_t\right)R^{*}E_t\left[\frac{C_{t+1}^{-\sigma}}{P_{t+1}}\frac{S_{t+1}}{S_t}\lambda_{t+1}\right], \tag{2.25}$$

where b_t is the leverage rate of firms, defined as $b_t \equiv B_t/Z_t$.

2.3 Retail firms

There is a continuum of size one of retail firms operating in a monopolistic competition environment. They purchase the domestic good from the representative wholesale firm, at price $P_{w,t}$, convert it at no additional cost into their own variety of the final good and sell it to both the domestic and foreign markets. There is price stickiness a la Calvo – with probability α_p each individual firm is not able to set prices in a given period. There is pricing to market with local currency pricing, so that $P_{H,t}$ denotes the price for the domestic market and $P_{H,t}^{*}$ the price for the foreign market. We assume identical elasticities for different varieties in both markets.

The preferences of the consumers for the different varieties of the domestic good are given by:

$$Y_t^i=\left(\int_0^1 Y_t^i\left(j\right)^{\frac{\eta-1}{\eta}}dj\right)^{\frac{\eta}{\eta-1}},$$

with $\eta > 1$ in order to imply elasticity of substitution above one. The demand for each variety is

$$Y_t^i\left(j\right)=Y_t^i\left(\frac{P_{H,t}^i\left(j\right)}{P_{H,t}^i}\right)^{-\eta}, \tag{2.26}$$

where, in equilibrium, the market must clear and

$$Y_t=C_{H,t}+C_{H,t}^{*}. \tag{2.27}$$

The global foreign demand for domestic goods has the following form:

$$C^*_{H,t} = \gamma^* \left(P^*_{H,t}\right)^{-\nu^*} C^* \tag{2.28}$$

where C^* is the foreign aggregate consumption level.

The problem of firm j in the domestic market is

$$\max_{\bar{P}_{H,t}(j)} E_t \sum_{\tau=0}^{\infty} \alpha_p^\tau \beta^\tau \Lambda_{t+\tau} C_{H,t+\tau} \left(\frac{\bar{P}_{H,t}(j)}{P_{H,t+\tau}}\right)^{-\eta} \left(\bar{P}_{H,t}(j) - P_{w,t+\tau}\right),$$

with $\bar{P}_{H,t}(j)$ denoting the price set in period t. The first order condition is

$$\bar{P}_{H,t} = \frac{\eta}{\eta-1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha_p^\tau \beta^\tau \frac{C_{t+\tau}^{-\sigma}}{P_{t+\tau}} C_{H,t+\tau} P_{H,t+\tau}^{\eta} P_{w,t+\tau}}{E_t \sum_{\tau=0}^{\infty} \alpha_p^\tau \beta^\tau \frac{C_{t+\tau}^{-\sigma}}{P_{t+\tau}} C_{H,t+\tau} P_{H,t+\tau}^{\eta}}, \tag{2.29}$$

where I used the fact that all firms able to set a new price at time t will choose exactly the same one. The aggregate domestic price index (DPI) is

$$P_{H,t} = \left[(1-\alpha_p) \bar{P}_{H,t}^{1-\eta} + \alpha_p P_{H,t-1}^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{2.30}$$

For the price setting in the export market we get equivalently

$$\max_{\bar{P}^*_{H,t}(j)} E_t \sum_{\tau=0}^{\infty} \alpha_{p^*}^\tau \beta^\tau \Lambda_{t+\tau} C^*_{H,t+\tau} \left(\frac{\bar{P}^*_{H,t}(j)}{P^*_{H,t+\tau}}\right)^{-\eta} \left(S_{t+\tau} \bar{P}^*_{H,t}(j) - P_{w,t+\tau}\right),$$

and note that because price is set in foreign currency, $S_t P^*_{H,t}(j)$, is the domestic currency value of each unit of exports. The first order condition is given by

$$\bar{P}^*_{H,t} = \frac{\eta}{\eta-1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha_{p^*}^\tau \beta^\tau \frac{C_{t+\tau}^{-\sigma}}{P_{t+\tau}} C^*_{H,t+\tau} \left(P^*_{H,t+\tau}\right)^{\eta} P_{w,t+\tau}}{E_t \sum_{\tau=0}^{\infty} \alpha_{p^*}^\tau \beta^\tau \frac{C_{t+\tau}^{-\sigma}}{P_{t+\tau}} C^*_{H,t+\tau} \left(P^*_{H,t+\tau}\right)^{\eta} S_{t+\tau}},$$

and the aggregate price index is

$$P^*_{H,t} = \left[(1 - \alpha_{p^*}) \left(\bar{P}^*_{H,t} \right)^{1-\eta} + \alpha_{p^*} \left(P^*_{H,t-1} \right)^{1-\eta} \right]^{\frac{1}{1-\eta}} . \tag{2.31}$$

2.4 Monetary policy

The role of the monetary authority is to control the interest rate, which is a very reasonable assumption given how modern monetary policy is conducted, including in emerging markets, as suggested in Hawkins (2005). In the absence of explicit monetary aggregates, it is possible to think of this economy as in the cashless-limiting case of Woodford (2003).

There are three types of monetary policy that are considered in the analysis: optimal monetary analysis in a timeless perspective, optimal monetary analysis under a new commitment and simple policy rules. The best policy should avoid the time inconsistency problems discussed in Kydland and Prescott (1977) among many others. This is the optimal policy with commitment in a timeless perspective, as proposed in Woodford (1999). It is nevertheless worth considering as well the optimal policy under a new commitment, which is not time consistent, in order to highlight the extent to which the sudden stop affects the time inconsistency of policy. In both cases the monetary authority maximizes the welfare of the households subject to the laws of motion of the economy as described in appendix B. Finally, several simple rules are considered, discussed in later sections.

2.5 General equilibrium and parameter values

The resources of this economy are determined by the budget constraint of the representative household. If we substitute out the profits from firms and making a few other manipulations we convert the budget constraint into the balance of payments (BP) of this economy:

$$0 = S_t P^*_{H,t} C^*_{H,t} - S_t C_{F,t} - S_t Z_t - \Gamma\left(\bar{\omega}_t\right) R_{Z,t} S_{t-1} Z_{t-1} + S_t B_t. \tag{2.32}$$

Finally, we can restate the relations described previously in terms of relative prices, inflation rates and real variables. We consider as well the real interest rate, $R^r_t \equiv E_t\left[R_t/\Pi_{t+1}\right]$, the real return on imported inputs, $R^r_{Z,t} \equiv R_{Z,t}/\Pi_t$ and the DPI inflation, $\Pi_{H,t} \equiv P_{H,t}/P_{H,t-1}$. The relative prices are all normalized by the domestic CPI and represented by small caps: the real exchange rate, s_t, the real wage rate, w_t, the relative wholesale prices, $p_{w,t}$, the relative price of the domestic good, $p_{H,t}$, and real net worth, n_t.[9] The list with all the equations in relative prices is shown in appendix B.

The structural parameter values used follow closely those of Cúrdia (2007), except that some of them were set to values more stylized in order to simplify the analysis. All of the parameters are listed in appendix 3 and are used in all experiments except when otherwise noted. The parameter values are based on the timing assumption that one period represents one quarter. The foreign interest rate is set to 1% per quarter. The country risk premium in steady state, λ, is set to 2.5% annual, as discussed in Cúrdia (2007). The assumptions on the foreign interest rate and risk premium imply that the value of β is 0.984.

The steady state leverage ratio of the firms, b, is set to 50%. The values of the frictions coefficients for μ and σ_ω are obtained in the process of calibrating the leverage ratio, the country spread and a firm-level debt annual spread of 4% (similar to the average for emerging markets). The implied values are 0.0191 for μ and 0.3922 for σ_ω.[10] The probability of exiting the sudden stop state, δ_n, is set to 10%, implying an average duration of a sudden stop of 2.5 years. The size of the misperceptions shock was set together with the remaining parameter configuration in order to imply a fall in the debt level of the firms – evaluated at the trough

[9] The price of exports could be equivalently normalized by the foreign CPI but it is assumed that P^*_t is constant at all times and therefore that would be a meaningless normalization.

[10] Cúrdia (2007) provides a comparison of these values with those found in Bernanke et al. (1999).

of the crisis – in the range of 10% to 15% of initial GDP (the exact value depending on the policy considered). This implies that κ_{ss} is set to 0.75.

The calibration of the more standard parameters follows the literature on open economies and emerging market crises and, in particular, Elekdag et al. (2006). The intertemporal elasticity of substitution, $1/\sigma$, is set to 1 and the labor supply elasticity, $1/\psi$, to 0.5. The elasticity of substitution of consumption between domestic and foreign goods, ν, is 1. The fraction of domestic goods in the consumption basket of the households, γ, is 75%.

The share of labor used in production, α, is 50%, comparable to Devereux et al. (2006) and others. The retailers face the impossibility to set prices with a probability, α_p, of 75%. Their demand elasticity of substitution, η, is set to 6, so that the monopolistic markup is 20%. The share of domestic good in the foreign consumption basket, γ^*, is 10% and $C^* = 5$. The total factor productivity in steady state, A, is set to one, just like all the foreign price levels.

One parameter of particular importance is the foreign demand price elasticity, ν^*, which is set to one in the baseline scenario. This parameter matters in particular to the outcomes of the economy in terms of output. Therefore even though the baseline case takes this elasticity to be unity, a special parameter sensitivity of the results is discussed below.

The solution method depends on the analysis being conducted. For the simple rules the model is log-linearized around the zero inflation steady state, which coincides with the optimal steady state. After log-linearization all variables are denoted by $\hat{x}_t \equiv \ln(x_t/x)$ with x denoting the steady state value of the variable. For the optimal policy under a new commitment the solution is computed in two steps: derivation of the FOC based on the non-linear equations, followed by log-linearization of all the equations in order to generate the solution to the rational expectations equilibrium (REE). The policy in a timeless perspective uses the linear quadratic approximation method proposed in Benigno and Woodford (2008). The latter is also used to compute a second order approximation to the welfare objective, that yields a criterion that is accurate up to second order.

3 Optimal monetary policy

The response of the economy to a sudden stop is thoroughly described in Cúrdia (2007), including the comparison of the impact of different policies in those responses. Here the object of interest is to characterize the optimal monetary policy under full commitment. Furthermore we consider optimal in a timeless perspective, which implies that policy makers maximize the welfare of households subject to the laws of motion of the economy as if they committed to this behavior far in the past. This has the advantage that the policy's response functional to any given shock is the same in the period of impact and afterwards. The timeless perspective was first proposed in Woodford (1999) and formalized in Benigno and Woodford (2008). in subsequent sections we compare the response of the economy under this notion of optimal policy to a time-inconsistent one. Therefore we will consider additionally the Ramsey equilibrium, in which case the policy makers commit in the initial period, hence the response in that period is different than what it would be in the following periods after the commitment is made. The difference between the optimal policy and the Ramsey gives a measure of how much the sudden stop aggravates the time-inconsistency problem, other than deterministic considerations.[11]

Figure 1 shows the responses of the economy to a sudden stop shock, in log-deviations relative to the scenario without shocks.[12] The figure plots responses under optimal policy, a simple Taylor rule,[13] a fixed exchange rate regime and the flexible-price equilibrium.[14] The

[11] This is not necessarily the only measure of the time-inconsitency problem, but is a possible one.

[12] All paths are multiplied by one hundred to give an interpretation of percentage deviations. The inflation and interest rates are further multiplied by four in order to yield annualized rate changes.

[13] In this simple Taylor rule we assume that the interest rate responds to CPI inflation and to output deviations from steady state, with elasticities of 2 and 0.75/4, respectively.

[14] Notice that nominal variables in the flex-price equilibrium depend on the policy conducted and hence are not shown for lack of relevance.

figures show that the optimal policy implies a stable interest rate in the period in which the sudden stop hits the economy, and a devaluation of the domestic currency. In the following period the interest rate is sharply increased and afterwards is gradually stabilized back to pre-shock levels. This policy leads to a strong contraction of consumption and output, with the latter falling by a smaller amount due to an increase in exports. Inflation initially increases but is stabilized afterwards.

By comparison, both the Taylor rule and the peg regimes imply higher interest rates on impact and stronger contraction in output and consumption. The Taylor rule implies a more persistent real depreciation of the currency while the peg implies a much smaller real depreciation. Inflation is also higher under the Taylor rule but is much lower under the peg (actually a sharp negative change relative to steady state). We can thus conclude that neither the Taylor nor the peg are very close to implement the optimal policy. If we focus on output and consumption the Taylor rule is much closer to the optimal than the peg. In terms of inflation it is less obvious how to compare the two policies.

It is important to mention that in several episodes of sudden stops the authorities tried to enforce fixed exchange rate regimes, failing in most cases and eventually allowing the currency to devalue. Instead, according to the results presented here, they should immediately devalue, followed by the stabilization of the currency by increasing the interest rate, not the other way around. This would allow them to get a smoother path for consumption and output, at a controlled cost in terms of inflation.

To understand optimal policy it is useful to think in terms of the current account adjustment. When the sudden stop hits the economy and generates a drop in capital inflows, there must be a symmetric increase in the current account. This is possible in two ways: increase exports revenues and/or reduce import expenditures. Figure 1 shows that optimal policy boosts significantly the exports while inducing a contraction in imports of final goods. It also keeps roughly stabilized the expenditures in imported inputs, which are necessary to allow the production of goods to be exported. The peg clearly implies a different adjustment strategy: by keeping the exchange rate constant it implies that the adjustment needs to come from the domestic side of the economy, hence the export revenues barely increase, while import expenditures on both final goods and inputs collapse. The Taylor rule implies paths for export revenues and expenditures in final goods fairly similar to the optimal policy but it is more inflationary, leading to an increase in the expenditures on imported inputs.

The comparison to the flex-price equilibrium shows that the output gap under the optimal policy is negative on impact but persistently positive afterwards. This is consistent with the idea that optimal policy implements some smoothing of the output, relative to the flex-price equilibrium. This translates also into some smoothing of domestic consumption, especially consumption of domestic goods.

The path of the interest rate under optimal policy compares to the work of Braggion et al. (2005). They present a model in which the optimal response to reduced access to the international capital markets is an initial sharp rise in the interest rate followed by a fall to below pre-crisis levels. The reason why, in their results, the interest rate falls to levels below pre-crisis levels is explained by the fact that the increased requirements for collateral are permanent and therefore the interest rate needs to move to a permanent lower level to discourage borrowing and make the collateral constraint marginally not binding in the new steady state. Instead, here the misperceptions are expected to eventually revert to normal levels and therefore there is no need to make such permanent changes in the interest rate, so that it converges back to the pre-crisis levels. However it is interesting to note that after the spike the interest rates do indeed reach levels lower than the no shock scenario and converge from below. The remainder difference requiring some interpretation is the initial response of the interest rate. They get an optimal immediate increase while here it is kept low on impact and only increased after the impact period. In order to consider this issue we compare the results with other parameter choices conclude that depending on the parameters considered we get an immediate increase of the interest rate or not, but this is not the crucial issue.

Figure 2 shows responses when $\alpha_p = \alpha_{p^*} = 0.5$ (instead of $\alpha_p = \alpha_{p^*} = 0.75$), hence implying smaller nominal rigidities. In this case both the nominal and real interest rates will spike on impact and then follow a gradual reduction, much like in the baseline scenario (including eventually reaching levels below pre-crisis levels and converging to those levels from below).

Figure 3 shows responses when the price elasticity of foreign demand is lower, with $\nu^* = 0.6$ (instead of $\nu^* = 1$). This case is very important in the case of sudden stops because, as discussed above, exports allow for an important channel to reduce the pressure on the domestic economy and the current account adjustment. However if many countries are subject to similar pressures and all try to devalue then the relative devaluation might be small.[15] It is also relevant in times in which the export markets are subject to pressures that lead them to reduce their imports from emerging markets and thus make this channel less effective.[16] This scenario, with low elasticity of foreign demand, thus illustrates what happens when exports are not very sensitive to depreciation of the domestic currency. Furthermore, some authors consider that the elasticity is lower than unity in emerging markets (e.g. Reinhart (1994) and Cook (2004)). The response of the economy in this scenario is very similar to the benchmark case, confirming that the peg appears to be worse than the Taylor rule. In this case optimal policy is more similar to the Taylor rule and more distant from the peg. The only more noticeable difference is that now the interest rate increases in the initial period of the sudden stop, just like in the previous case considered.

We can further conclude that as nominal rigidities are smaller or the elasticity of foreign

[15] This was the case during the Asian crisis of 1997.

[16] This appears to be the case in the more recent world financial crisis of 2008-2009. In this case there was a significant contraction in the more advanced markets that spread to emerging markets through a significant a process called deleveraging, in which banks and investors in advanced economies withdrew their investments and lending to emerging markets, at the same time that a significant contraction in their domestic economies led to a sharp fall in emerging markets exports.

demand is lower the emphasis is less on the depreciation and more on the increase of the interest rate. Regarding the smaller nominal rigidities that ought to be expected given that as the economy gets closer to flexible prices the prices do more of the adjustment towards the required real exchange rate depreciation that is needed and therefore less adjustment in the nominal exchange rate is needed.

The only reason why there is a devaluation of the currency is that it implies higher value of the export revenues. The downside is that it also increases the cost of imported inputs, creating pressure on costs. Furthermore, it will also have a direct impact on the reset price[17] of exports (set in local currency). If reset lower prices in exports are introduced then there is an increase in foreign demand for the domestic goods, which will lead to higher labor demand and wage pressure. This compounds to generate higher marginal costs and higher reset prices also in the domestic retail price of the domestic good, which will have the negative impact of driving lower consumption of the domestic goods as well as total consumption. This mechanism is very important for other results but in particular it explains why higher nominal rigidities lead to stronger depreciation rates of the currency. If nominal rigidities are stronger then the transmission from reset prices to actual prices is smaller and the cost of a devaluation is smaller.

The above also explains why the elasticity of foreign demand influences the optimal policy. If the elasticity is lower then foreign demand will not react as much to the reduction in foreign prices and therefore the cost of the devaluation will be lower. However the benefit of the depreciation falls too, because this strategy implies a fall in revenue in foreign currency (given that the price of exports falls more than the exports' demand increases), so that a bigger depreciation would be needed to attain the same goal. Figure 3 shows that this reduction in benefits is more prevalent than the reduction in costs, hence the smaller devaluation. It can be shown that if nominal rigidities are not present in the export sector then a reduction in

[17] This is the price set by those firms that are able to set a new price in period t.

foreign demand elasticity promotes a bigger devaluation in response to the sudden stop.

From the above we can conclude that sudden stops pose non-trivial trade-offs that the policy maker needs to address. It is interesting to ask the question of whether it also aggravates the usual time-inconsistency problem that is typical in dynamic forward-looking problems. Aside from the deterministic component there is the possibility that the reaction to unexpected shocks is different today than the reaction if the commitment had occurred in the past. A possible measure of this problem can be the comparison of the responses under a sudden stop, relative to the no sudden stop case for both the timeless perspective optimal policy and for the Ramsey equilibrium, in which the commitment is made in the initial period, shown in figure 4. The difference is stark: Ramsey implies a much stronger devaluation on impact and much lower interest rates. Indeed this policy increases the value of exports by so much that there is no need to impose a contraction on domestic consumption of the domestic goods – at least not on the initial period. It is also noticeable that in this case output, on impact actually increases due to a stable domestic demand and increased foreign demand. The need to keep producing in order to supply for exports, together with the real devaluation explain why expenditures on imported inputs increase.

The gap between the two policies can be interpreted as a measure of the time inconsistency problem. For periods after the initial one the two policies imply exactly the same reaction function to disturbances in the economy (other than deterministic components) while in the initial period the two reaction functions are different. This suggests that policy makers have an incentive to boost the economy more in the initial period in order to stabilize output and consumption, at the expense of increased price pressures, as cleared shown in the figure, exploiting precisely the fact that prices are sticky. This and the fact that optimal policy does not fully stabilize both output and inflation shows that the sudden stop creates a cost-push shock, that poses a non-trivial problem to the policy makers.

In order to understand the time-inconsistency issue, we can go back to the benefits and costs of a devaluation. The cost is determined by the extent to which the desired price changes are translated into actual price changes and the time inconsistency emerges from the fact that by not taking into account how past expectations were formed, the Ramsey policy exploits this to the extreme. The time consistent optimal policy instead does not exploit it as much precisely due to the commitment to take into account past expectations about current policy behavior. However, if we eliminate the nominal rigidities in the foreign export sector (but keep the ones in the domestic retail sector), shown in figure 5, then the time-inconsistency is considerably reduced, even if not fully eliminated. Curiously the optimal policy implies a slightly stronger devaluation which might be explained by the fact that it is less constrained by past expectations. It is thus reasonable to conclude that a key driver of why the sudden stop increases the time inconsistency of policy is due to the existence of nominal rigidities in the export sector.

4 Simple rules

In the literature monetary policy is frequently represented as following simple rules, the most prominent of which is the Taylor rule introduced by Taylor (1993). Such rules stipulate that the monetary authority commits to follow a simple interest rate rule. Taylor showed that an empirical rule in which the interest rate responds to inflation and the output deviations from trend is a good representation of how the US Federal Reserve conducted policy over a period in which monetary policy is generally considered to have done a good job. This however is an empirical statement. Nothing is said about the optimality of such rules. However they are very attractive especially in cases in which monetary policy is not very credible and therefore the monitoring of the compliance to such a simple policy can be tracked fairly easily by the economic agents. The obvious question is how well do simple rules perform, relative to the optimal policy, from a welfare perspective. A second issue is the possibility that a simple rule might actually implement the optimal policy or, at least, get very close to the optimal policy. These are precisely the two issues discussed in this section.

4.1 Benchmark rules

The first question that should be posed whenever a simple rule is proposed is how good such a rule is. That will generally depend on the economic structure, taking into consideration all the types of shocks that the economy faces. Here the exercise is not so much the discussion of whether such policies are the best to implement in the type of economies under consideration, but a narrower one: how good are those policies in the event of a sudden stop. Furthermore how do different types of rules compare relative to each other, from a welfare perspective?

This section performs a welfare comparison of rules based on the quadratic approximation suggested in Benigno and Woodford (2008) and the resulting welfare criterion is both time-invariant (does not depend on the initial conditions of the economy) and penalizes rules that violate the initial pre-commitment condition that is implicitly imposed when solving for the timeless perspective optimal policy.[18] The analysis will be a conditional exercise in the sense that we will compare the welfare under alternative policies conditional on the arrival of a sudden stop.

Aside from the two rules already incorporated in the discussion of the optimal policy, the peg and the simple Taylor rule (in terms of CPI inflation and output deviations from steady state), we further consider several alternatives, starting with a similarly defined Taylor rule, but where interest rates respond to DPI inflation, instead of CPI inflation.[19] Two other obvious relevant rules, at least as benchmarks, are strict inflation stabilization in terms of

[18] In particular the criterion integrates over a distribution of possible initial conditions.

[19] In both Taylor rules the coefficient on inflation is 2 and the coefficient on output is 0.75/4.

the CPI and in terms of the DPI. We also consider rules in which the interest rate further reacts directly to the exchange rate, here labeled as the CPI dirty float and the DPI dirty float, to convey precisely the idea that these are flexible exchange rate regimes but in which policy responds to the exchange rate.[20]

In general, showing the value of the loss function allows for a welfare ranking of the alternative policies but the number itself is completely meaningless and is difficult to judge what is a big and a small number. In order to get around this limitation, the welfare comparison will be performed based on the following relative welfare metric:

$$\tilde{W}_i \equiv \frac{W_i - W_{Ref}}{W_{Opt} - W_{Ref}} \tag{4.1}$$

which compares the gap in welfare between policy i and a reference policy relative to the welfare gap between the optimal policy and that same reference policy. This can be interpreted as a measure of how much of the welfare gap for the reference policy is reduced by policy i. If the value is negative then it means that the welfare gap is increased. Two obvious reference policies can be considered: the Taylor CPI rule and the peg, which were already used before in order to discuss optimal policy. Here we choose as a reference the Taylor CPI, simply because it is a standard rule usually considered in describing the behavior of monetary policy and therefore we can discuss how a given policy fares compared to that. The resulting welfare comparison is shown in table 4 and the numbers in the table are thus the welfare gap reduction measure.

The table suggests that the peg is the worst policy among the ones considered, significantly increasing the welfare gap relative to the CPI Taylor, which confirms the visual analysis of figure 1. We can further say that a simple DPI Taylor rule is the best of these rules, reducing the welfare gap by two thirds. This suggests that it is better for the interest

[20] In both the coefficient on nominal exchange rate depreciation is 0.5.

rate to respond only to domestic prices, without any response to the exchange rate (the DPI dirty float is better than the CPI Taylor but worse than the DPI Taylor).[21] Interestingly the table also shows that strict inflation stabilization, whether in terms of CPI or DPI inflation, is worse than the simple Taylor rule, even if not much worse.

These results are consistent with Cúrdia (2007), in which it was argued that a simple Taylor rule is better than the peg at stabilizing the economy, as measured by stabilizing output. This is also consistent with a vast literature on this subject. Namely, Devereux et al. (2006) compare both the volatility of responses as well as the expected welfare and conclude that it is best to have a policy rule in terms of non-traded goods inflation or in terms of CPI, depending on the pass-through but in any case either of those fares better than an exchange rate peg. Céspedes et al. (2004) and Gertler et al. (2003) perform similar exercises in terms of a response to the foreign interest rate and also conclude that the peg is the worst policy in terms of stabilization of the economy (purely positive result). The only reference to a result in which the peg is a better policy than a Taylor-type interest rate rule is provided by Cook (2004), which analyzes a similar question by comparing the volatility of some key variables under alternative policy rules and concludes that a peg is more stabilizing than interest rate rules targeting inflation.

It is important to understand the extent to which the ranking changes for different parameterizations. Therefore the table presents as well three additional scenarios, much like those considered in the previous section: lower nominal rigidities ($\alpha_p = 0.5$ and $\alpha_{p^*} = 0.5$), no nominal rigidities in the export sector and two different elasticities of foreign demand ($\nu^* = 0.6$ and $\nu^* = 20$).

Let us consider first the case with low elasticity of foreign demand, which is an important case, as already mentioned in the previous section. This scenario confirms that the peg is

[21] However, we should note that, at this stage, we considered only these rules with the coeffcients set at standard values but not optimized in any way. In the following section we will consider the case in which the coefficients are optimized to get the best out of each type of rules.

worse than the Taylor rule – if anything it is even worse than in the benchmark scenario – but it is no longer the worst of these simple policies, now strict DPI inflation stabilization attains a lower level of welfare. The fact that now the best of the simple rules is the DPI dirty float suggests that it is better for the interest rate to respond to both the domestic price inflation and to the exchange rate, but not in the way implied by the consumer basket composition.[22]

If the nominal rigidities in both sectors are lower or if the elasticity of foreign demand is very high then the peg performs relatively better and it actually becomes the best out of the simple rules considered here. The reason is that with low nominal rigidities the relative prices adjust more and thus it is possible to reach more real depreciation without resorting as much to the nominal depreciation. With high elasticity of foreign demand the explanation is completely different: with high elasticity, small changes in the real exchange rate lead to big changes in exports, hence even with nominal rigidities small real depreciation leads to significant increases in exports, hence a peg is not as much a constraint. The important lesson from this is that it is possible for the peg to be a good policy, provided that the conditions are favorable. If nominal rigidities in exports are eliminated then the best of these rules is to stabilize the domestic price inflation, which is not unreasonable given that in this case domestic prices are the only source of nominal rigidities and therefore should be the focus of the monetary policy stabilization strategy as discussed in Aoki (2001) and Benigno (2004).

4.2 Optimal rules

Comparison of simple rules among themselves and with the optimal policy is an informative exercise, but it can be subject to the criticism of why certain coefficients are used

[22] Notice that the CPI inflation is a convex linear combination of the DPI inflation and the depreciation rate, where the weights are given by the share of domestic and foreign goods in the consumption basket.

instead of others, and whether these influence the results. Therefore we now discuss which are the best simple rules within a certain class of rules, by optimizing the coefficients. We further extend the classes of rules considered. The simple interest rate rules considered focus on response to inflation, the exchange rate and output, however what the original Taylor rule considers is inflation and the output gap, instead of the output deviations from steady state. From a normative perspective Woodford (2003) shows that optimal policy considers output deviations from the target level of output. Furthermore, Benigno and Woodford (2005) show that the optimal policy can be implemented through a targeting criterion stabilizing a combination of inflation and the output gap. Cúrdia and Woodford (2008) show that even with credit frictions such a targeting criterion performs very well and it can be implemented through an interest rate rule responding to the natural rate of interest inflation and output gap. We thus consider two very broad classes of rules: interest rate rules and targeting rules.

The first set of rules generalizes the Taylor rule as follows,

$$\hat{R}_t = \phi_{R^n} \hat{R}_t^n + \phi_\pi \hat{\Pi}_t + \phi_{\pi_H} \hat{\Pi}_{H,t} + \phi_s \Delta S_t + \phi_y \hat{Y}_t + \phi_x x_t, \tag{4.2}$$

where variables with hat refer to the log-difference between the corresponding variable without hat and its steady state value. Furthermore we allow for the response of interest rate to natural variables, here defined as those prevailing in an equivalent economy with prices of all types perfectly flexible. Therefore $\hat{R}_t^n$ corresponds to deviations in the natural real interest rate relative to its steady state and $x_t \equiv \hat{Y}_t - \hat{Y}_t^n$ corresponds to deviations of output relative to its natural level. Notice further that we only consider values for the response to the natural interest rate of either zero (no response) or one (one-to-one response). When we allow the interest rate to respond to the output gap, x_t, we set $\phi_y = 0$, and when we consider rules responding to the domestic price inflation, $\phi_{\pi_H} > 0$, we set $\phi_\pi = 0$, and vice-versa, when we set $\phi_\pi > 0$ we require $\phi_{\pi_H} = 0$. All responses are restricted to assume non-negative values.

We also consider simple "specific targeting rules," in the terminology of Svensson and Woodford (2005). These involve the contemporaneous stabilization of a basket of variables, each with a given weight, and can be represented as

$$0 = \phi_\pi \hat{\Pi}_t + \phi_{\pi_H} \hat{\Pi}_{H,t} + \phi_s \Delta S_t + \phi_y \hat{Y}_t + \phi_x x_t, \tag{4.3}$$

in which one of the coefficients is normalized to one.[23]

The full ranking of optimized interest rate rules is presented in table 5 and the full ranking of optimized targeting rules is presented in table 6. For the benchmark parameter values, the best rule within these two broad classes turns out to be an interest rate rule responding to the natural rate, domestic price inflation, output and the exchange rate:

$$\hat{R}_t = \hat{R}_t^n + 1.938 \hat{\Pi}_{H,t} + 0.897 \hat{Y}_t + 0.169 \Delta \hat{S}_t. \tag{4.4}$$

It is worth noting that there is no big difference in welfare between this rule and the best interest rate rule without the natural rate, except for the important difference that in that case the optimal coefficients all diverge to infinity, and the limiting case implies a targeting rule

$$0 = \hat{\Pi}_{H,t} + 0.3775 \hat{Y}_t + 0.062 \Delta \hat{S}_t. \tag{4.5}$$

Both rules imply a welfare gap reduction of about 95% relative to the CPI Taylor rule, which means that these two rules get very close to implement the optimal policy, as shown in figure 6.[24] This figure confirms that even though the simple rules do not exactly imple-

[23] Without this normalization there is always an infinite number of solutions yielding exactly the same outcome for the economy, because we can multiply all coefficients by a constant without changing the outcome.

[24] The figure compares the optimal policy, basic CPI Taylor rule, best interest rate rule, best targeting rule and an approximately optimal simple rule discussed below.

ment the optimal policy they get really close to it and furthermore they constitute a big improvement over the basic CPI Taylor rule. In particular it is a very good approximation to the paths of output and inflation (both CPI and DPI). This shows as well that the welfare metric used here is very informative of how good a rule performs.

It is important to notice that in the best simple interest rate rule the coefficient on inflation is very similar to that used in standard Taylor rules, and in particular it is nearly the same as in our baseline Taylor rule. The response to output is somewhat bigger than usual, roughly 0.9, while more standard values are 0.25 or 0.5. In any case it is worth noting that the coefficients are not that different from those in standard rules. The response to the depreciation rate is not very big, around 0.17, however if we take into account that the nominal exchange rate depreciates significantly this term is non-negligible. Therefore we can conclude that it is important for the policy to respond to the natural interest rate and to the exchange rate in order to implement optimal policy.

One might argue that this simple rule requires the knowledge of the natural interest rate in the event of a sudden stop which in practice is a non-trivial informational requirement. But it is comforting to know that a similar equilibrium is reached with a policy that does not require such knowledge, as is the targeting rule in terms of inflation, output and exchange rate. The only problem of such a targeting criterion is that it is not a very clear guideline for the policy makers, at least it is not immediately obvious how to implement it in terms of interest rate response. We can then recall that this targeting rule is the limiting case of an interest rate rule responding to inflation, output and exchange rates, but requiring all the coefficients to diverge to infinity. We can thus ask the question of how much do we need to increase the coefficients in order to get a reasonable approximation. We can therefore set a rule as

$$\hat{R}_t = \phi_{\pi_H} \left[\hat{\Pi}_{H,t} + 0.378\hat{Y}_t + 0.062\Delta\hat{S}_t \right] \tag{4.6}$$

and see how big does ϕ_{π_H} need to be to reach a given target of welfare gap reduction relative to the CPI Taylor rule. We find that setting $\phi_{\pi_H} = 2.95$ allows for a welfare gap reduction of 75% and if we are willing to consider interest rate responses as aggressive as $\phi_{\pi_H} = 6$ then we can reach a welfare reduction of 90%, which does not compare too unfavorably relative to the best simple rule described previously. Indeed figure 6 shows that this rule implies a response of the economy that is very similar to that under the optimal rules discussed above. This shows that, provided that policy is aggressive enough, we can easily approximate the optimal policy using a very simple rule.

However, it is important to consider how robust are these optimized rules across alternative parameter values, much like we did for the optimal policy and the benchmark rules. When performing this type of analysis we always get the result that optimal policy is very well approximated by a rule in which the interest rate responds to the natural interest rate, DPI inflation, output deviations from steady state and the exchange rate, just like in the benchmark best simple rule (4.4). The only scenario in which this rule performs less well is the one with low nominal rigidities, in which case this is still the best of the rules considered here but in that case the best that it can do is to reduce the welfare gap of the Taylor rule by about 50% (compared to 95% in the baseline calibration. Therefore this type of rule is consistently a very good one, even across calibrations in which the simple benchmark rules seem to alternate their relative performance. Notice that even in the case of high elasticity of foreign demand, in which the peg almost completely closes the welfare gap of the Taylor rule, this generalized interest rate rule still manages to do better, halving the remaining welfare gap of the peg relative to the optimal policy.

We should notice that saying that this class of rules is consistently the best one does not mean that the optimal coefficients are always the same. Indeed we get fairly different values for the coefficients across parameter specifications. For example in the case in which the elasticity of foreign demand is lower the coefficients diverge to infinity, and hence the best rule can better be characterized by a flexible targeting rule of the type described in (4.5). In this case we get the optimized rule to look like

$$0 = \hat{\Pi}_{H,t} + 0.897\hat{Y}_t + 0.426\Delta\hat{S}_t \tag{4.7}$$

which means that in this scenario policy ought to increase the weight on the stabilization of output and the exchange rate, relative to inflation. The coefficient on output is actually roughly double than the one in the baseline case and the coefficient on the exchange rate is one order of magnitude higher. This rule is able to close 85% of the welfare gap of the Taylor rule, hence it is not as good in this case as in the baseline but it is still a significant improvement over the basic Taylor rule and the peg. Figure 7 (the figure compares the optimal policy, basic CPI Taylor rule, best targeting rule and an approximately optimal simple rule discussed below) actually shows that this targeting rule is a very good one, and that the reason why it is not able to improve as much as before is that the basic Taylor is not as bad as in the baseline case, hence there is less room for improvement. In terms of implementability of this targeting criterion we can repeat the experiment we conducted before for the benchmark case. Therefore let us consider the following interest rate rule

$$\hat{R}_t = \phi_{\pi_H}\left[\hat{\Pi}_{H,t} + 0.897\hat{Y}_t + 0.426\Delta\hat{S}_t\right] \tag{4.8}$$

and search for the ϕ_{π_H} that can close a significant part of the welfare gap. If we allow for a moderate value, of the order of magnitude of about $\phi_{\pi_H} = 3$, then we are only able to get a welfare gap reduction of roughly 50% but if we allow for more aggressive response, of the order of $\phi_{\pi_H} = 6$ then it is possible to close as much as 75% of the welfare gap of the basic CPI Taylor rule. Figure 7 shows that this approximately optimal rule fares indeed very well.

In the case with no nominal rigidities in export prices, it is best to not respond to the exchange rate and instead focus on the domestic prices and output

$$\hat{R}_t = \hat{R}^n_t + 1.305\hat{\Pi}_{H,t} + 0.621\hat{Y}_t \tag{4.9}$$

which closes roughly 85% of the welfare gap of the basic CPI Taylor rule, and we can further mention that a policy simply focusing on strict DPI inflation stabilization is the best policy if we exclude the natural rate from the policy rule and is able to reduce the welfare gap of the basic Taylor rule by roughly 76%.

If we consider the case in which nominal rigidities are smaller ($\alpha_p = \alpha_{p^*} = 0.5$), then we get less satisfactory results, with the best rule closing only 50% of the welfare gap of the basic CPI Taylor rule. Furthermore the rule looks very different from the others, consisting of a targeting rule that focus on stabilizing the output and the exchange rate

$$0 = 1.837\hat{Y}_t + \Delta\hat{S}_t \tag{4.10}$$

so in this case the direct nominal anchor is the nominal exchange rate, instead of the domestic inflation. However, it is worth noting that this rule still manages to improve on the peg by reducing its welfare gap by 20%.

The conclusion is that optimal policy can be fairly well approximated by a simple rule that either specifies an interest rate response to the natural interest rate, domestic price inflation, output deviations from steady state and the exchange rate or by a flexible inflation targeting rule in which policy stabilizes a combination of domestic price inflation, output and the exchange rate. The only exception is the case with low nominal rigidities, in which case the simple rules are not as good an approximation to the optimal policy.

5 Conclusion

In the event of a sudden stop in capital inflows optimal monetary policy exploits the export revenues in order to minimize the impact on the domestic economy. However this will not completely insulate the economy from some contraction. A domestic currency depreciation is combined with high interest rates to achieve this result. Furthermore, the arrival of the sudden stop increases the problem of time inconsistency of policy, highlighting the importance of credibility and commitment for emerging markets.

We also conclude that for all parameter configurations but the one in which nominal rigidities are smaller, the optimal policy is well approximated by an interest rate rule responding to the natural interest rate, domestic price inflation, output and the exchange rate. In some cases the optimal level of the interest rate response diverges to infinity, in which case the limiting case is a flexible inflation targeting rule in which authorities stabilize contemporaneously a combination of domestic prices, output and the exchange rate. However, the weights on the different variables are sensitive to parametrization.

An important outcome of the paper is to show that whether a fixed exchange rate regime is a good policy depends on the economic environment (or in the model, on the parameterization). For the benchmark parameterization, the peg performs badly, from a welfare perspective. If we consider lower nominal rigidities or high elasticity of foreign demand, then the peg performs relatively better.

The analysis presented here does not close the subject of optimal policy in an emerging market subject to sudden stops. A relevant limitation of it is the consideration of the shock to be completely exogenous. Actually most papers on the matter are subject to this criticism and it would be important to analyze the case in which the arrival of the sudden stop is not exogenous or in which policy can influence the duration of such episodes. Caballero and Krishnamurthy (2005) discuss the consequences for monetary policy of the threat of a sudden stop that can occur in the future and how current and future expected policies interact. This type of exercise should be extended further to incorporate more complete frameworks such as the one considered here.

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A Variables and parameters

Table 1: Variables present in the model

P_t	consumption price index (CPI)	Π_t	CPI inflation rate
$P_{H,t}$	domestic price index (DPI)	$\Pi_{H,t}$	DPI inflation rate
$P^*_{H,t}$	exports price index$^{(1)}$	$p_{H,t}$	relative dom. goods retail price
$P_{w,t}$	wholesale dom. goods price	$p_{w,t}$	wholesale dom. goods relative price
W_t	nominal wage rate	w_t	real wage rate
R_t	domestic interest rate	R^r_t	real interest rate
R^*	foreign risk free interest rate	λ_t	risk premium term
$R_{Z,t}$	returns on imported inputs	$R^r_{Z,t}$	real returns on imported inputs
S_t	nominal exchange rate	s_t	real exchange rate
C_t	consumption bundle	$C^{*`}$	foreign aggregate consumption
$C_{H,t}$	consumption of domestic goods	$C^*_{H,t}$	foreign consumption of dom. goods
$C_{F,t}$	consumption of foreign goods	Y_t	domestic goods production
L_t	labor	Z_t	imported inputs
B_t	debt$^{(1)}$	b_t	leverage ratio
$\omega_t(j)$	imported input productivity shock	$\omega^*_t(j)$	foreigners perceptions about $\omega_t(j)$
$\bar{\omega}_t$	default threshold	$R_{B,t}$	gross interest rate in debt contract
$\pi_{r,t}$	profits of retail firms	$\pi_{w,t}$	profits of wholesale firms
N_t	nominal net worth	n_t	real net worth
D_t	domestic assets	κ_t	misperception factor

(1) defined in foreign currency

Table 2: Parameters present in the model

β	discount factor
σ	inverse of the intertemporal elasticity of substitution
ψ	inverse of the labor supply elasticity
γ	share of the domestic good in the consumption under unit elasticity of substitution
α	share of labor to the production of the domestic goods under unit elasticity of substitution
σ_ω^2	variance of the log-normal distribution of ω
μ	monitoring costs
δ_n	probability of exit from sudden stop
κ_{ss}	misperception factor during sudden stop
η	elasticity of substitution among the different varieties of the domestic goods
ν^*	foreign demand price elasticity
γ^*	share of the domestic good in the foreign consumption under unit elasticity of substitution
α_p	probability that a firm is not able to set prices in the domestic market in a given period
α_{p^*}	probability that a firm is not able to set prices in the export market in a given period

Table 3: Parameter values

β	0.98401	α	0.5	ν^*	1	μ	0.019065
σ	1	α_p	0.75	γ^*	0.1	σ_ω	0.392202
ψ	2	α_{p^*}	0.75	C^*	5	δ_n	0.10
γ	0.75	η	6	R^*	1.01	κ_{ss}	0.75

B All equations describing the economy

We can summarize all the equations of the economy:

$$C_t^{-\sigma} = \beta E_t \left[C_{t+1}^{-\sigma} \frac{R_t}{\Pi_{t+1}} \right] \tag{B.1}$$

$$w_t = L_t^{\psi} C_t^{\sigma} \tag{B.2}$$

$$C_{H,t} = \gamma \frac{C_t}{p_{H,t}} \tag{B.3}$$

$$C_{F,t} = (1-\gamma) \frac{C_t}{s_t} \tag{B.4}$$

$$1 = p_{H,t}^{\gamma} s_t^{1-\gamma} \tag{B.5}$$

$$Y_t = \left(\frac{L_t}{\alpha} \right)^{\alpha} \left(\frac{Z_{t-1}}{1-\alpha} \right)^{1-\alpha} \tag{B.6}$$

$$L_t = \alpha \frac{p_{w,t} Y_t}{w_t} \tag{B.7}$$

$$n_t = (1-b_t) s_t Z_t \tag{B.8}$$

$$B_t = b_t Z_t \tag{B.9}$$

$$\bar{\omega}_t = \frac{R_{B,t-1}}{R_{Z,t}^r} \frac{s_t}{s_{t-1}} b_{t-1} \tag{B.10}$$

$$E_t \left[\Omega \left(\bar{\omega}_{t+1}; \kappa_t \right) R_{Z,t+1}^r \frac{s_t}{s_{t+1}} \right] = R^* b_t \tag{B.11}$$

$$E_t \left[C_{t+1}^{-\sigma} \left[1 - \Gamma \left(\bar{\omega}_{t+1} \right) \right] R_{Z,t+1}^r \right] = (1-b_t) E_t \left[C_{t+1}^{-\sigma} \frac{R_t}{\Pi_{t+1}} \right] \tag{B.12}$$

$$E_t \left[C_{t+1}^{-\sigma} \frac{R_t}{\Pi_{t+1}} \right] = E_t \left[C_{t+1}^{-\sigma} \lambda_{t+1} \frac{s_{t+1}}{s_t} R^* \right] \tag{B.13}$$

$$\lambda_t = \frac{\Gamma' \left(\bar{\omega}_t \right)}{E_t \left[\Omega' \left(\bar{\omega}_{t+1}; \kappa_t \right) \right]} \tag{B.14}$$

$$R_{Z,t}^r = (1-\alpha) \frac{p_{w,t} Y_t}{s_{t-1} Z_{t-1}} \tag{B.15}$$

$$Y_t = C_{H,t} + C_{H,t}^* \tag{B.16}$$

$$C_{H,t}^* = \gamma^* \left(P_{H,t}^* \right)^{-\nu^*} C^* \tag{B.17}$$

$$F_t = C_t^{-\sigma} C_{H,t} p_{H,t}^{\eta} p_{w,t} + \alpha_p \beta E_t \left[\Pi_{t+1}^{\eta} F_{t+1} \right] \tag{B.18}$$

$$K_t = C_t^{-\sigma} C_{H,t} p_{H,t}^{\eta} + \alpha_p \beta E_t \left[\Pi_{t+1}^{\eta-1} K_{t+1} \right] \tag{B.19}$$

$$p_{H,t} = \left[(1-\alpha_p) \left(\frac{\eta}{\eta-1} \frac{F_t}{K_t} \right)^{1-\eta} + \alpha_p \left(\frac{p_{H,t-1}}{\Pi_t} \right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{B.20}$$

$$F_t^* = C_t^{-\sigma} C_{H,t}^* \left(P_{H,t}^* \right)^{\eta} p_{w,t} + \alpha_{p^*} \beta E_t \left[F_{t+1}^* \right] \tag{B.21}$$

$$K_t^* = C_t^{-\sigma} C_{H,t}^* \left(P_{H,t}^* \right)^{\eta} s_t + \alpha_{p^*} \beta E_t \left[K_{t+1}^* \right] \tag{B.22}$$

$$P_{H,t}^* = \left[\left(1-\alpha_{p(}\right) \left(\frac{\eta}{\eta-1} \frac{F_t^*}{K_t^*} \right)^{1-\eta} + \alpha_{p^*} \left(P_{H,t-1}^* \right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{B.23}$$

$$0 = s_t P_{H,t}^* C_{H,t}^* - s_t C_{F,t} - s_t Z_t - \Gamma\left(\bar{\omega}_t\right) R_{Z,t}^r s_{t-1} Z_{t-1} + b_t s_t Z_t \tag{B.24}$$

Notice the addition of four artificial variables, F_t, K_t, F_t^* and K_t^* to allow for a recursive formulation of the DPI and the price of export goods.

C Welfare ranking

Table 4: Welfare comparison of benchmark rules under alternative scenarios

$\tilde{W}_i$ [1]	benchmark	low elast. foreign demand[2]	high elast. foreign demand[3]	low nominal rigidities[4]	no nominal rigidities in exports[5]
Peg	-2.32471	-3.35814	0.98534	0.44339	-0.86164
CPI stabilization	-0.04583	-0.26787	0.97645	-0.13861	-0.26684
DPI stabilization	-0.14138	-5.89867	0.77878	-1.00183	0.75638
CPI Taylor	0.00000	0.00000	0.00000	0.00000	0.00000
DPI Taylor	0.67529	-0.84930	0.09191	-0.34083	0.63184
CPI dirty float	-0.36327	0.27340	0.41624	0.15799	-0.25318
DPI dirty float	0.40555	0.47200	0.38742	-0.07254	0.20398

[1] $\tilde{W}_i = (W_i - W_{\text{CPI Taylor}})/(W_{\text{Optimal}} - W_{\text{CPI Taylor}})$, with $\tilde{W}_{\text{Optimal}} = 1$.
[2] $\nu^* = 0.6$; [3] $\nu^* = 20$; [4] $\alpha_p = \alpha_{p^*} = 0.5$; [5] $\alpha_p = 0.75$ and $\alpha_{p^*} = 0$.

Table 5: Welfare comparison of optimized interest rate rules under alternative scenarios

$\tilde{W}_i^{(1)}$	benchmark	low elast. foreign demand[2]	high elast. foreign demand[3]	low nominal rigidities[4]	no nominal rigidities in exports[5]
Π, Y	0.51377†	0.82642†	0.98595†	0.18268†	0.13313
Π, Y, R^n	0.88052	0.82642†	0.98753	0.18273†	0.73318
Π, x, R^n	0.86092†	-0.03581†	0.98549	-0.13865†	0.73415†
Π, x	0.90534	0.55818	0.97593†	-0.01056	0.74008†
$\Pi, Y, \Delta S$	0.50754†	0.84565†	0.98442†	0.53745†	0.13280
$\Pi, Y, \Delta S, R^n$	0.88048	0.84628†	0.98720	0.53747†	0.73318
$\Pi, x, \Delta S, R^n$	0.87874†	0.53674†	0.98518†	0.44321†	0.73065†
$\Pi, x, \Delta S$	0.90401	0.58710†	0.98412†	0.48739	0.75278†
Π_H, Y	0.91380	-0.44587	0.93634†	-0.06225†	0.74906†
Π_H, Y, R^n	0.92060	-1.75136	0.99293	-0.07405†	0.85856
Π_H, x, R^n	0.47198	-2.80000	0.99218	-0.41029†	0.75601†
Π_H, x	0.89214	-0.44587	0.85684†	-0.32037	—
$\Pi_H, Y, \Delta S$	0.93771†	0.84602†	0.98745†	0.53789†	0.75612†
$\Pi_H, Y, \Delta S, R^n$	0.95649	0.84609†	0.98814	0.53796†	0.85855
$\Pi_H, x, \Delta S, R^n$	0.83743†	0.54783	0.98524†	0.44334†	0.75360†
$\Pi_H, x, \Delta S$	0.90678	0.56739	0.98508†	0.48674	—

[1] $\tilde{W}_i = (W_i - W_{\text{CPI Taylor}})/(W_{\text{Optimal}} - W_{\text{CPI Taylor}})$, with $\tilde{W}_{\text{Optimal}} = 1$.

[2] $\nu^* = 0.6$; [3] $\nu^* = 20$; [4] $\alpha_p = \alpha_{p^*} = 0.5$; [5] $\alpha_p = 0.75$ and $\alpha_{p^*} = 0$.

† optimized coefficients diverge to infinity

Table 6: Welfare comparison of optimized targeting rules under alternative scenarios

$\tilde{W}_i^{(1)}$	benchmark	low elast. foreign demand[2]	high elast. foreign demand[3]	low nominal rigidities[4]	no nominal rigidities in exports[5]
Π, Y	0.51387	0.82646	0.98611	0.18275	-0.26685
Π, x	0.86095	-0.03489	0.97640	-0.13865	0.73514
$\Pi, Y, \Delta S$	0.51387	0.84646	0.98845	0.53803	-0.26686
$\Pi, x, \Delta S$	0.87888	0.26142	0.98526	0.44334	0.73519
Π_H, Y	0.77913	-1.84801	0.93457	-0.06190	0.75635
Π_H, x	-0.14147	-5.89853	0.77872	-1.00181	0.75635
$\Pi_H, Y, \Delta S$	0.93775	0.84646	0.98845	0.53804	0.75635
$\Pi_H, x, \Delta S$	0.87888	0.26139	0.98526	0.44334	0.75635

[1] $\tilde{W}_i = (W_i - W_{\text{CPI Taylor}}) / (W_{\text{Optimal}} - W_{\text{CPI Taylor}})$, with $\tilde{W}_{\text{Optimal}} = 1$.
[2] $\nu^* = 0.6$; [3] $\nu^* = 20$; [4] $\alpha_p = \alpha_{p^*} = 0.5$; [5] $\alpha_p = 0.75$ and $\alpha_{p^*} = 0$.

D Impulse response functions

Figure 1: Responses under optimal policy

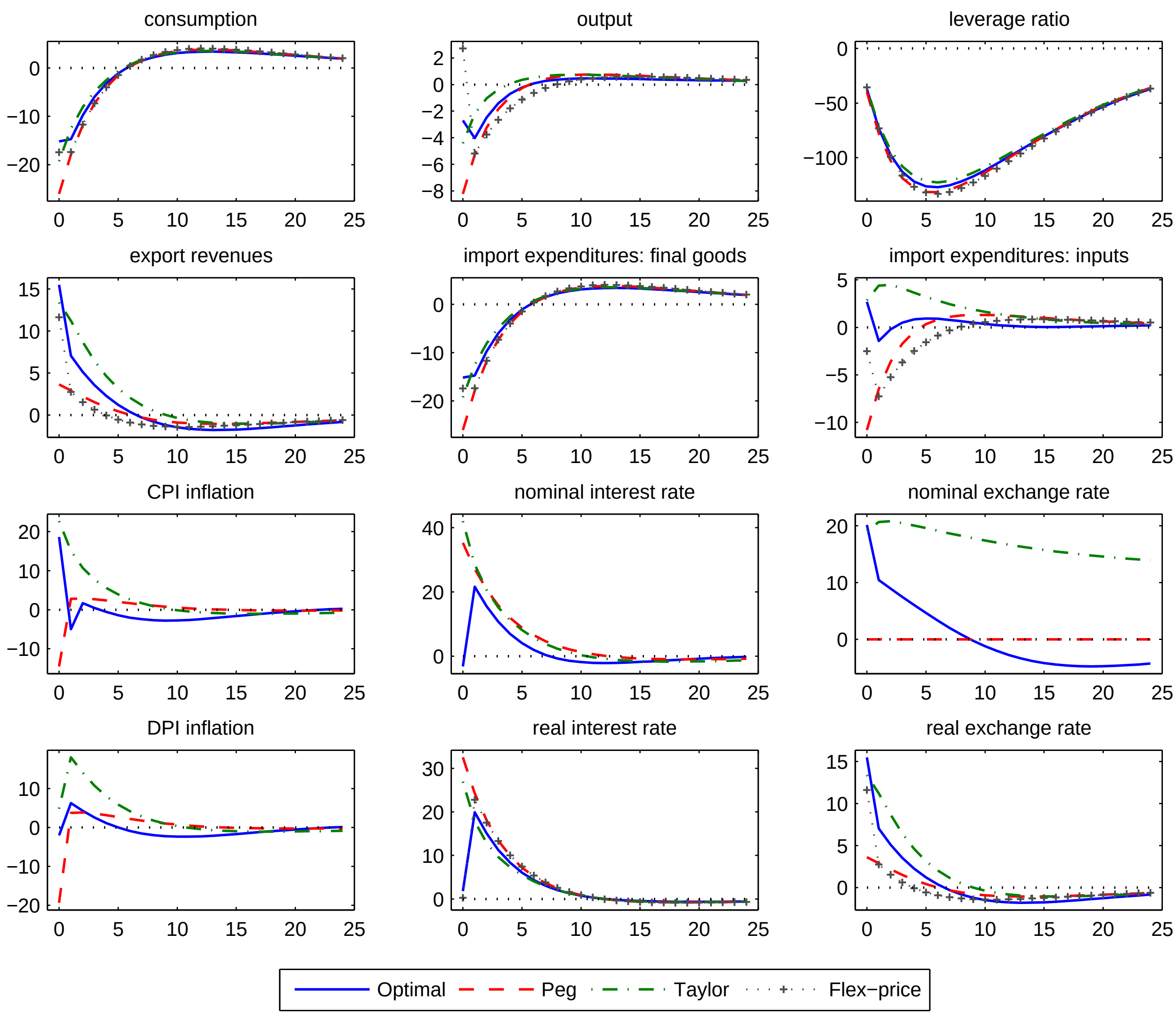

Figure 2: Responses under optimal policy with smaller nominal rigidities

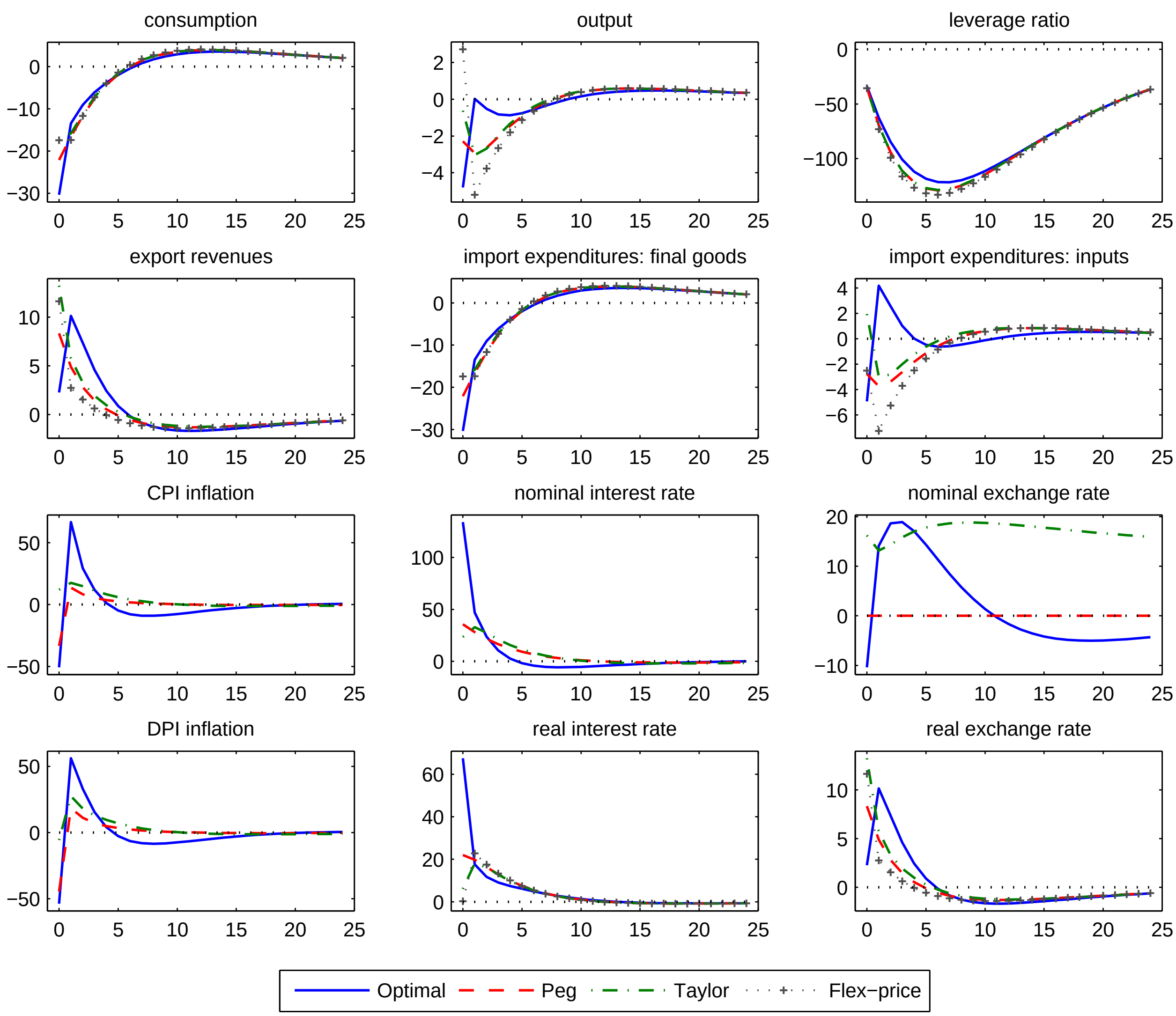

Figure 3: Responses under optimal policy with low elasticity of foreign demand

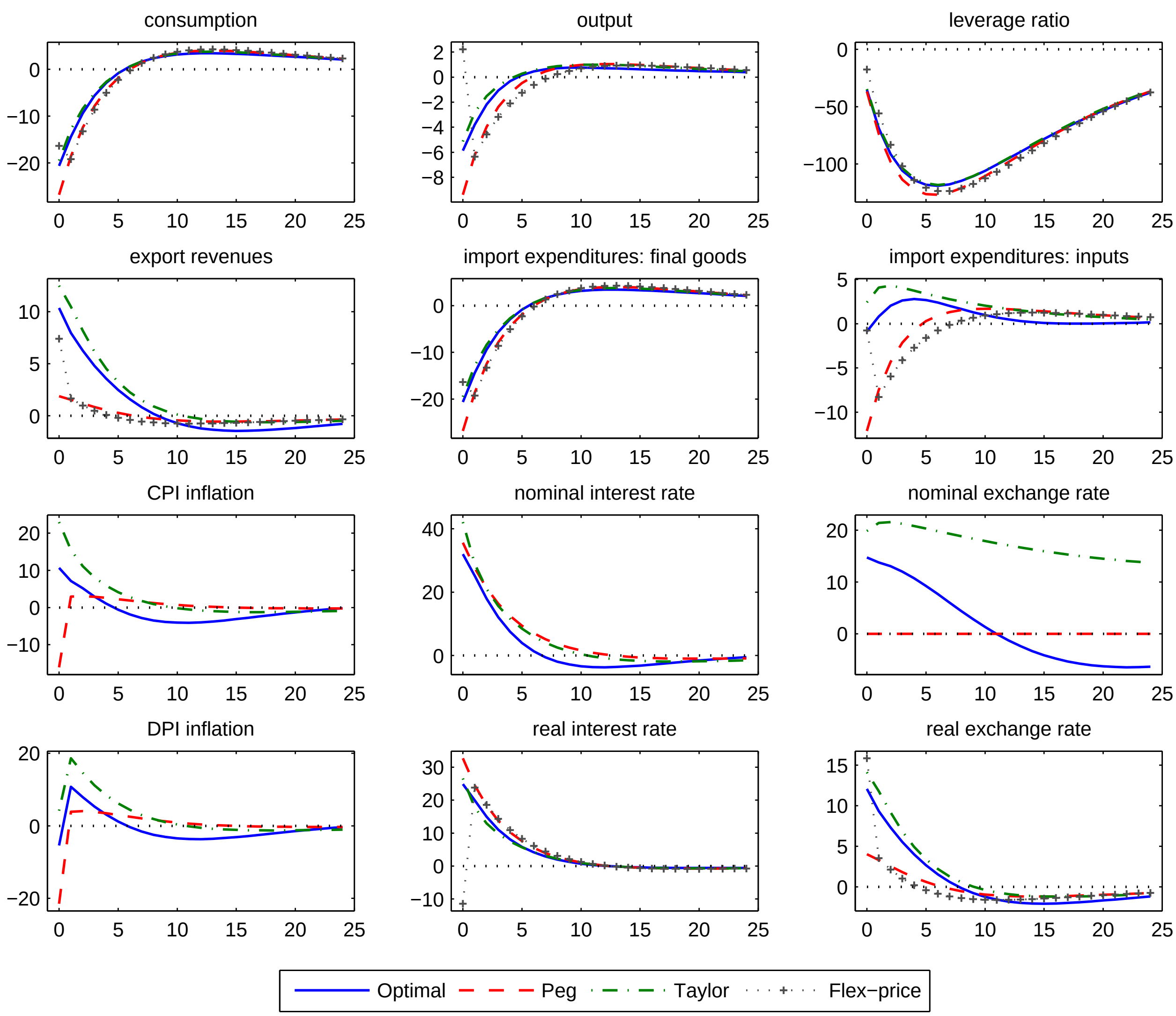

Figure 4: Responses under optimal policy and Ramsey

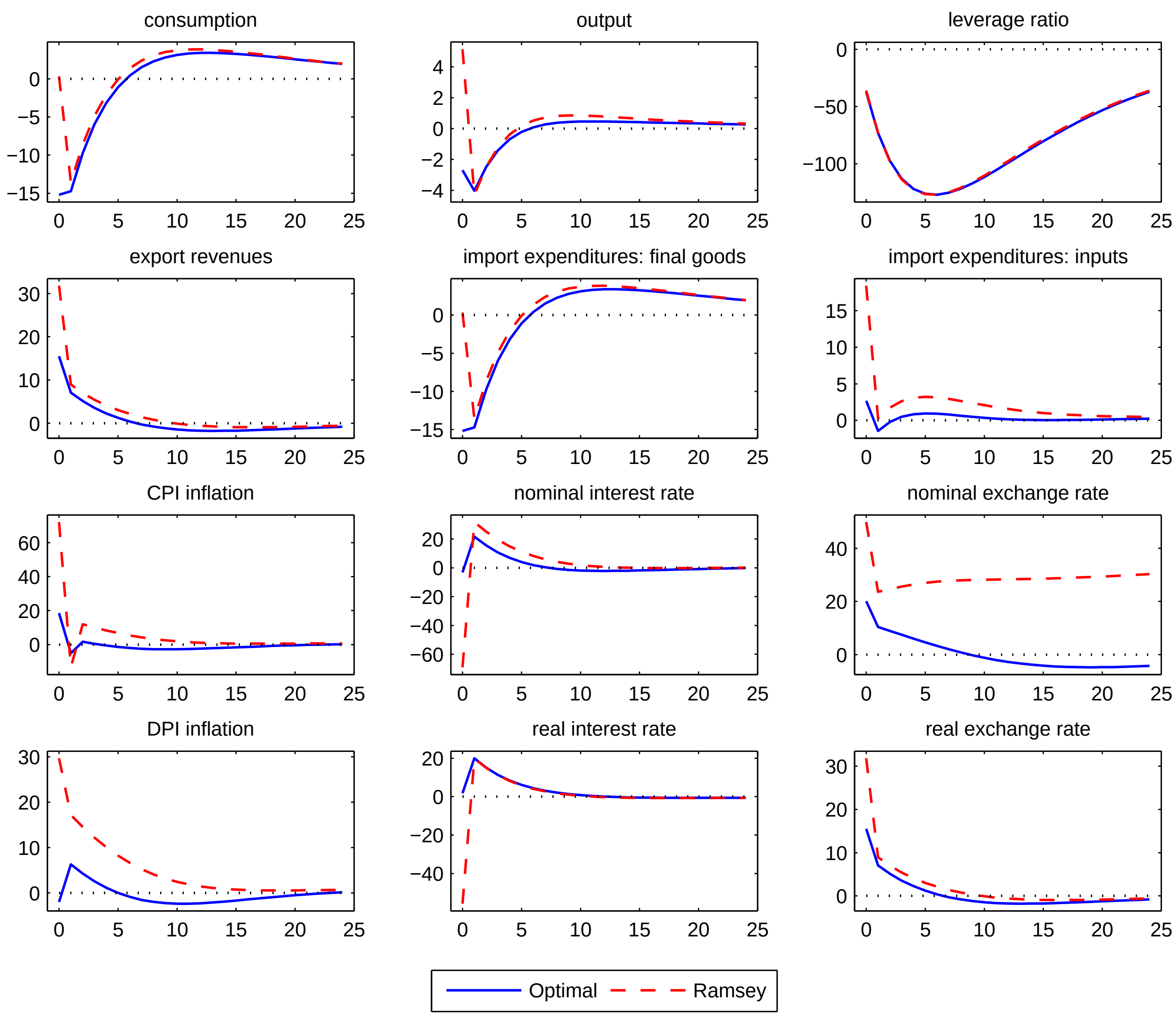

Figure 5: Responses under optimal policy and Ramsey in the case without nominal rigidities in export sector

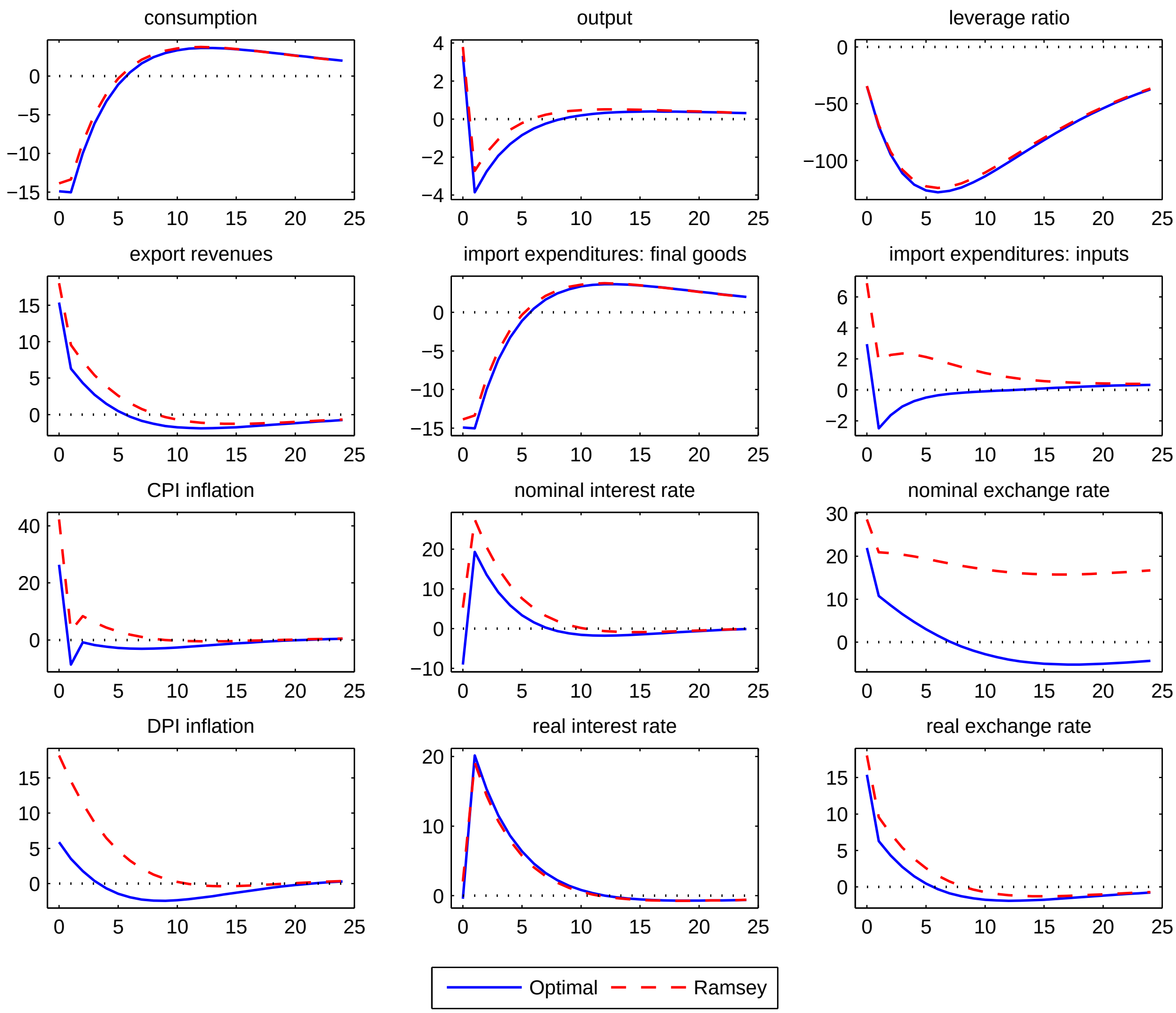

Figure 6: Responses under optimal policy and the best simple rule

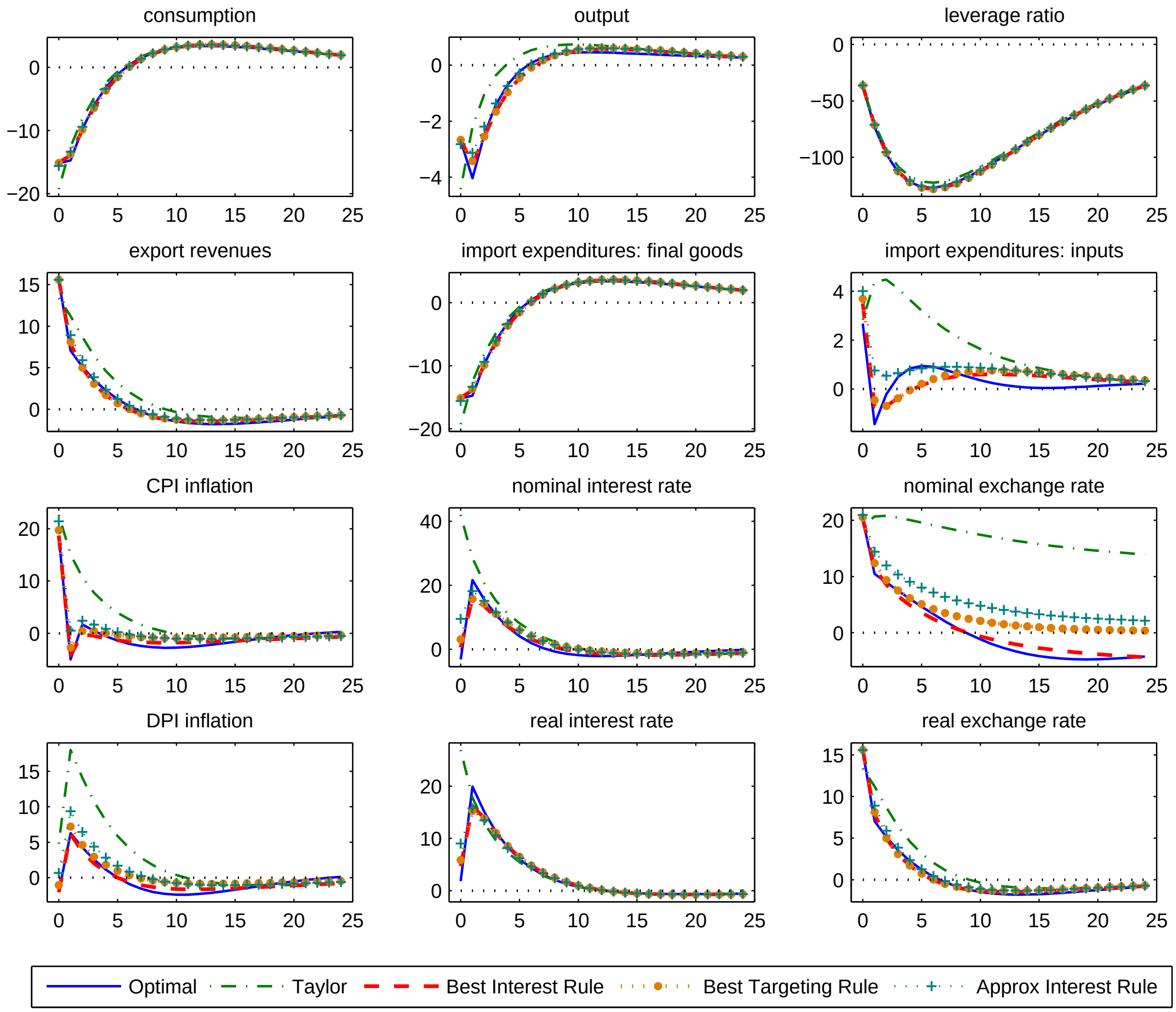

Figure 7: Responses under optimal policy and the best simple rulein the case with low elasticity of foreign demand