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# The Impact of the Financial Crisis and Policy Responses in Croatia



CROATIAN NATIONAL BANK



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The views expressed in this paper are not necessarily  
the views of the Croatian National Bank.

December 2009



CROATIAN NATIONAL BANK

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Croatian National Bank  
Publishing Department  
Trg hrvatskih velikana 3, 10002 Zagreb  
Phone: 385-1-4564-555  
Contact phone: 385-1-4565-006  
Fax: 385-1-4564-687

*Website:*

<http://www.hnb.hr>

*Editor-in-chief:*

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*Technical editor:*

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*Printed by:*

Denona d.o.o., Zagreb

Those using data from this publication are requested to cite the source.  
Any additional corrections that might be required will be made in the website version.

Printed in 350 copies

ISSN 1331–8586

# The Impact of the Financial Crisis and Policy Responses in Croatia<sup>1</sup>

Nikola Bokan, Lovorka Grgurić, Ivo Krznar, Maroje Lang

## Abstract

We conduct simulations of the impact of the financial crisis on the Croatian economy using the newly developed DSGE model for Croatia. The impact of the crisis is modeled by proxying it with two distinct shocks: an increase in the foreign interest rate (cost of foreign borrowing) and a drop in export demand. Furthermore, we introduce a monetary policy response in the form of regulatory requirement reduction. The results to a large extent match the actual data, confirming the early impact of the crisis. More precisely, the financial crisis led to a significant slowdown in real activity, international trade and financial aggregates. Real activity is in decline, despite significant monetary policy response. With a monetary policy regime based on a stable exchange rate, the central bank is limited in its attempt to counter the impact of foreign shocks and significantly stimulate real activity by adjusting the regulatory framework. By decreasing the regulatory burden and thereby increasing bank liquidity, the CNB has managed to offset the negative impact of foreign shock(s) only partially and to a small extent. However, this limited success must be evaluated in the context of a highly euroized small open economy, where the primary goal of the monetary authority is to keep the exchange rate broadly stable.

**JEL:** C61, D50, E58

**Keywords:** small open economy, financial crisis, euroization

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<sup>1</sup> This paper represents the personal opinion of the authors and does not necessarily reflect the views of the Croatian National Bank. We would like to thank David Vavra, Jaromir Benes and Jan Vlček for helping us with model development, as well as Ana Maria Čeh and Vjerana Spajić for help with editing.



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# 1 Introduction

The current economic and financial crisis presents a new and large challenge for monetary policy throughout the world. In order to understand the possible impact of the crisis and choose the appropriate policy response, it is important to understand the mechanisms by which the crisis propagates throughout the economy. In the case of a small open economy, the impact of the crisis comes from abroad in the form of smaller and dearer capital (in)flows and weaker export demand. The question is how to analyze this effect. It is widely accepted that, due to large and unprecedented shocks, standard econometric methods for assessing the possible impacts of this crisis may not be appropriate. For that reason, we have built a dynamic stochastic general equilibrium model (DSGE) of a small open economy to analyze the impact of the crisis and the monetary policy response on the Croatian economy. The model was initially built as a policy analysis tool to be used for assessing various scenarios. Therefore it includes many sectors with many shocks, in order to capture as much of the real world as possible. As such, the model is not simulated and evaluated in terms of the standard norms found in the “academic” DSGE literature. Instead, the outputs of our model are impulse responses of the macroeconomic variables of interest. These impulse responses are used as a practical guide for understanding possible economic developments in Croatia.

The model differs from the standard inflation targeting model because of a different monetary policy regime. A high level of euroization in the Croatian economy and, in particular in the financial sector, makes the nominal exchange rate a natural anchor. Keeping the exchange rate stable has been very successful, achieving low inflation during the last 15 years and contributing to the stability of the financial system. Therefore, standard monetary instruments, such as foreign exchange interventions and domestic liquidity management, are used primarily to keep the exchange rate stable. Alternatively, the Croatian National Bank (CNB) relies heavily on administrative measures, in particular different regulatory requirements (similar to reserve requirements), to influence the domestic economy through the banking system.

We model the impact of the crisis by proxying it with two distinct shocks. More precisely, an exogenous increase in foreign interest rates (the cost of foreign borrowing) and a drop in export demand are assumed to be the triggers through which the world financial crisis will affect the Croatian economy. Furthermore, we introduce monetary policy response in the form of regulatory requirement reduction. The magnitudes of the shocks are calibrated on actual data, and the model was used both for simulation of the impact and analysis of the transmission mechanism of these shocks through the model economy.

The results to a large extent correspond to the actual and expected macroeconomic development. In particular, the financial crisis led to a significant slowdown in real activity, international trade and financial aggregates. Monetary easing in the scenario analyzed was not able to counter the negative real effect of the financial crisis. However, by reducing the regulatory requirement, the CNB can create

enough foreign currency liquidity to offset some of possible problems that could develop in the financial sector.

The paper proceeds as follows. The next section describes the monetary policy framework and recent economic developments in Croatia. It is followed with a detailed description of the model, its calibration and the main findings. The last section concludes.

## 2 Recent Economic Developments and the Financial Crisis

The current financial crisis was slow to unfold. It gradually escalated from summer 2007 when the problems with subprime mortgages became known. However, the full extent to which those products were spread throughout the financial system had yet to be discovered. By spring 2008, the US authorities were recapitalizing some of their largest financial institutions. The peak of the financial crisis happened at the end of September 2008 with the fall of Lehman Brothers, which shook the entire financial world.

The first impact of the financial crisis on the emerging markets<sup>2</sup> was transmitted through financial markets as aversion to risk increased. The stock markets fell worldwide, and capital flows to emerging markets retracted. As a result, the cost of foreign borrowing increased for many emerging markets, despite the loosening of monetary policy by the FED and the ECB that lowered interest rates in the developed economies. The increase in the cost of borrowing was particularly pronounced following September 2008 (Figure 1.a).<sup>3</sup>

Faced with increasing borrowing costs, real activity in Croatia started slowing down from mid-2008.<sup>4</sup> The economy decelerated further by the end of the year, and in the beginning of 2009 a significant recession took place. The annual rate of contraction of industrial production and retail trade was in double digits (Figure 1.b).<sup>5</sup> Similarly, the growth of GDP and personal consumption also slowed down in the second half of 2008, while preliminary data indicate severe recession in the first half of 2009 (Figure 1.c).

As the financial crisis spread to the real sector in developed economies, final demand has also contracted. This has decreased demand for Croatian exports, which started to decline in mid-2008. It further affected already weakened demand for both final and intermediary goods, so merchandise imports also contracted.

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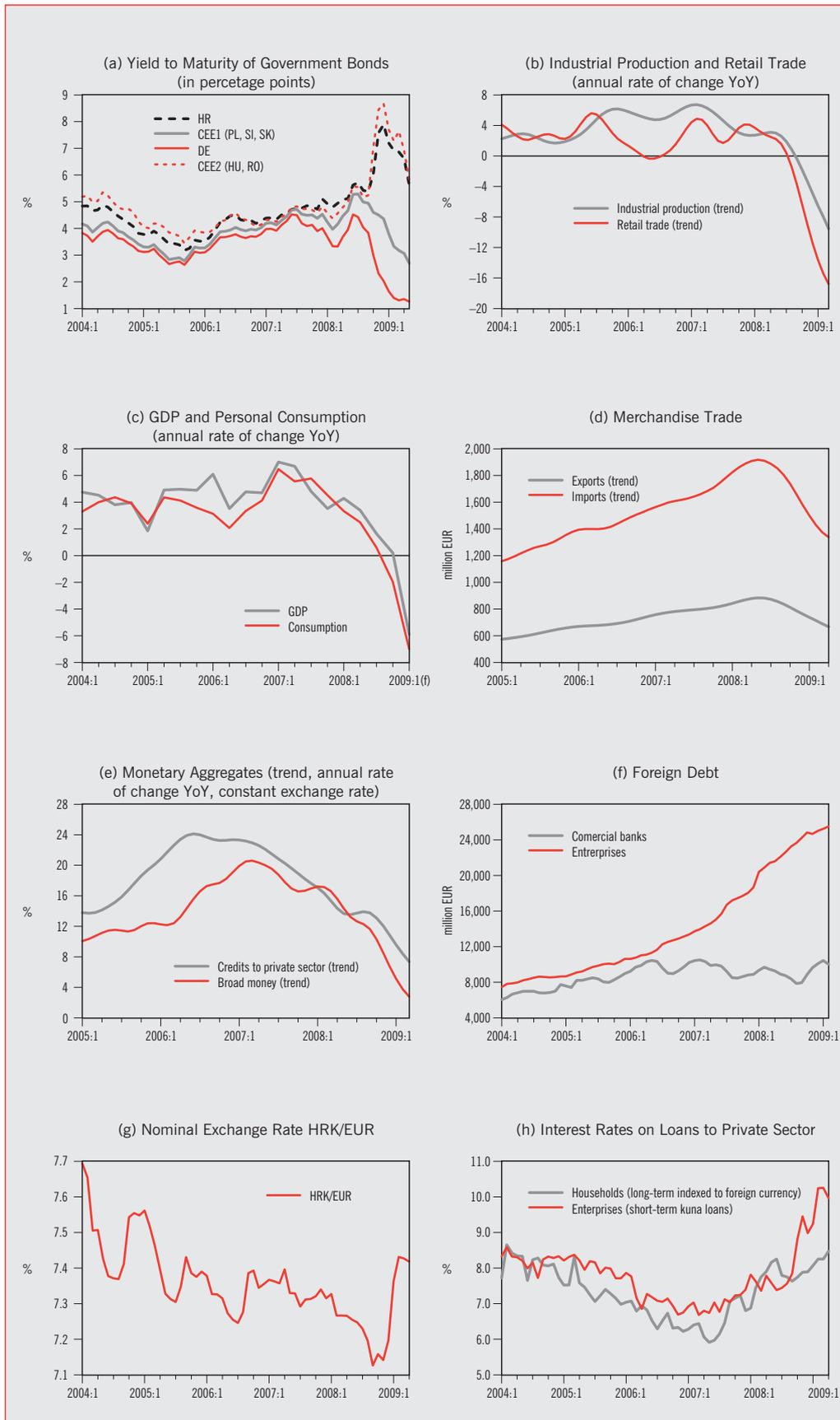
2 There was significant drop in commodity prices, which severely affected commodity exporters. However, this shock is not particularly important for Croatia. In addition, the slowdown of commodity (especially oil) prices has helped as it had positive effect on the economy.

3 The increase in credit default swaps (CDS) might overemphasize the actual increase in the cost of foreign borrowing for emerging markets, since some of the large players in the CDS market faced significant problems so the liquidity of such instruments retracted. Also, virtually no emerging markets issued bonds during 2008, and the actual increase in the price of foreign borrowing is difficult to assess.

4 Oil prices reached their peak in summer 2008, which also had additional negative effect on real activity.

5 Croatia was also severely affected by the natural gas dispute between Ukraine and Russia, as many factories and retailers had to reduce their activity due to a temporary gas shortage.

**Figure 1** Recent Economic Developments



Due to weak domestic consumption, imports contracted more than exports, and the chronic merchandise trade deficit slightly improved (Figure 1.d).

In the financial sector, CNB measures were successful in keeping nominal domestic credit growth contained at around 12% per annum over the last few years. However, since mid-2008, credits to households virtually stopped, and the growth of total credits to the private sector has slowed down further (Figure 1.e). As a result, monetary aggregates have also decelerated, especially in the last quarter of 2008 when rumors about problems in “mother banks” (foreign banks owning Croatian subsidiaries) led to a massive deposit withdrawal from the Croatian banks. Instead of lending to the private sector, banks have lent heavily to the government. Interestingly, borrowing from abroad continued, although slower, for both banks and firms, regardless of the interest rate increase (Figure 1.f). Banks borrowed from their owners (mother banks) to obtain needed funds, especially during the deposit withdrawal in the last quarter of 2008. The CNB abolished the marginal reserve requirement, which has presented a heavy tax on banks’ foreign borrowing during the previous few years, thereby encouraging foreign borrowing by commercial banks as a way of providing necessary foreign liquidity.

Increases in domestic interest rates were relatively modest. Interest rates on short-term loans (to firms) reacted the most, while other kinds of loans reacted less. The reasons for relatively modest increase in interest rates were the CNB’s reaction that decreased regulatory cost and also popular pressures that prevented banks from putting the entire burden of the interest rate increase on borrowers. High interest rates and bank profits prior to the crisis provided additional cushion for banks to be able to bear some of the funding cost. However, there is also evidence that banks have engaged in credit rationing in order to improve their loan portfolio.

### 3 Simplified Monetary Policy Framework and Policy Response in Croatia

Monetary policy in Croatia is based on a nominal exchange rate anchored to the euro. Such a monetary regime was chosen because of the high levels of euroization present in the Croatian economy and, in particular, in the financial sector, as most of banks’ assets and liabilities are in or indexed to a foreign currency (primarily euro). Since 1993 this policy has been very successful in achieving low inflation and has helped to keep the banking sector stable. The exchange rate is not fixed and small oscillations are tolerated in order to discourage likely speculators. The CNB uses standard monetary policy instruments, such as money market operations and foreign exchange interventions, to keep the exchange rate stable.

However, by concentrating on exchange rate stability, the central bank lost maneuvering space for an active monetary policy. Also, the central bank’s ability to act as lender of last resort is greatly reduced and amounts to the level of its foreign currency reserves, as the bulk of commercial banks’ liabilities is in foreign

currency.<sup>6</sup> In such circumstances, the CNB relies heavily on administrative measures, such as different regulatory requirements, in order primarily to insure banking sector stability and to influence the domestic economy through bank behavior.

The CNB's regulatory framework is quite complex, and at its core there are four different regulations resembling the reserve requirement.<sup>7</sup> The first is the *proper* reserve requirement, which is levied on almost all liabilities, regardless of their maturity.<sup>8</sup> In addition to there being a very broad base, the rate is also very high and currently amounts to 14%. Furthermore, a part of the reserve requirement is maintained in domestic and another part in foreign currency, both at the CNB and in the form of liquid foreign assets. There have been many changes in the rate, scope and maintenance procedure of the reserve requirement primarily in order to change the monetary policy stance, but also to create and withdraw both kuna and foreign exchange liquidity.

The second type of regulatory requirement is the Minimum Required Amount of Foreign Currency Claims, which requires banks to hold a certain ratio of their foreign currency liabilities in the form of liquid foreign assets. This requirement stems from the facts that Croatian households prefer to keep their savings in foreign currency. Since the central bank is unable to create foreign currency, commercial banks have to keep a large share of their foreign currency liabilities in the form of liquid foreign currency assets, to be used when needed. This instrument has also experienced a number of changes in its rate and scope.<sup>9</sup> The rate is quite high and during the last year has been lowered from 32% to 20%, serving as the main channel for providing foreign currency liquidity, as capital inflows decreased during the crisis.

The third type of regulatory requirement was the "marginal reserve requirement" levied on new commercial banks' foreign borrowing from 2005.<sup>10</sup> It was introduced to discourage heavy foreign borrowing by commercial banks to be used to finance domestic credit expansion, which was prevalent in the mid 2000s. The rate was gradually increased from 25% up to 55% of commercial banks' new foreign borrowing. This measure managed to stop the growth of commercial banks' foreign borrowing, and stimulated heavy recapitalization of banks (foreign mother banks have increased capital of domestic banks to avoid the marginal reserve, which made Croatian banks highly capitalized) and direct foreign borrowing by firms. The marginal reserve was revoked in October 2008 to remove a strong obstacle for capital inflows through the banking sector during the crisis.

The last regulatory requirement is a penalty on fast growing banks in the form

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6 The issue of the lender of last resort in case of crisis was analyzed by Čeh and Krznar (2008).

7 For discussion of reserve requirement see Lang (2007).

8 All liabilities except capital and liabilities due to the government and central bank.

9 It was initially levied only on short-term foreign exchange liabilities (up to 1 year) and from 2001 was extended to include all foreign currency liabilities; in addition, in 2006 it was extended to include liabilities indexed to foreign currency as commercial banks were encouraging this type of savings due to lower regulatory costs.

10 There was also the special reserve requirement, which was similar to the marginal reserve requirement. It was introduced as some banks tried to circumvent the marginal reserve requirement by issuing domestic securities which were supposed to be purchased by foreigners.

of the Obligatory CNB Bills. Commercial banks whose credit to the private sector grows above a certain limit are required to purchase low yielding Obligatory CNB Bills in the amount of 75% of the “prohibited” excess credit growth. This measure was put in place in 2003, removed in 2004 and enacted again in 2006. In both episodes, it effectively managed to decrease the growth of domestic credits in Croatia, while other countries in the region have experienced much faster credit growth.

In addition to those regulatory reserve requirements, the CNB requires commercial banks to meet high capital adequacy requirements. In addition, loans granted in foreign currency (or indexed to exchange rate) to clients who do not have appropriate income or assets in foreign currency are marked as especially risky. As a result, the Croatian banks have entered the financial crisis with higher capital cushion and a sounder credit portfolio than banks in the region, which has proven to be very helpful in the present circumstances.

Such complexity of the regulatory requirements is quite difficult to model, as each particular requirement can influence the behavior of commercial banks and other economic agents in a slightly different way. In order to simplify our analysis without a loss of generality, we define the “total regulatory cost” as a percentage of liquid assets (defined as banks’ assets held at the CNB and foreign assets) to total liabilities (excluding capital accounts and credits received from the government and central bank). The regulatory cost is very high and amounts to approximately a third of total bank liabilities (Figure 2).

**Figure 2** Regulatory Cost



The monetary policy response to the financial crisis was constrained by the limited ability of the Croatian National Bank to act countercyclically, and at the same time protect exchange rate stability. In such circumstances, at the beginning of the crisis the CNB reacted strongly to prevent exchange rate depreciation, hoping to reduce the danger of self-fulfilling depreciation expectations (Figure 1.h). This was especially the case since the demise of Lehman Brothers started rumors about similar problems in some Italian banks that own Croatian banks. As confidence in Croatian banks became (temporarily) shaken, a significant withdrawal of

household deposits took place in October 2008.<sup>11</sup> To protect the exchange rate, the CNB provided foreign currency through foreign exchange interventions and kept domestic money market interest rates high through a limited supply of domestic liquidity. While these measures were restrictive in the sense that they increased domestic interest rates, the CNB engaged in a series of measures to relax regulatory cost (Table 1). This provided the necessary foreign liquidity to counter the withdrawal of deposits from the banking sector and also to provide additional funding for domestic credits. Moreover, this has particularly helped the government, whose ability to access the financial markets was (temporarily) impaired. In addition, measures put in place during the previous years to contain fast credit growth were successful and have contributed to the soundness of the Croatian banking system. This has further encouraged the foreign mother banks to retain trust in their holdings in Croatia and keep investing in Croatia. Finally, a stable exchange rate insured that debt service of households and firms remained intact since most credits are indexed to foreign currency. As a result, the impact of the financial crisis on Croatian banking and financial sector has so far been limited.

**Table 1** Measures Taken by the CNB for Containing the Impact of the Financial Crisis

Date	Change in regulatory requirement	Impact on liquidity (regulation cost)
May 2008	Minimum required amount of foreign currency claims lowered from 32% to 28.5%	Relaxation
October 2008	Restrictions in the maintenance of the required reserve (cash in vaults no longer counted for maintaining the reserve requirement)	Tightening
October 2008	Marginal reserve requirement abolished	Relaxation
December 2008	Reserve requirement lowered from 17% to 14%	Relaxation
January 2009	Kuna share of maintenance of reserve requirement on foreign liabilities raised from 50% to 75%	Tightening
February 2009	Minimum required amount of foreign currency claims lowered from 28.5% to 25%	Relaxation
February 2009	Special reserve requirement abolished	Minor relaxation
February 2009	Minimum required amount of foreign currency claims lowered from 25% to 20%	Relaxation

## 4 The Model Economy

In this section, we first describe the environment of the model. Then we present our model together with its calibration. We provide and interpret the optimality conditions that are used in order to calculate impulse responses in the next section.

### 4.1 The Environment

The model economy consists of nine sectors: households, a labor union, domestic

<sup>11</sup> The Croatian oil company (INA) was purchased by a foreign company (MOL) in October 2008. This was very helpful as it provided additional capital inflow at a very sensitive time. Indeed, the CNB raised regulatory tax as it feared that this inflow could bring some appreciation pressures to the economy.

producers, retail firms, importers and exporters of final goods, banks, a monetary authority and a foreign sector.

Households consume two types of goods: imported final goods and goods that are produced on the domestic market. Both goods are bought on a monopolistically competitive market where households meet importers and retailers. Demand for imported and domestic goods depends on the relative prices (hence on the exchange rate) and the overall amount of consumption as a function of the households' income. We assume persistence of domestic and imported goods consumption over time, reflecting the existence of habits. Households' labor services are "sold" to the labor union that is involved in a "bargaining" process over households' wage with domestic producers. In a bargaining process, the union negotiates a wage that keeps pace with the domestic prices and workers' productivity growth. Since the households are at the same time owners of the firms (in the model economy), they are entitled to the profits from all of the sectors in the economy.

Households take loans from banks to finance their consumption expenditure.<sup>12</sup> Excess income is invested in bank deposits. Therefore, high deposit and loan interest rates make households inclined to postpone their consumption. It is important to point out that the exchange rate will not only affect households' decisions about the consumption of imported goods, but it will also have intertemporal effects on overall consumption since loans and deposits are linked to the exchange rate.

On the production side, domestic producers use capital, labor and intermediate goods to produce final goods. Capital and oil are imported from abroad, whereas labor is "bought" from the labor union. Producers take loans either from domestic banks or from abroad to pay for their input costs. Demand for loans depends on the relative interest rates (making substitution between domestic and foreign financing possible) and total borrowing (which depends on total production). Produced final goods are sold to retail firms. The amount of produced final goods depends on the cost of production (determined by interest rates on loans, kuna depreciation, and factor prices) and retailers' demand that is induced by household demand for domestic goods. To close out the producer sector, under the assumption of a small open economy we model exporting firms' behavior as exogenous.

Finally, we describe the financial side of the model. We treat domestic banks as loan granting institutions to both households and domestic producers. To finance loans, banks collect deposits from households and borrow from abroad, thereby making interest rates on households' and producers' loans dependent on the foreign interest rate. Moreover, the regulation costs in terms of reserve requirements imposed by monetary authority as well as the aggregate amount of deposits and loans determine the interest rates charged by the commercial banks. The exchange rate has negligible effects on interest rates since banks completely transfer exchange rate risk to households and firms as a consequence of the full euroization assumption (household income, wages and profits, are in domestic currency). In

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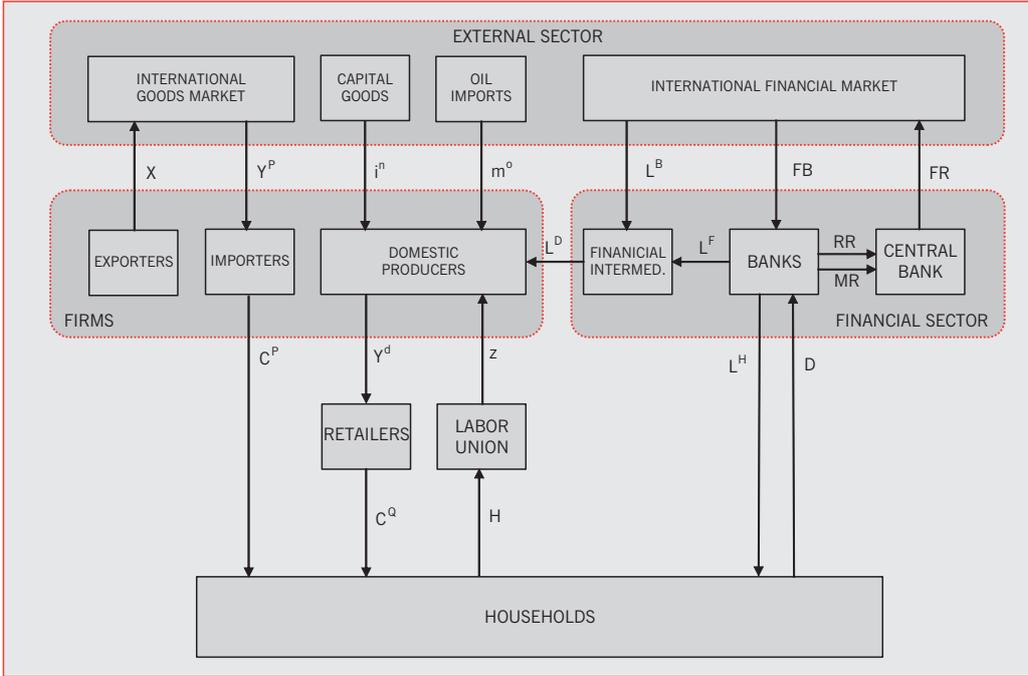
12 We assume full euroization in our model economy, making the loans fully indexed to the exchange rate. Although it might seem extreme, it makes sense because of the high euroization in the banking sector; at the same time, it simplifies the model's analytical tractability without having an impact on the general results.

order to make the model suitable for policy analysis in the context of the Croatian economy, we model the monetary authority as the one in charge of the reserve requirement rate imposed on both total and specifically foreign liabilities of commercial banks.

Even though we are aware of the important effects that depreciation might bring about, our model is not an appropriate tool for analyzing those effects. Large depreciation would probably lead to banking sector instability as burden of repaying loans (indexed to exchange rate) would become too large for households and firms. This might also involve bankruptcy of a part of the non-financial sector, raising the number of non-performing loans, which would result in problems for banking sector stability. In our model exchange rate depreciation has positive wealth effect that derives from the rising competitiveness of the export sector and rising value of deposits (indexed to the exchange rate). On the other hand even though there are negative effects of depreciation in terms of the rising burden of repaying debt (foreign and domestic indexed to the exchange rate) there will be no bankruptcy in equilibrium as rational agents will do everything to avoid it.<sup>13</sup>

The structure of our model economy is shown in Figure 3.

**Figure 3** The Structure of the Model Economy



**4.2 Households**

We assume the existence of a continuum of infinitely lived households, of measure one. All households have identical preferences that are subject to a preference

<sup>13</sup> See Schneider and Tornell (2004) for one possible way of analyzing bankruptcy in the midst of exchange rate depreciation.

shock – shock to the discount rate,  $e_t^{cd}$ . These preferences are over a real composite consumption index,  $q_t$  and leisure,  $(1-H_t)$ , where  $H_t$  denotes hours spent at work (normalized to one). The composite index represents a bundle of real consumption of imported goods,  $c_t^p$ , real consumption of domestically produced goods,  $c_t^q$ , past consumption of both type of goods denoted by  $h_t^p$  and  $h_t^q$ . Both imported and domestic good represent a bundle of different varieties of the same good,  $c_{it}^p$  and  $c_{it}^q$ , respectively, over which households do not form habits. Imported goods are bought from importers, whereas domestic goods are bought from retailers. Preferences are represented by constant relative risk aversion utility function. We consider simple time additive non-persistent habit specification proposed by Constantinides (1990).<sup>14</sup>

On the other hand, households “sell” their working services,  $H_t$ , to domestic producers, letting the labor union negotiate their wages. In exchange for their work, households obtain wages  $v_t$ . Households take bank loans,  $l_t^h$ , to buy goods.<sup>15</sup> Loans are repaid the next period, together with interest  $(1+i_t^h)$ . As already pointed out, we assume full euroization so the interest rate on loans is completely indexed to the exchange rate change,  $\frac{S_t}{S_{t-1}}$ . In addition to the consumption decision on both type of goods, households also decide on their savings in the form of real deposits,  $d_t$ . We also assume incomplete markets, thereby making it impossible for the representative household fully to insure against aggregate shocks.

We can state the representative household optimization problem as follows:

$$\max_{\{d_t, l_t^h, q_t, c_t^q, c_t^p, H_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} (\beta^t \exp(e_t^{cd})) \left[ \frac{q_t^{1-\sigma}}{1-\sigma} - \frac{H_t^{1+\eta}}{1+\eta} \right] \quad (1)$$

subject to a nominal budget constraint:

$$P_t d_t + P_t^q c_t^q + P_t^p c_t^p + (1+i_{t-1}^h) \frac{S_t}{S_{t-1}} P_{t-1} l_{t-1}^h = v_t H_t + P_t l_t^h + (1+i_{t-1}^d) \frac{S_t}{S_{t-1}} P_{t-1} d_{t-1} + \pi_t + P_{t-1} \vartheta(D_{t-1}, L_{t-1}) + AC_t + e_t^{bop} \quad (2)$$

a credit-in-advance constraint

$$\kappa^h (P_t^q c_t^q + P_t^p c_t^p - \varphi^h (P_{ss}^q c_{ss}^q + P_{ss}^p c_{ss}^p)) \exp(e_t^{hh}) \frac{1}{1-\varphi^h} = P_t l_t^h \quad (3)$$

with

$$d_{-1}, l_{-1}^h \text{ given.}$$

<sup>14</sup> In other words we adopt “external habits” or “Catching up with the Joneses” formation. This assumption allows us to capture hump-shaped impulse responses of the consumption.

<sup>15</sup> When buying goods households only need to borrow a certain percentage of the consumption bundle price. This threshold value takes the value of the steady state consumption of non-tradable and tradable goods with the parameter of elasticity of household loans to consumption being different from one.

where  $\beta$  is the discount rate,  $P_t^q$  and  $P_t^p$  denote prices of domestically produced and imported goods,  $\kappa^h$  is the share of consumption purchases financed through a bank loan,  $\varphi^h$  is the parameter that controls elasticity of loans with respect to consumption. The parameter  $\sigma$  denotes the curvature of the utility curve (coefficient of relative risk aversion). The cost of financial intermediation,  $\vartheta(D_{t-1}, L_{t-1})$ , as well as all adjustment costs,<sup>16</sup>  $AC_t$ , are transferred to households as a lump sum for reasons explained later. Adjustment costs include adjustment costs on capital, employment, oil (faced by domestic producers) and wage changes (faced by labor union) and are

$$\begin{aligned} AC_t = & \overline{Z_t W_t} \frac{\xi_z}{2} (\ln(z_t) - \ln(z_{t-1}))^2 + \overline{p_t^n m_t^n} \frac{\xi_n}{2} (\ln(m_t^n) - \ln(m_{t-1}^n) - \alpha)^2 + \\ & + \overline{Z_t W_t} \frac{\xi_w}{2} (\Delta \ln(w_{it}) - \Delta \ln(P_{it-1}) - \alpha + e_t^w)^2 + \\ & + \overline{p_t^o m_t^o} \frac{\xi_o}{2} (\ln(m_t^o) - \ln(m_{t-1}^o) - \alpha)^2 \end{aligned} \quad (4)$$

We also introduce an additive exogenous income shock,  $e_t^{hop}$  which can be interpreted as a balance of payments shock, as well as a multiplicative loan demand shock,  $e_t^h$ .

It is useful to define households' current income. It consists of three components: wages, interest on deposits, and nominal profits from domestic producers, retailers, labor union, importers, exporters, banks, financial intermediaries, including net operating surplus of monetary authority which can be considered as lump sum transfer:

$$\pi_t = \Pi_t^d + \int_0^1 \Pi_{it}^i di + \int_0^1 \Pi_{it}^h di + \Pi_t^b + \Pi_t^f + \Pi_t^{mp} + \int_0^1 \Pi_{it}^m di + \int_0^1 \Pi_{it}^x di \quad (5)$$

Like Obstfeld and Rogoff (1999), we define the real consumption index in a Cobb-Douglas fashion as:

$$q_t = \frac{1}{\omega^\omega (1-\omega)^{1-\omega}} (c_t^q - \chi e_t^\alpha h_t^q)^\omega (c_t^p - \chi e_t^\alpha h_t^p)^{1-\omega} \quad (6)$$

where  $\chi$  denotes the habit importance parameter which is assumed to be the same in the consumption of both types of goods.<sup>17</sup> The parameter  $\omega$  represents the share of each type of good in the composite index adjusted for habits. The parameter  $\alpha$  denotes the growth rate of consumption along the balanced growth path and is determined by the growth rate of technological progress. Furthermore, both types

<sup>16</sup> We need adjustment costs to enter households' budget constraint for the balance of payments equation to look nice and intuitive.

<sup>17</sup> The possibility that households do not simply form habits over their overall consumption level, but rather are capable of becoming "addicted" to the consumption of tradable and non-tradable goods is a generalized concept of habit formation – deep habits that was introduced in the literature by Ravn et al (2006). Notice that this is not really the case of deep habits as in Ravn et al (2006) since households' preferences do not include habits in individual goods (on interval [0,1]) "inside" tradable or non-tradable good.

of goods,  $c_t^q$  and  $c_t^p$ , are represented by Dixit-Stiglitz constant elasticity of substitution (CES) indices defined over the varieties of each type of good

$$c_t^q = \left[ \int_0^1 c_{it}^q{}^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (7)$$

$$c_t^p = \left[ \int_0^1 c_{it}^p{}^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (8)$$

where  $c_{it}^j$  denotes the demand for consumption good sold by a monopolistically competitive firm  $i$  in the sector  $j$ , for  $j = \{n, \tau\}$ , and  $\varepsilon$  denotes the elasticity of substitution among various goods. The overall real consumption index is defined as:

$$c_t = \frac{1}{\omega^\omega (1-\omega)^{1-\omega}} (c_t^q)^\omega (c_t^p)^{1-\omega} \quad (9)$$

In addition to the aggregate consumption and savings and working decisions, a household must decide how to allocate its consumption expenditures among different type of goods. Optimal demands of different varieties of imported and domestic goods are given by

$$c_{it}^p = \left( \frac{p_{it}^p}{P_t^p} \right)^{-\varepsilon} c_t^p \text{ and } c_{it}^q = \left( \frac{p_{it}^q}{P_t^q} \right)^{-\varepsilon} c_t^q \quad (10)$$

respectively, where the  $P_t^p$  and  $P_t^q$  are the aggregate price of imported and domestic goods given by:

$$P_t^p = \left[ \int_0^1 p_{it}^{p^{1-\varepsilon}} di \right]^{\frac{1}{1-\varepsilon}} \text{ and } P_t^q = \left[ \int_0^1 p_{it}^{q^{1-\varepsilon}} di \right]^{\frac{1}{1-\varepsilon}} \quad (11)$$

Once the household decides on optimal expenditure on different varieties of different types of goods, it decides on the domestic and imported aggregate consumption. Optimality conditions for domestic and imported aggregate consumption are:

$$c_t^q = \omega \left( \frac{P_t^q}{P_t} \right)^{-1} q_t + \chi e_t^\alpha c_{t-1}^q \text{ and } c_t^p = (1-\omega) \left( \frac{P_t^p}{P_t} \right)^{-1} q_t + \chi e_t^\alpha c_{t-1}^p \quad (12)$$

where  $P_t$  is the overall consumption price index:

$$P_t = (P_t^q)^\omega (P_t^p)^{1-\omega} \quad (13)$$

Optimality conditions (12) yield demand functions for imported and domestic goods – demand for each good is proportional to the real consumption index, with the proportionality index being equal to a decreasing function of the relative price (goods price to the overall price index). Moreover, consumption today will

be higher if aggregate consumption yesterday was high, reflecting the existence of habits.

Finally the representative household decides on the real composite consumption index,  $q_t$ , real deposits,  $d_t$  and labor,  $H_t$  by maximizing (1) subject to (2). The solution gives an Euler condition determining the optimal intertemporal allocation of consumption given by:

$$q_t^{-\sigma} = \beta(1+i_t^d)E_t \left[ q_{t+1}^{-\sigma} \frac{P_t}{P_{t+1}} \frac{s_{t+1}}{s_t} \frac{\frac{1+i_t^h}{1+i_t^d} \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} + 1 - \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h}}{\frac{1+i_{t+1}^h}{1+i_{t+1}^d} \kappa^h \frac{\exp(e_{t+1}^{lh})}{1-\varphi^h} + 1 - \kappa^h \frac{\exp(e_{t+1}^{lh})}{1-\varphi^h}} \exp(e_{t+1}^{cd} - e_t^{cd}) \right] \quad (14)$$

and labor supply function

$$H_t^n = \frac{v_t}{P_t} \frac{1}{q_t^\sigma \left[ \frac{1+i_t^h}{1+i_t^d} \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} + 1 - \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} \right]} \quad (15)$$

The Euler equation implies that if a household decides to consume less and save more today, it will have more money for buying goods tomorrow, taking into account that a part of the spending is financed through loans. In other words, if the deposit rate rises, it will be more attractive to postpone consumption today. The same will happen if loan rates increase today, if the exchange rate depreciates tomorrow (since saving today or taking fewer loans today is more attractive) or if expected future inflation is lower. The labor supply equation determines the amount of labor offered to the labor union depending on the real wage (measured in utility units).

### 4.3 Labor Union

The labor union buys working services from households at a competitive market and then resells them to the domestic producers. Before selling to domestic producers, the labor union differentiates the working services  $Z_{it}$  bought from households. Thus, the labor union faces a downward sloping demand for working services. In other words, working services are sold to domestic producers at a monopolistically competitive market at a markup over the labor union's marginal cost (wage that is paid to households). On the other hand, the labor union faces costs that will be nonnegative if the wage,  $w_{it}$ , that the union gets from domestic producers deviates from the last period domestic inflation and/or their productivity growth. This is to say that the labor union is introducing indexation of wages and has almost all power in negotiating over wages with domestic producers.

In deciding how much working services to supply to domestic producers, the labor union is deciding about the wage level to maximize its profit. The profits depend on the wage bill that the labor union gets from producers as its revenue,

whereas the wage bill that it has to pay to households together with wage adjustment costs constitute the labor union's costs. The maximization problem is:

$$\max_{\{w_{it}, Z_{it}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} Q_{t,0} \left\{ Z_{it} w_{it} - h_t v_t - \overline{Z}_t \overline{W}_t \frac{\zeta_w}{2} (\Delta \ln(w_{it}) - \Delta \ln(P_{it-1}) - \alpha + e_t^w)^2 \right\}$$

subject to the demand for labor given by

$$z_{it} = \left( \frac{w_{it}}{W_t} \right)^{-\varepsilon} z_t \quad (16)$$

$$\text{where } Q_{t,0} = \left( \frac{(\beta^t \exp(e_t^{cd})) u'(q_t) s_t P_0 \left( \frac{1+i_0^h}{1+i_0^d} \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} + 1 - \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} \right)}{\exp(e_0^{cd}) u'(q_0) s_0 P_t \left( \frac{1+i_t^h}{1+i_t^d} \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} + 1 - \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} \right)} \right) \text{ is the}$$

firm's stochastic discount factor (the marginal rate of substitution of consumption between the time period  $t$  and time period 0 of the firm's owner) for nominal payoffs.<sup>18</sup>  $\overline{Z}_t, \overline{W}_t$  are average values of  $z_{it}, w_{it}$ ,<sup>19</sup> and  $\zeta_w$  is the wage adjustment cost parameter. There is also an additive exogenous wage shock  $e_t^w$ .

By substituting market clearing condition between households and the labor union

$$h_t = \int_0^1 Z_{it} di$$

representing differentiation process of work in services and taking the first derivative with respect to  $w_{it}$ , the supply of labor services is

$$\begin{aligned} \frac{\mu}{w_{it}} v_t - 1 = & (\mu - 1) \zeta_w \left[ (\Delta \ln(w_{it}) - \Delta \ln(P_{it-1}) - \alpha + e_t^w) - \right. \\ & \left. - \frac{1}{1+i_t^d} (\Delta \ln(w_{it+1}) - \Delta \ln(P_{it}) - \alpha + e_{t+1}^w) \right] \end{aligned} \quad (17)$$

or substituting for  $v_t$

$$\begin{aligned} \frac{\mu}{w_{it}} P_t h_t^\eta q_t^\sigma \left[ \frac{1+i_t^h}{1+i_t^d} \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} + 1 - \kappa^h \frac{\exp(e_t^{lh})}{1-\varphi^h} \right] - 1 = & \\ = (\mu - 1) \zeta_w \left[ (\Delta \ln(w_{it}) - \Delta \ln(P_{it-1}) - \alpha + e_t^w) - \right. & \\ \left. - \frac{1}{1+i_t^d} (\Delta \ln(w_{it+1}) - \Delta \ln(P_{it}) - \alpha + e_{t+1}^w) \right] & \end{aligned} \quad (18)$$

<sup>18</sup> Remember that the owners of the firms are households, which derive utility from real consumption goods.

<sup>19</sup> This is introduced for the sake of analytical convenience.

where  $\mu = \frac{\varepsilon}{\varepsilon - 1} > 1$ . The supply function of labor services determines the wage in a bargaining process with domestic producers. The wage would be a markup over the labor union's marginal cost (wage that it is paying to the households,  $v_t$ ) taking into account that it is costly for the labor union to set wage increases different from the previous period price inflation and/or technological progress (which is labor augmented). Wage (inflation) adjustment costs bring dynamics into play, since setting the wage today has influence on the wage decision tomorrow.

Notice that in the case of no indexation ( $\zeta_w = 0$ ), the supply of labor services is given as a simple markup over the labor union's marginal cost:

$$\begin{aligned} w_{it} &= \mu v_t \\ &= \mu P_t h_t^\eta q_t^\sigma \left[ \frac{1 + i_t^h}{1 + i_t^d} \kappa^h \frac{\exp(e_t^{lh})}{1 - \varphi^h} + 1 - \kappa^h \frac{\exp(e_t^{lh})}{1 - \varphi^h} \right] \end{aligned} \quad (19)$$

#### 4.4 Domestic Producers

Each variety of domestic goods is produced by a monopolistically competitive firm. Hence, our small open economy is inhabited by a representative producer producing a domestic good,  $Y_t^d$ . We assume that the firm has access to production technology of the Cobb-Douglas form with labor,  $z_t$ , oil,  $m_t^o$ , and imported capital,  $m_t^n$ , as factors of production. Moreover, the production function exhibits decreasing return to scale and is given by:

$$Y_t^d = (m_{t-1}^n)^{1-\gamma_o-\gamma_h} (m_t^o)^{\gamma_o} (z_t)^{\gamma_h} A_t^{\gamma_h} \quad (20)$$

where  $\gamma_o + \gamma_h < 1$  controls the property of decreasing returns and where the log of labor augmented total factor productivity,  $A_t$ , follows a random walk with drift

$$\log(A_t) = \log(A_{t-1}) + \alpha + e_t^A \quad (21)$$

We also assume that firms face “credit-in-advance” constraint,<sup>20</sup> i.e. producers must use financial intermediary credit to pay for their input factor bill in advance. As a result, firms have to borrow from the financial intermediary to purchase input factors at the beginning of the period. Formally the “credit-in-advance” constraint is:

$$P_t l_t^d = \kappa^d \left( z_t W_t + p_t^n i_t^n + p_t^o m_t^o - \varphi^d \left( z_{ss} W_{ss} + p_{ss}^n i_{ss}^n + p_{ss}^o m_{ss}^o \right) \right) \frac{1}{1 - \varphi^d} \exp(e_t^{ld}) \quad (22)$$

20 This kind of constraint implicitly recognizes that monetary policy, if conducted through the interest rate channel, has an impact on the supply side of economy (unexpected interest rate shock raises the input bill. See Christiano et al (1997).

where  $l_{it}^d$  denotes the real stock of financial intermediary loans,  $\varphi^d$  is the parameter that controls elasticity of loans with respect to input costs,  $\kappa^d$  is the share of input costs that is financed through a bank loan, and  $e_t^{ld}$  represents loan demand shock. Repayment of the loan occurs in the next period when each firm has to pay the nominal lending rate,  $i_t^{nl}$ , adjusted for the nominal exchange rate growth. Consequently, firm's total cost at time  $t$  are given by the input factor bill, and by the interest on the loan used to pay the input bill at  $t-1$ , given by  $(1 + i_{t-1}^{nl}) \frac{S_t}{S_{t-1}} l_{t-1}^d$ . Again,  $z_t$  denotes the aggregate labor force that is supplied by the labor union and  $W_t$  denotes the aggregate wage that is paid to the labor union in exchange for labor services. While labor is a domestic factor of production, capital and oil are traded on an international competitive market. The prices  $p_t^o$  and  $p_t^n$  are prices of oil and investment that are simply oil and investment prices in kuna and are equal to foreign prices multiplied by the exchange rate:

$$p_t^n = s_t p_{it}^{*n} \quad (23)$$

$$p_t^o = s_t p_{it}^{*o} \quad (24)$$

Capital follows a standard law of motion

$$m_t^n = (1-\delta)m_{t-1}^n + i_t^n \quad (25)$$

where  $\delta$  is depreciation rate of old capital. We also assume that the domestic producer faces convex adjustment costs when changing any of the factors of production.

Once the good,  $Y_t^d$  is produced, it is sold to retailers at a competitive price  $p_t^d$ . This implies that the firm's profit at time  $t$ ,  $\Pi_t^d$ , can be written as:

$$\begin{aligned} \Pi_t^d = & p_t^d Y_t^d - (1 + i_{t-1}^{nl}) \frac{S_t}{S_{t-1}} P_{t-1} l_{t-1}^d + P_t l_t^d - (z_t W_t + p_t^n i_t^n + p_t^o m_t^o) - \\ & - \overline{Z_t W_t} \frac{\xi_z}{2} (\ln(z_t) - \ln(z_{t-1}))^2 - \overline{p_t^n m_t^n} \frac{\xi_n}{2} (\ln(m_t^n) - \ln(m_{t-1}^n) - \alpha)^2 - \\ & - \overline{p_t^o m_t^o} \frac{\xi_o}{2} (\ln(m_t^o) - \ln(m_{t-1}^o) - \alpha)^2 \end{aligned} \quad (26)$$

where  $\xi_z, \xi_n, \xi_o$  denote labor, capital and imported oil adjustment cost parameters.

Similarly to the households, the firms initially decide on the needed variety of labor services whose demand is represented by the following expression:

$$z_{it} = \left( \frac{w_{it}}{W_t} \right)^{-\varepsilon} z_t \quad (27)$$

where  $z_{it}$  is the firm's demand for the labor variety  $i$ . The demand for a single variety of labor is proportional to the aggregate demand for labor. The proportionality

coefficient is an iso-elastic function of the ratio of the variety's price to the price index of labor (aggregate wage). The elasticity of substitution between two varieties represents at the same time the price elasticity of demand for labor variety  $i$ . As  $\varepsilon \rightarrow \infty$ , varieties become close substitutes, and as a consequence individual firms have less market power.

After determining the variety of labor services needed, the firm's problem consists of maximizing its expected discounted profit (26) by choosing the amount of factors and taking prices as given:

$$\max_{\{Y_t^d, m_t^o, m_t^n, z_t, i_t^d, i_t^n\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} Q_{t,0} \Pi_t^d \quad (28)$$

subject to the production function (20), "credit in advance constraint" (22) and the law of motion for imported capital (25).

Substituting for  $Y_t^d$  and  $l_t^d$  in the objective function, and solving for the optimal factors we can obtain demand functions for oil, labor and capital, which are respectively given by:

$$\begin{aligned} \gamma_o p_t^d Y_t^d &= p_t^o m_t^o \left\{ \kappa^d \frac{1}{1-\varphi^d} \exp(e_t^{ld}) \left[ \frac{1+i_t^{nl}}{1+i_t^d} \frac{s_{t+1}}{s_t} - 1 \right] + 1 + \right. \\ &\left. + \xi_o (\ln(m_t^o) - \ln(m_{t-1}^o) - \alpha) - \frac{\xi_o}{1+i_t^d} (\ln(m_{t+1}^o) - \ln(m_t^o) - \alpha) \right\} \end{aligned} \quad (29)$$

$$\begin{aligned} \gamma_h p_t^d Y_t^d &= z_t W_t \left\{ \kappa^d \frac{1}{1-\varphi^d} \exp(e_t^{ld}) \left[ \frac{1+i_t^{nl}}{1+i_t^d} \frac{s_{t+1}}{s_t} - 1 \right] + 1 + \right. \\ &\left. + \xi_z (\ln(z_t) - \ln(z_{t-1})) - \frac{\xi_z}{1+i_t^d} (\ln(z_{t+1}) - \ln(z_t)) \right\} \end{aligned} \quad (30)$$

$$\begin{aligned} (1-\gamma_h-\gamma_o) p_{t+1}^d Y_{t+1}^d &= p_t^n m_t^n \left\{ \kappa^d \frac{1}{1-\varphi^d} \exp(e_t^{ld}) \left[ (1+i_t^{nl}) \frac{s_{t+1}}{s_t} - (1+i_t^d) \right] - \right. \\ &- \kappa^d \frac{1-\delta}{1-\varphi^d} \exp(e_{t+1}^{ld}) \frac{p_{t+1}^n}{p_t^n} \left[ \frac{1+i_{t+1}^{nl}}{1+i_{t+1}^d} \frac{s_{t+2}}{s_{t+1}} - 1 \right] + \\ &+ (1+i_t^d) - (1-\delta) \frac{p_{t+1}^n}{p_t^n} + \\ &+ \xi_n (1+i_t^d) (\ln(m_t^n) - \ln(m_{t-1}^n) - \alpha) - \\ &\left. - \xi_n (\ln(m_{t+1}^n) - \ln(m_t^n) - \alpha) \right\} \end{aligned} \quad (31)$$

Demand for each different factor depends on its price, the amount of overall production, the loan interest rate, expected exchange rate change and the fact that changing the amount of factors is costly (which brings dynamics into the decision making process). For example, if investment gets more expensive, a domestic producer will buy fewer investment goods and will produce less. The same will

happen if the loan interest rate increases (financing of production becomes more expensive) or if the kuna depreciates (the price of imported investment goods is higher). Moreover, by buying more investment from abroad today, domestic producer will be able to produce more in the future (since the capital stock, part of which is depreciated, increases).

Notice that if capital is not financed by a loan but through retained profit, demand for capital becomes:

$$\begin{aligned} (1 - \gamma_h - \gamma_o) p_{t+1}^d Y_{t+1}^d &= p_t^n m_t^n \left\{ (1 + i_t^d) - (1 - \delta) \frac{p_{t+1}^n}{p_t^n} + \right. \\ &+ \xi_n (1 + i_t^d) (\ln(m_t^n) - \ln(m_{t-1}^n) - \alpha) - \\ &\left. - \xi_n (\ln(m_{t+1}^n) - \ln(m_t^n) - \alpha) \right\} \end{aligned} \quad (32)$$

#### 4.5 Retailers

We again assume the existence of a large number of retail shops of measure one. The role of retailers is to buy a single good on a competitive market from domestic producers,  $Y_t^q$ , differentiate them into a number of finished goods,  $Q_{it}^q$ , and sell them to households at a monopolistically competitive price,  $p_{it}^q$ , which is defined as a markup over the marginal cost,  $p_t^d$ . In choosing how much goods to sell, every retailer is determining the price of a variety of finished goods to maximize its profits subject to the demand for finished goods  $Q_{it}^q = \left( \frac{p_{it}^q}{P_t^q} \right)^{-\varepsilon} Q_t^q$ . Substituting for market clearing condition for domestic goods between producers and retailers  $Y_t^q = \int_0^1 Q_{it}^q di$  and market clearing condition for finished goods between retailers and households  $Q_{it}^q = c_{it}^q$ , the solution to retailers' problem is:

$$p_{it}^{q*} = \mu p_t^d \quad (33)$$

where  $\mu = \frac{\varepsilon}{\varepsilon - 1}$  is the desired markup over nominal marginal costs,  $p_t^d$ . Hence, the only thing that a retailer does is charge a markup over its cost of production. Similarly to the households problem, the price index of finished goods,  $P_t^q$  is given by  $P_t^q = \left[ \int_0^1 (p_{it}^q)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}}$ .

In addition to the flexible price case, we assume that the firms are subject to a costly price adjustment in a fashion introduced by Rotemberg (1982). In the Rotemberg (1982) framework, it is costly to change prices (menu costs or implicit costs that result from unfavorable reactions of customers).<sup>21</sup> The existence of costs of changing prices alters the firms' maximization problem. In the presence of price

21 See Caplin and Leahy (1991) or Dotsey et al. (1999) for models with the microfoundation of price stickiness.

adjustment costs, today's price decision affect tomorrow's profits since tomorrow it will be costly to charge a price different from the one the firm decides to charge today, making the firm's decision problem dynamic. For example, at time  $t=0$ , the optimal price for  $t=0$  must be determined by maximizing the expected present discounted value of future profits. As shown in Rotemberg (1982), this expected discounted values can be approximated (to a second order, around  $p_{it}^q$ ) by:

$$E_0 \sum_{t=0}^{\infty} Q_{t,0} \left\{ \Pi_{it}^q(p_{it}^{q*}) - w_q (\ln(p_{it}^q) - \ln(p_{it}^q))^2 - c_q (\ln(p_{it}^q) - \ln(p_{it-1}^q))^2 \right\} \quad (34)$$

where  $w_q$  is the coefficient in the second order expansion of the profit function around  $p_{it}^q$ ,  $c_q$  is a price adjustment cost parameter and  $\Pi_{it}^q(p_{it}^{q*})$  denotes the profits in the flexible price equilibrium,  $p_{it}^{q*}$ , discussed above. Notice that with flexible prices, the last two terms disappear (since  $p_{it}^{q*} = p_{it}^q$  and there is no price adjustment costs i.e.  $c_q=0$ ), and the objective function of the firm can be written as in (26). Now the firm chooses  $p_{it}^q$  to maximize (34), taking  $p_{it}^{q*}$  as given. Hence  $\Pi_{it}^q(p_{it}^{q*})$  is given, the firm's problem in the sticky price environment is the following:

$$\min_{\{p_{it}^q\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} Q_{t,0} \left\{ \xi_q (\ln(p_{it}^{q*}) - \ln(p_{it}^q) + e_t^q)^2 + (\ln(p_{it}^q) - \ln(p_{it-1}^q))^2 \right\}$$

where  $\xi_q$  is defined as a ratio of  $w_q$  and  $c_q$  and will be loosely interpreted as the price adjustment cost parameter,<sup>22</sup> while  $e_t^q$  is a cost push shock. In other words, the firm minimizes its costs that consist of the cost of deviating from flexible price equilibrium and the cost of deviating from the last period's price.

The first order condition of (34) with respect to  $p_{it}^q$  yields the dynamics of the aggregate price index of a domestic, finished good:

$$\Delta \ln(p_{it}^q) = \frac{E_t(\Delta \ln(p_{it+1}^q))}{1 + i_t^d} - \frac{\Delta \ln(p_{it}^q)}{1 + i_t^d} + \Delta \ln(p_{it-1}^q) + \xi_q (\ln(p_{it}^{q*}) - \ln(p_{it}^q) + e_t^q) \quad (35)$$

Today's individual price change depends on today's and yesterday's overall price change, expected future individual price change and the price adjustment cost if the individual price deviates from the optimal flexible price equilibrium. The interpretation of the law of motion of aggregate price index will be given in the next section.

#### 4.6 Importers

Similarly to the case of retailers, the economy is populated by a continuum of importers of mass one indexed by  $i \in [0,1]$ . We model importers as the sellers of finished foreign goods to households. More precisely, each importer buys a single

<sup>22</sup> Notice that  $\xi_q = \infty$  implies a flexible price environment.

variety of foreign good  $y_{it}^p$  at price  $p_{it}^{*p}$ , transforms it to the same variety of tradable good,  $Y_{it}^p$ , at no cost, and sells it on the domestic market to the households, whose demand for a single variety of imported good at the price  $p_{it}^p$  is given by (10). We abstract from any impediments to trade, which allows us to impose the law of one price condition for each variety of imported good. Using the nominal spot exchange rate,  $s_t$ , we can write

$$p_{it}^m = s_t p_{it}^{*m} \quad (36)$$

Under the assumption of monopolistically competitive markets for different varieties of imported goods, each importer determines the domestic price of its own diversified good  $p_{it}^p$ , by maximizing its profits,  $\Pi_{it}^p = p_{it}^p Y_{it}^p - p_{it}^m Y_{it}^p$  subject to demand condition  $Y_{it}^p = \left(\frac{p_{it}^p}{P_t^p}\right)^{-\varepsilon} y_t^p$ , where  $y_t^p$  denotes overall demand for tradable goods. Optimal behavior implies the following price setting condition:

$$p_{it}^{*p} = \mu p_{it}^m \quad (37)$$

where  $\mu = \frac{\varepsilon}{\varepsilon - 1}$  is the desired markup over nominal marginal cost,  $p_{it}^m$ . Implicit in all of our demand functions is the assumption of zero price homogeneity, which allows us to normalize one of the prices for analytical convenience. Thus we set the price of imported goods  $p_{it}^{*m} = 1$ .

As in the retailers' problem, we proceed by solving for the sticky price equilibrium where producers face convex costs of price adjustment as in Rotemberg (1982). The first order condition with respect to  $p_{it}^p$  yields the dynamics of individual price of imported good given by:

$$\Delta \ln(p_{it}^p) = \frac{E_t(\Delta \ln(p_{it+1}^p))}{1 + i_t^d} - \frac{\Delta \ln(P_t^p)}{1 + i_t^d} + \Delta \ln(P_{t-1}^p) + \xi_p (\ln(p_{it}^{*p}) - \ln(p_{it}^p) + e_t^p) \quad (38)$$

where  $\xi_p$  denotes the imported goods price adjustment costs parameter, and  $e_t^p$  represents importers' cost-push shock. Interpretation of this first order condition follows the analogue in the retailers case.

To complete the description of the production side of our model economy, we need to describe the behavior of the exporting sector. As stated in the introductory model description, we abstract from explicit modeling of the export sector. Instead, the decisions about exports,  $x_t$  and its price,  $p_{it}^x$ , are exogenous. Exporters costlessly sell varieties of goods,  $x_{it}$  on foreign markets at price  $p_{it}^{x*}$ . Assuming the law of one price holds, we can write  $p_{it}^x = s_t p_{it}^{p*}$  where  $p_{it}^x$  is the home currency price of a single variety of exported good and  $p_{it}^{p*}$  is the foreign currency price of the same variety of exported good. The profit of the whole export sector that represents the net earnings of households is given by

$$\int_0^1 \Pi_{ii}^x di = \int_0^1 p_{ii}^x x_{ii} di = p_i^x x_i \quad (39)$$

where the log of exports follows a first order autoregressive process given by:

$$\ln x_t = \rho_x \ln x_{t-1} + e_t^x \quad (40)$$

#### 4.7 Financial Intermediaries

There is an infinite number of financial intermediaries involved in perfect competition for loan supply to domestic producers. The role of financial intermediaries is to link the foreign financial sector and banking sector with domestic producers. More precisely, financial intermediaries serve as a financing agent, which borrows from both domestic banks,  $l_t^f$ , and foreign banks,  $l_t^{fb}$ , and then extends the “loan bundle”,  $L_t^d$ , to domestic producers at the cost of the nominal interest rate,  $(1+i_t^{nl})$ , using constant elasticity of substitution technology.<sup>23</sup> Therefore, the representative financial intermediary problem can be stated in the following way:

$$\max_{\{l_t^f, l_t^{fb}, L_t^d\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} Q_{t,0} \left\{ P_t l_t^f + P_t l_t^{fb} - P_t L_t^d + P_{t-1} L_{t-1}^d (1+i_{t-1}^{nl}) \frac{S_t}{S_{t-1}} - \right. \\ \left. - P_{t-1} l_{t-1}^f (1+i_{t-1}^f) \frac{S_t}{S_{t-1}} - P_{t-1} l_{t-1}^{fb} (1+i_{t-1}^{fb}) \frac{S_t}{S_{t-1}} \right\}$$

subject to the bundling constraint

$$L_t^d = \psi \left[ \eta (l_t^f)^{\frac{\nu-1}{\nu}} + (1-\eta) (l_t^{fb})^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \quad (41)$$

where  $\eta$  is the share of bank loans in financial intermediary loans,  $\nu$  is elasticity of substitution between domestic bank loan and foreign bank loan, and  $\psi$  is a scaling parameter.

Optimality conditions for financial intermediaries are summarized by the following demand function for the domestic bank loan and demand function for the foreign loan:

$$l_t^f = \psi^{\nu-1} \left( \frac{1+i_t^f}{1+i_t^d} E_t \left( \frac{S_{t+1}}{S_t} \right) - 1 \right)^{-\nu} \left( \frac{1}{\eta} \right)^{-\nu} L_t^d \quad (42)$$

23 We can think of financial intermediaries as a credit department within a domestic producer that borrows money from the bank ( $l_t^f$ ) and from abroad ( $l_t^{fb}$ ) and delivers the loan bundle ( $L_t^d$ ) to finance domestic production.

$$l_t^{fb} = \psi^{\nu-1} \left( \frac{\frac{1+i_t^*}{1+i_t^d} E_t \left( \frac{s_{t+1}}{s_t} \right) - 1}{\frac{1+i_t^{nl}}{1+i_t^d} E_t \left( \frac{s_{t+1}}{s_t} \right) - 1} \right)^{-\nu} \left( \frac{1}{1-\eta} \right)^{-\nu} L_t^d \quad (43)$$

where the nominal interest rate charged to a domestic producer is variant of a CES aggregator of the interest rate paid on bank loans and the interest rate paid on foreign loans:

$$\frac{1+i_t^{nl}}{1+i_t^d} E_t \left( \frac{s_{t+1}}{s_t} \right) - 1 = \left( \frac{1}{\psi} \right) \left[ \eta^\nu \left( \frac{1+i_t^f}{1+i_t^d} E_t \left( \frac{s_{t+1}}{s_t} \right) - 1 \right)^{1-\nu} + (1-\eta)^\nu \left( \frac{1+i_t^*}{1+i_t^d} E_t \left( \frac{s_{t+1}}{s_t} \right) - 1 \right)^{1-\nu} \right]^{\frac{1}{1-\nu}} \quad (44)$$

Demand for each type of loan depends on the overall demand for a loan bundle, both interest rates, and the exchange rate. If domestic producers' demand for the loan bundle is high, financial intermediaries will borrow from banks abroad to finance this loan bundle. Furthermore, if the interest rate on foreign borrowing increases, there will be less demand for foreign loans. On the other hand, domestic borrowing will increase since it is now relatively cheaper. The euroization assumption implies small effects of the exchange rate changes on demand for both type of loans, since financial intermediaries are completely transferring the exchange rate risk to domestic producers.

#### 4.8 Banks

We consider a simple version of the banking sector of Edwards and Vegh (1997) where the only role of banks is to take deposits,  $D_t$ , from households and extend loans,  $L_t$ , to financial intermediaries,  $L_t^f$ , and households,  $L_t^h$ . Assuming perfect competition in the banking sector, the whole sector is represented by a representative bank. The representative bank's real assets consists of domestic loans  $L_t$ , foreign assets, and reserves at the central bank  $R_t$ . Reserves represent various types of regulatory reserve requirements that the monetary authority imposes on bank's sources of funds.<sup>24</sup>

Liabilities consist of deposits and foreign borrowing. Foreign assets and foreign liabilities can be combined in net foreign borrowings,  $FB_t$ . Investing abroad pays the fixed nominal interest rate,  $i_t^*$ , which is the same as the cost of borrowing abroad. Again, assuming full euroization, loan and deposit values expressed in national currency between two periods depend on the nominal exchange rate growth.

Moreover, we assume that financial intermediation is costly. A bank needs real resources,  $Q$ , to collect real deposits,  $D_t$ , and extend real loans,  $L_t$ , through a

<sup>24</sup> We simplify our analysis by assuming the monetary authority pays no interest on these reserves.

production function implicitly defined by  $H(D_t, L_t, Q)$ . Intuitively this production function implies that it is costly to maintain any level of loans or deposits.

Assuming that we can solve  $H(\cdot)$  for  $Q$  we obtain  $Q = \vartheta(D_t, L_t)$  where  $\vartheta(\cdot)$  is a convex, strictly increasing, homogenous of degree one cost function. This last property of the bank's cost function allows us to use nominal values since  $P_t Q = P_t \vartheta(D_t, L_t) = \vartheta(P_t D_t, P_t L_t)$ . In order to produce nominal deposits and nominal loans, the bank needs real resources that should be paid in nominal terms. Moreover, linear homogeneity implies that partial derivatives of this cost function depend only on the ratio of loans to deposits  $\vartheta_1(D_t, L_t) = \vartheta_1\left(\frac{D_t}{L_t}, 1\right)$  and  $\vartheta_2(D_t, L_t) = \vartheta_2\left(1, \frac{L_t}{D_t}\right)$ .

The representative bank chooses the amount of real domestic deposits, real domestic loans and foreign (net) borrowings optimally, i.e. to maximize its profit, taking the nominal interest rates,  $i_t^f, i_t^h, i_t^d$  and  $i_t^*$ , the nominal exchange rate,  $s_t$ , and the aggregate price index,  $P_t$ , as given. The bank earns profits by extending loans. We assume that the maturity of bank loans is one period. We also assume that deposits become due after one period. Hence the amount of deposits that the bank has to return to households determines its current costs. Furthermore, if the bank borrows from abroad ( $FB_t > 0$ ), it will have to return it in the next period together with interest determined by exogenous nominal interest rate and exchange rate. By extending loans abroad ( $FB_t < 0$ ) the bank makes profit in the next period when the loan comes due.

In order for the model to resemble Croatian monetary policy specifics, we impose the reserve requirement. In other words, bank has to meet a reserve requirement rate on both domestic and foreign liabilities,  $r_t^r$ , and an additional reserve requirement rate on foreign borrowing,  $r_t^m$ :

$$R_t = r_t^r (D_t + FB_t) + r_t^m FB_t \quad (45)$$

where  $FB_t$  equals the excess domestic assets over domestic liabilities, i.e. the net foreign borrowing of banks:

$$FB_t = R_t + L_t - D_t \quad (46)$$

The reserves are due in the next period and constitute the bank's profit.<sup>25</sup> Total loans consist of loan to households and loans to financial intermediaries:

$$L_t = L_t^f + L_t^h \quad (47)$$

Given the previous description of the bank's environment, we can state the bank's problem as follows:

<sup>25</sup> Note that the reserves have no rate of return.

$$\begin{aligned} & \max_{\{D_t, L_t^f, L_t^h, FB_t, R_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} Q_{t,0} \left\{ P_t D_t + P_t FB_t - P_t L_t^f - P_t L_t^h - P_t R_t + \right. \\ & \left. + P_{t-1} L_{t-1}^f (1 + i_{t-1}^f) \frac{S_t}{S_{t-1}} + P_{t-1} R_{t-1} + P_{t-1} L_{t-1}^h (1 + i_{t-1}^h) \frac{S_t}{S_{t-1}} - \right. \\ & \left. \left\{ -P_{t-1} FB_{t-1} (1 + i_{t-1}^*) \frac{S_t}{S_{t-1}} - P_{t-1} D_{t-1} (1 + i_{t-1}^d) \frac{S_t}{S_{t-1}} - P_{t-1} \vartheta(D_{t-1}, L_{t-1}) \right\} \right\} \end{aligned}$$

subject to equations (45) and (46).<sup>26</sup>

The first order conditions represent the bank's optimal behavior given the foreign interest rate, the rate of reserve requirement, expected exchange rate dynamics, domestic interest rates and domestic loan or lending market conditions given by:

$$i_t^f = \frac{1}{(1 - r_t^r - r_t^m)} i_t^* + \frac{(r_t^r + r_t^m)}{(1 - r_t^r - r_t^m)} \left( 1 - \frac{S_t}{E_t(S_{t+1})} \right) + \vartheta_2(D_t, L_t) \frac{S_t}{E_t(S_{t+1})} \quad (48)$$

$$i_t^d = \frac{1 - r_t^r}{1 - r_t^r - r_t^m} i_t^* + \frac{r_t^m}{1 - r_t^r - r_t^m} \left( 1 - \frac{S_t}{E_t(S_{t+1})} \right) + \vartheta_1(D_t, L_t) \frac{S_t}{E_t(S_{t+1})} \quad (49)$$

$$i_t^h = \frac{1}{(1 - r_t^r - r_t^m)} i_t^* + \frac{(r_t^r + r_t^m)}{(1 - r_t^r - r_t^m)} \left( 1 - \frac{S_t}{E_t(S_{t+1})} \right) + \vartheta_3(D_t, L_t) \frac{S_t}{E_t(S_{t+1})} \quad (50)$$

Using the properties of the linear homogenous function, we parameterize the partial derivatives of the costs function as:<sup>27</sup>

$$\vartheta_1(D_t, L_t) = \xi_D (\ln(D_t) - \ln(L_t^f + L_t^h)) + e_t^{id} \quad (51)$$

$$\vartheta_2(D_t, L_t) = \xi_{L^f} (\ln(L_t^f + L_t^h) - \ln(D_t)) + sp_t^f \quad (52)$$

$$\vartheta_3(D_t, L_t) = \xi_{L^h} (\ln(L_t^f + L_t^h) - \ln(D_t)) + sp_t^h \quad (53)$$

where  $\xi_D$  and  $\xi_L$  are positive parameters (loosely interpreted as elasticities of the bank's cost function),  $e_t^{id}$  is the deposit rate shock and  $sp_t^f$  and  $sp_t^h$  denote deposit-loan rate spreads that follow AR(1) stochastic processes:

$$sp_t^f = \rho_{sp} sp_{t+1}^f + e_t^{spf} \quad (54)$$

<sup>26</sup> Notice that  $P_t D_t + P_t FB_t - P_t L_t^f - P_t R_t = 0$  because of (46).

<sup>27</sup> Notice that if the function is homogenous of degree 1, then its first derivative is homogenous of degree 0.

$$sp_t^h = \rho_{sp} sp_{t+1}^h + e_t^{sph} \quad (55)$$

Each interest rate depends on the foreign interest rate, regulation costs captured by reserve requirements, as well as on the banking cost, implicitly defined through the amount of deposits and loans. Again, the exchange rate effects are small due to assumed full euroization.

Costly banking introduces an additional wedge between the lending rates and the deposit rate (in addition to the reserve requirement levied on all liabilities). Higher banking costs imply a higher spread between active and passive interest rates. It is also necessary to include banking costs in the budget constraint of households so as to make it only a private cost for the bank, but not a social cost.<sup>28</sup> Also notice that both lending and deposit supply schedules give uncovered interest parity conditions.

We should also point out that the bank's cost function is introduced in order to circumvent non-stationarity problems associated with market incompleteness. Using the cost function we close our small economy model in a way similar to those surveyed by Schmitt and Uribe (2003).

#### 4.9 Monetary Authority

We model monetary policy by introducing three policy instruments: the reserve requirement (rate) on all bank's liabilities,  $r_t^r$ , the reserve requirement (rate) on bank's foreign liabilities,  $r_t^m$ , and foreign exchange interventions. All policy instruments are used discretionally by the central bank. We abstract from the micro-founded modeling of foreign exchange interventions in order to concentrate on the various reserve requirements used by the CNB. However, we implicitly allow for the central bank to intervene in the foreign exchange market to control against large swings of nominal exchange rate, whereby foreign exchange interventions alter official foreign exchange reserves,  $FR_t$ , which are invested in foreign securities abroad and remunerated at the world interest rate in the next period. To capture this effect, we allow for disturbances or monetary policy surprises in the foreign exchange market. We also assume that the nominal exchange rate is not fluctuating around some central parity and describe the nominal exchange rate process as a random walk:

$$s_t = s_{t-1} + e_t^{mp} \quad (56)$$

where  $e_t^{mp}$  represents a monetary policy shock that can be thought of as a result of foreign exchange policies.<sup>29</sup>

28 Including bank's profit and banking costs in the budget constraint of households implies that the latter does not have any effect on income of households (see the Balance of payment identity in the next section). We assume that banking costs are not a social cost since we only focus on the distortion introduced by costly financial intermediation.

29 This disturbance can have wider interpretation and can be also thought as a result of all other factors that are not under the direct influence of monetary policy.

Croatian monetary policy can hardly be captured by a single policy reaction function. In order to simplify the analysis without losing general insights, we assume that the reserve requirement rates follow stationary first order autoregressive processes around their unconditional means:

$$r_t^r = \rho_{rr} r_{t-1}^r + (1 - \rho_{rr}) Rr^{ss} + e_t^{rr} \quad (57)$$

$$r_t^{mr} = \begin{cases} \rho_{mr} r_{t-1}^{mr} + (1 - \rho_{mr}) Mr^{ss} + e_t^{mr} & \text{for } 2004 : 3 - 2006 : 3 \\ 0 & \text{for } 1999 : 1 - 2004 : 3 \end{cases} \quad (58)$$

where  $\rho_{rr}$  and  $\rho_{mr}$  are autoregressive coefficients of the processes,  $Rr^{ss}$  and  $Mr^{ss}$  denote the unconditional mean of two reserve-requirement ratios, and  $e_t^{rr}$  and  $e_t^{mr}$  represent shocks of each reserve requirement rate's processes.

To complete the description of the monetary authority we need to define its profit function. The central bank earns money by receiving interest on its net foreign assets (foreign exchange reserves) that are invested abroad in the previous period and by collecting the required reserve. The outflows include a new flow of purchasing foreign assets and paying back the reserves that were deposited on the central bank's account in the last period. Hence the profit of the central bank is:

$$\Pi_t^{mp} = P_t R_t + P_{t-1} FR_{t-1} (1 + i_{t-1}^*) \frac{S_t}{S_{t-1}} - P_{t-1} R_{t-1} - P_t FR_t \quad (59)$$

We assume that all of the central bank profits are transferred to households.

#### 4.10 The Rest of the World

Since Croatia is a small open economy, all variables that pertain to the rest of the world are exogenous: the foreign-currency import price of finished goods,  $p_t^{m*}$ , the foreign-currency import price of oil,  $p_t^{o*}$ , the foreign-currency import price of investment goods,  $p_t^{n*}$  and the world interest rate,  $i_t^*$ . Each of these variables, together with terms of trade,  $\tau_t$ , defined as the ratio of  $p_t^{x*}$  and  $p_t^{m*}$ , follows a stationary, first order autoregressive process:

$$\ln \tau_t = \rho_{tot} \ln \tau_{t-1} + (1 - \rho_{tot}) \tau_{ss} + e_t^{\tau} \quad (60)$$

$$i_t^* = \rho_{if} i_{t-1}^* + (1 - \rho_{if}) i_{ss}^* + e_t^i \quad (61)$$

$$\ln p_t^{m*} - \ln p_{t-1}^{m*} = \rho_{pmf} * (\ln p_{t-1}^{m*} - \ln p_{t-2}^{m*}) + (1 - \rho_{pmf}) \pi_{ss}^{pmf} + e_t^{pmf} \quad (62)$$

$$\ln p_t^{n*} - \ln p_{t-1}^{n*} = \rho_{pmf} * (\ln p_{t-1}^{n*} - \ln p_{t-2}^{n*}) + (1 - \rho_{pmf}) \pi_{ss}^{pmf} + e_t^{pmf} \quad (63)$$

$$\ln p_t^{o*} - \ln p_{t-1}^{o*} = \rho_{pof} * (\ln p_{t-1}^{o*} - \ln p_{t-2}^{o*}) + (1 - \rho_{pof}) \pi_{ss}^{pmf} + e_t^{pof} \quad (64)$$

We also assume that prices of imported final and investment goods, as well as the oil prices have the same steady state growth rate. The terms of trade and domestic exports follow a first order autoregressive process in logs. Foreign interest rate and foreign inflation of the three imported goods also behave according to an AR(1) process but they fluctuate around their unconditional means,  $i_{ss}^*$  and  $\pi_{ss}^{pmf}$ , respectively. Shocks  $e_t^r$ ,  $e_t^i$ ,  $e_t^{pmf}$ ,  $e_t^{pof}$ , and  $e_t^{pmf}$  represent the corresponding AR(1) innovations.

## 5 Equilibrium

We now turn to the description of the equilibrium in our model economy. We consider symmetric equilibrium in which all of the firms behave identically. Hence for two firms  $i$  and  $j$  ( $i, j \in 0, 1$ ) we have that  $p_{it}^p = p_{jt}^p = P_t^p$ ,  $p_{it}^q = p_{jt}^q = P_t^q$ ,  $Y_{it}^p = Y_{jt}^p = Y_t^p$ ,  $Q_{it}^q = Q_{jt}^q = Q_t^q$ ,  $z_{it} = z_{jt} = z_t$ .

**Definition 1** *The equilibrium of our small open economy is a set of stochastic processes for prices  $\{P_t\}_{t=0}^\infty = \{p_{it}^p, p_{it}^q, p_{it}^m, p_{it}^o, p_{it}^n, p_{it}^{*m}, p_{it}^{*o}, p_{it}^{*n}, i_t^d, i_t^h, i_t^f, i_t^{nl}, i_t^*, s_t, w_t, v_t\}_{t=0}^\infty$  for all the histories of shock realizations, for all time periods  $t > 0$  and for all good varieties  $i \in 0, 1$ , such that a list of stochastic processes for*

1. an allocation  $\{d_t, l_t^h, c_t^p, c_t^q, q_t, H_t\}_{t=0}^\infty$  solves the household's problem given a sequence of prices  $\{P_t\}_{t=0}^\infty$  and the initial conditions for deposits and household loans;
2. an allocation  $\{Z_t\}_{t=0}^\infty$  and prices  $\{w_t\}_{t=0}^\infty$  solve the labor union's problem
3. an allocation  $\{Y_t^d, l_t^d, z_t, m_t^n, m_t^o, i_t\}_{t=0}^\infty$  solves the domestic producer's problem taking sequence of prices  $\{P_t\}_{t=0}^\infty$  as given
4. an allocation  $\{Q_{it}^q\}_{t=0}^\infty$  and the price of a single variety of domestic finished good  $\{p_{it}^q\}_{t=0}^\infty$  solve the retailer's problem given the exchange rate process,  $\{s_t\}_{t=0}^\infty$ , and price of domestic producers,  $\{p_t^d\}_{t=0}^\infty$ ;
5. an allocation  $Y_{it}^p$  and the price of a single variety of imported good  $p_{it}^p$  solve the tradable firm's problem i.e. an allocation and the price that satisfy equations (35) in the case of flexible prices or (38) in the case of sticky prices taking as given the foreign price and the exchange rate and assuming that PPP holds (equation (36));
6. an allocation  $\{l_t^f, l_t^{fb}, L_t^d\}_{t=0}^\infty$  solves the financial intermediary's problem given interest rates and the exchange rate process;
7. an allocation  $\{D_t, L_t^f, L_t^h, FB_t, R_t\}_{t=0}^\infty$  solves the bank's problem given interest rates and the exchange rate process; given processes for export, (40), technological progress, (21), spreads (54) and (55), exchange rate, (56), reserve requirement ratios, (57), (58), terms of trade, (60), foreign interest rate, (62), foreign price of oil, (63), and foreign export prices, (64).
8. All markets clear (supply equals demand):

- a) the market for domestic goods:  $Y_t^q = \int_0^1 Q_{ii}^q di$  for every  $i \in [0, 1]$  and  $Q_{ii}^q = c_{ii}^q$  or  $Y_t^q = c_t^q$  at aggregated level
- b) the market for imported goods:  $Y_{it}^p = c_{it}^p$  for every  $i \in [0, 1]$  or  $Y_t^p = c_t^p$  at aggregated level
- c) the market for deposits:  $d_t = D_t$
- d) the market for domestic production loans:  $l_t^d = L_t^d$
- e) the market for household loans:  $l_t^h = L_t^h$
- f) the market for financial intermediary loans:  $l_t^f = L_t^f$
- g) the market for labor (between households and labor union):  $h_t = H_t$
- h) the market for labor (between labor union and domestic producers):  

$$\int_0^1 Z_{ii} di = z_t$$

9. All agents have rational expectations over the sequences of the following shock processes:  $e_t^{cd}, e_t^{ld}, e_t^{lh}, e_t^{pn}, e_t^{pr}, e_t^{id}, e_t^{bop}, e_t^{spf}, e_t^{sph}, e_t^x, e_t^{mp}, e_t^{rr}, e_t^{mr}, e_t^\tau, e_t^{i*}, e_t^{pmf}, e_t^{pnf}, e_t^{pof}, e_t^w, e_t^a$

Assuming symmetry, (35) can be rewritten as:

$$\begin{aligned} \Delta \ln P_t^q &= \frac{1}{2 + i_t^d} E_t (\Delta \ln P_{t+1}^q) + \frac{1 + i_t^d}{2 + i_t^d} \Delta \ln P_{t-1}^q + \frac{1 + i_t^d}{2 + i_t^d} \xi_q (\ln P_t^{q*} - \ln P_t^q + e_t^q) \\ &= \frac{1}{2 + i_t^d} E_t (\Delta \ln P_{t+1}^q) + \frac{1 + i_t^d}{2 + i_t^d} \Delta \ln P_{t-1}^q + \frac{1 + i_t^d}{2 + i_t^d} \xi_q \ln (m c_t^q \mu + e_t^q) \end{aligned} \quad (65)$$

which gives the hybrid New Keynesian Phillips curve. It implies that the inflation process is determined by marginal costs and is both forward and backward looking.

Similarly, inflation of imported goods can be rewritten as:

$$\Delta \ln P_t^p = \frac{1}{2 + i_t^d} E_t (\Delta \ln P_{t+1}^p) + \frac{1 + i_t^d}{2 + i_t^d} \Delta \ln P_{t-1}^p + \frac{1 + i_t^d}{2 + i_t^d} \xi_p (\ln P_t^{p*} - \ln P_t^p + e^p) \quad (66)$$

Nominal GDP is given as the sum of consumption, investment and net exports:

$$\begin{aligned} NGDP_t &= p_t c_t + p_t^n i_t + n x_t = \\ &= p_t^q c_t^q + p_t^p c_t^p + p_t^n i_t + (p_t^x x_t - p_t^n i_t - p_t^o m_t^o - p_t^m c_t^p) \end{aligned}$$

whereas the budget constraint of a representative household can be rewritten to obtain the balance of payments identity. By substituting all profits into (2) and interpreting the income shock,  $e_t^{bop}$  as a balance of payments shock capturing accounting discrepancies, we obtain:

$$\begin{aligned} FR_t - FB_t - L_t^{fb} &= (1 + i_{t-1}^*) \frac{S_t}{S_{t-1}} (FR_{t-1} - FB_{t-1} - L_{t-1}^{fb}) \frac{P_{t-1}}{P_t} \\ &\quad - \frac{1}{P_t} \left( \left( \int_0^1 p_{ii}^m Y_{ii}^p di + p_t^n i_t^n + p_t^o i_t^o \right) - p_t^x x_t \right) + e_t^{bop} \end{aligned} \quad (67)$$

Since  $FR_t$  represents the central bank's net foreign reserves, whereas  $FB_t$  and  $L_t^{fb}$  are net foreign borrowing of commercial bank and financial intermediary respectively,  $FR_t - FB_t - L_t^{fb}$  represents the net foreign borrowing of the economy as a whole. This net foreign position today is equal to the net foreign position in the previous period augmented by the foreign interest rate that the economy has to pay (in the case of a short position) or receive (in the case of a long position) and the current account that increases the foreign debt if it is negative or decreases it if it is positive.

Notice also that the following identity holds:

$$FR_t - FB_t - L_t^{fb} = D_t - L_t^h - L_t^f - L_t^{fb} \quad (68)$$

This is the consequence of the consolidated balance sheet of the financial sector that includes the banking sector and the monetary authority, but excludes the financial intermediary, so that the balance of payment identity (67) can be rewritten as:

$$\begin{aligned} D_t - L_t^h - L_t^f - L_t^{fb} &= (1 + i_{t-1}^*) \frac{S_t}{S_{t-1}} (D_{t-1} - L_{t-1}^h - L_{t-1}^f - L_{t-1}^{fb}) \frac{P_{t-1}}{P_t} \\ &- \frac{1}{P_t} \left( \left( \int_0^1 p_{it}^m Y_{it}^p di + p_{it}^n i_{it}^n + p_{it}^o i_{it}^o \right) - p_{it}^x x_{it} \right) + e_{it}^{bop} \end{aligned} \quad (69)$$

Using  $E_t(s_{t+1}) = s_t$ , bank behavior, (49), (50) and (48) can be rewritten as:

$$\begin{aligned} i_t^f &= \vartheta_2(D_t, L_t) + \frac{i_t^*}{(1 - r_t^r - r_t^m)} = \\ &= \xi_{L^f} (\ln(L_t^f + L_t^h) - \ln(D_t)) + sp_t^f + \frac{i_t^*}{(1 - r_t^r - r_t^m)} \end{aligned} \quad (70)$$

$$\begin{aligned} i_t^h &= \vartheta_3(D_t, L_t) + \frac{i_t^*}{(1 - r_t^r - r_t^m)} = \\ &= \xi_{L^h} (\ln(L_t^f + L_t^h) - \ln(D_t)) + sp_t^h + \frac{i_t^*}{(1 - r_t^r - r_t^m)} \end{aligned} \quad (71)$$

$$\begin{aligned} i_t^d &= -\vartheta_1(D_t, L_t) + \frac{i_t^* (1 - r_t^r)}{(1 - r_t^r - r_t^m)} = \\ &= \frac{i_t^* (1 - r_t^r)}{(1 - r_t^r - r_t^m)} - \xi_D (\ln(D_t) - \ln(L_t^f + L_t^h)) - e_{it}^{id} \end{aligned} \quad (72)$$

## 6 Calibration and Solution

In calibrating the model, we assign numerical values to the model's parameters

that characterize the stochastic disturbances, preferences and technology to make it roughly consistent with some empirical regularities that reflect the structure of the Croatian economy. This requires construction and reorganization of the data set for the Croatian economy in a way that makes it consistent with our model economy. Furthermore, if the parameter value cannot be pinned down from the constructed data, we adopt its value from the existing literature or match the data as best as possible.

In our model economy, most of the parameters are pinned down from the steady state conditions. In what follows, we will divide the set of parameters for calibration into four major groups: the preference, technology, financial and foreign sector parameters.

### Preference Parameters

There are eleven parameters related to households that need to be calibrated: the discount factor,  $\beta$ , coefficient of relative risk aversion,  $\sigma$ , the inverse of Frisch elasticity (labor supply elasticity),  $\eta$ , share of consumption financed by household's loans,  $\kappa^h$ , steady state consumption,  $c_{ss}$ , steady state of prices,  $p_{ss}^p$  and  $p_{ss}^q$ , elasticity parameter of loans with respect to consumption,  $\phi^h$ , the habit importance parameter,  $\chi$ , the share of domestically produced good in the composite index,  $\omega$ , and the elasticity of substitution,  $\varepsilon$ . The last three parameters are assumed to be equal among imported and domestically produced goods. Furthermore, only  $\beta$ ,  $\kappa^h$ ,  $\omega$  and  $\varepsilon$ ,  $c_{ss}$ ,  $p_{ss}^p$  and  $p_{ss}^q$  can be pinned down from the steady state of the model by imposing real world restriction. Values for other parameters are either based on the values of corresponding parameters in the literature or were estimated.

The discount rate,  $\beta$ , was pinned down from the steady state version of the Euler equation, (14). The weighted average nominal interest rate on kuna and foreign deposits of households (all durations, with the weight on kuna interest rates equal to 0.14<sup>30</sup>),  $i_t^d$ , from the Croatian data is 3.99% annually,<sup>31</sup> and the assumed annual steady state inflation of 0% is also assumed to be equal to foreign inflation, so that on a quarterly basis we have  $\pi_{ss} = \pi_{ss}^{pmf} = 1,000$ . This results in  $\beta$  equal to 0.9913.

The share of domestically produced consumption good in the composite good,  $\omega$ , was pinned down from the demand function for a domestic good, (12), which in a steady state equals  $\frac{p^q c^q}{p c_{ss}}$ . Hence,  $\omega$  was calibrated so as to match the ratio of domestic goods in overall consumption (that includes both domestic and imported goods) that fluctuates around 0.4. This restriction was taken from the consumption price index statistics (COICOP disaggregation<sup>32</sup>) where the weight of a particular good is actually its share in overall private consumption.

30 The weight on kuna interest rates was calculated as an average share of household kuna deposits in overall household deposits that consist of kuna and foreign exchange deposits.

31 This value has to be calibrated to be almost equal to foreign interest rate (4%, the average is 4.22%) so that cost parameter of deposit production is close to zero. Otherwise, this parameter would take negative values i.e. elasticity of bank's costs with respect to production of deposits would be negative.

32 The following categories were considered as tradable: non-alcoholic drinks, alcoholic beverages, clothing, energy and gas, furniture, textile products, medical products, cars, audio, video and other electrical accessories, as well as 50% of meat, fruit and vegetables.

Steady state consumption,  $c_{ss}$  and steady state prices,  $p^q$  and  $p^p$  were calculated as a solution of the system of the model's steady state equations. The share of consumption financed by household's loans,  $\kappa^h$ , was calculated from household's cash-in-advance constraint and is equal to 4. The elasticity of substitution between varieties of goods,  $\varepsilon$ , was calibrated from the steady state balance of payments identity by finding a reasonable value for the desired markup so that the value for nominal exports to overall nominal consumption, the ratio of net foreign assets (net international investment position, H16 Table CNB Bulletin) to overall consumption, investment to consumption ratio, and imported oil to consumption ratio match averages of these ratios in the Croatian data. They are equal respectively to 0.85,  $-1$ , 0.4, and 0.05. Given the calibrated value for  $\omega$ ,  $\pi_{ss}$  and  $i^*$  (average of 1-year Euribor equal to 5.2% plus spread), we found a quarterly markup equal to 33%,  $\mu = 1.33$  which gives us  $\varepsilon = 4$ . This markup value is in line with most of the existing literature (see for example Domowitz et al (1988), Morrison (1994) or Olive (2002)).

As mentioned before, values of other parameters cannot be pinned down from the steady state. Values of those parameters were set using the values from the corresponding literature or to match the data as best as possible. Therefore, we set the risk aversion parameter  $\sigma$  to 2 and the inverse of Frisch elasticity,  $\eta$  to 3. We adopt the habit importance parameter,  $\chi$ , from empirical studies that suggest plausible estimates to take values between 0.4 and 0.8. We choose  $\chi = 0.4$ . This value seems to match the overall consumption volatility reasonably well. Finally, loan elasticity parameter,  $\varphi^h$ , is set to 0.4.

### Technology Parameters

There are eighteen technology parameters that we need to calibrate: parameters that control the diminishing returns to scale,  $\gamma_h, \gamma_o$ , the share of the input bill financed by a firm's loans,  $\kappa^d$ , the two parameters that characterize the sticky price environment: price adjustment parameters,  $\xi_q$  and  $\xi_p$ , wage adjustment cost,  $\xi_w$ , labor, capital and oil adjustment costs,  $\xi_z, \xi_n$  and  $\xi_o$ , a parameter that controls elasticity of firm's loans with respect to input bill,  $\varphi^d$ , capital depreciation rate,  $\delta$ , growth rate of technological progress,  $\alpha$ , and  $z_{ss}, W_{ss}, p_{ss}^n, i_{ss}^n, p_{ss}^o, m_{ss}^o$ . The steady state values of the last six variables are found again as a solution of the system of the model's steady state equations. Parameters that pertain to exogenous processes of exports and terms of trade were simply estimated.

The depreciation rate of capital was pinned down from the capital law of motion (25) assuming that the investment to *GDP* ratio and capital to *GDP* ratio are equal to 0.2 and 10 respectively. Hence,  $\delta = 0.03$  (on a quarterly basis). The share of the input bill financed by producer loans,  $\kappa^d$ , was calculated from firms' cash-in-advance constraint and is equal to 8.

We calibrate  $\gamma_h$  from the steady state producer's demand for labor that is approximately equal to the share of the total wage bill in domestic production and set its value to 0.68. The parameter  $\gamma_o$  is calibrated from the producer's steady state

demand for oil and is approximately equal to the share of nominal spending on imported oil in domestic production (domestic consumption) equal to 0.1.

Price adjustment parameters  $\xi_q$  and  $\xi_p$  were calibrated to match domestic and imported inflation as best as possible and are set respectively to 100 and 0.1. The wage adjustment cost parameter,  $\xi_w$ , labor, capital and oil adjustment costs parameters,  $\xi_z$ ,  $\xi_n$  and  $\xi_o$  were set to capture impulse responses of wages, employment, investment and oil as best as possible

The technological progress growth  $\alpha$  is set to 0 and the loan elasticity parameter,  $\varphi^d$ , is set to 0.15.

The autoregressive coefficients in exports and terms of trade processes are estimated to be  $\rho_{tot}=0.77$  and  $\rho_x=0.99$ . The terms of trade coefficient in the steady state is set to the average value of its counterpart in the data and is equal to one.

### Financial Sector Parameters

Financial sector parameters include parameters that characterize the financial intermediary sector ( $\psi, \eta, \nu$ ) and parameters that pertain to the banking sector ( $Rr^{ss}, Mr^{ss}, \xi_D, \xi_{L_f}, \xi_{L_h}, i^*$ ). Furthermore, there are parameters that characterize exogenous processes of foreign interest rates, reserve requirement ratios, spreads, and foreign prices that we parameterize by estimation.

Banking costs parameters  $\xi_D, \xi_{L_f}$  and  $\xi_{L_h}$  were calculated from the steady state supply functions of deposits, firm's loans and household's loans, (49), (48) and (50).<sup>33</sup> We set the values for these parameters such that the interest rates on deposits, interest rates on firm's loans, interest rates on household loans<sup>34</sup> and foreign interest rates in the model match the average (annual) interest rates in the data ( $i^d=3.5\%$ ,  $i^*=5.2\%$ ,  $i^f=7.2\%$ ,  $i^h=7.3\%$ ). Furthermore, we match deposits to total loans ratio ( $\frac{d}{l^f + l^h} = 1$ ), long run values of both total reserve requirement ratio  $Rr^{ss}=0.33$  and marginal reserve requirement ratio<sup>35</sup>  $Mr^{ss}=0.01$ . Hence,  $\xi_D=0.44$ ,  $\xi_{L_f}=0.14$ ,  $\xi_{L_h}=0.17$ . Estimation of processes (58), (57), (54), (55), (61) and (62) yields the value of the autoregressive coefficients  $\rho_{mr}=0.83$ ,  $\rho_{rr}=0.61$ ,  $\rho_{spf}=0.9$ ,  $\rho_{sph}=0.9$ ,  $\rho_{if}=0.92$ ,  $\rho_{pmf}=0.01$ .<sup>36</sup>

33 Since the banking costs are introduced to solve the technical problem of closing the model, in general, costs parameters should be such that these costs are minimal and do not affect the short-run properties of the model.

34 Interest rates on deposits are defined as the weighted average of interest rates on kuna deposits (where the weight was calculated as the ratio of kuna deposits in overall deposits (8.86) and interest rates on foreign exchange deposits (0.14)). Interest rates on a firm's loans are defined as the weighted average of interest rates on kuna loans (0.57) and interest rates on foreign exchange loans (0.43). Interest rates on household's loans are defined as the weighted average of interest rates on kuna loans (0.70) and interest rates on foreign exchange loans (0.30).

35 Marginal reserve requirement ratio was calculated as the ratio of the sum of marginal reserve requirement values paid on the base I (40%) and base II (15%) and the stock of foreign borrowings over the period 2004-2007. Notice that in practice the marginal reserve requirement is paid on the change of foreign borrowings and not on the stock.

36 All the processes were estimated using quarterly data over the period 1997-2006 except for the marginal reserve requirement where we used monthly data over the period 2004-2007. For in-sample shock calibration (see Shock processes below) we set  $Mr=0$  for all the periods before the third quarter of 2004.

Two of three financial intermediary sector parameters were pinned down from the steady state by imposing data restriction. The elasticity of substitution,  $\nu$ , was set arbitrarily to 4 implying the fact that foreign and domestic borrowing are substitutes. The “share” parameter,  $\eta$ , is calculated from demand for loans, and is equal to 0.67, implying that a firm’s overall borrowing is slightly home-biased. Finally, the normalization parameter,  $\psi$ , was calculated from the CES aggregation function, (41), such that the aggregator equals the sum of a firm’s domestic

$$\text{loans and foreign borrowing by firms } L^n = l^f + l^{fb} = \psi \left[ \eta (l^f)^{\frac{\nu-1}{\nu}} + (1-\eta) (l^{fb})^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}$$

By imposing that  $l^f=105$  billion of kunas and  $l^{fb}=80$  billion of kunas (values for 2nd quarter of 2007) and using the previously calculated share parameter and the elasticity of substitution, we calibrate the normalization parameter to take the value of  $\psi=2.1$ .

### Foreign Sector Parameters

Foreign sector parameters pertain to autoregressive parameters of processes for foreign interest rate ( $\rho_{if}$ ), foreign inflation of final goods ( $\rho_{pmf}$ ), foreign inflation of investment goods ( $\rho_{pmf}$ ) and foreign inflation of oil ( $\rho_{pof}$ ). These were estimated as AR(1) processes with autoregressive coefficients equal to 0.92, 0.01, 0.01 and 0.01 respectively.

The model is solved using the IRIS toolbox which implements first order approximation techniques based on the Schur decomposition developed by Klein (2000).

## 7 Findings

Using the model, we conducted simulations of the crisis. The results indicate the impact and possible transmission channels of the crisis. We use the results to assess possible monetary policy responses. At the end, we compare the simulation results with the actual data on the initial effects of the crisis, as a way of evaluating the simulation exercise.

### 7.1 Crisis Simulation

From the perspective of a small open economy, the current financial crisis can be treated entirely as an external shock. Domestic economic circumstances influence the propagation and severity of the impact of such an external shock on the local economy. For that reason, we treat the crisis as a combination of two external shocks: an increase in the price of foreign borrowing (foreign interest rate) and a drop in export demand. The results of the simulation are shown in the Appendix.

In reality, the crisis initially manifested itself through a drop in demand for risky investments, i.e. an increase in the borrowing cost for emerging market debt, which escalated in September 2008. Expansionary monetary policy and interest

rate decreases by the FED and the ECB were not enough to compensate for the increase in the spreads of the emerging market debt, so the net effect was an increase in the cost of foreign borrowing for emerging markets.

As the financial crisis spread to the real sector, final demand in developed economies dropped. This decreased the demand for imports. From the perspective of a small open economy, this can be treated as a negative export demand shock.

The existence of both shocks (the foreign interest rate shock and the export demand shock) in the model, allows us to analyze the impact of the crisis on the Croatian economy. We proceed by simulating the impact of these shocks on various variables of interest. The size of the foreign interest rate shock was based on the actual increase in the cost of foreign borrowing measured by the price of Croatian government bonds at the peak of the crisis and amounts to 300 bp. The size of the export demand shock was more difficult to assess. In line with the expected drop in consumption and investment in the eurozone, this shock was calibrated to reflect a 10% drop in exports. Simulation results are shown in figures 4,5 and 6.

#### 7.1.1 Transmission of the Foreign Interest Rate Shock

As is widely accepted, economic developments in a small open economy are to a large extent determined by foreign variables and driven by external shocks (see for example Mackowiak (2006)). The level of foreign interest rates (the cost of foreign borrowing) determines the domestic interest rates due to free capital flows. Therefore, the increase of foreign interest rates makes foreign borrowing more expensive for domestic banks and firms. However, regulation cost, in the form of reserve requirements, implies that domestic interest rates are higher than foreign rates, as regulatory cost acts as a wedge between foreign and domestic interest rates.

The model further implies that the increase in the domestic interest rate results in lower credit demand by households and firms. For that reason, banks need fewer funds to finance domestic credits, so they decrease their foreign borrowing. As both banks and firms decrease their foreign borrowing, the total foreign debt also decreases. Faced with higher foreign interest rates, banks try to substitute less expensive domestic funds for more expensive foreign funds, offering higher deposit interest rates to attract household deposits. Nevertheless, household deposits decrease, as household wealth and income also decrease, as explained below.

The increase of interest rates transmits to the real sector through its effect on household consumption and increase in production cost. The decrease in demand for domestic goods leads to a drop in their supply, i.e. domestic production, which results in lower employment, investments and imports of intermediary goods. This, together with the interest rate increase, leads to lower credit demand by firms, and their lower domestic and foreign borrowing.

Finally, the lower aggregate demand decreases inflationary pressures, and net exports improve due to a decline in imports of both final, intermediate, and investment goods. Nominal wages drop as there is less demand for labor.

Notice that the effects of foreign interest rate shock capture well the stylized facts of a sudden stop (except depreciation of the exchange rate). Hence, one

could use the foreign interest rate shock to analyze the effects of a possible sudden stop.

### 7.1.2 Transmission of the Export Demand Shock

After being initially hit by a foreign interest rate shock, the Croatian economy was hit by yet another foreign shock. As the financial crisis caused recession abroad, export (demand) declined. A drop in exports by definition decreases domestic production, which further decreases household income. With less income, households must decrease their consumption. A decrease in household consumption (and exports) leads to lower demand for goods, which transmits into lower production, employment, wages, import of intermediaries and investments. On the financial side, the model indicates that household credits and deposits also decrease due to the loss of income, while lower production leads to less borrowing by firms (both domestic and foreign). Lower aggregate demand reduces inflation pressures (prices decrease).

The full impact of the financial crisis can be derived by combining the effects of both shocks. Interestingly, both shocks affect the main variables in the same direction, so their combined effect is potentially quite large. The expected impact of the crisis on the Croatian economy, as suggested by the model, is a significant decline in real activity and consumption. Lower domestic demand reduces inflationary pressures and lowers imports. Finally, both shocks suggest significant drop in domestic credits and foreign borrowing.

### 7.1.3 Simulation of the Monetary Policy Response

As already discussed, there is limited scope for countercyclical monetary policy in Croatia. As the main effort is put into preserving the exchange rate stability, the only channel through which monetary policy can act is reduction of the regulatory cost.

Therefore, the policy response to the crisis is simulated as a reduction in the rate of reserve requirement, which reflects the recent CNB behavior. The model itself does not assume any active monetary policy response to the crisis, so we treat this rate reduction as an exogenous discretionary shock. The size of the reduction of the reserve requirement rate is calibrated to 10 percentage points, which approximately reflects the amount of liquidity released through the actual measures undertaken by the CNB in the aftermath of the crisis.<sup>37</sup>

Regulatory cost (reserve requirement) acts as a wedge between domestic and foreign interest rates. Thus, by lowering the reserve requirement, the central bank can in effect lower domestic interest rates. Even more importantly, a decrease in the reserve requirement releases a significant amount of previously immobilized assets that can be used for financing domestic credits or reducing commercial banks' foreign liabilities. Since the model itself does not create enough domestic

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<sup>37</sup> This may actually somewhat overstate the policy response, as the regulatory reserve declined less (see Figure 2).

demand for the released reserves (the decrease in domestic interest rates creates only modest initial domestic credit demand), banks use the released funds to reduce their foreign borrowing.

Therefore, a lower reserve requirement decreases domestic interest rates, which increases the credit demand of both households and firms. At the same time, interest rates (and amounts) on household deposits rise, as banks try to attract deposits to meet increasing credit demand. As the interest rates for domestic borrowing decrease, firms substitute a portion of their foreign credits with cheaper domestic ones.

The lower interest rate encourages households to increase their consumption, both of domestically produced and imported goods. Increased demand and cheaper credits are met by higher domestic production, which further leads to increases in employment, investments and imports of intermediary goods. Increased domestic demand leads to an increase in domestic prices and imports, so real wages decline.

When comparing the estimated impact of the financial crisis with the impact of the monetary policy response, the real effects of the financial crisis dominate. This suggests that monetary policy response was not large enough fully to counter the expected impact of the crisis. However, the size of the simulated response (10 pp reduction in the regulatory cost) symbolizes a limit to which the CNB can release its international reserves without endangering the present monetary regime.<sup>38</sup>

As the decline in interest rates due to lower regulatory cost (reserve requirement) is smaller than the expected increase in the cost of foreign borrowing, and as the household income drops due to the decline in exports, the net effect suggests a significant decrease of domestic credits.

Both the financial crisis and the monetary policy response imply a decrease in foreign borrowing. However, the reasons for this are quite opposite. On one hand, increase in interest rates and the slowdown in real activity and consumption lead to decreased demand for credits, which also decreases demand for foreign borrowing by banks and firms. On the other hand, lowering the reserve requirement releases large amount of assets, which banks use to finance domestic credits, so they need less foreign borrowing (foreign debt decreases). Therefore, while the financial crisis implies a slowdown in capital inflows, the main effect of the monetary policy response is to substitute for dearer foreign funds by previously accumulated reserves.

#### 7.1.4 What Happened in Reality

The results of the simulation exercise can be compared with the actual (early) impact of the crisis. The expected slowdown in real activity is already present in the high frequency data, as described in section 2. Industrial production slowed markedly in the first quarter of 2009 and a similar slowdown is expected to occur in GDP and consumption. In addition, international trade is also decreasing, with imports reacting more than the exports, which also corresponds to the results predicted by the model.

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<sup>38</sup> Even a larger policy response is unable to counter the impact of the crisis on real variables (see Section 7.1.5.).

The simulation results differ from the actual data in two areas: the actual increase of domestic interest rates is smaller than the model suggests, and growth of foreign borrowing did not slow as much as the model implied.

The difference between strong expected growth in domestic interest rates and their modest increase in reality can be explained by three reasons. The first is that the actual foreign interest rate shock used in the model might be exaggerated. It was calibrated as the increase in price of government bonds (yield to maturity) at the peak of the crisis. But government bond prices decreased significantly thereafter. Thus, it is likely that many banks borrowed from their owners more cheaply than the government bonds indicate, while some foreign borrowing by firms might have been postponed, expecting future foreign interest rate decreases. The second reason is that the CNB, by reducing the regulatory cost, made financial intermediation cheaper, which to some extent dampened the effect of the foreign interest rate shock. Finally, banks faced popular pressure, so, instead of increasing the interest on the domestic loans, they engaged in credit rationing and restricted their credit supply by increasing credit quality and granting credits only to clients with better credit-worthiness. Already high interest rates and profits from the previous period made it possible for banks to bear some of the cost of interest rate increases instead of transferring it to borrowers.

The second difference, a modest slowdown of the growth of foreign borrowing instead of its significant reduction suggested by the model, is easy to explain. The model assumes only a minor increase in credit demand as a result of the policy response, so the banks use the funds released to reduce their foreign borrowing. In reality, there was a strong fiscal demand for funds, as government spending remained high regardless of weak fiscal revenues. Thus the released funds were used to support fiscal policy during the time of crisis.

#### 7.1.5 Possible Worst-Case Scenarios

Here (figures 7,8,9) we analyze two possible worst-case scenarios that could hit the Croatian economy in today's uncertain world. First we examine the effect of a double-dip recession in the EU (Croatian main trading partner) which is approximated by a further decrease in exports of 10 percentage points in the period after the initial export shock (of 10 percentage points also) has taken place. Then we study the effect of possible monetary tightening in EMU countries and/or possible increase in risk premium by another 2 percentage points in the period after initial interest rate shock (of 3 percentage points). Lastly, we study further decline of reserve requirement by another 10 percentage points in the second period. We see that scenario as the worst-case situation in which the present monetary regime would be endangered as the CNB would be releasing its international reserves in trying to prevent exchange rate depreciation (something not captured by the model).

As expected, the pattern of the worst-case effects did not change with respect to the benchmark crisis simulation (figures 4,5,6). Hence, the interpretation of the effect is the same as before. What changed are the magnitude and persistence

of the effects.<sup>39</sup> Even though the decline in the reserve requirement has a larger counter-effect on reducing interest rate and thus has a larger positive effect on economic activity it is doubtful whether these positive effects would emerge. Such an expansionary monetary policy would probably bring about negative effects (not captured by the model) that would come out with the realization of international reserves.

## 8 Conclusion

We conducted a simulation of the impact of the financial crisis on the Croatian economy using a newly developed DSGE model for Croatia. The results to a large extent match the actual data confirming the early impact of the crisis. Real activity is in decline, despite significant monetary policy response. With the monetary policy regime based on a stable exchange rate, the central bank is limited in its attempt to counter the impact of foreign shocks and significantly stimulate real activity by simply adjusting the regulatory framework. In other words, by decreasing the regulatory burden and thereby increasing banks' liquidity, the CNB managed only partially (and to a small extent) to offset the negative impact of the foreign shock(s). However it is important to point out that this limited success must be evaluated in the context of a highly euroized small open economy, where the primary goal of the monetary authority is to keep the exchange rate broadly stable. Nevertheless, it would be wrong to say that monetary policy effect on real activity was completely absent.

The major difference between the simulation results and the actual economic developments is caused by the existence of forces not captured by our model. Since we do not model government explicitly we were not able to capture the effect of government financial needs on the economy. The significant decline of fiscal revenue in the aftermath of the crisis imposed the need for extra funding to the government. What happened is that, instead of the reduction in the foreign borrowing suggested by the model, the funds released were channeled to the government. However, the easing of the regulatory burden, and the liquidity provided by this easing, prevented the government from crowding-out the real sector. Therefore, the effect of reduction in regulatory cost was larger than was captured by the model, but its direction was the same. Abstracting from the effects induced by government behavior, this exercise shows the potential capacity of the model to be employed as a tool for understanding the mechanisms at work in the Croatian economy, making it useful for policy analysis.

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<sup>39</sup> Since impulse responses are calculated using a linearized version of the model, a change in the magnitude of the effects should correspond to a change in the magnitude of a particular shock. This relationship will not be one-for-one since there are many variables modeled to have persistence in their behavior.

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## Appendix

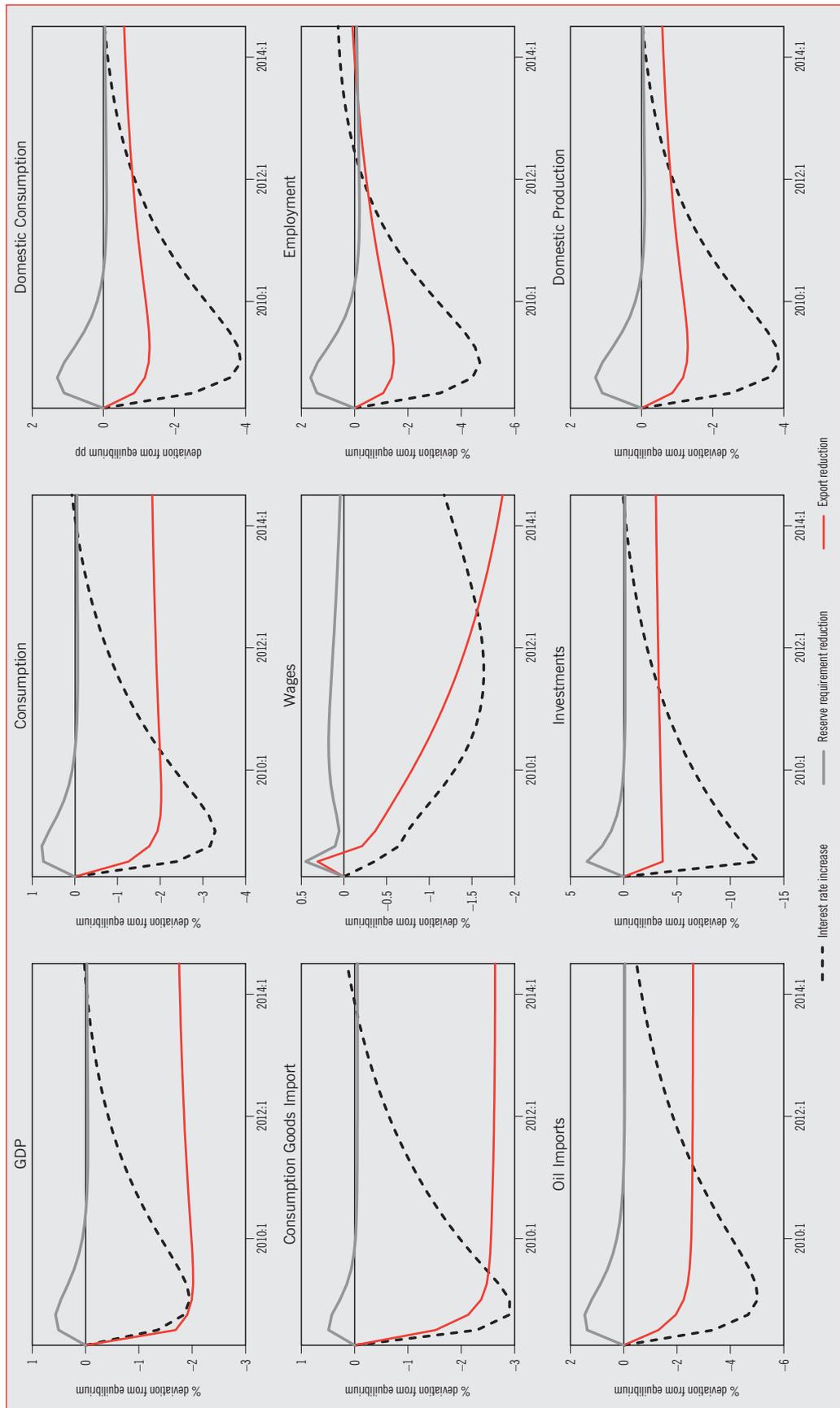
**Table 2** Calibrated Parameters

Parameter	Description	Value
<i>Households</i>		
$\beta$	discount factor	0.99
$\sigma$	relative risk aversion	2
$\eta$	labor supply elasticity	3
$\kappa^h$	consumption/household loans	2
$c_{ss}$	steady state consumption	1.53
$p_{ss}^p$	steady state of "imported" prices	1.55
$p_{ss}^d$	steady state of "domestic" prices	1.19
$\varphi^h$	loan elasticity parameter	0.75
$\chi$	habit importance parameter	0.4
$\omega$	dom. produced good/composite index	0.4
$\varepsilon$	elasticity of substitution	4
$\alpha$	growth rate of technology	0
<i>Labor union</i>		
$\xi_w$	wage adjustment cost	100
<i>Retailers</i>		
$\xi_q$	price adjustment cost	100
<i>Importers</i>		
$\xi_p$	price adjustment cost	0.1
<i>Exporters</i>		
$\rho_x$	AR coefficient	0.99

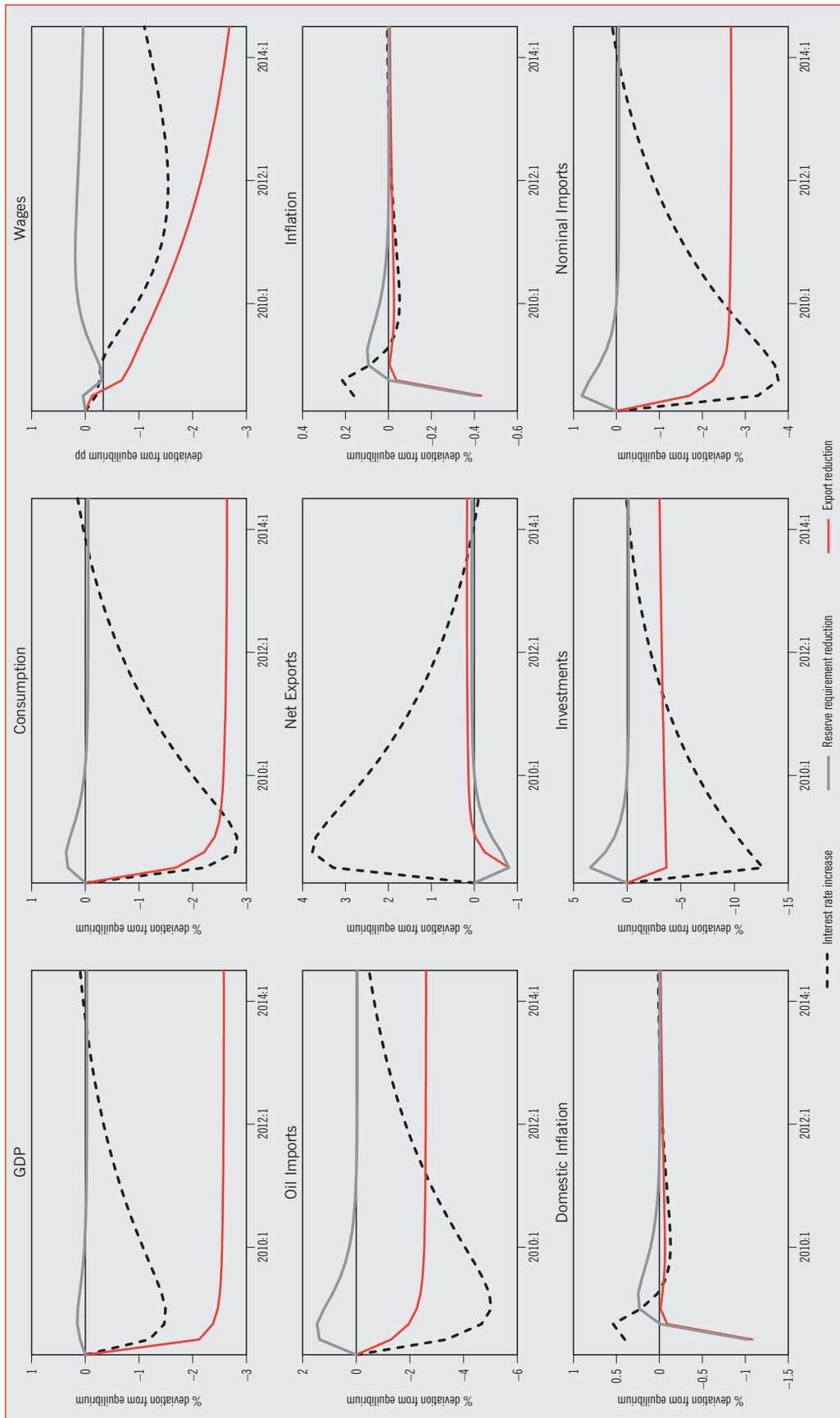
**Table 3** Calibrated Parameters

Parameter	Description	Value
<i>Domestic producers</i>		
$\gamma_o$	share of oil in production function	0.10
$\gamma_h$	share of labor in production function	0.67
$\kappa^d$	input costs/bank loan	6
$\delta$	depreciation rate (quarterly)	3%
$\varphi^d$	elasticity of loans	0.2
$\xi_n$	capital adjustment cost	20
$\xi_z$	labor adjustment cost	20
$\xi_o$	oil adjustment cost	50
<i>Banks</i>		
$r_t^r$	reserve requirement ratio	1%
$r_t^m$	GOP	33%
$\xi_D$	elasticity of deposit rate with respect to costs	0.44
$\xi_{Lf}$	elasticity of corporate rate with respect to costs	0.17
$\xi_{Lh}$	elasticity of household rate with respect to costs	0.14
$\rho_{sp}$	AR coefficient in spread	0.9
<i>Monetary policy</i>		
$\rho_{rr}$	AR coefficient of reserve requirement	0.61
$\rho_{mr}$	AR coefficient of GOP	0.83
<i>Financial intermediaries</i>		
$\psi$	scaling parameter	2.1
$\nu$	elasticity of substitution	4
$\eta$	share of bank loan in financial intermediary loan	0.67
<i>External sector</i>		
$\rho_{tot}$	AR coefficient of terms of trade	0.77
$\rho_{if}$	AR coefficient of terms of foreign inflation rates	0.92
$\rho_{pmf}$	AR coefficient of terms of imported inflation	0.01
$\rho_{pnf}$	AR coefficient of terms of investment inflation	0.01
$\rho_{pof}$	AR coefficient of terms of oil inflation	0.01

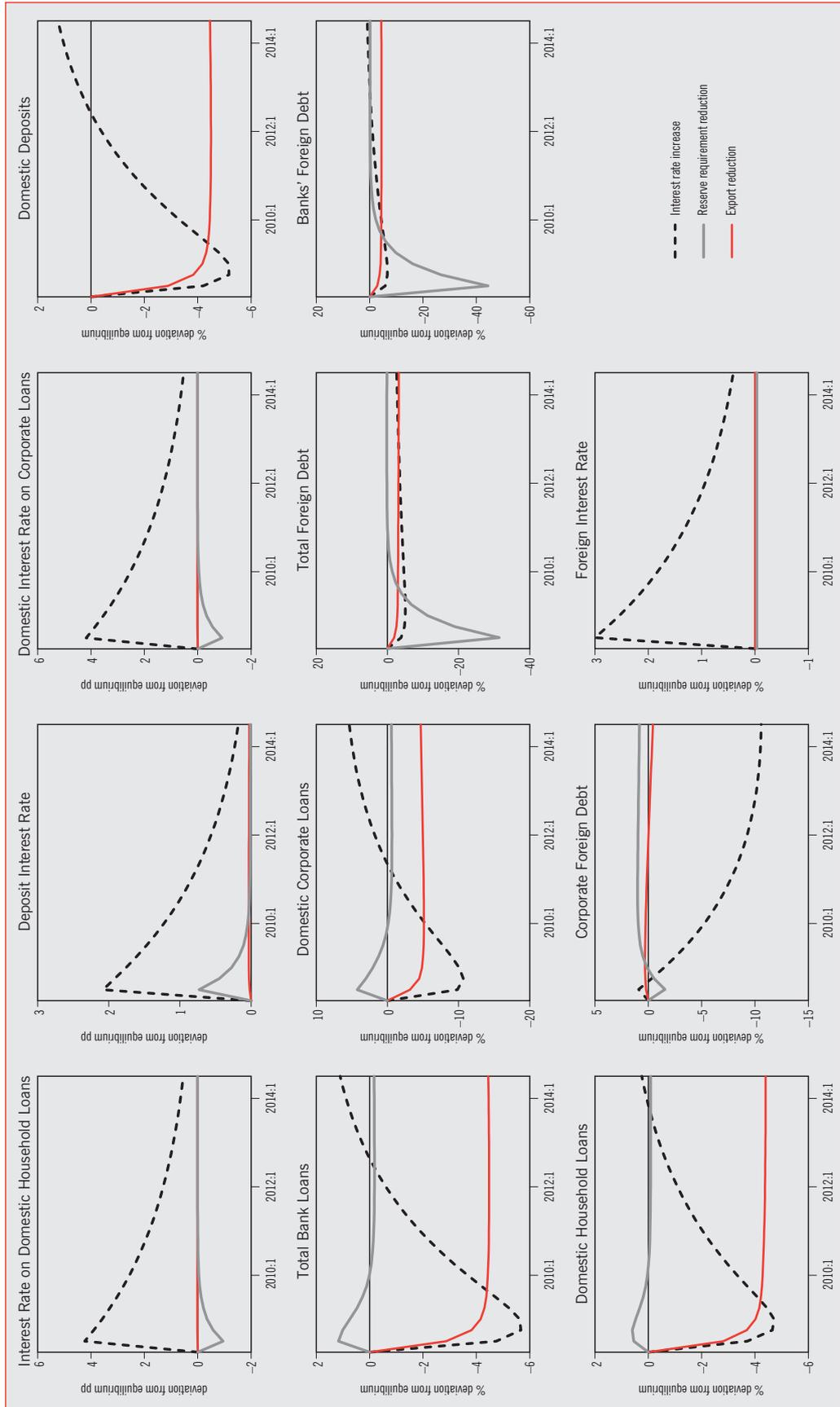
**Figure 4** Impact of Shocks on Real Variables, Impulse Responses



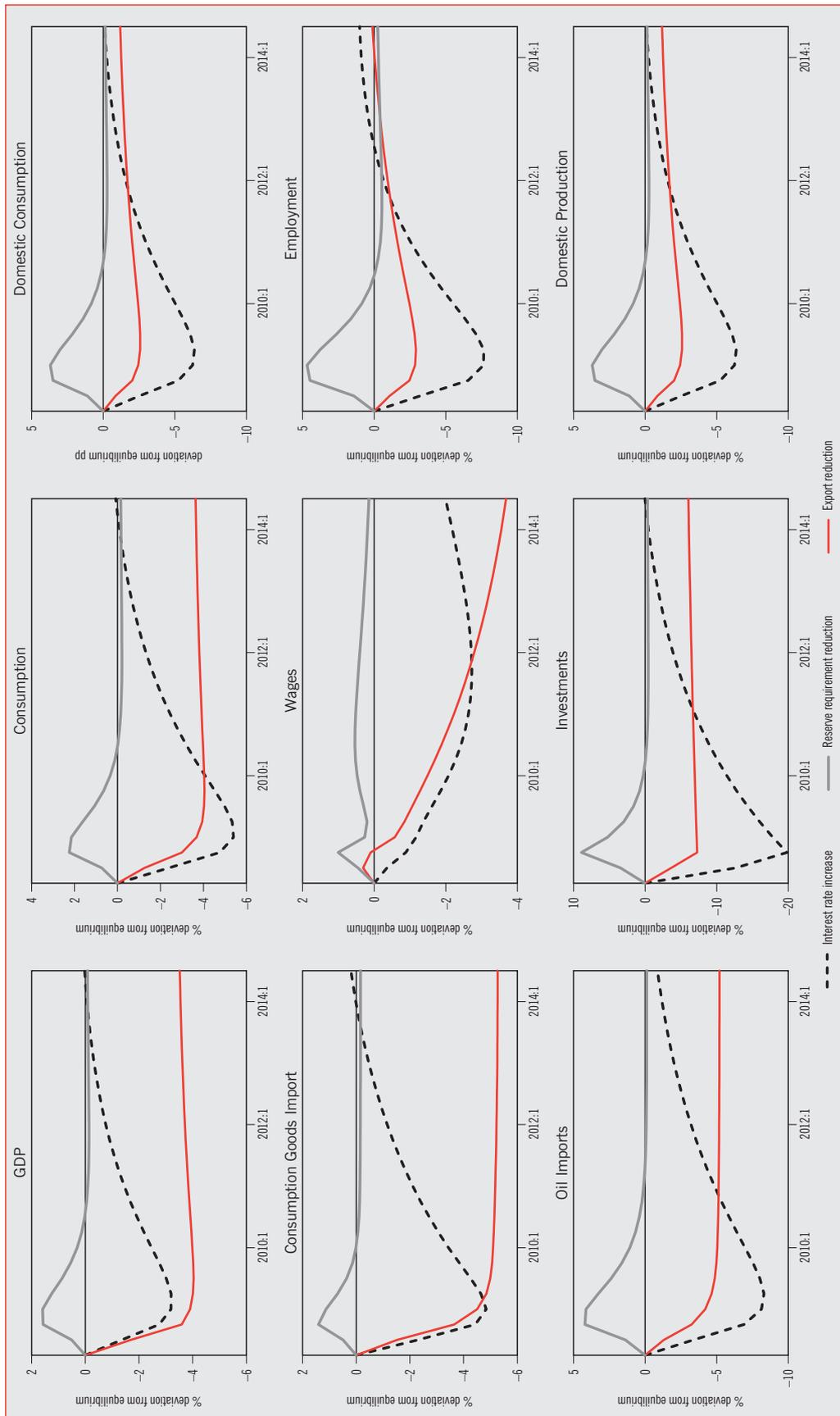
**Figure 5** Impact of Shocks on Nominal Variables, Impulse Responses



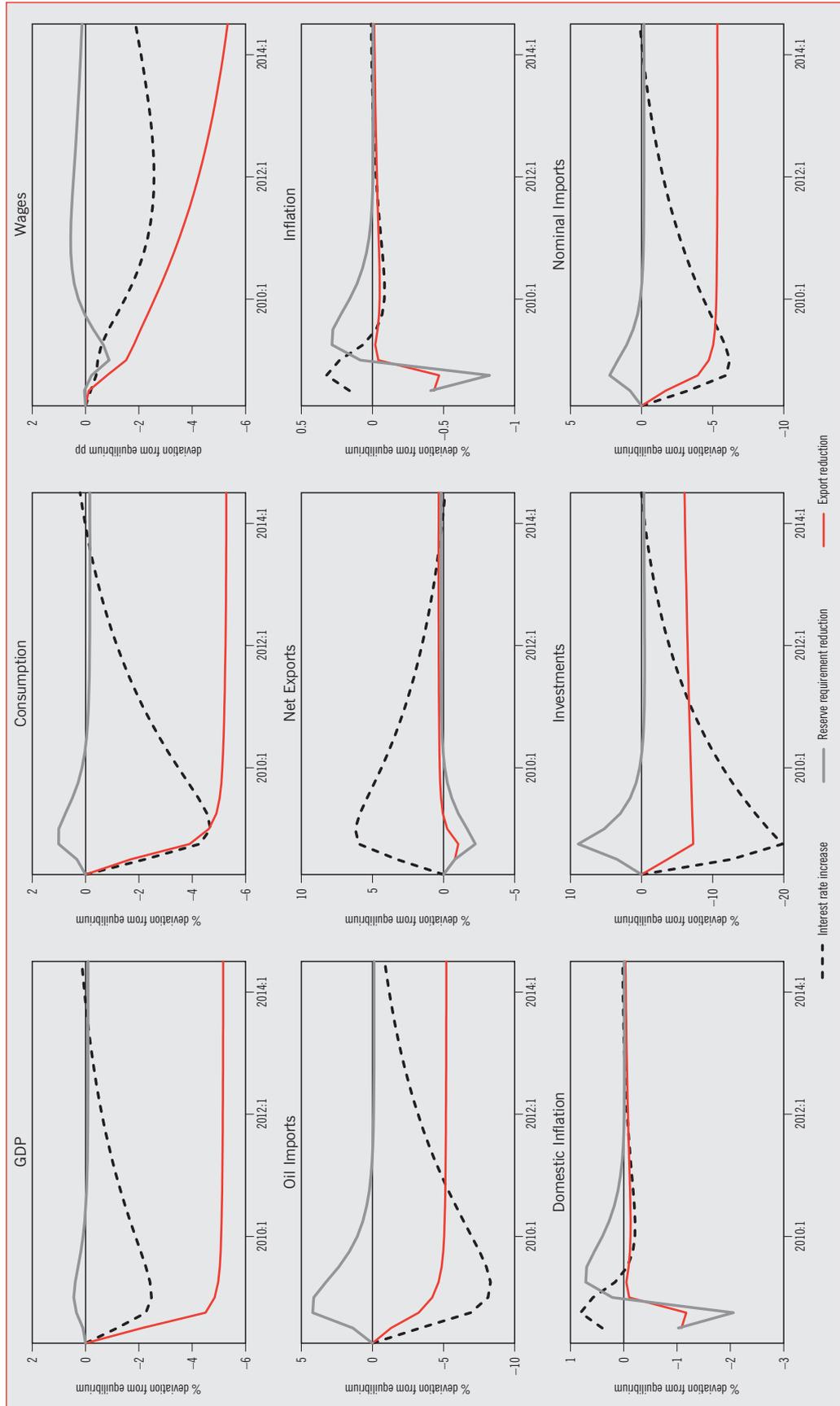
**Figure 6** Impact of Shocks on Financial Variables, Impulse Responses



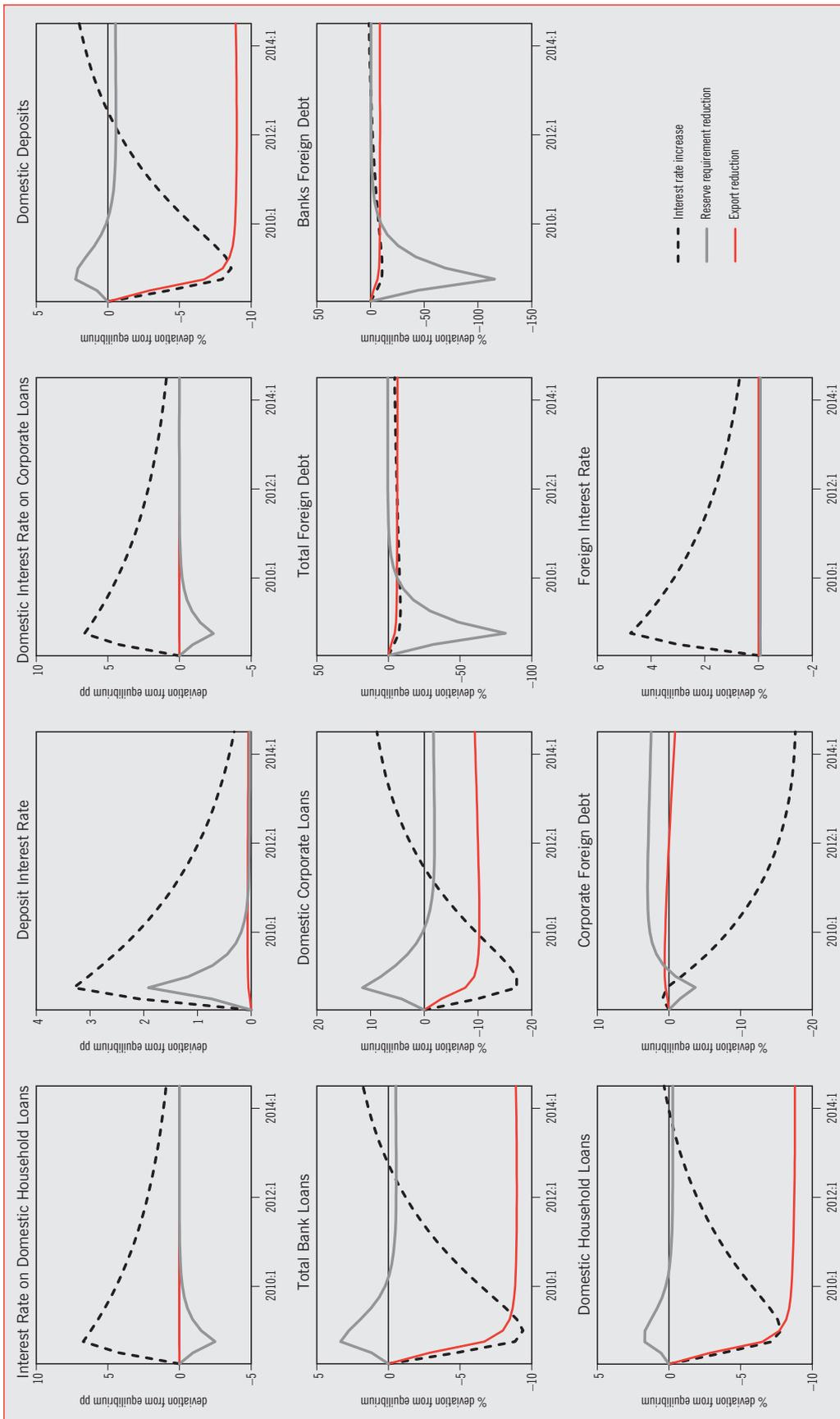
**Figure 7** Impact of Shocks on Real Variables, Impulse Responses



**Figure 8** Impact of Shocks on Nominal Variables, Impulse Responses



**Figure 9** Impact of Shocks on Financial Variables, Impulse Responses





## The following Working Papers have been published:

No.	Date	Title	Author(s)
W-1	December 1999	Croatia in the Second Stage of Transition, 1994–1999	Velimir Šonje and Boris Vujčić
W-2	January 2000	Is Unofficial Economy a Source of Corruption?	Michael Faulend and Vedran Šošić
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In its periodical publications *Working Papers, Surveys and Discussion Papers*, the Croatian National Bank publishes scientific and scholarly papers of the Bank's employees, visiting scholars, and other associate contributors.

After the submission, the manuscripts shall be subject to peer review and classification by the Manuscript Review and Classification Committee. The authors shall be informed of the acceptance or rejection of their manuscript for publication within two months following the manuscript submission.

Manuscripts are submitted and published in Croatian and/or English language.

Manuscripts submitted for publication should meet the following requirements:

Manuscripts should be submitted via e-mail, in magnetic or optical storage media, accompanied by one printed paper copy. The acceptable text format is Word.

The first page of the manuscript should contain the article title, first and last name of the author and his/her academic degree, name of the institution with which the author is associated, author's co-workers, and the complete mailing address of the corresponding author to whom a copy of the manuscript with requests for corrections shall be sent.

Additional information, such as acknowledgments, may be included in the first page. If this information is extensive, it is preferred to incorporate it within the text, whether at the end of the introductory section or in the special section preceding the list of references.

The second page should contain the abstract and the key words. The abstract is required to be explicit, descriptive, written in third person, consisting of not more than 250 words (maximum 1500 characters). The abstract should be followed by maximum 5 key words.

A single line spacing and A4 paper size should be used. The text must not be formatted, apart from applying bold and italic script to certain parts of the text. Titles must be numerated and separated from the text by a double line spacing, without formatting.

Tables, figures and charts that are a constituent part of the paper must be well laid out, containing: number, title, units of measurement, legend, data source, and footnotes. The footnotes referring to tables, figures and charts should be indicated by lower-case letters (a,b,c...) placed right below. When the tables, figures and charts are subsequently submitted, it is necessary to mark the places in the text where they should be inserted. They should be numbered in the same sequence as in the text and should be referred to in accordance with that numeration. If the tables and charts were previously inserted in the text from other programs (Excel...), these databases in the Excel format should also be submitted (charts must contain the corresponding data series).

The preferred formats for illustrations are EPS or TIFF with explanations in 8 point Helvetica (Ariel, Swiss). The scanned illustration must have 300 dpi resolution for gray scale and full color illustration, and 600 dpi for lineart (line drawings, diagrams, charts).

Formulae must be legible. Indices and superscript must be explicable. The symbols' meaning must be given following the equation where they are used for the first time. The equations in the text referred to by the author should be marked by a serial number in brackets closer to the right margin.

Notes at the foot of the page (footnotes) should be indicated by Arabic numerals in superscript. They should be brief and written in a smaller font than the rest of the text.

References cited in the text are listed at the last page of the manuscript in the alphabetical order, according to the authors' last names. References should also include data on the publisher, city and year of publishing.

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Publication providing survey of data on banks.

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ISSN 1331–8586